

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

Milk Segregation on Dairy Farms

**A thesis presented in partial fulfilment
of the requirements for the
degree of Doctor of Philosophy
in Agricultural Systems and Management
at Massey University**

Anne Elizabeth Dooley

2002

MASSEY UNIVERSITY

APPLICATION FOR APPROVAL OF REQUEST TO EMBARGO A THESIS
(Pursuant to AC98/168 (Revised 2), Approved by Academic Board 16.02.99)

Name of Candidate: Anne Elizabeth Dooley I.D. Number: 02013225

Degree: PhD in Ag Systems & Mgmt Dept / Institute / School: IVASS

Thesis Title: Milk segregation on dairy farms

Name of Chief Supervisor: Prof. Hugh Blair Telephone Ext: 5122

As author of the above named thesis, I request that my thesis be embargoed from public access until (date) 30 June 2003 for the following reasons:

- Thesis contains commercially sensitive information.
- Thesis contains information which is personal or private and / or which was given on the basis that it not be disclosed.
- Immediate disclosure of thesis contents would not allow the author a reasonable opportunity to publish all or part of the thesis.
- Other (specify) : _____

Please explain here why you think this request is justified:

Nothing has been published from this work as yet

Signed (Candidate): A.E Dooley Date: 5/4/02

Endorsed (Chief Supervisor): H. Blair Date: 5/04/02

Approved / ~~Not Approved~~ (Representative of VC): [Signature] Date: 3/4/02

Note: Copies of this form, once approved by the representative of the Vice Chancellor, must be bound into every copy of the thesis.

ABSTRACT

Milk composition varies between herds, and between cows within herds. The opportunity therefore exists to segregate milk from cows with different milk composition on farm, based on its suitability for the manufacture of particular dairy products. Benefits can result from increased yields, reduced processing costs or the suitability of differentiated milk for the production of high value niche market products.

A model was developed to determine the break even premium required for farmers producing differentiated milk to be no worse off economically than under the status quo. This model incorporated breeding (quantitative and qualitative traits), cow requirements and feeding, transport, and economic sub-models. Cows were segregated within herd and milk composition was altered over time by breeding. Four quantitative trait ("white" milk colour) scenarios and two qualitative trait (BB β -lactoglobulin milk) scenarios were considered. Manipulation of milk composition by feeding was allowed for in the model, although an example was not modelled. The transport model was developed to calculate the increase in milk collection costs associated with differentiated milk and this extra cost was included in the milk volume charge. A cost-benefit analysis was run over 20 years using a partial budget approach. This timeframe allowed for the long transition time required to manipulate milk composition by breeding. The breakeven premium on the status quo milksolids price was calculated over 10 year, 20 year and infinity time periods at a 7% discount rate.

Milk selection on a "differentiated" trait can lead to lower genetic gain in other production traits compared to the status quo. Lower production per cow allows for higher stocking rates (and therefore increased costs), and lower production per hectare. The scenarios modelled also included initial setup costs e.g. vat, cow testing, cow purchase. Sensitivity analyses were conducted on transport costs, premiums, and discount rates. The possibility of redistributing premium payments so a higher price was paid in earlier years was also explored.

The premium required to break even for the quantitative scenarios was \$1.11/kg of "white" milkfat over 20 years. The lower production of the "white" milk cows compared to their status quo counterparts had a considerable impact on the premium. The premium was lower (\$0.46/kg milkfat) where a greater proportion of the cows produced "white" milk in year 1. The premium required for the qualitative scenarios was lower, requiring an extra 3.4% to 4.1% for differentiated milkfat and protein compared to the status quo to break even over 20 years. Production per cow was similar to the status quo for these scenarios, and transport costs contributed to a high proportion of the premium required. Risk associated with a discontinuance of a differentiated milk policy is high. The breakeven premium required was considerably greater when a premium was received for only a few years e.g. \$0.92/kg milkfat for 20+ years compared to \$9.66/kg milkfat if the premium was discontinued after 10 years.

The rate of technology adoption will be important to the success of a differentiated milk policy. The premium required for milk differentiation policies may need to be considerably greater than the breakeven value to compensate for risk and encourage technology adoption. Farmers already producing milk closer to the required specifications could initially be targeted. Companies may need to consider taking some of the risk e.g. through price redistribution. Effective strategies involving both industry and farmers will need to be developed to facilitate the uptake of milk segregation. This research model could be used by dairy companies and farmers considering milk segregation policies.

Keywords: milk segregation, modelling

Title: Milk segregation on dairy farms.

Author: Anne Elizabeth Dooley

Degree: PhD in Agricultural Systems and Management

ACKNOWLEDGEMENTS

Many people contributed towards the completion of this study, and I am very grateful for their input. While those who contributed are too many to mention, I would like to thank the following:

My supervisors, official and unofficial, for their editing of the script, advice and encouragement. I would particularly like to thank Dr Warren Parker at AgResearch for his enthusiasm and interest in this study; Professor Hugh Blair at Massey University for his good humour in debating thesis issues; and Ms Evelyn Hurley at MAF Policy for helping with information and contacts, and for showing me other ways of looking at things.

The many people who helped with information and advice, including: Dr Nicolás López-Villalobos at Massey University for explanations and breeding model inputs; Dr Ian Brookes at Massey University for the cow requirements model; Dr Chris Daké at AgResearch for assistance with modelling; Ms Nicola Shadbolt and Dr Dave Gray at Massey University for advice on economic model inputs; Mr Peter Spooner, Mr Bob Franks and Mr Colin Corney of New Zealand Dairy Group for the transport, milk production and farms distribution data; and Dr Lawrie Creamer, Dr Alastair MacGibbon, Dr Jeremy Hill and Dr Peter Wiles from the New Zealand Dairy Research Institute for information on milk.

My sister, Judith Dooley, and friends George and Sharon Moss, for providing information for this thesis, and also for their interest and encouragement. Similarly, I would like to thank Professor Al Rae and Clare Callow for their encouragement during this study.

I wish to acknowledge the financial assistance provided by the Massey University PhD scholarship, and the funding provided by the Post-graduate Research Fund.

Finally, many thanks to those in the Agricultural and Horticultural Systems Management Group in the Institute of Natural Resources at Massey University for including me as part of the group, most especially Janet Reid, Ewen Cameron, Dave Gray and Denise Stewart for their friendship, support and encouragement during the highs and lows of thesis production and PhD study.

TABLE OF CONTENTS

ABSTRACT	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	xiii
LIST OF FIGURES	xxi
CHAPTER ONE	1
INTRODUCTION	1
PURPOSE AND SCOPE OF THE STUDY	3
AIM AND OBJECTIVES	3
OUTLINE OF THE THESIS	3
LITERATURE REVIEW	5
1.1 MILK COMPOSITION	5
1.1.1 Composition of milk	5
1.1.1.1 Fat	6
1.1.1.2 Protein	8
1.1.1.3 Carbohydrates	11
1.1.1.4 Minerals, Vitamins and Other	12
1.1.2 Why alter milk composition?	14
1.1.2.1 Fat	17
1.1.2.2 Protein	19
1.1.2.3 Lactose	20
1.1.3 Factors affecting milk composition and manipulation of milk composition	22
1.1.3.1 Breed	22
1.1.3.2 Selection	23
1.1.3.3 Transgenics and cloning	27
1.1.3.4 Feeding and nutrition	28
1.1.3.5 Season	29

1.1.3.6	Stage of lactation and calving spread	30
1.1.3.7	Milking frequency and interval.....	31
1.1.3.8	Age.....	32
1.1.3.9	Climate.....	33
1.1.3.10	Health, mastitis and somatic cell counts	33
1.1.3.11	Other	34
1.1.4	Two potentially useful milk traits.....	35
1.1.4.1	β -lactoglobulin protein variants.....	35
1.1.4.2	Milk colour	35
1.1.5	Conclusion	36
1.2	THE NEW ZEALAND DAIRY INDUSTRY	37
1.2.1	Dairy industry structure	37
1.2.1.1	Dairy industry structure – past and present	37
1.2.1.2	Structure of Fonterra.....	39
1.2.2	Milk payment system.....	41
1.2.2.1	NZDB to the Dairy Company.....	41
1.2.2.2	Dairy Company to the farmer	42
1.2.2.3	Future milk valuation and payment possibilities	43
1.2.3	Value-added systems and vertical integration	44
1.2.3.1	Value-added systems and vertical integration	44
1.2.3.2	Cooperatives	52
1.2.3.3	Vertical integration in the New Zealand dairy industry.....	53
1.2.4	Conclusion	54
1.3	AGRICULTURAL SYSTEMS AND MODELLING	55
1.3.1	Systems	55
1.3.2	Models	57
1.3.2.1	Simulation models	59
1.3.2.2	Modelling process.....	60
1.3.3	Conclusion	62
1.4	RISK.....	62
1.4.1	Decision making and risk	63
1.4.1.1	Risk and uncertainty	63
1.4.1.2	Perceived riskiness of an action.....	63
1.4.1.3	Downside risk versus pure risk.....	64

1.4.2	Farmer attitude to risk.....	64
1.4.3	Risk decisions and techniques	65
1.4.4	Types of risk	66
1.4.5	Strategies to avoid risk.....	67
1.4.6	Risk and technology adoption	69
1.4.7	Conclusion	69
1.5	TECHNOLOGY TRANSFER AND ADOPTION	71
1.5.1	The innovation-decision process	72
1.5.2	Time factors associated with technology adoption.....	72
1.5.3	Farmer factors affecting technology adoption	73
1.5.4	Technology factors affecting technology adoption	73
1.5.5	The effect of social factors and farmer attitudes on technology adoption	74
1.5.6	Communication and technology adoption	75
1.5.7	Identification of the decision makers.....	75
1.5.8	Technology transfer models and approaches.....	76
1.5.9	Conclusion	77
CHAPTER TWO	.....	79
OVERVIEW OF THE MODEL	.....	79
CHAPTER THREE	.....	85
BREEDING FOR A QUALITATIVE TRAIT: B HOMOZYGOUS β - LACTOGLOBULIN COWS		85
3.1	INTRODUCTION.....	85
3.2	METHOD.....	87
3.2.1	Genotypic frequencies	88
3.2.2	Production.....	90
3.2.2.1	Calculation of base level of production and gain per year by genotype ..	90
3.2.2.2	Calculation of production by genotype.....	91
3.2.3	Breed Effect.....	93
3.2.4	Model Parameters	94
3.3	RESULTS	96
3.3.1	Genotypic and gene frequencies	96
3.3.2	Production.....	98

3.3.3	Herd Structure.....	101
3.3.4	Initial gene frequency	102
3.3.5	Using AB and BB β -lactoglobulin bulls.....	102
3.3.6	Breed and Regional Effects	103
3.4	DISCUSSION	105
CHAPTER FOUR	.....	113
LOGISTICS OF TRANSPORTING TWO DIFFERENT MILK TYPES	.....	113
4.1	INTRODUCTION.....	113
4.1.1	Transport issues	113
4.1.2	Transport routing problem.....	114
4.1.3	Genetic algorithms.....	114
4.1.3.1	Crossover	115
4.1.3.2	Mutation.....	116
4.1.3.3	Proportion of population replaced and individuals replaced	116
4.1.3.4	Population size.....	116
4.1.4	Description of Evolver: a genetic algorithm software package	116
4.1.5	Recommendations for genetic algorithm parameters	117
4.2	METHOD.....	118
4.3	RESULTS AND DISCUSSION	125
4.3.1	Model inputs used in the transport model scenarios.....	125
4.3.2	Average milk collection cost	126
4.3.2.1	Comparison with the SQ (0% of farms changing).....	126
4.3.2.2	Stage of lactation comparison.....	126
4.3.2.3	Variation in average milk collection costs over the years	127
4.3.3	Technology adoption time frame.....	135
4.3.4	Average minimum load size	135
4.3.5	Farm and herd size.....	136
4.3.6	Time taken for milk collection and tanker requirements	136
4.3.7	Milk collection cost with type 1 milk collection at SQ cost.....	138
4.3.8	Discounted cost of milk collection	139
4.3.8.1	Type 1 milk at SQ cost	139
4.3.8.2	SQ cost constant over the years	142

4.3.9	Average milk collection cost: one milk type per run and every second day collection	143
4.3.9.1	One milk type collected per run.....	144
4.3.9.2	Milk collected every second day	144
4.3.10	Extra costs to a farmer over the 20 years.....	144
4.3.11	Other factors	148
4.4	CONCLUSION.....	148
CHAPTER FIVE	.....	151
DESCRIPTION OF THE MODELS	.....	151
5.1	DESCRIPTION OF THE QUANTITATIVE BREEDING MODEL	151
5.1.1	Base level of production and change in genetic gain over time	152
5.1.2	Change in the selected trait and herd segregation.....	153
5.1.2.1	Calculations relating to the RHS of cut-off value on the normal distribution curve.....	154
5.1.2.2	Calculations relating to the LHS of cut-off value on the normal distribution curve.....	155
5.1.2.3	Average production in the selected trait for each of the herds	155
5.1.3	Production in the correlated and production traits for each herd.....	155
DESCRIPTION OF THE FEED MODELS	.....	157
5.2	DESCRIPTION OF THE COW REQUIREMENTS MODEL.....	158
5.2.1	Allowance for younger cows growing out.....	158
5.2.2	Energy requirements for milk, allowing for changes in milk composition	158
5.2.3	Calculation of calving spread	162
5.2.4	Culling	163
5.2.5	Calculation of overall feed requirements and production over the year	163
5.2.6	Calculation of milk fat colour over the year.....	164
5.3	DESCRIPTION OF THE FEED BUDGET MODEL.....	166
5.3.1	Feed requirements.....	167
5.3.2	Calculation of stocking rate	168
5.3.3	Production per cow, herd and hectare.....	171
5.3.4	Model outputs.....	171

DESCRIPTION OF THE ECONOMIC MODEL	171
5.4 DESCRIPTION OF FEED COMPONENT COSTS AND GRAZING OFF	172
5.4.1 Hay	172
5.4.2 Maize silage purchased	176
5.4.3 Concentrates purchased	172
5.4.4 Nitrogen	172
5.4.5 Crop	173
5.4.6 Grass silage	173
5.4.7 Grazing	173
5.5 DESCRIPTION OF THE STOCK RECONCILIATION	173
5.5.1 Stock reconciliation calculations	173
5.5.1.1 Opening and closing stock numbers	174
5.5.1.2 Natural increase	175
5.5.1.3 Numbers of specified sales and purchases	175
5.5.1.4 Numbers of culls, and deads, killers and missings	176
5.5.1.5 Numbers of sales and purchases	176
5.5.1.6 Outputs	177
5.5.2 Stock income and expenditure	177
5.5.3 Capital value of stock on hand	177
5.5.4 Grazing, calf rearing and stock freight costs	178
5.6 DESCRIPTION OF THE MILK INCOME MODEL	179
5.7 DESCRIPTION OF THE OVERALL ECONOMIC MODEL	181
5.8 MODEL INPUTS	183
5.8.1 Quantitative Breeding Model	183
5.8.2 Cow Requirements Model	184
5.8.3 Feed Model	186
5.8.4 Stock Reconciliation Model	187
5.8.5 Economic Model	188
5.8.5.1 Feed Model	188
5.8.5.2 Stock Reconciliation Model	188
5.8.5.3 Milk Model	189
5.8.5.4 Economic Model	189

5.8.6	Assumptions that differ in the with and without scenario	190
5.8.6.1	Quantitative breeding model.....	190
5.8.6.2	Qualitative breeding model.....	191
5.8.6.3	Economic model - Quantitative trait.....	191
5.8.6.4	Economic model - Qualitative trait.....	193
CHAPTER SIX	.....	195
MODEL RESULTS	.....	195
6.1	QUANTITATIVE TRAIT	195
6.2	QUALITATIVE TRAIT	201
6.3	SENSITIVITY ANALYSES.....	205
6.4	REDISTRIBUTION OF THE PREMIUM PAID	208
CHAPTER SEVEN	.....	213
GENERAL DISCUSSION	.....	213
7.1	QUANTITATIVE SCENARIOS	214
7.1.1	Factors affecting selection for, and production of, differentiated milk	214
7.1.2	Calculation to infinity	216
7.1.3	Initial milkfat colour in the base herd	216
7.1.4	Low initial volumes of white milk and associated risk.....	218
7.1.5	Stage of lactation	220
7.2	QUALITATIVE MODEL.....	222
7.2.1	Factors affecting selection for, and production of, differentiated milk	222
7.2.2	Breed distribution	223
7.2.3	Value of premium required.....	223
7.2.4	Strategies used to alter herd genotype	224
7.2.5	Comparisons with current industry applications	225
7.3	TECHNOLOGY UPTAKE.....	226
7.3.1	Industry perspective	226
7.3.2	Factors affecting technology uptake	228
7.3.3	Some experiences in extending proposed changes	230
7.4	RISK AND SENSITIVITY	232
7.4.1	Effect of altering the discount rate.....	232
7.4.2	Sensitivity to transport collection cost and premium.....	232

7.5 PREMIUM REDISTRIBUTION	233
7.6 FACTORS AFFECTING THE PRICE RECEIVED PER KILOGRAM OF MILKSOLIDS: MILK CONCENTRATION, PROTEIN: MILKFAT RATIO AND COMPONENT PRICES	236
7.7 OTHER FINANCIAL CONSIDERATIONS	238
7.8 MILK SEGREGATION AND PAYMENT OPTIONS	240
7.9 INDUSTRY STRUCTURE, AND TRANSPORT AND PROCESSING ISSUES AND STRATEGIES.....	243
7.10 BREEDING TECHNOLOGIES	246
7.11 MODEL APPLICATION AND EVALUATION.....	248
7.12 SUMMARY	252
CHAPTER EIGHT	253
SUMMARY AND RECOMMENDATIONS	253
8.1 MODEL DEVELOPMENT, RESULTS AND GENERAL DISCUSSION.....	253
8.2 MODEL APPLICATION AND EVALUATION	258
8.3 RESEARCH RECOMMENDATIONS	259
REFERENCES	261
APPENDIX ONE	289
MODEL INPUTS AND OUTPUTS	289
QUANTITATIVE BREEDING MODEL	289
QUALITATIVE BREEDING MODEL	290
COW REQUIREMENTS MODEL.....	291
FEED MODEL	292
STOCK RECONCILIATION MODEL	293
MILK INCOME MODEL	294
ECONOMIC MODEL.....	295
APPENDIX TWO	297
QUALITATIVE BREEDING MODEL TABLES	297
APPENDIX THREE	303
TRANSPORT MODEL TABLES.....	303

APPENDIX FOUR	315
DESCRIPTION OF THE COW REQUIREMENTS MODEL DEVELOPED BY DR IAN BROOKES	315
NOTE ON TRANSPORT RELATED COSTS	327
 APPENDIX FIVE	 329
OVERALL MODEL OUTPUT TABLES	329
QUANTITATIVE APPENDICES	331
QUALITATIVE APPENDICES	358
PREMIUM REDISTRIBUTION	370
MILKSOLIDS AT STATUS QUO PRICES	372

List of Tables

CHAPTER ONE: Introduction and Literature Review

Table 1.1: Components of cows' milk per kilogram of milk (from Mulder and Walstra 1974, p. 21).....	7
Table 1.2: Milk protein genetic variants (from Ng-Kwai-Hang and Grosclaude 1992).....	11
Table 1.3: Percentage milk composition for various breeds of dairy cattle.....	22
Table 1.4: Predicting organisational forms of alternative business linkages (from Boehlje <i>et al.</i> 1999, p. 28).....	49

CHAPTER THREE: Breeding for a Qualitative Trait

Table 3.1: Herd age structure and age adjustments used in the model example.....	91
Table 3.2: Gene and genotypic frequencies by breed.....	93
Table 3.3: Parameters used and first year production in selection for BB β -lactoglobulin cows.....	95
Table 3.4: Cow gene and genotypic frequencies after 20 years of selection at 2 initial gene frequencies (0.2 and 0.3), using BB only or a combination of both AB and BB bulls (testing and no-testing for genotype, no yearling AB).	103
Table 3.5: Gene and genotype frequencies by region.....	104

CHAPTER FOUR: Transport Logistics

Table 4.1: Operational parameters recommended for genetic algorithms.....	117
Table 4.2: Transport model scenarios run.	123
Table 4.3: Total milk volumes collected per day (litres) for each of the 20 years.	125
Table 4.4: Percentage of the total milk supply that changed to Type 2 over the 20 years for different rates of farm adoption.....	126
Table 4.5: Total net present value of the extra cost incurred in transporting type 2 milk over 20 years (at a discount rate of 7%) at a day in either peak or late lactation.	140
Table 4.6: Total net present value of the extra cost incurred in transporting type 2 milk over 20 years (at a discount rate of 10%) at a day in either peak or late lactation.	141
Table 4.7: Total extra cost of transporting type 2 milk at a discount rate of 7% over 20 years with the status quo cost adjusted to a constant value over time.	142
Table 4.8: The extra cost per year to a North Island and a South Island farmer for milk collection, and the proportional increase over a non-differentiated milk policy.	147

CHAPTER FIVE: Description of the Models

Table 5.1: Stock reconciliation calculation table for years 1 and 2.....	175
Table 5.2: Traits and trait parameters used in the quantitative breeding model.....	184
Table 5.3: Condition score at four periods of the year.....	185
Table 5.4: Wood equation parameter values.....	185
Table 5.5: The proportion of the day 1 fat colour value associated with the mid-day in each period. Period 1 is the beginning of the lactation.....	186
Table 5.6: Pasture values used in the Feed Model.....	187
Table 5.7: Herd structure, losses and culls percentages.....	188
Table 5.8: Milk component prices for 3 years.....	189
Table 5.9: Variable costs used in the Economic Model.....	190
Table 5.10: Weightings and genetic gains used in the quantitative breeding model.....	191

CHAPTER SIX: Model Results

Table 6.1: Premium required per kilogram of milkfat for each scenario for the NPV to equal zero over periods of 10, 20 and 20+ years. The total milkfat price and percentage increase in milkfat price required compared to the status quo (SQ) are also shown in row 2.....	195
Table 6.2: The discounted difference (\$) between each quantitative trait scenario for milk colour and the status quo in milk income, sales and purchases income (S&P), farm working expenses (FWE), capital expenses (CE) and net income total for the period specified, where NPV for the period equals zero (or the closest premium value to 2 decimal places).....	196
Table 6.3: Cow numbers, and milksolids and milkfat production per cow and per hectare for year 20, and the percentage change in these attributes over the 20 years and between the status quo (SQ) and the other scenarios.....	199
Table 6.4: The net discounted salvage value of the stock, the percentage of salvage values required for the net discounted salvage value to be zero, and milksolids production of scenario cows as a percentage of status quo (SQ) cows, for the four scenarios at the end of 10 and 20 years.....	201
Table 6.5: Cow numbers, and milksolids production per cow and per hectare at year 20, and the percentage change in these attributes over the 20 years.....	202
Table 6.6: The multiplier and milkfat, protein and milksolids values required for the differentiated milk in each scenario for the NPV to equal zero over periods of 10, 20 and 20+ years. Milksolids price inclusive of volume charges (above) and exclusive of volume charges (below) are given. The difference between the scenario and the status quo milksolids value is shown in brackets (in cents per kg).....	202

Table 6.7: The discounted difference (\$) between the qualitative scenarios and the status quo in milk income, sales and purchases income (S&P), farm working expenses (FWE), investment expenses (IE) and net income total for the period specified, where NPV for the period equals zero (or the closest multiplier value to 3 decimal places).....	204
Table 6.8: Milkfat premium (\$/kg milkfat) required for two quantitative scenarios and the premium (cents/kg milksolids) required for two qualitative scenarios for the NPV to equal zero over periods of 10, 20 and 20+ years at 3 discount rates.	206
Table 6.9: The change in the NPV over 10, 20 and 20+ years associated with a \$0.10 increase in the milkfat premium for the desired milk type or a 0.1 cent per litre reduction in transport costs for two quantitative scenarios at three discount rates.....	207
Table 6.10: The change in the NPV over 10, 20 and 20+ years associated with a 1% (of the status quo price) increase in milkfat and protein (i.e. 4.37c/kg milksolids) for the desired milk type or a 0.1 cent per litre reduction in transport costs for two qualitative scenarios at three discount rates.	207
Table 6.11: The premium required on white milkfat in quantitative scenario 1 for the NPV to equal zero at a 7% discount rate over three time periods, with the premium either evenly or unevenly distributed over the time period. The year value in brackets is the proportion of the year 1 value. The data value in brackets is the difference between that value and its associated even distribution value in cents.....	209
Table 6.12: The payment required on BB milksolids (before transport cost deduction) in qualitative scenario 2 for the NPV to equal zero at a 7% discount rate over three time periods, with the premium either evenly or unevenly distributed over the time period. The year value in brackets is the proportion of the year 1 value. The data value in brackets is the difference between that value and its associated even distribution value in cents.	209

CHAPTER EIGHT: Summary and Recommendations

Table 8.1: The premium required per kilogram of protein and milkfat for each scenario, for the NPV to equal zero over 20 years. The total component value is shown in the first row and the increase over the status quo is shown in the second row.	254
---	-----

APPENDIX TWO: Qualitative Breeding Model Tables

Table A2.1: Selection for BB β -lactoglobulin cows at a .684 gene frequency for the B allele with no heifer AI.....	297
Table A2.2: Selection for BB β -lactoglobulin cows at a .684 gene frequency for the B allele with heifer AI.....	298

Table A2.3: Parameters used and first year production in selection for BB β -lactoglobulin cows at a 0.5 gene frequency for the B allele.	299
Table A2.4: Selection for BB β -lactoglobulin cows at a .5 gene frequency for the B allele with no heifer AI.....	300
Table A2.5: Selection for BB β -lactoglobulin cows at a .5 gene frequency for the B allele with heifer AI.....	301
Table A2.6: Year in which proportion of BB cows is over the stated amount with and without yearling mating to AI at .5 gene frequency.	302

APPENDIX THREE: Transport Model Tables

Table A3.1: Transport information for the North Island, at peak lactation and able to collect two milk types in the same run.	305
Table A3.2: Transport information for the North Island, in late lactation and able to collect two milk types in the same run.	306
Table A3.3: Transport information for the South Island, at peak lactation and able to collect two milk types in the same run.	307
Table A3.4: Transport information for the North Island, at peak lactation, able to collect two milk types in the same run and collected every second day. Transport information for the South Island, at peak lactation and able to collect only one milk type per run.....	308
Table A3.5: Average cost of milk collection (\$/kilolitre), and the increased cost compared to the status quo cost in that year (%).	309
Table A3.6: Cost of collection of Type 2 milk (\$/kilolitre) assuming Type 1 milk collection cost is equal to the status quo cost, and the increased cost compared to the status quo cost in that year (%).	310
Table A3.7: The extra collection cost to the farmer in dollars per annum and percentage above the status quo (herd not changing) for a North Island farm for 25% of farms changing. Costs used are those for peak lactation, late lactation and an average of the two. Three different ways of calculating costs have been used.	311
Table A3.8: The extra collection cost to the farmer in dollars per annum and percentage above the status quo (herd not changing) for a North Island farm, for 50% of farms changing. Costs used are those for peak lactation, late lactation and an average of the two. Three different ways of calculating costs have been used.	312
Table A3.9: The extra collection cost to the farmer in dollars per annum and percentage above the status quo (herd not changing) for a South Island farm where 25% and 50% of farms are changing. Costs used are those for peak lactation. Three different ways of calculating costs have been used.	313
Table A3.10: Time taken to collect the milk (hours).....	314

APPENDIX FOUR: Note on Transport Related Costs

Table A4.1: Premium required for two quantitative and two qualitative scenarios at different increases in volume charges for differentiated milk (over 20+ years).....	328
Table A4.2: Premium required for quantitative scenario 1 over three time periods with different increases in volume charges for differentiated milk.	328

APPENDIX FIVE: Overall Model Output Tables

Table A5.1: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years under the status quo scenario.....	331
Table A5.2: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.....	332
Table A5.3: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.....	333
Table A5.4: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.....	334
Table A5.5: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.....	335
Table A5.6: The proportion of cows in each herd, and the production per farm over the 20 years under the status quo scenario.....	336
Table A5.7: The proportion of cows in herd 1, and the production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.....	337
Table A5.8: The proportion of cows in herd 1, and the production per farm over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.....	338
Table A5.9: The proportion of cows in herd 1, and the production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.....	339
Table A5.10: The proportion of cows in herd 1, and the production per farm over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.....	340
Table A5.11: The proportion of cows in herd 1, and the production per hectare over the 20 years under the status quo scenario.....	341

Table A5.12: The proportion of cows in herd 1, and the production per hectare over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.	342
Table A5.13: The proportion of cows in herd 1, and the production per hectare over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.....	343
Table A5.14: The proportion of cows in herd 1, and the production per hectare over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.	344
Table A5.15: The proportion of cows in herd 1, and the production per hectare over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.	345
Table A5.16: Milkfat production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.	346
Table A5.17: Milkfat production per farm over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.	347
Table A5.18: Milkfat production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.	348
Table A5.19: Milkfat production per farm over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.	349
Table A5.20: The proportion of milksolids attracting a premium and the proportion of the income from this milk for the four quantitative scenarios and the first qualitative scenario. The proportion of income is based on the return at which the NPV = 0 over 20 years.....	350
Table A5.21: A comparison of milk colour and the amount of milk that meets the colour criteria over the lactation in year 20 for scenarios 1 and 3. Both these scenarios put all selection pressure on colour, however the initial colour between the herds is different (8.0 in scenario 1 and 6.0 in scenario2).	351
Table A5.22: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 1 and 2) over 20 years. Note: stock income differences are not shown but are included in the total value. NPV over 20 years equals 0.	352

Table A5.23: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 3 and 4) over 20 years. Note: stock income differences are not shown but are included in the total value. NPV over 20 years equals 0.....	353
Table A5.24: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 1 and 2) over 20+ years. Note: stock income differences are not shown but are included in the total value. NPV over 20+ years equals 0.....	354
Table A5.25: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 3 and 4) over 20+ years. Note: stock income differences are not shown but are included in the total value. NPV over 20+ years equals 0.....	355
Table A5.26: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 1 and 2) over 10 years. Note: stock income differences are not shown but are included in the total value. NPV over 10 years equals 0.....	356
Table A5.27: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 3 and 4) over 10 years. Note: stock income differences are not shown but are included in the total value. NPV over 10 years equals 0.....	357
Table A5.28: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years under the status quo scenario.....	358
Table A5.29: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with cows tested and BB cows' milk segregated from the remaining milk.....	359
Table A5.30: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with the whole herd BB genotype from year 1.....	360
Table A5.31: The proportion of cows in herd 1 and the production per farm over the 20 years under the status quo scenario.....	361
Table A5.32: The proportion of cows in herd 1 and the production per farm over the 20 years with cows tested and BB cows' milk segregated from the remaining milk.....	362
Table A5.33: The proportion of cows in herd 1 and the production per farm over the 20 years with the whole herd BB genotype from year 1.....	363

Table A5.34: The proportion of cows in herd 1 and the production per hectare over the 20 years under the status quo scenario.....	364
Table A5.35: The proportion of cows in herd 1 and the production per hectare over the 20 years with cows tested and BB cows' milk segregated from the remaining milk.....	365
Table A5.36: The proportion of cows in herd 1 and the production per hectare over the 20 years with the whole herd BB genotype from year 1.....	366
Table A5.37: Difference in income, expenses, and nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the qualitative comparisons (Scenarios 1 and 2) over the 20 years. Note: stock income value differences are not shown but are included in the total value. NPV over 20 years equals 0.....	367
Table A5.38: Difference in income, expenses, and nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the qualitative comparisons (Scenarios 1 and 2) over 20+ years. Note: stock income value differences are not shown but are included in the total value. NPV over 20+ years equals 0.....	368
Table A5.39: Difference in income, expenses, and nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the qualitative comparisons (Scenarios 1 and 2) over 10 years. Note: stock income value differences are not shown but are included in the total value. NPV over 10 years equals 0.....	369
Table A5.40: The effect of redistributing the premium paid for the desired milk type in quantitative scenario 1 over 3 time periods at a 7% discount rate. The premium value specified is that for year 1. Distribution over the years is given in the table, relative to the year 1 value.....	370
Table A5.41: The effect of redistributing the premium paid for the desired milk type in qualitative scenario 2 over 3 time periods at a 7% discount rate. The multiplier value and dollar value specified is that for year 1. Distribution over the years is given in the table, relative to the year 1 value.....	371
Table A5.42: The difference in milk composition in year 20 between the scenarios, and the effect this has on the price received per kilogram milksolids (MS) using status quo prices. The difference in milk income is also shown, but it should be noted that this is affected by milk production as well as milk composition.....	372

List of Figures

CHAPTER ONE: Introduction and Literature Review

Figure 1.1: The s-shaped curve of technology adoption (from Rogers 1983, p. 11). 72

CHAPTER TWO: Overview of the Model

Figure 2.1: The segregated milk value-added chain. 80

Figure 2.2: Some non-economic factors impacting on the milk production on-farm. 81

Figure 2.3: Factors that affect farm profitability, particularly milk income, and milk yield and composition. 82

Figure 2.4: Model design and information flow. 83

CHAPTER THREE: Breeding for a Qualitative Trait

Figure 3.1: Proportion of BB cows over time using different selection policies (gene frequency of B = 0.684 in Year 1, i.e. BB = 0.468 in Year 1). YM = yearling mating with AI. CULL = culling on genotype. 96

Figure 3.2: Frequency of the B allele over the 20 years for the three breeding scenarios (gene frequency of B = 0.684 in Year 1, No yearling AI). 97

Figure 3.3: Frequency of the B allele over the 20 years for the three breeding scenarios (gene frequency of B = 0.684 in Year 1, Yearling AI). 98

Figure 3.4: Average protein production per cow per herd per year over 20 years (gene frequency of B = 0.684 in Year 1). 99

Figure 3.5: Average protein production per cow by the different genotypes over the 20 years (gene frequency of B = 0.684 in Year 1). 100

Figure 3.6: Frequency of the B allele over 20 years at initial frequencies of 0.1, 0.3, 0.5, and 0.7 (testing for genotype, no yearling AB). 102

Figure 3.7: Proportion of BB cows by breed over time (testing scenario). 104

Figure 3.8: Proportion of BB cows by breed over time (no testing scenario). 105

CHAPTER FOUR: Transport Logistics

Figure 4.1: Average milk collection cost for the North Island farm set at peak lactation, with two types of milk able to be collected per run for 0, 25%, 50% and 100% of farms changing to type 2 milk. 129

Figure 4.2: Cost of status quo (equals type 1) and type 2 milk collection for the North Island farm set at peak lactation, with two types of milk able to be collected per run for 25%, 50% and 100% of farms changing to type 2 milk. 129

Figure 4.3: Average cost of milk collection for the North Island farm set in late lactation, with two types of milk able to be collected per run for 0%, 25% and 50% of farms changing to type 2 milk.	130
Figure 4.4: Cost of status quo (equals type 1) and type 2 milk collection for the North Island farm set in late lactation, with two types of milk able to be collected per run for 25% and 50% of farms changing to type 2 milk.....	130
Figure 4.5: Average cost of milk collection for the South Island farm set at peak lactation, with two types of milk able to be collected per run for 0%, 25% and 50% of farms changing to type 2 milk.	131
Figure 4.6: Cost of status quo (equals type 1) and type 2 milk collection for the South Island farm set at peak lactation, with two types of milk able to be collected per run for 25% and 50% of farms changing to type 2 milk.....	131
Figure 4.7: Average cost of milk collection for the North Island farm set at peak lactation, with two types of milk able to be collected per run for 0, 25%, 50% and 100% of farms changing to type 2 milk.	132
Figure 4.8: Average cost of milk collection for the North Island farm set in late lactation, with two types of milk able to be collected per run for 0, 25% and 50% of farms changing to type 2 milk.	132
Figure 4.9: Average cost of milk collection for the South Island farm set at peak lactation, with two types of milk able to be collected per run for 25%, and 50% of farms changing to type 2 milk.	133
Figure 4.10: Average milk collection cost, number of tanker runs and volume of milk collected for the North Island farm set at peak lactation, with two types of milk collected per run and 25% of farms changing to type 2 milk.	134
Figure 4.11: Average milk collection cost, number of tanker runs and volume of milk collected for the North Island farm set at peak lactation, with two types of milk collected per run and 50% of farms changing to type 2 milk.	134
Figure 4.12: Average cost of milk collection for the South Island farm set at peak lactation, with both (2T) or only one (1T) type of milk able to be collected per run, and 25% and 50% of farms changing to type 2 milk.	145
Figure 4.13: Average cost of milk collection for the North Island farm set at peak lactation, with two types of milk able to be collected per run, and milk collected daily (D) or every second day (2D), for 25%, and 50% of farms changing to type 2 milk.....	145

CHAPTER FIVE: Description of the Models

Figure 5.1: Average of selected records, i_p , from a standardised normal distribution (average = 0, and variance of 1) when a fraction p of the best records are selected (from Van Vleck <i>et al.</i> 1987 p. 298).....	154
Figure 5.2: Regression line showing the relationship between T1 and T2.....	156
Figure 5.3: Change in fat colour, β -carotene yield and fat yield over lactation for a Friesian cow.....	165
Figure 5.4: Change in fat colour, β -carotene yield and fat yield over lactation for a Jersey cow.....	165

CHAPTER SIX: Model Results

Figure 6.1: Net present value at a range of milkfat premium values for three scenarios (1, 2 or 3) over 20 (20), 20+ (20+) and 10 (10) years at a discount rate of 7%.....	197
Figure 6.2: The percentage of milk attracting a premium over the 20 years for 3 quantitative scenarios and the first qualitative scenario.	198
Figure 6.3: Net present value at a range of multiplier values for the two scenarios (1 or 2) over 20 (20), 20+ (20+) and 10 (10) years at a discount rate of 7%.....	205
Figure 6.4: The cumulative present values over the 20 years for all scenarios, including the two redistributed premium scenarios, at the premium for each of these where NPV=0.....	210
Figure 6.5: The cumulative present values over the 20 years for qualitative scenarios 1 and 2, and qualitative scenario 2 with the premium redistributed so years 2 to 20 are 0.90 and 0.95 of the year 1 value. The premium is for milkfat and protein is 6.1% of the status quo value.	211

CHAPTER ONE

INTRODUCTION

New Zealand has traditionally exported bulk commodity dairy products. However, to remain competitive in the international market there has been a steady move towards producing more branded and value-added dairy products aimed at niche markets; products that require greater emphasis on meeting customer specifications for quality and consistency. Product type and quality, the amount of product able to be produced, and the timing of manufacture for some products are all affected by milk composition and quality. Milk varies in its composition and consistency, and thus its suitability for manufacturing various dairy products. Milk composition and quality affects product values and therefore dairy industry returns, because of its influence on the product mix made, and the timing and quality of the products produced.

Increasingly, dairy processing companies are recognising that natural variation exists between cows and herds in the many proteins, fats, carbohydrates, vitamins and micro-elements that constitute milk. An opportunity exists to take advantage of this natural variation by ensuring milk from different cows, herds or regions is kept separate until processing can commence at the factory. Segregating milk into “lots” based on a milk characteristic that influences milk quality provides the opportunity to generate high value products with specific characteristics and may reduce the need to standardise bulk milk before processing at the factory.

Cows with specialist characteristics could be aggregated onto particular farms. Farmers would then be able to further modify milk characteristics by management, feeding and selection. The majority of past research has been on milk yield, milkfat and protein production. Selection of cows based on a particular milk trait is likely to affect other milk characteristics through correlations between traits. The genetic and environmental (e.g. nutrition, cow age, stage of lactation) effects on milk characteristics other than milk yield, milkfat and protein need to be better defined. Opportunities also exist for the use of new genetic technologies. A further implication is that some cows may be traded on their ability to produce milk of a particular type, rather than solely on breeding worth. Cows will need to be herd tested for the desired milk components, and selection may be based on specialised

breeding indices. Sellers of semen, such as the Livestock Improvement Corporation (LIC), will also need to provide information on sires relating to these desired milk characteristics.

Farmers will require a financial incentive before they supply dairy companies with segregated milk. Extra on-farm costs may be incurred in the production of specialised milk e.g. extra milk testing, differential feeding. Genetic selection on specialised milk traits may result in slower improvement in traits such as protein and fat yield, and in the long term, payout made on a standard payment basis (milkfat and protein less milk yield) may be lower than it would otherwise have been. Dairy processing companies, however, will be unable to determine what premium is feasible until they know the increased value of the product or the decreased processing cost, and the extra costs associated with specialised milk production. Milk segregation may incur greater transport and processing costs because of the need for milk tanker re-routing and perhaps more milk storage facilities at the factory to keep “lots” of milk separate. Intensity of segregation (between herds, or between cows within herds) will affect costs associated with segregation and the magnitude of differences between lots, and there will be an optimal point of segregation at which maximum economic benefit is derived.

This study will consider the implications of milk separation based on two milk trait examples, largely from an on-farm perspective. Volumes and average levels for specified milk characteristics for the different lots of milk due to biological variation will be defined, and the management and financial implications associated with milk segregation will be considered. A model quantifying the biological and economic effects of dairy segregation will be developed. This will indicate the change in the volumes of differentiated milk produced over time at specified “cut-off” levels of segregation, and the price premium that would need to be paid for segregation to be financially beneficial to the farmer. Processing and market implications are discussed but are not quantified.

An outline of the thesis is presented in the next section of this chapter followed by a review of the literature relevant to this study. Each literature review section concludes with a brief summary of its relevance to this study including any issues not directly discussed in the literature that may also be pertinent to the study. These ideas may have arisen as a result of reading the literature and associated publications, including the farming press, and from discussions with industry people. When combined, this information provides the context and rationale for the purpose and scope of the study.

PURPOSE AND SCOPE OF THE STUDY

AIM AND OBJECTIVES

The New Zealand dairy industry is moving away from the production of commodity-based production and processing to one where product specification drives the industry. The next step is to produce much more tightly defined products based on specialised milk production systems. The purpose of this study was to explore issues relating to milk segregation on dairy farms based on milk composition. This study will consider possible ways of manipulating milk composition on-farm, and the extra returns required to make this economically viable from a farmer's perspective.

The objectives are to:

1. identify factors that affect milk composition and ways these could be manipulated;
2. develop a simulation model for milk transportation and use this to identify the extra transport costs associated with milk segregation;
3. develop a dynamic simulation model incorporating the effects of breeding, feeding, stage of lactation and management to calculate the break-even premium required by a dairy farmer for adoption of a milk segregation policy to be economically viable;
4. use this model to determine the break-even premium required for a number of scenarios. A qualitative breeding trait (milk from B β -lactoglobulin cows) and a quantitative breeding trait ("lighter" coloured milk) are considered.
5. identify other issues that will be important in the implementation of milk segregation policies.

OUTLINE OF THE THESIS

A context for this study will be provided from literature reviewed later in this chapter. Milk components and the variation in milk composition will be described. The reasons why milk composition might be altered or different milks segregated will be discussed, along with factors that might affect milk composition and ways of manipulating these. The New Zealand dairy industry structure and payment system will be outlined, and value chain concepts introduced. Agricultural systems and systems modelling will be considered. Technology adoption and risk aspects, which have implications in the uptake of new systems and technologies, will be reviewed. An overview of the model developed will be provided in Chapter Two.

The qualitative breeding model is described in Chapter Three. Segregation of milk from B β -lactoglobulin cows is given as an example. Outputs are presented (proportion of β -lactoglobulin cows in the herd, and changes in the quantities of the milk components over time). The effect of different management and breeding techniques on these changes are presented and discussed.

The transport model is described in Chapter Four, and the results and discussion related to this are presented. The extra cost of milk transport associated with milk segregation is calculated. Inputs from Chapter Three are used in this model to describe milk flows over time.

The quantitative breeding model, the cow requirement and feeding models, and the milk income and economic models are described in Chapter Five. Model input parameters are specified. The quantitative breeding model uses milk colour as an example.

The model outputs originating from six different breeding scenarios (four quantitative and two qualitative) are presented in Chapter Six. Changes in production and stocking rate over time, the premium required for the milk segregation policies to be economic for a farmer, and sensitivity analysis results are presented.

The results, issues that relate to the implementation or success of a milk segregation policy, and the modelling method used are discussed in Chapter Seven. Finally, the results and conclusions from this study are summarised in Chapter Eight, and recommendations for future research are made.

LITERATURE REVIEW

1.1 MILK COMPOSITION

Milk is secreted by mammals primarily to provide the complete nutritional requirements of the neonate of the species (Fox and Flynn 1992), although there is growing evidence that milk also contains a range of milk components, such as bioactives, which have specific physiological roles (Kennelly and Glimm 1998). There are over 4000 species of mammals and the milk of each species is unique, varying in its milk components and their relative concentrations. As mankind evolved he domesticated many species (including cows, sheep, goats, buffalo, horses, reindeer, yak), and in time harvested their milk for his own requirements. Total world milk production is 560×10^6 tonnes per annum. Of this, 85% is bovine, 11% is buffalo, 2% is from sheep, 2% from goats and the remainder from camels, mares, reindeer and yaks (Fox and Guinee 2000). In New Zealand dairy products are primarily manufactured from bovine milk, and unless specified otherwise, this discussion will relate to bovine milk.

1.1.1 Composition of milk

Milk consists of over 2000 components, yet in the past only fat (4.6%), protein (3.6%), lactose (4.5%), vitamins and minerals (0.3%), and water (87%) have been considered to any great extent (Mackle and Bryant 1996; Ryan 1996). This has been reflected in the payment system which was traditionally based on milkfat, and in more recent years has included protein and milk yield as well. The importance of milk composition and quality in producing high quality products, and the potential to use the variability in milk to produce different products, has led to increased interest in the properties of milk attributed by the various milk components (Fenwick and Marshall 1991; Hobman 1992; Kolver and Bryant 1992; Mackle and Bryant 1995; Ryan 1996).

The main components found in cows' milk are listed in Table 1.1. Milk components are synthesised in the udder (lactose, most casein proteins, α -lactalbumin, β -lactoglobulin, short and medium chain fatty acids), secreted from the blood (serum albumin and immunoglobulins, medium chain and long chain fatty acids, vitamins, minerals, hormones and somatic cells) or derived from the breakdown of other components either in the udder or after milk removal (γ -casein and protease peptones from β -casein breakdown in the udder,

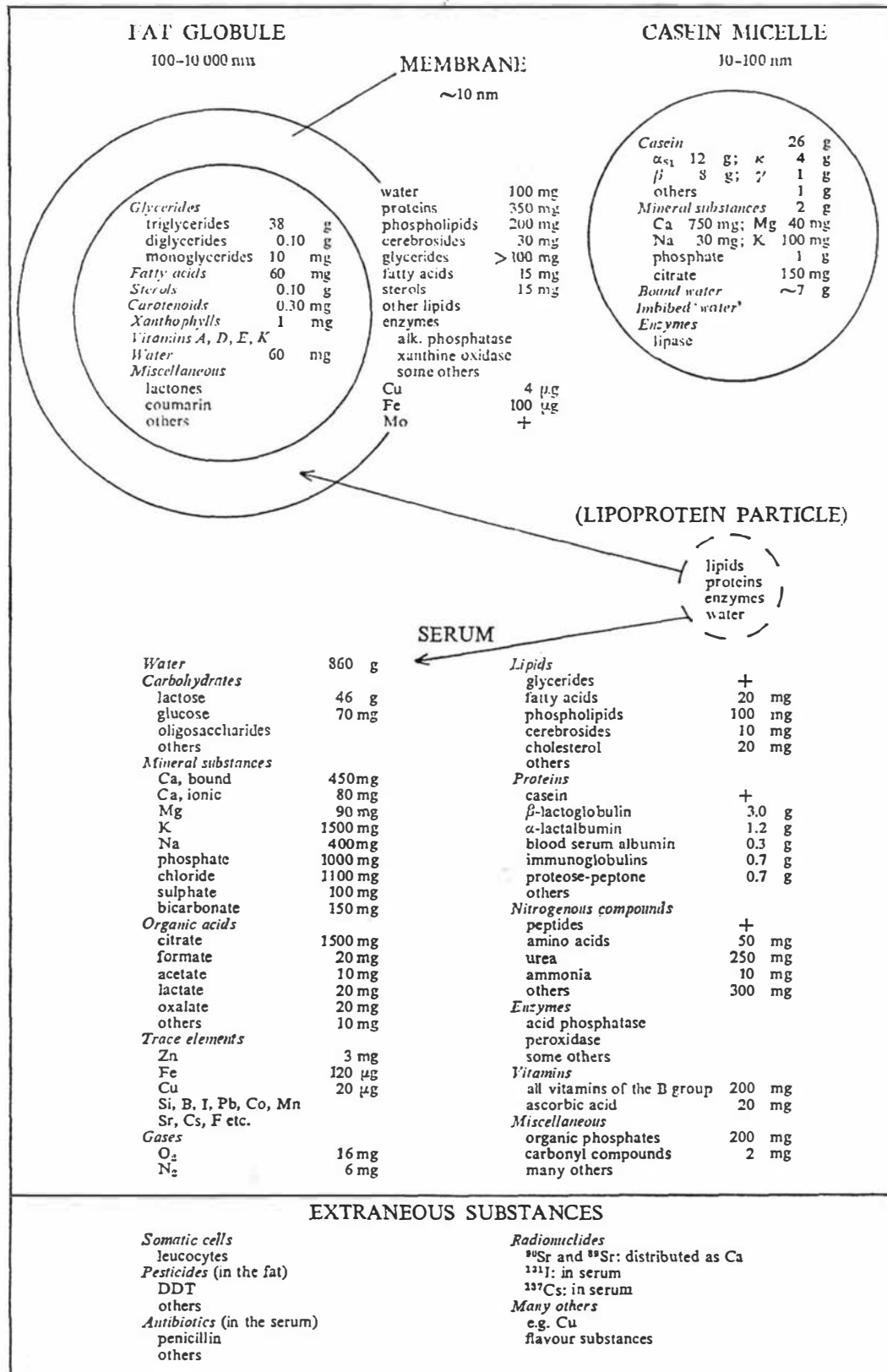
free fatty acids from fat damage during and after milking) (Mackle and Bryant 1995; Mackle and Bryant 1996).

1.1.1.1 Fat

Bovine milk contains 3.5% to 5.0% fat, with most found in emulsified globules coated with a membrane derived from a secretory cell in the udder (Jensen *et al.* 1991). These globules range in size from 0.1 to 20 μm , with 90% of the fat found in globules of around 4 μm (Jensen *et al.* 1991; Fox and Guinee 2000). About 98% of the lipid (i.e. fat) is triglycerides, which have a glycerol backbone with three fatty acids attached (Thomas and Rowney 1996; German *et al.* 1997). Milkfat is one of the most complex fats containing more than 400 different fatty acids with carbon numbers ranging from C_4 to C_{20} (Jensen *et al.* 1991; Banks 1991; Thomas and Rowney 1996). There are about ten major fatty acids. The composition and properties of milkfat have been reviewed by Mulder and Walstra (1974), Walstra and Jenness (1984), Jensen *et al.* (1991), Rajah and Burgess (1991), Goff and Hill (1993), Fox (1995), German *et al.* (1997) and Fox and Guinee (2000). The functional (crystallisation, plasticity and melting properties) and nutritional properties of milkfat are largely determined by the fatty acid composition, the position of the fatty acids on the glycerides and the polymorphic forms of the fat crystals (Thomas and Rowney 1996; German *et al.* 1997).

Phospholipids, found in the membrane, are about 0.5 to 1% of total lipids, and have an important role to play in maintaining the stability of the milk emulsion (Jensen *et al.* 1991). The membrane also protects the milkfat from lipolysis (Goff and Hill 1993; Fox and Guinee 2000). Sterols (mainly cholesterol), primarily found in the fat globule, are 0.2% to 0.5% of total lipids (Walstra and Jenness 1984; Jensen *et al.* 1991). The cholesterol content of milk has been measured at 33 mg/dl (Bernier 1993; cited German *et al.* 1997), and in amounts ranging from 10 to 20 mg/dl with the quantities related to the fat content (Jensen *et al.* 1990; cited by Jensen *et al.* 1991). Milkfat also contains a number of components that contribute to flavour and colour, most notably carotene (Knight and Waghorn 1993), as well as fat soluble enzymes and vitamins.

Table 1.1: Components of cows' milk per kilogram of milk (from Mulder and Walstra 1974, p. 21).



The spreadability and plasticity of milkfat are important characteristics, particularly in the production of butter. These are determined by the melting point and crystallisation properties of the milkfat. Spreadability is accounted for physically by the presence of liquid oil within the three dimensional lattice structure of crystallised and annealed solid fat (German *et al.* 1997). Milkfat does not have a specific melting point, but melts over a range between -40°C and 40°C , and between these temperatures is a mixture of solid fat and liquid oil (Campbell and Marshall 1975; Baer 1991; German *et al.* 1997). Short chain and unsaturated fatty acids lower the melting temperature of milkfat; long chain and saturated fatty acids increase it.

Triglycerides with long chain, fully saturated fatty acids at all three positions (approximately 14% of triglycerides), are responsible for the crystallisation and many of the plastic functions of milkfat (German *et al.* 1997). A high proportion of these triglycerides will give a brittle, unspreadable milkfat; a low proportion will reduce the plasticity of milkfat. Californian butters are high in C18:1 and low in C16:0 fatty acids, and on this basis could be expected to be particularly soft. They are, however, solid and poorly spreadable, and this is attributed to the unusually high proportion of highly saturated, long chain triglycerides (German *et al.* 1997). Triglycerides are polymorphic, and may pack together differently when they crystallise, depending on the rotation of the fatty acids on the glycerol. The crystals can therefore have different densities and melting points.

Processing techniques have been developed which can affect the properties of milkfat e.g. heating and cooling, homogenisation, and interesterification (Mulder and Walstra 1974; Walstra and Jenness 1984; Rajah and Burgess 1991; Goff and Hill 1993; Fox 1995).

1.1.1.2 Protein

Milk contains 3.0% to 4.8% protein (Holmes *et al.* 1984). Milk proteins are produced in the udder, with the exception of serum albumin and immunoglobulins which come from the blood. Approximately 80% of proteins are in the casein fraction and 20% in the whey fraction. A small proportion (1.2%) is included in the milk fat globule membranes (Walstra and Jenness 1984). Nineteen amino acids are available from milk protein, including all the essential amino acids. Tryptophan and lysine are plentiful, whereas sulphur-containing cystine and methionine are at less than optimal concentrations for human nutrition (Campbell and Marshall 1975; Hambraeus 1992; O'Connor *et al.* 1997). The whey proteins are of higher nutritional quality (for humans) than the caseins (Hambraeus 1992). Fox (1992) provides a comprehensive review of milk proteins. Detailed descriptions of the structure and properties

of milk proteins can also be found in Campbell and Marshall (1975), Walstra and Jenness (1984), Goff and Hill (1993) and Fox and Guinee (2000). Various aspects of milk proteins are discussed in Welch *et al.* (1997).

Caseins are milk specific, phosphate-containing proteins that precipitate out at an acidity of pH 4.6. They are found in casein micelles which are spherical particles containing caseins (92%) in complex with inorganic salts (8%), principally calcium phosphate (Swaisgood 1992). The majority of micelles are approximately 15 nm, with the size distribution continuing up to 600 nm (Rollema 1992). The average volume diameter of a casein micelle is about 100 nm (Goff and Hill 1993). There are between 12 and 10,000 casein monomers in each micelle. The casein particles are voluminous, holding large amounts of water as well as casein (Walstra and Jenness 1984). The principal caseins are α_{s1} -casein, α_{s2} -casein, β -casein and κ -casein (FitzGerald 1997). κ -casein is important as it stabilises the other caseinates in the presence of calcium. The breakdown of β -casein also produces γ -casein, and proteose peptones (found in whey).

The remaining proteins are found in the whey, which is the serum remaining, after the caseinates have been precipitated out of the skim milk. Whey proteins have a radius of between 1.8 and 6 nm (de Wit 1998). The major whey proteins are β -lactoglobulin, α -lactalbumin, bovine serum albumin and immunoglobulins (Table 1.1). Whereas the function of casein is primarily nutritional, whey proteins have biological functions or act as carriers of minerals or vitamins e.g. iron (de Wit 1998).

β -lactoglobulin is the dominant whey protein in cows' milk, although it is not found in the milk of all mammals, including human beings. Its role or function is not entirely understood (Hambling *et al.* 1992; Hambraeus 1992; Hill *et al.* 1997; de Wit 1998). β -lactoglobulin may be involved in the transport of retinol and fatty acids within the gut, and its resistance to peptic hydrolysis would be important in this function (Fox and Flynn 1992). It has also been suggested by Thompson and Farrell (1974; cited by Hambling *et al.* 1992) that it may have a regulatory role in phosphorus metabolism in the mammary gland. It has a key role in determining the physical and chemical properties of milk and many milk products (Hill *et al.* 1997), and may be partly responsible for cows' milk intolerance in some people (Hambraeus 1992).

α -lactalbumin, at less than 4% total protein is a minor constituent of milk, however it does have an important biochemical and physiological role in milk production (Wilkins 1991; Brew and Grobler 1992; Hambraeus 1992; de Wit 1998). It has a biological role in the biosynthesis of lactose (de Wit 1998), forming a transient complex with galactosyltransferase, an enzyme which catalyses the production of lactose from glucose and galactose (Wilkins 1991; Brew and Grobler 1992; Holsinger 1997). Consequently, there is a positive relationship between the content of lactose and α -lactalbumin in mammals, with the exception of human milk (Hambraeus 1992). Lactose is important in maintaining the osmolarity of milk at a similar level to that of blood: as the yield of lactose increases, the milk yield increases. Fat and protein concentrations have a negative correlation with lactose and α -lactalbumin concentrations. α -lactalbumin also has a metal-binding site, which normally binds calcium but also strongly binds manganese, zinc, cobalt, copper and aluminum (Hambraeus 1992; Holsinger 1997). It has been suggested that α -lactalbumin has a key role in the biosynthesis of casein (Hiraoka *et al.* 1980; Lonnerdal and Glazier 1985; cited by Hambraeus 1992). α -lactalbumin is also highly nutritious and easily digested by humans (Hambraeus 1992), unfolding and becoming susceptible to digestion at a pH lower than 4 (de Wit 1998).

Bovine serum albumin in milk is identical to that in blood, and is probably transported into milk via leaky blood vessel junctions in the mammary gland (Walstra and Jenness 1984; de Wit 1998). It appears to be a carrier of small molecules and insoluble free fatty acids in the blood. It is only found in small quantities in milk, and little is known of its influence on milk and milk products.

Most immunoglobulins are derived from the blood, with the dominant immunoglobulin in bovine milk, IgG, being the same as the IgG found in the blood of almost all mammalian species (Larson 1992; McFadden *et al.* 1997; de Wit 1998). Immunoglobulins are produced to provide passive immunity to the offspring, and their concentration is high immediately after birth (colostrum 30 - 150 g/l), tending to decrease with advancing lactation (mature milk 0.2 - 1.4 g/l) (Holmes *et al.* 1984; Walstra and Jenness 1984). About 75.5% of the immunoglobulin in milk is IgG, with IgA and IgM being 18.0% and 6.5%, respectively (Walstra and Jenness 1984). The cold agglutination of milkfat in cow's milk is associated with the IgM immunoglobulins (Walstra and Jenness 1984; de Wit 1998).

Other whey proteins include enzymes, proteose peptones, vitamin and hormone-binding proteins and various bioactive proteins (Fox and Flynn 1992; Hambraeus 1992; Regester *et al.* 1997; de Wit 1998; Fox and Guinee 2000). Bioactive proteins in milk with commercial applications include lactoferrin, lactoperoxidase, lysozyme and growth factors (Regester *et al.* 1997; de Wit 1998). Lactoferrin is an iron-binding protein which also has antibacterial properties. Transferrin is another iron-binding protein found in milk (Walstra and Jenness 1984). Lactoperoxidase and lysozyme are natural antimicrobial whey proteins.

The caseins, α -lactalbumin, and β -lactoglobulin variants all exhibit genetic polymorphism, controlled by co-dominant alleles (Ng-Kwai-Hang and Grosclaude 1992; Hill *et al.* 1997; IDF 1997). The main genetic variants are shown in Table 1.2. Most variant forms differ in the amino acid at one or two positions in the primary sequence of the protein. There is close linkage between the genes encoding for the caseins. The simple inheritance of these milk proteins and the development of techniques to type these protein genes at the DNA level has led to interest in using these as marker genes for milk production and composition traits. The different variants, their effects and possible manipulation will be discussed later.

Table 1.2: Milk protein genetic variants (from Ng-Kwai-Hang and Grosclaude 1992).

Milk Protein	Genetic Variants ¹
α_{s1} -casein	A,B,C,D,E
α_{s2} -casein	A,B,C,D,
β -casein	A¹,A²,A³,B,C,D,E
κ -casein	A,B,C,E
α -lactalbumin	A,B,C
β -lactoglobulin	A,B,C,D,E,F,G

¹ Common variants in *Bos taurus* are shown in bold.

1.1.1.3 Carbohydrates

Lactose is the primary carbohydrate found in milk. Milk is the sole source of lactose for all practical purposes (Holsinger 1997). Bovine milk contains 4.8% to 5.2% lactose, with lactose comprising about 52% of the solids-not-fat and 70% of the whey solids in milk (Goff and Hill 1993). Lactose is synthesised in the mammary gland, and is a disaccharide of glucose and galactose. It has two crystalline forms, α and β which exist in equilibrium. The α form is relatively insoluble and can cause problems in dairy products such as ice cream and condensed milk (Goff and Hill 1993).

As previously discussed, α -lactalbumin has an important role in the synthesis of lactose. Lactose, along with some salts (K^+ , Na^+ and Cl^-), affects the osmotic pressure of milk, with water being drawn in to dilute the sugar (Holsinger 1997). The role of lactose in maintaining osmolarity makes it difficult to alter the concentration of lactose in milk. As lactation progresses, the concentration of salts increases and lactose decreases (Goff and Hill 1993). Mastitic milk and colostrum are high in salts and low in lactose (Holsinger 1997). A high level of lactose production relative to fat and protein will give a high milk yield with a low concentration of fat and protein (Wilkins 1991; Davis S.R. 1997). Trials with α -lactalbumin deficient mice (knockouts) found they produced reduced volumes of a highly viscous, lactose deficient milk, rich in fat and protein, which was unable to be expressed from the mammary gland (Holsinger 1997; Karatzas and Turner 1997).

Seventy percent of the glucose entering the blood system is used for lactose production, and some diets, particularly pasture diets, may be incapable of providing sufficient quantities of glucogenic precursors, resulting in limited milk output (Davis S.R.1997). Small amounts of other carbohydrates are found in milk, free or bound to phosphate, lipids and proteins. Other carbohydrates in milk include glucose (1 mg/ml), galactose (1 mg/ml) and oligosaccharides (0.1 mg/ml) (Goff and Hill 1993; Holsinger 1997).

1.1.1.4 Minerals, Vitamins and Other

All twenty-two minerals considered essential for human nutrition are present in cows milk, with cows' milk containing higher levels of minerals than human milk (7.3 g/l versus 2.0 g/l). This is mainly due to greater levels of sodium, potassium, chloride, calcium, phosphorus and magnesium (Goff and Hill 1993; Flynn and Cashman 1997). Flynn and Cashman (1997) provide a comprehensive review of the nutritional aspects of bovine and human milks. Cows' milk is considered a good source of minerals, particularly calcium, with up to 75% of calcium requirements provided by milk and dairy products in some countries (Flynn and Cashman 1997). Absorption of minerals, such as calcium, phosphorus and zinc, from the human intestine is high, making milk a good source of minerals (Walstra and Jenness 1984). Milk and milk products are a poor source of iron. The mineral content of milk is variable and can be influenced by stage of lactation, nutritional status, environmental and genetic factors (Flynn and Cashman 1997).

Sodium, potassium and chlorine exist as free ions in milk and have a role in maintaining osmolarity. Their concentrations are negatively correlated to lactose concentration and are higher in early lactation than late lactation. Some minerals exist in colloidal state, primarily

in the casein micelle. These include two-thirds of the calcium, one-third of the magnesium, half the inorganic phosphorus and a small proportion of the citrate and concentrations of these are therefore correlated to the casein content of the milk. A third group exists as salts and concentrations are affected by the pH of the milk. This group includes diffusible calcium and magnesium, and citrate and phosphate salts (Goff and Hill 1993).

Bovine and human milk both contain all known vitamins. Vitamins in milk and milk products have been reviewed by Oste *et al.* (1997). Vitamins A, D, E and K occur in the fat globules, the remainder in the plasma of the milk (Oste *et al.* 1997). Milk is an important source of dietary vitamin A (retinol), which occurs in the milk as retinol and β -carotenes (Oste *et al.* 1997). β -carotene is responsible for the yellow colour of milkfat. Both cows and humans are able to convert β -carotenes to retinol. The rate of conversion varies between cows and breeds (Keen and Wilson 1993; Newman *et al.* 1994). Channel Island breeds (Jerseys and Guernseys) convert about 60% of β -carotenes to retinol compared to 80% for Holsteins and Ayrshires, hence the yellower milkfat of the Channel Island breeds (Campbell and Marshall 1975). The concentration of total vitamin A and carotenoids in the milk is strongly dependent on the amount of carotenoids in the feed. The vitamin A content in milk in spring or summer, when cows were fed green leafy pasture, was 1.5 to 1.6 times that of winter milk (Campbell and Marshall 1975; Oste *et al.* 1997). As the vitamin A is found in the milk fat globule, the amount of vitamin A in milk is also proportional to the amount of milkfat produced (Campbell and Marshall 1975).

Bovine milk is not an important source of the fat soluble vitamins D, E and K for humans, containing only small amounts of vitamins D and E, and only trace amounts of vitamin K (Campbell and Marshall 1975; Walstra and Jenness 1984; Oste *et al.* 1997). The amount of vitamin D is higher in summer and is related to the amount of sunlight and diet (exposure of plants to sunlight or feeding substances rich in vitamin D such as yeast). In some countries vitamin D is added to milk. The vitamin E content of milk is low and can vary throughout the season depending on feed. Winter milk concentrations of vitamin E have been found to be 15% to 35% lower than summer concentrations.

Milk also contains the water-soluble vitamins B and C (Campbell and Marshall 1975; Walstra and Jenness 1984; Oste *et al.* 1997). Milk is not an important dietary source of vitamin C, as levels are reduced during handling and storage. However, milk and dairy products are an important dietary source of the B vitamins, B₁, B₂, B₆, B₁₂, niacin, pantothenic acid, biotin and folic acid. The B-complex vitamins are synthesised by rumen

microflora in the alimentary canal and their concentrations in milk are independent of the quantity consumed in feed. Some of the B vitamins can be lost from milk through light sensitivity or heating.

B₁, niacin, and B₁₂ concentrations are independent of feed, breed, season or stage of lactation influences. The concentration of riboflavin (B₂) is usually higher in spring or summer and has also been found to vary between breeds (Oste *et al.* 1997). The concentration in milk is seasonal, being higher in spring, probably because of changes in the rumen microflora. There is no breed effect. Pantothenic acid concentration is affected by feeding, breed and season. Milk is important in providing niacin; although it only supplies a small proportion of the niacin requirements, it is high in tryptophan which humans can use to synthesise niacin.

Milk also contains other nutrients known to be essential to humans. Milk is a good source of choline, which is used in the production of lecithin and sphingomyelin. Half the choline is water soluble, the remainder is bound to phospholipids (Campbell and Marshall 1975). Taurine is necessary for the development of nervous tissue. Bovine milk contains 1-7 mg/kg of taurine compared to 40-50 mg/kg in human milk and there is evidence that some milk formulae have insufficient taurine (Walstra and Jenness 1984). Citrates form a stable ion with calcium and their concentrations are correlated. Citrates are produced from glucose and are part of the fatty acid synthesis chain. When high concentrate diets are fed citrates can be depressed, contributing to low-fat syndrome (Walstra and Jenness 1984). The citrate content of milk declines slightly over lactation. The stability of concentrated skim milk, and calcium and citrate levels are also highly correlated (Hettinga 1989).

1.1.2 Why alter milk composition?

Milk was originally regarded as an entire product, but is increasingly being seen as a collection of components (Gibson 1989). Originally, most New Zealand milk was made into butter (with skim milk fed to pigs) or cheese, and payment was made on milkfat. In the 1930's it was recognised that the protein component used in cheese production was also valuable, and it would be more equitable to pay for milk used in cheese-making on a protein as well as milkfat basis. However, a lack of technology to measure protein quickly and reliably made this impractical (Marshall 1989a). In the 1980's milkfat, protein, milk yield and lactose were all being considered as separate milk components with different values, and a payment system was developed that included the first three components (A+B-C). Lactose is ignored as having no net value (about half the lactose produced has an economic value while the remainder is dumped at a cost) (AEU 1997). More recently, minor milk components have

been recognised as having potential, or are being, used to add value to dairy products e.g. various caseins and whey proteins, lactoferrin, immunoglobulins, sphingiolipids and conjugated linoleic acid (CLA) (Kennelly and Glimm 1998; Fox and Guinee 2000).

The economic value of the various milk components is dependent on the amount used in the production of the various milk products, and the demand for and value of those products (Larking 1989). Greater consumer awareness of nutritional and health issues, and lifestyle changes, have led to increasing demand for non-fat products and an associated decline in demand for fats in recent years (Gibson 1989, 2000; Hettinga 1989; White 2000). The type and range of dairy products produced has also increased and will continue to do so (Hettinga 1989; White 2000). Consequently, the economic value of the protein component in milk has increased relative to the value of the milkfat component, with the current value of protein being about three times that of the milkfat component (Macmillan 1990; Moss 2001, *pers. comm.*). The casein component of the protein fraction is more valuable to the industry than the whey component, although this is not yet reflected in most payments to dairy farmers in New Zealand (Anon. 1998a). The dairy industry would benefit from changing the composition of milk to better meet the requirements for the various milk components. The demand for, and therefore the economic value of, the various milk components to dairy processing factories, companies or even countries may vary, depending on the product mix produced or required by the market (Gibson 1989). This is illustrated by the differences found in the supply and demand for the protein, milkfat and lactose components of milk in the British, Canadian and USA markets (Gibson 1989). Altering milk composition would be beneficial in all cases, but the optimum composition would differ for the markets. A further challenge to altering milk composition lies in predicting the future demand for the various milk components (Hettinga 1989).

The New Zealand dairy industry is moving away from the production of bulk commodity dairy products towards increasing the production of value-added dairy products such as branded products, selective food ingredients and food servicing products (Ryan 1996; Larsen 1997). The composition, yield and quality of milk products are dependent on the composition of the milk used in processing (Mackle and Bryant 1996). The highly automated production process, and the customer demand for products with consistent composition and quality requires good quality milk with consistency in processing properties (Fox and Guinee 2000). Altering the composition of the raw milk to improve the quality, consistency or yield of the products produced, therefore better facilitating the production of higher value products is likely to increase dairy industry returns.

Some minor components of milk, often previously unidentified or disregarded, are now being recognised as useful or desirable for health, medical, pharmaceutical or cosmetic reasons. These components may be valuable on their own e.g. for use in pharmaceuticals and cosmetics (Regester *et al.* 1997; Anon. 1998b) or their presence in a product may increase that product's value e.g. health benefits of immune milk, CLA as a cancer preventative (Parodi 1994, 1999; McFadden *et al.* 1997; Regester *et al.* 1997; Anon. 1998c). Manipulating milk composition to increase the concentration of these valuable components, either for extraction, or for the production of high value products could increase returns to the dairy industry. Similarly, the alteration of milk composition to more closely resemble that of human milk for the production of infant formulas, or to eliminate or reduce milk allergies and intolerances (Kuwata *et al.* 1997; Vilotte *et al.* 1997; de Wit 1998), is likely to either add value to the end product or reduce processing costs associated with adapting the product during manufacture to meet specifications.

In the past it was believed that processing costs were a small proportion of the total value of milk sales (approximately 20% of the free on board value), and there was little to be gained by manipulating milk on-farm as it would be cheaper and easier to manipulate milk during processing (Thomson 1993). However, 1989 NZDB statistics showed that the collection and processing costs of milk were 43% of the production and processing costs for dairy products in New Zealand, compared to 55% for farm costs (Thomson 1993). If the return on investment to the farmer was excluded these costs would be similar. These results suggest that there may be opportunities to solve manufacturing and marketing problems for dairy products by manipulating milk composition on-farm rather than during processing. It has been suggested that manipulation of milk composition other than for fat, protein or milk yield may be best left to processors rather than attempted at farm level (Gibson 1989, 1991; Hettinga 1989; Thomson 1993). However, these opinions are based on a whole industry perspective. The possibility of manipulating the milk composition in select herds to provide milk suited to a particular site for the production of a particular product was not considered.

Government or international regulations often determine the standards for dairy products. Specifications governing the amount of modification permitted during processing to obtain a final product with the desired characteristics can be stringent (Hettinga 1989). Altering the composition of raw milk used in processing to produce a more functional, higher value end product, which still meets the specifications for that dairy product would be advantageous to the dairy industry. A current example of this is the classification of spreadable butter

produced from the lower melting point fatty acid components of milkfat, as butter (Hobman 1992). However, the addition of components such as vegetable oils or water to increase spreadability, disallows the classification of the end product as butter.

The next sections describe the disadvantages and advantages of traits associated with the milkfat, protein and lactose components of milk, giving examples of potential manipulations.

1.1.2.1 Fat

Milkfat is a natural product that has been regarded as a valuable source of edible fat for centuries. The large percentage of short and medium chain fatty acids, and the position of the fatty acids on the triglycerides contribute to making milkfat highly absorbable by humans, as well as being responsible for the functional properties of milkfat e.g. spreadability and plasticity (German *et al.* 1997). Milkfat has an important role in the taste and texture of foods (Gurr 1991). Many of the compounds that affect milk flavour are found in the milkfat component e.g. fatty acids, ketones, lactones, aldehydes, sulphur compounds and terpenoids (Joblin and Hudson 1997).

In recent years consumer demand for products containing milkfat has decreased because of its high calorie, cholesterol and saturated fatty acid content compared to alternative products (Hettinga 1989; Fox 1995; German *et al.* 1997). Some industry analysts believe that this trend has bottomed out, whereas others believe it will continue (Kennelly and Glimm 1998). The demand for milkfat or milkfat products may increase if the fatty acid composition was altered or the cholesterol level was reduced, making them more acceptable to the consumer from a nutritional or health perspective. Some fatty acids, previously believed to be harmful, have now been found to be neutral or even beneficial e.g. C18:0 and C18:1 (Jensen *et al.* 1991; Kennelly and Glimm 1998). Palquist *et al.* (1993) found variability between cows and breeds in the fatty acid composition of milk. The amount and composition of milkfat can also be affected by stage of lactation, and by differential feeding (Sutton and Morant 1989; Palquist *et al.* 1993; Ashes *et al.* 1997). Noakes *et al.* (1996; cited by Ashes *et al.* 1997) reported that that consumer acceptance of fat-modified dairy foods containing 35% *cis*-C_{18:1} and 6% to 8% C_{18:2} was very positive. A marketing alternative may be to focus attention on “healthy” components in milkfat e.g. CLA.

Another objective for manipulating fatty acid composition could be to increase milkfat softness for the production of naturally spreadable butter as previously mentioned. The plasticity and melting properties of milkfat are also important in the production of other

products that derive their structure from milkfat, such as whipped cream and icecream (Goff and Hill 1993). However, it should be noted that a property of milkfat that may be useful in the production of one product may be a disadvantage in the production of another. For example, while a lower melting point milkfat may be beneficial for butter makers, a higher melting point milkfat is preferable for whipping cream (Banks and Muir 1984).

The yellow colour of some of NZ dairy products (e.g. butter, ghee, white cheeses, cream toppings) is seen as undesirable in some Middle Eastern and Asian markets (Keen 1986; Keen and Wilson 1993). This yellow colour is due to the carotene, found primarily in the fat globule. While processing techniques developed to remove this colour are suitable for the production of products such as anhydrous milkfat, they are unsuitable for products such as gammar cream which require white raw milk for their production. The carotene level of milk from pasture-fed cows is higher in the spring than at other times of the year. There is also variation between breeds and cows within breed in the colour of the milkfat produced (Keen and Wilson 1993). Manipulation of these factors to allow the production of “white” milk throughout the year would increase production flexibility, and enable high value, short shelf life products in this category to be manufactured throughout the year.

Some fatty acids are known to have an important part to play in the development of the neonate, particularly retina and brain structure. Others are precursors for several bioactive compounds involved in immune and blood cell functions (Regester *et al.* 1997). There has been recent interest in conjugated linoleic acid, a fatty acid which has been found to have anti-carcinogenic properties (Parodi 1994, 1999; Anon. 1998c). Dairy products are the richest source of CLA, with CLA being found at higher levels in milk from cows fed on pasture, rather than stored feeds. Countries like New Zealand and Australia where cows are predominately fed on pasture all year round are able to manufacture dairy products with higher CLA levels than their American or European counterparts, which could give them a marketing advantage.

Some bioactives components found in the lipid fraction of milkfat are of very high value. Sphingolipids, used in antifungals and cosmetics, are a recently reported example, with one kilogram being worth up to \$100,000 (Anon. 1998b). This amount is extracted from five tanker and trailer units of milk, and the separation of milk from herds with higher levels of these very valuable components could well be economic. The identification of valuable bioactives in milk with health, pharmaceutical and nutritional benefits, and the recent

development of technology to extract these from milk on a commercial basis, could lead to the future development of markets with huge earning potentials.

Complex mixtures of compounds, many of which are found in the milkfat component, are responsible for the flavour in milk. Some are produced during processing, while others are found in the raw milk and originate from feed constituents, the rumen and metabolism during milk formation (Joblin and Hudson 1997). Keen (1993), Joblin (1993), Wilson, R.D. (1993) and Joblin and Hudson (1997) suggest that diet and breed affect milk flavour, and that manipulation of milk flavour may be possible by selection of a particular breed, differential feeding and manipulation of the rumen environment.

1.1.2.2 Protein

Milk proteins possess a wide range of functional properties, are easily isolated from raw milk, provide essential amino acids, show versatility during processing, and form network structures and stabilise emulsions and foams (Robin *et al.* 1993). Functional properties of milk proteins include solubility, water-holding capacity, gelation, emulsifying, foaming properties and flavour binding (Robin *et al.* 1993; Dalgleish 1997). Reviews of milk protein functionality can be found in Mulvihill (1992), Robin *et al.* (1993), Dalgleish (1997) and Fox and Guinee (2000). Milk proteins are widely used to provide textural and other attributes to dairy products, bakery products, beverages, desserts, pastas, confectionery, meat products, convenience foods and textured products (Mulvihill 1992). Milk proteins also have industrial applications: casein has been used in the production of adhesives, fibres, paints, concrete, plastics and animal feeds (Southward 1986), and whey proteins in the production of alcohol, citric acid and single cell protein for animal feeds (Zadow 1986).

Different functional properties are required for the production of the various milk products (Dalgleish 1997) therefore the production of milks with different protein compositions could be an advantage in the manufacturing of milk products. There have been a number of studies on the effect of the different genetic variants on the functional properties of milk proteins, in particular, their renneting and heating properties, some of which will be discussed more fully later. The different variants cause changes in the properties of milk proteins, both in the milk and in food products (Dalgleish 1997). It was found that variants that are useful in processing one product can be less useful in the production of another. For example, the κ -casein B variant is good for cheese-making but leads to instability in concentrated milks (Dalgleish 1997). Therefore, the manipulation of milk protein composition would need to be targeted to a particular product, with differentiated herds supplying milk for the production of specific

products. Identification of genetic variants is already in use in a number of countries now and may become more widespread in the future as useful proteins and protein variants are identified, and the technology to identify cows with these genetic variants becomes available on a commercial and cost-effective basis (Kennelly and Glimm 1998).

Milk proteins also have nutritional, medical, pharmaceutical and cosmetic applications, and are included in diet formulas, infant formulas and drug production (Mulvihill 1992; Regester *et al.* 1997; de Wit 1998). There is interest in altering bovine milk to more closely resemble human milk for use in infant formulas (Kuwata *et al.* 1997; O'Connor *et al.* 1997; de Wit 1998). Human milk contains about a quarter of the casein in bovine milk, and about 3.5 times more whey proteins. The protein components and the amino acid balance also differ between the milks e.g. human milk contains no α -casein or β -lactoglobulin. A pharmaceutical application is the production of immune milks containing immune-induced bioactives that provide protection from specific pathogens. Immune milks, such as Stollait milk, are now being produced commercially (Dingwall 1991; Fenwick and Marshall 1991; Regester *et al.* 1997). Work continues on identifying milk proteins that are valuable from a nutritional, pharmaceutical or immunological perspective. Whey protein is nutritionally superior to casein as well as containing many of the bioactives (Paquin 1998), but currently has lower net value than casein because of its higher extraction cost. There is likely to be a greater interest in milk proteins, particularly whey proteins, in the future as these valuable proteins are identified and new technologies become commercially available to economically separate these milk proteins (Mulvihill 1992; Marshall and Fenwick 1998; Paquin 1998).

1.1.2.3 Lactose

Functional properties attributed to food products by lactose include texture, solubility, bulk and viscosity (Campbell and Marshall 1975; Goff and Hill 1993; Holsinger 1997). Lactose can alter the crystallisation behaviour of other sugars, add stability to proteins, act as a carrier for flavours and aromas, act as a free flow agent and enhance creaming of shortenings. The α -form can cause problems in foods due to its relative insolubility. It is often used as an agent for coating tablets. Lactose reacts with protein under heat in a process called the Maillard reaction (O'Brien 1997). This is an advantage in products where browning is required (e.g. salami, baked products), and can also have functional advantages e.g. can provide heat stability (Holsinger 1997; O'Brien 1997). Disadvantages of the Maillard reaction include browning in products such as milk powder and the breakdown of some essential amino acids e.g. lysine. Whey lactose is used as a substrate for industrial fermentation processes (Holsinger 1997).

The most important use of lactose in milk and dairy products is as a fermentation substrate (Campbell and Marshall 1975; Goff and Hill 1993). Lactose is broken down into glucose and galactose by lactic acid bacteria. The acidity of these naturally fermented dairy products acts as a preservative. Enzymatic hydrolysis (with the enzyme lactase) is also used to produce lactose-reduced products suitable for people with insufficient lactase. The majority of the world's population (approximately 70%) are deficient in this enzyme which breaks down lactose in the intestine, and as a result are lactose intolerant to some degree (Karatzas and Turner 1997; Vilotte *et al.* 1997). To counter this problem Karatzas and Turner (1997) suggested the use of genetic technology to reduce the amount of lactose in milk, either by the removal of α -lactalbumin, or by the overexpression of a lactase in milk. However, the first alternative is likely to lead to a reduced volume, highly viscous milk while the latter will produce more dilute milk due to increased osmotic pressure. Trials to date have not been successful (Karatzas and Turner 1997; Vilotte *et al.* 1997).

From a nutritional perspective, lactose is added to infant formulae so that its composition more closely resembles human milk (about 7% lactose). Lactose aids in mineral absorption, particularly calcium. The insolubility of lactose allows it to pass undigested to the intestines where conversion to lactic acid creates acidic conditions, encouraging the growth of natural intestinal bacteria and inhibiting the growth of pathogenic bacteria. These intestinal bacteria also produce many of the B-complex vitamins. As a result lactose is included in the production of nutraceutical foods aimed at Asian markets. (Campbell and Marshall 1975; Holsinger 1997; Mustapha *et al.* 1997)

There is interest in reducing the amount of lactose in milk in order to lower milk volumes, thereby reducing storage, transport and processing costs, enabling once a day milk without a loss in production and possibly producing a milk suitable for those who are lactose intolerant (Wilkins 1991; Davis S.R. 1997). A reduction in lactose would also reduce the animal's glucose requirement during lactation (Davis S.R. 1997). Lactose reduction is likely to be complicated by the role of lactose has in maintaining the osmolarity of milk. There are breed differences, with breeds that have a low level of lactose production relative to fat and protein producing a more concentrated milk e.g. Jerseys compared to Friesians (Davis S.R.1997) which could be exploited.

1.1.3 Factors affecting milk composition and manipulation of milk composition

Milk composition is influenced by both genetic and environmental factors, making it possible to manipulate milk composition through both breeding and management. This section will briefly discuss factors affecting milk composition, and how the farmer can manage these.

1.1.3.1 Breed

Although many dairy breeds exist worldwide, the main dairy breeds farmed in New Zealand are the Holstein-Friesian (57%), Jersey (15%), Friesian-Jersey cross (20%) and Ayrshire (1%) breeds (LIC 2000). Milk composition from cows of different breeds varies, both between, and within breed (Crabtree 1984; Nickerson 1995). Table 1.3 shows the milk composition for various breeds. Milk yield also varies between breeds with the heavier breeds e.g. Friesian producing a greater yield of less concentrated milk. The variation in milk yield between breeds is greater than the variation in milk components (Nickerson 1995). Average annual milk yields for Friesians, Jerseys and Ayrshires in New Zealand in 1999/2000 were 3803, 2791 and 3452 litres, respectively (LIC 2000).

Table 1.3: Percentage milk composition for various breeds of dairy cattle¹.

Breed	Fat	Casein	Whey protein	Protein	Lactose	Ash	Total solids
Ayrshire	3.97	2.68	0.60	3.28	4.63	0.72	12.69
Brown Swiss	3.80	2.63	0.55	3.18	4.80	0.72	12.69
Guernsey	4.58	2.88	0.61	3.49	4.78	0.75	13.69
Holstein-Friesian	3.56	2.49	0.53	3.02	4.61	0.73	11.91
Jersey	4.97	3.02	0.63	3.65	4.70	0.77	14.15

¹ Adapted from Nickerson (1995).

The minor milk components (proteins, minerals and fatty acids) also vary between breeds and these differences are shown in Jenness (1974), Beaulieu and Palmquist (1995), DePeters *et al.* (1995), Nickerson (1995), Townsend *et al.* (1997). Differences also exist between breeds in the frequencies of the different protein genetic variants (McLean *et al.* 1984; Ng-Kwai-Hang and Grosclaude 1992; Jakob 1994; Jakob and Puhan 1995; Winkelman and Wickham 1996; Ng-Kwai-Hang 1998).

There is potential to exploit these breed differences by utilising milk produced from particular breeds for production of the different milk products (Gibson 1989; Kennelly and Glimm 1998). In general, higher yielding breeds such as Friesians currently produce milk for the fresh milk market, whereas a range of breeds produce milk for processing in New Zealand (Holmes *et al.* 1984). Other opportunities exist to take advantage of breed differences. The

milk from Brown Swiss cows has a low milkfat to protein ratio, which is an advantage in cheese-making (Kennelly and Glimm 1998). This ratio is also desirable with the current trend to increase the protein level in milk relative to the level of milkfat, which is reflected by the economic values of the components (Fenwick and Marshall 1991). The differences between breeds in fatty acid composition of milk or protein fractions could also be utilised by selecting breeds with milk compositions that have superior milk processing properties or enhance the functional properties of the product e.g. spreadability, cheese yields (Gibson 1989, 1991; Kennelly and Glimm 1998). The fatty acid composition of milk from Jersey cows differs from, and tends to be harder than, that of Friesian cows (Stull and Brown 1964; Banks 1991; Palmquist and Beaulieu 1992; DePeters *et al.* 1995; MacGibbon 1996; Townsend *et al.* 1997). The higher β -carotene concentration in Jersey milk makes this milk yellower than milk from Friesian cows (Keen and Wilson 1993). Therefore, Friesian milk would have advantages over Jersey milk for the manufacture of products for colour-sensitive markets. Garrick and Lopez-Villalobos (2000) developed a model to consider the effect of breed choice on the value of the milk. Milk composition (milk yield, protein, milkfat and lactose) differed between breeds, and a number of standard product mixes were considered. The superiority of the breed differed for the various product mixes.

Within breed variation is greatest in milkfat, followed by solids-not-fat, protein and lactose (Jenness 1974; Nickerson 1995). The range in variation within breed can vary according to location, sampling time (within and across years) and herd management (Crabtree 1984; Nickerson 1995). These between cow differences are useful in modifying milk composition by selection and this will be discussed in the next section.

1.1.3.2 Selection

Past selection in the dairy industry has traditionally been on milk yield, and milkfat and protein production or concentration. Although changes associated with quantitative genetic approaches (selection) are small (usually less than 2%), gains are cumulative. Quantitative genetic approaches aim at long term improvement in a population, but are not practical short term approaches (Kennelly and Glimm 1998; Gibson 1991, 2000). Modern breeding programmes have led to considerable increases in the production of these milk components through the use of herd testing, central record keeping, artificial insemination (AI) and genetic evaluation using selection index methodology (Gibson 1989, 1991, 2000; Kennelly and Glimm 1998). In New Zealand the top bulls are identified and progeny tested by LIC (Livestock Improvement Corporation) and other companies, and semen is made available to farmers. Over 80% of the 3.3 million cows were herd tested and mated by AI to less than 400

bulls in 1999/2000 (LIC 2000). This very high selection intensity farm has led to rapid progress in the production traits. Herd testing and cow records to assist farmers with selection decisions contributes slightly to genetic gain although most culling is for reasons other than genetic worth.

The price the farmer receives for milk provides the main economic incentive for genetic change (Gibson 1989). Milk payment systems vary throughout the world with payment made variously on one or more milk component yields or concentrations, with these components being given economic weightings (Gibson 2000). In New Zealand payment was originally made on milkfat production only and this was altered to include protein production and milk yield in 1990 (Stewart 1989). Payment is made on casein instead of protein at the Kaikoura cheese factory (Boland *et al.* 2000).

The potential for the greatest gains occurs in traits where breeding values are estimated with greater accuracy (i.e. high heritabilities and more information), greater variability (measured in standard deviations), shorter generation intervals and high selection intensity (Van Vleck *et al.* 1987; Bourdon 1997; Smith 1998). Rates of genetic change are in the range of 0.5% to 3.0% per year (Gibson 1991; Smith 1998). Selection is usually based on an index, which is made up of breeding values for a number of traits, each weighted by an economic value. Economic weightings reflect long term expectations rather than current markets and are therefore likely to differ from current milk prices (Gibson 1989, 2000; LIC 2000).

The Livestock Improvement Council in New Zealand changed their selection objective to include protein and milk yield, as well as milkfat in 1987. Economic weightings for milkfat and protein were the same in 1987 (Wickham 1989). However, the weighting for protein is now three times that of milkfat (LIC 2000) reflecting the expected relative value of these components on world markets. Two other traits, liveweight and longevity, have more recently been identified as being of economic importance as they affect farm costs, and are now included in the selection index along with milk, milkfat and protein yields (Spelman and Garrick 1997b; LIC 2000).

Correlations between traits will affect genetic gains (Gibson 1989, 1991, 2000; Spelman and Garrick 1997b). Milk, milkfat, protein and lactose yields are all positively correlated, therefore increases in one trait will lead to increases in the other traits (Gibson 1989; Van Vleck *et al.* 1987; Bourdon 1997; Johnson *et al.* 2000). Gains achieved are affected by the economic weightings applied to each trait. The more traits in a selection objective, the less

selection pressure that can be applied to each trait. It is possible to hold a trait constant, or select against it, but this will result in reduced gains in other, possibly desirable traits e.g. protein. For example, selection to increase the protein:milkfat ratio will lead to reduced gains in milkfat, but will also result in lower gains in protein than would be achieved by selecting on protein and fat production (Gibson 2000).

The difficulty lies in deciding on the traits to include in the objective and assigning economic values. As production in a trait increases, the increased production of a correlated component that is in oversupply is often sold at a lower value i.e. as a low value commodity product (Gibson 1989, 2000). For example, selection for protein will increase milkfat. However, Gibson (2000) showed that it was better to select for high-producing cows resulting in a protein to milkfat imbalance, with the milkfat surplus sold at lower prices, than to select for the required milkfat:protein ratio and have lower gains in the production of both components. Determining the economic weighting to use can be difficult because of difficulties in predicting long term market price signals (Gibson 2000).

Past studies in quantitative selection have generally considered the four main milk components. Other quantitative traits could be included in an objective, and past work has shown that there is variation in milk fat composition (Palmquist *et al.* 1993; Bobe *et al.* 1999) and in milk colour (Winkelman *et al.* 1999), and that these traits are heritable and could therefore be included in a selection objective. As mentioned though, the inclusion of another trait in the objective may reduce gain in the production traits. Selection intensity in the production traits, and therefore genetic gain, could also be reduced because animals may need to be selected from a subset of the population

There has been considerable interest in the genetic polymorphism of milk proteins. The effect of milk protein polymorphism on milk composition and milk processing properties has been well reviewed (McLean *et al.* 1984; Ng-Kwai-Hang and Grosclaude 1992; Jakob 1994; Jakob and Puhan 1995; FitzGerald 1997; Hill *et al.* 1997; IDF 1997; Winkelman and Wickham 1996; Ng-Kwai-Hang 1998). Fox and Guinee (2000) concluded that although the effect of milk protein polymorphism on milk, milkfat and protein yield appeared to be small, there were significant effects on milk processing properties. This can be attributed to the structure of the protein alleles, which affects their reactions during processing (Dalglish 1997) or to the level of the more minor milk components in the milk. For example, cows with the B variant of β -lactoglobulin have more casein and less whey than those with the A variant, which is an advantage in cheese making (Hill *et al.* 1997).

There is interest in using these milk protein genes as qualitative traits in selection because of their straightforward Mendelian mode of inheritance (Sabour *et al.* 1996; Georges 1997; Spelman and Garrick 1997a; Kennelly and Glimm 1998; Ng-Kwai-Hang 1998; Visscher *et al.* 1998; Freyer *et al.* 1999; Spelman *et al.* 1999). These can act as qualitative trait loci (QTL) affecting a milk production trait directly, or act as a marker gene i.e. be associated with QTL for a milk production trait (Bovenhuis *et al.* 1992). It is unclear as to whether some of the variants act as marker genes or QTLs (Gibson 2000). These protein variants could be used for screening animals (e.g. bulls) or included in a selection index as marker genes, or used to identify embryos to transfer, young bulls to progeny test or heifers to rear allowing selection at an early age (Meuwissen and Van Arendonk 1992; Sabour *et al.* 1996).

Marker assisted selection may need to be used with caution. Selection for a particular variant may improve milk composition or processing properties in one respect but disadvantage it in another (Bovenhuis *et al.* 1992; Ng-Kwai-Hang 1998). Jakob (1994, 1995) and Aggrey *et al.* (1998) warn that the effect of a variant needs to be evaluated within a population or family because the association between markers and a trait does not occur in all families. Some effects may be the result of linked genes rather than the effect of a single gene (Bovenhuis *et al.* 1992; Ojala *et al.* 1997).

The inclusion of marker genes in selection schemes have been discussed by Gibson *et al.* (1991), Pederson (1991), Meuwissen and Van Arendonk (1992), Harris (1997), Rendel and Harris (1997), and Spelman and Garrick (1997a). Qualitative traits are already included in selection in New Zealand and overseas. Milk with the B κ -casein milk protein variant has better quality for cheese making, and is already bred for specifically in Austria, Switzerland and Italy, with Italy including this in the selection index (FitzGerald 1997; Kennelly and Glimm 1998; Ng-Kwai-Hang 1998). In New Zealand, Kaikoura factory suppliers select bulls that carry the B variant of β -lactoglobulin to improve the cheese making quality of the milk (Boland *et al.* 2000).

A variety of technologies can be used to increase the rate of genetic gain. These include animal recording, use of breeding schemes and estimation of breeding values, use of heterosis, artificial insemination (AI), multiple ovulation, embryo transfer, in vitro fertilisation and maturation, sexing of semen and embryos, oocyte pick-up (eggs from juvenile heifers), cryopreservation of semen and embryos, genome mapping and marker assisted selection, identification of QTLs, and detection of genetic disorders. These have

been reviewed by Baker *et al.* (1990), Fennessey (1990), Freeman and Lindberg (1993), den Daas (1997), Georges (1997), Macmillan *et al.* (1997), Tervit (1997), Wilmut *et al.* (1997), Cunningham (1998, 1999), Einarsson and Rendel (1998), Guilbault *et al.* (1998), McClintock (1998), Visscher *et al.* (1998), and Smidt and Niemann (1999). Animal recording, AI and exploitation of heterosis have been widely used for years in the dairy industry. Embryo transfer although readily available, is less widely used (less than 1% in developed dairy populations) due to its higher cost and lower gains compared to AI (Cunningham 1999). Many of the remaining technologies mentioned are rarely used commercially although there is potential for greater use in the future. Use of these technologies, or combinations of them, depend on the benefits exceeding costs (Cunningham 1999). Transgenics and cloning will be considered in the next section.

The economic implications and/or the logistics of changing selection to produce milk with a composition specific to a particular product for supply to a particular factory or company have been discussed by Boland (1997), Harris (1997), Rendel and Harris (1997), Fearon and Maine (2000), Garrick and Lopez-Villalobos (2000), Henning *et al.* 2000; Shanahan (2000) and Boland *et al.* (2000). Consumers must benefit in order to pay a premium, and this premium must be sufficient to cover any extra transport, storage, processing, packaging and marketing costs incurred by the company as well as any extra costs incurred by the farmer e.g. testing and monitoring, breeding, feeding, purchase of stock and opportunity costs associated with lost production. The examples discussed by Fearon and Maine (2000), Shanahan (2000) and Boland *et al.* (2000) were industry initiatives and included expert, industry and farmer involvement throughout the process.

1.1.3.3 *Transgenics and cloning*

Transgenics and cloning in livestock is still largely at the experimental stage. These processes are very expensive and in the future are likely to be viable commercially only for the production of high value products e.g. high value milk proteins, or human proteins using milk from other species as a medium to produce these. For example, Garner and Colman (1998) identified a number of therapeutic proteins in milk some of which were introduced into the milk by transgenic means. Cloning offers the opportunity to reproduce high genetic merit animals or genetically modified animals, or the production of animals for phenotypic evaluation. Transgenics and cloning have been reviewed by Jimenez-Flores and Richardson (1988), Bremel *et al.* (1989), Baker *et al.* (1990), Karatzas and Turner (1997), Vilotte *et al.* (1997), Wall *et al.* (1997), Wilmut *et al.* (1997), Clark (1998), Cunningham (1998, 1999), Dematawewa and Berger (1998), Guilbault *et al.* (1998), Kennelly and Glimm (1998),

McClintock (1998), Wells *et al.* (1998), Wilmut (1998), Smidt and Niemann (1999), Bonneau and Laarveld (1999), L'Huillier (1999) and Wall (1999).

1.1.3.4 Feeding and nutrition

The effect of feeding a range of diets on milk composition has been well researched. Most studies considered the effect of feeding on milk yield and the main milk components (milkfat, protein and lactose). The effect of feeding on milk composition has been reviewed by Bryant (1979), Holmes (1989), Sutton (1989), Sutton and Morant (1989), Sykes (1989), Kolver and Bryant (1992), AFRC (1998) and Kennelly and Glimm (1998). Sutton (1984), Thomas, C. (1984), Grummer (1991), Palmquist *et al.* (1993), Beaulieu and Palmquist (1995), Ashes *et al.* (1997) and Murphy (2000) specifically reviewed the effect of feeding on milkfat production and composition. Rogers and Stewart (1982), Thomas, P.C. (1984), Murphy and O'Mara (1993) and MacRae *et al.* (2000) reviewed the effect of feeding on protein production and composition. The level of feeding (pre-calving and during lactation), and the quality and composition of the diet, including pasture species and supplements, influences milk production and composition. Stocking rate, cow performance, and cow condition score are affected by nutrition and therefore also influence milk production (Kolver and Bryant 1992).

New Zealand reviews on the effect of feeding on milk composition include Bryant (1979), Holmes (1989), Kolver and Bryant (1992) and Clark *et al.* (1997). Recent studies conducted in New Zealand on specific issues related to the effect of nutrition on milk yield and composition include: Mackle *et al.* (1997), Neil and Thomson (1997), Petch *et al.* (1997), MacDonald *et al.* (1998), Mackle *et al.* (1999b) on concentrate and/or silage supplementation; Thomson (1999) and Thomson *et al.* (2000) on fodder crops; Johnson and Thomson (1996) on pasture species; Pacheco-Rios *et al.* (1997), and Harris and Lee (1998) on methionine supplementation; and Mackle *et al.* (1999a) on cows of different phenotypes. Feed can also influence the flavour and colour of milk (Keen 1993; Waghorn and Knight 1993; Wilson, G.F. 1993; Wilson, R.D. 1993).

The various nutritional effects discussed in the literature are too numerous to summarise here. However, two desirable milk compositional changes will be briefly mentioned. These alter the milkfat composition and possibly concentration, and may affect the protein concentration in the milk. As a result protein: milkfat ratios can also be affected (Kennelly and Glimm 1998).

There is interest in naturally softer milkfat for the production of spreadable butter. This can be achieved by increasing the proportion of short-chain or saturated fats in the milkfat by adding fats, either protected or unprotected from rumen micro-organisms, to the diet (Sutton 1989; Sutton and Morant 1989; Grummer 1991; Kolver and Bryant 1992; Palmquist *et al.* 1993; Nickerson 1995; Ashes *et al.* 1997; Kennelly and Glimm 1998; Murphy 2000). This increases the supply of long-chain fatty acids available to the animal, thus increasing the concentration in the milk. However, this can also decrease protein concentration.

Milk with a low concentration of milkfat is desirable. However, this is not easily achieved by breeding as milkfat production is strongly positively correlated with milk yield. This can be manipulated by feeding concentrates. As the proportion of grain in the diet increases the milkfat concentration decreases (Thomas, C. 1984; Sutton 1989; Sutton and Morant 1989; Kolver and Bryant 1992; Kennelly 1996; Ashes *et al.* 1997; Kennelly and Glimm 1998; Murphy 2000). Low milkfat concentrations of 2% to 4% are achievable, and protein concentration tends to increase. This strategy is most effective in mid to late lactation (Kennelly 1996).

Feed effects can also be interrelated or confounded with seasonality and stage of lactation. These are discussed in the following two sections.

1.1.3.5 *Season*

In New Zealand most cows are calved in spring to allow feed requirements to meet feed availability, and as a result there are marked changes in milk supply and milk composition over the season (Mackle and Bryant 1995, 1996; Clark *et al.* 1997; Auldist *et al.* 1998; Garcia and Holmes 1999). Hence, milk processing capacity has to be sufficient to process large volumes of milk in spring (approximately 30% of the total in October-November) and capacity is under-utilised for the rest of the year (Paul 1982,1985; McCombs 1986; Gray *et al.* 1994), and the variation in milk composition over the season can result in milk with poor processing properties in early and late lactation which can affect product processability and consistency (Mackle and Bryant 1995, 1996; Ostensen *et al.* 1997; O'Brien 2000).

This seasonal effect has been attributed to nutritional factors associated with changes in pasture availability and quality over the season, physiological factors associated with stage of lactation (SOL), changes in the incidence of mastitis over the season, and climatic factors, or combinations of these factors (Jenness 1974; Kolver and Bryant 1992; Nickerson 1995; Garcia and Holmes 1999). The influence of the individual factors is difficult to determine in a

seasonal calving dairy system. A New Zealand study (Auldist *et al.* 1997, 1998) found that season of the year and SOL both affected milk components, with time of year having a greater effect on milk processability because of nutritional factors. This supports Australian findings (Kefford *et al.* 1995). Auldist *et al.* (1997, 1998) identified seasonal differences in milk, not affected by SOL, including the casein:whey ratio and the protein:milkfat ratio. These ratios affect milk processability. Seasonal factors have largely been discussed in relation to stage of lactation (see Section 1.1.3.6).

1.1.3.6 *Stage of lactation and calving spread*

The effect of stage of lactation on milk yield and milk composition, particularly milkfat, lactose and protein, has been well studied. This has been discussed or reviewed by (Crabtree 1984; Holmes *et al.* 1984; Walstra and Jenness 1984; Nickerson 1995; Mackle and Bryant 1996; Auldist *et al.* 1997, 1998; McFadden 1997; Garcia and Holmes 1999; O'Brien 2000). In general, yields of milk, milkfat, protein and lactose increase in the first few weeks then decline. Lactose concentration declines slightly over lactation. Concentrations of milkfat and protein decrease initially, then increase, as the decline in milk yield is greater than that of milkfat or protein yields. Wood's lactation model which predicts the change in milk components over the season is widely known, and can be fitted to a range of lactation curves (Wood 1967, 1976, 1979, 1980). The peak and slopes on the lactation curve can be affected by calving season, age of cow (heifers versus cows), pregnancy, diet and supplementation, and genetics (individual cows and sire groups) (McFadden 1997).

Less is known about the more minor milk components over lactation. Concentrations of chlorine and sodium increase over lactation while those of potassium decline. Phosphate and calcium decrease, then increase again slightly. While the proportion of whey remains similar, serum albumin increases and immunoglobulins decrease with lactation (Holmes *et al.* 1984; Walstra and Jenness 1984). Somatic cell counts (SCC) are high in early lactation and increase again in the last few weeks of lactation (Holmes *et al.* 1984; Franks 1993). The pH changes over lactation starting at about 6.6 and rising to 6.9 toward the end (Walstra and Jenness 1984). Processability of milk is poorer in early and late lactation (Mackle and Bryant 1995, 1996; Auldist *et al.* 1996; Rowney and Christian 1996; Ostersen *et al.* 1997; Sapru *et al.* 1997; O'Brien 2000), although some of this is attributed to nutritional factors and it is suggested that ensuring cows are fed a quality diet throughout lactation will reduce or eliminate these effects (Auldist *et al.* 1997, 1998; O'Brien 2000).

There is interest in changing the fatty acid composition of milk to increase spreadability and reduce the saturated fatty acid content for health reasons (Thomson and Van der Poel 2000). There is considerable seasonal variation in the fatty acid composition of milk over lactation, although this is likely to be due to dietary effects (Holmes *et al.* 1984; MacGibbon and McLennan 1987; Baer 1991; Palmquist *et al.* 1993; Hawke and Taylor 1995; Papalois *et al.* 1996; Thomas and Rowney 1996; Auldist *et al.* 1998; Thomson and Van der Poel 2000). Butter made in the spring is softer than that made in the summer because of the higher level of unsaturated long chain fatty acids. The greater reliance on the breakdown of body reserves and the composition of spring pasture result in a higher level of unsaturated fatty acids being available for milkfat production at this time.

The composition of colostrum, which is produced in the first few days of lactation, is very different to that of milk. Colostrum is nature's way of providing passive immunity to the neonate. The composition of colostrum is described by Crabtree (1984), Holmes *et al.* (1984), Walstra and Jenness (1984) and Nickerson (1995), and may contain up to 25% solids. It is higher in casein and whey proteins (serum albumin and immunoglobulins), somatic cells, leucocytes, minerals and sometimes milkfat, and is lower in lactose, than normal milk. The enzyme content is also different to that of milk. Colostrum is usually fed to calves, but colostrum products are available in some markets now as high value products with immunological properties and health benefits (McFadden *et al.* 1997; Korhonen 1998; Stevenson 2000).

Spreading calving throughout the year will lessen seasonal variation in milk composition throughout the year but not eliminate this, because nutritional factors associated with season of the year affect milk processability separate from SOL (Kefford *et al.* 1995; Auldist *et al.* 1997, 1998; Garcia and Holmes 1999). Altering calving pattern will also have other management implications. Costs will increase as supplements will need to be purchased, or production may be reduced because a lower stocking rate may be carried (Holmes *et al.* 1984; Gray *et al.* 1994; Garcia and Holmes 1999). Autumn milk could also be blended with spring milk to improve year round processability (O'Brien 2000).

1.1.3.7 *Milking frequency and interval*

During milking the milkfat content of the milk leaving the udder increases (e.g. from 1% to 10%) (Walstra and Jenness 1984; Nickerson 1995). Consequently, if the cow is incompletely milked out, any milk left in the udder is high in milkfat and the next milking will have a higher milkfat concentration. A shorter time interval between the morning and evening

milking means that evening milk yield is often less than morning milk yield. Protein and lactose concentrations are not affected. Increasing the frequency of milking increases milk yields, with increases of over 20% recorded: the effect on the milk concentrations of the main milk components and casein is negligible or slightly reduced (Dodd 1984; Sapru *et al.* 1997; Davis *et al.* 1999; Vetharaniem *et al.* 2001). The deterioration over lactation in the processing qualities of milk because of protein degradation can be reduced by thrice daily milking (Knight *et al.* 2000).

Reducing the frequency of milking reduces lactose concentration and milk yields (by up to 40%) but also increases milkfat and protein concentrations although the yields of these components are less affected (Holmes *et al.* 1984; Nickerson 1995; Davis *et al.* 1999; Knight *et al.* 2000; Vetharaniem *et al.* 2001). SCC can also be increased by milking once a day (Nickerson 1995). β -lactoglobulin concentrations were higher in milk after longer milking intervals, but α -lactalbumin was unaffected (McLaren *et al.* 1998). Auldism and Prosser (1998) found once a day milking reduced milk yield and casein: whey ratios, but increased milkfat serum albumin, immunoglobulin G, whey protein and somatic cells. Developing a more concentrated milk with a lower lactose concentration, requiring once a day milking would be advantageous if this could be achieved without the associated large losses in milk component yields (Knight *et al.* 2000). Interactions in the size of the responses can occur between milking frequencies and feeding levels (Auldism and Prosser 1998) or stage of lactation (McLaren *et al.* 1998).

1.1.3.8 Age

Age has the largest effect on milk yield with younger cows producing the least and those in their fifth lactation producing the most. This is because younger cows require feed to grow out and have lower udder capacity. Milk composition changes slightly as cows age with a small drop in milkfat and lactose concentration (2 to 3 gram/litre) and a smaller drop in protein concentration (Rogers and Stewart 1982; Holmes *et al.* 1984; Walstra and Jenness 1984; Nickerson 1995) Age probably has little application in managing milk composition. Herd structure could be modified slightly but the lower yields of younger cows and replacement requirements put constraints on herd structure. The effect on composition is likely to be insufficient to warrant this.

1.1.3.9 *Climate*

High temperatures reduce milk production, reduce lactose and protein concentrations, possibly increase milkfat concentration, reduce the proportion of short chain fatty acids in the milk, alter the relative proportions of protein, and influence the curd firmness and heat stability of the milk (Pan *et al.* 1978; cited by Mackle and Bryant 1995; Holmes *et al.* 1984). Low temperatures reduce milk production, increase lactose, milkfat and protein concentrations, reduce the proportion of short chain fatty acids in the milk, alter the relative proportions of protein, and influence the curd firmness and heat stability of the milk (Pan *et al.* 1978; cited by Mackle and Bryant 1995; Holmes *et al.* 1984). There are breed differences with Friesians being more sensitive to high temperatures than Jerseys, and Jerseys being more sensitive to lower temperatures (Holmes *et al.* 1984). Differences are due to behavioural (eating less in heat and wet, windy conditions, and more under cold calm conditions), greater maintenance requirements under stress, and physiological changes (Holmes *et al.* 1984; Nickerson 1995). New Zealand conditions do not usually affect milk production, except possibly in Northland and town supply cows in the South Island (Holmes *et al.* 1984). In New Zealand, where cows are grazed outdoors, the effect of climate on pasture production and feed availability is likely to have a greater influence on milk composition and yield (Holmes *et al.* 1984).

1.1.3.10 *Health, mastitis and somatic cell counts*

Animal health affects milk composition. The main health concern is mastitis, which increases SCC. This decreases milk yield, increases the number of somatic cells (especially leukocytes), serum albumin, immunoglobulins, enzymes and peptones, and reduces β -lactoglobulin and α -lactalbumin. Casein, milkfat and lactose concentrations are reduced. The composition of the casein and milkfat components (fatty acids) also alters. SCC and mastitis are discussed in Holmes *et al.* (1984), Walstra and Jenness (1984), Franks (1993), Steffert (1993) and Harmon (1995). SCC can be affected by individual cow factors and mastitis history, age (increases), stage of lactation (greater at the beginning and end) and management (e.g. milking practices) (Holmes *et al.* 1984; Walstra and Jenness 1984; Harmon 1995). SCC is heritable and selection on this trait is possible (Shook and Schutz 1994).

Mastitic milk (or high SCC, low quality milk) has poor processing qualities and can cause taints. Coagulation in cheese making is poor reducing cheese yield and quality, fermented products tend to separate out and milk from mastitic cows has poor heat stability affecting milk powders and reconstituted milks (Holmes *et al.* 1984; Harmon 1995). Dairy companies

usually have milk quality measures in place with penalties for milk with high SCC, and cows are usually herd tested and those with high SCC are treated or culled (Holmes *et al.* 1984; Franks 1993).

1.1.3.11 Other

Milk production and composition can be manipulated by biotechnological means, and three methods that are either currently used or have been proposed will be discussed here.

Immunomodulation is any technique which modifies the immune response of an animal, and includes the induction of responses to antigens within the animal (e.g. hormones) or using passive antibodies to alter endocrine function (Pell and Flint 1997; Bonneau and Laarveld 1999; Cunningham 1999). Growth hormone has been used to increase milk production, the most widely known example being bovine somatotrophin (BST). BST, when injected into cows, increases milk production by 10% to 20%. The increased production is from more efficient production by the cow (more milk, less body fat) and management changes may be required to ensure cows are adequately fed to support this extra production. Effects on milk composition are minimal. BST is not used in New Zealand and is unlikely because of consumer resistance to milk produced by this means (Fenwick and Marshall 1991; Atkinson 1999). BST use is discussed by Bauman (1992), Collier (1997), Bonneau and Laarveld (1999) and Cunningham (1999).

Immunoglobulins in milk and colostrum are bioactive proteins that can be used to produce hyperimmune milk and milk products with health promoting properties (McFadden *et al.* 1997; Regester *et al.* 1997). These are produced at a naturally high level in colostrum, which has already been mentioned. Select herds of cows can also be injected with vaccines, resulting in antibodies being passed into the milk. In New Zealand this technique is used for the production of Stollait immune milk (Dingwall 1991; West 1991; Fenwick and Marshall 1991; McFadden *et al.* 1997; Regester *et al.* 1997).

Rumen microflora can be manipulated through diet, management, food additives (antibiotics, methane inhibitors, enzymes) and engineered microbial strains. This can result in increased productivity, and alteration of milk composition and flavours. This has been discussed by Joblin (1993), Joblin and Hudson (1997), Wallace (1997), Teather and Forster (1998), and Bonneau and Laarveld (1999).

Milking and storage practices on-farm can affect milk composition and processing properties e.g. breakdown of milk components through excessive agitation during milking, spoilage if not cooled adequately. Contamination of milk by bacteria or other substances after milking, or from the inclusion of milk from mastitic cows or cows treated with antibiotics can also occur. Milk composition can be altered during processing by technological means e.g. whitening milkfat. However, this discussion has focussed on issues related to the cow and on farm practices and these issues are not considered here.

1.1.4 Two potentially useful milk traits

Two milk traits that are recognised as being useful, or potentially useful, are milkfat colour and the B variant of β -lactoglobulin. Milkfat colour will be reviewed here. β -lactoglobulin protein variants will be briefly discussed, but are reviewed in more detail in Chapter 3.

1.1.4.1 β -lactoglobulin protein variants

Milk from cows with the BB β -lactoglobulin genotype is superior to milk from cows with AA or AB β -lactoglobulin genotypes for cheesemaking, milk powder production and UHT milk production. The polymorphism of β -lactoglobulin has been included in general reviews by Ng-Kwai-Hang and Grosclaude (1992), Jakob (1994), Jakob and Puhan (1995), IDF (1997), Ng-Kwai-Hang (1998) as well as being specifically reviewed by Hill *et al.* (1997). BB β -lactoglobulin genotype cows have higher casein and lower whey protein production (including β -lactoglobulin), and in some trials higher fat concentration and production, lower total protein production and lower milk yields compared to AA β -lactoglobulin cows. Milk from BB β -lactoglobulin cows gives higher cheese yields due to the higher total solids, fat and casein content in their milk. The polymorphism of β -lactoglobulin is discussed further in Chapter 3.

1.1.4.2 Milk colour

The colour of New Zealand milkfat products is generally more yellow than that of other countries because of our pasture-based dairy farming, and in some markets this is seen as being less desirable in products (e.g. some butter markets, ghee and white cheeses for the Middle East and whipped toppings for Japan). Although this colour can be removed by processing this can remove some of the desirable flavour characteristics making the milkfat unsuitable for processing some products (Keen 1986; Hobman 1992; Keen and Wilson 1993).

The colour variation is due to carotene, a precursor of vitamin A, which is readily available in fresh forages (Walstra and Jenness 1984; Keen and Wilson 1993; Waghorn and Knight 1993; Section 1.1.1.4). Season also has an effect on milk colour, probably due to nutritional factors with spring pasture being high in carotene (Walstra and Jenness 1984), although Knight and Waghorn (1993) suggested some of this could be changes in plant composition that reduce carotene absorption e.g. lignin, waxes, sterols. In New Zealand studies McDowell and McDowell (1953), Thompson *et al.* (1964), Keen (1986), Keen and Wilson (1993) and Winkelman *et al.* (1999) measured the change in milkfat colour over lactation. This was high in early lactation and decreased over time, increasing slightly again in late lactation.

There are breed differences in milk colour with Friesian cows having whiter milk than Jersey cows due to either absorbing less carotene or converting more carotene to vitamin A (Holmes *et al.* 1984; Keen and Wilson 1993; Section 1.1.3.1). Newman *et al.* (1994) measured plasma levels of carotene in 4000 dairy heifers to reflect what was being absorbed by the diet. They found Jersey heifers had significantly greater carotene levels than Friesian heifers (18.2 versus 14.4 µg/ml). They also found a large variation in carotene levels between cows run under the same conditions, suggesting colour was moderately heritable. This was supported by Winkelman *et al.* (1999) who found heritabilities for milk colour traits from 0.40 to 0.49 for Friesians and 0.17 to 0.31 for Jerseys, suggesting it may be possible to reduce carotene concentrations relatively quickly by selection.

Knight and Waghorn (1993) suggested milk colour manipulation could be achieved by feeding, or interfering with the carotene uptake path. Cows could be fed diets low in carotene e.g. concentrates. Alternatively, addition of non-absorbable fats, waxes, oils and sterols to the diet decrease absorption of carotene and vitamin A. However, this requires relatively large volumes of lipids to be fed e.g. up to 300 mls of paraffin per cow per day. Feeding a non-absorbable compound that will absorb carotene may be a better option e.g. antioxidants.

1.1.5 Conclusion

There are over 2000 constituents in milk. While milk yield, milkfat, protein and lactose have been widely researched there is less known about the other milk constituents. As these components are identified and more information becomes available about their functional, nutritional and biological properties, opportunities for new and improved products will be developed. At the same time, technology is developing to assist in the identification and extraction of milk components and manufacture of new products. Research to identify factors that affect milk composition on farm continues.

Milk composition is affected by a number of factors. There is wide variation in the composition of different breeds and individual cows. Therefore, opportunities exist to segregate and breed specialty cows, using traditional and developing breeding technologies. Milk composition can be affected by other factors and some of these can be manipulated by management practices to change milk composition e.g. feeding, stage of lactation.

Changes will need to be led by economic signals. Extra costs will be incurred with many milk differentiation policies e.g. cost of extra feeding or non-pasture feeds, altering calving patterns will increase farm costs, while decreasing processing costs by spreading milk flow and enabling product production all year round. Therefore manipulating milk composition and segregation will only be worthwhile for herds producing milk for the manufacture of more valuable or lower cost milk products.

1.2 THE NEW ZEALAND DAIRY INDUSTRY

1.2.1 Dairy industry structure

1.2.1.1 Dairy industry structure – past and present

Although New Zealand's milk production is small in world terms, it is significant in that 95% of its products are exported (Spring 1997). Only 5% of the world's dairy products are traded internationally, and of these, New Zealand exported 31% (excluding trade within the EU countries) in 1998/1999 (MAF 1999). New Zealand is the world's largest butter exporter and the second largest cheese, and skim milk and whole milk powder exporter (MAF 1999). Dairy products are produced without reliance on subsidies or protection of the domestic market from overseas competition. In contrast, New Zealand has free access to only 5% of the world dairy markets because of trade barriers, although GATT and APEC trade agreements will see some freeing up of world dairy markets in the future (Marshall 1995; Spring 1997; MAF 1999). New Zealand's main export markets are the USA, UK, other EU countries, Asia and Latin America (MAF 1999; Wardle 2001). World trade in milk is increasing at a rate of 1% to 2% per year, mainly because of growing markets in South-East Asia and Latin America, and from the freeing-up of market access (Kelly 1997). In 2000/2001 export receipts from the sale of dairy products (including casein and caseinates) were \$7,407 million, contributing about 20% of New Zealand's export returns, or 7% of the country's GDP (Wardle 2001).

New Zealand has almost 14,000 dairy farmers milking approximately 3.3 million cows. The average New Zealand dairy farm in 1999/2000 was 93 hectares, with 236 cows producing 288 kilograms of milksolids (milkfat plus protein) per cow, or 768 kilograms of milksolids per hectare. Average production per farm has been increasing at a rate of about 5% per year (LIC 2000). A total of 970 million kilograms of milksolids was processed nationally in 1999/2000 (LIC 2000), with the majority of the production coming from the Waikato, Taranaki and Northland regions of the North Island. The large number of South Island dairy conversions in recent years has seen the South Island's share of production increase from 9% in 1980 to 23% in 2001 (Wardle 2001; Fonterra 2001a).

Most New Zealand dairy farmers produce milk seasonally to match pasture supply to pasture demand, calving cows in spring and drying cows off for a few weeks in winter. About 30% of the total milk is supplied in the peak months of October and November (Gray *et al.* 1994). This seasonal pasture-based production system makes New Zealand one of the lowest cost milk producers in the world (MAF 1999; Anon 2001). However, it does also impose constraints in terms of income (McCombs 1986; Gray *et al.* 1994; Eman and Gommans 2001). The investment in manufacturing capacity relative to total production is high compared to overseas countries, in order to cope with peak milk flows. The product mix over the peak may be less than optimal i.e. a higher proportion of commodity products may be made as the priority is to ensure all milk is processed. At other times of the year milk supply may be insufficient to meet the demand for some products, particularly those with short storage life. Milk quality at some times of year can affect the ability to make some products and/or the quality of the products made. Some product from high milk flow periods needs to be stored, increasing market risk due to potential lower returns in the future.

New Zealand dairy farmers supply whole milk to their farmer-owned cooperative dairy manufacturing companies. The first cooperative dairy company was formed in 1871 and by 1935 New Zealand had over 400 dairy companies (MAF 1999). Amalgamations saw this number decline to just four by 2001, with 95% of the milk in New Zealand processed by the two largest companies: New Zealand Dairy Group (NZDG) and Kiwi Co-operative Dairies (Fonterra 2001b). Over 80% of the shareholders in NZDG and Kiwi voted in favour of a merger in June 2001. Legislation was passed in September 2001 allowing these two companies to merge, creating the Fonterra Co-operative Group Ltd (formerly known as GlobalCo). Fonterra also incorporated the assets held by the New Zealand Dairy Board (NZDB) at that time.

The primary function of the NZDB, New Zealand's largest company, was to control the marketing of all exported dairy products (Fonterra 2001b). The NZDB was also responsible for dairy industry research and development. Prior to the recent merger, the NZDB was owned by all the cooperative dairy companies, and therefore ultimately by all dairy farmers. It also owned the Livestock Improvement Corporation (LIC), the New Zealand Dairy Research Institute (NZDRI), and jointly owned the Dairy Research Corporation (DRC) with AgResearch (Spring 1997; MAF 1999). The LIC was responsible for animal improvement, providing a livestock recording service, bull testing and semen sales, and consultancy. The NZDRI and the DRC were dairy research organisations, with the NZDRI developing processing technologies and the DRC conducting on-farm research.

The dairy industry was deregulated prior to the merger of the NZDB and the two large dairy companies. The single desk exporter status of the NZDB was removed (MAF 2001), and the marketing and NZDRI components of the NZDB passed to Fonterra with the merger. Via Lactia, a subsidiary of the NZDB formed to manage investment in biotechnology (Marshall 2000), also went to Fonterra. The commercial component of the LIC (animal recording, semen sales, and the paid consultancy service) became a stand-alone commercial company, with those farmers who had used its services in the past as shareholders. The DRC and the free consultancy service operated by the LIC combined to form Dexcel (Woodward and Macdonald 2001). Funding for Dexcel is proposed to come from DairyInsight, which has been formed to allocate funds for public good dairy research from a levy on all milk produced in New Zealand (DairyInsight 2001). Legislation under the Commodities Levies Act has yet to be passed to allow this levy to be collected. A condition of the merger was that Fonterra sell their 50% share of Dairy Foods, the NZDG company supplying the local dairy market, to ensure they do not have a monopoly in the New Zealand dairy market (MAF 2001). They retained their interest in Mainland, Kiwi's local dairy market company.

The two dairy companies remaining outside Fonterra are the Waikato-based Tatua Co-operative Dairy Company and the Westland Co-op Dairy Company Ltd. on the West Coast of the South Island (Wardle 2001). Tatua manufactures high-value products (e.g. caseinates, protein products, dessert toppings, creams, sauces). Westland produces milk powders, protein concentrate, casein and butter.

1.2.1.2 Structure of Fonterra

Fonterra is New Zealand's biggest company and the World's 9th largest dairy company. It is governed by a board controlled by New Zealand dairy farmers. Shareholders views are

represented by a Shareholders' Council. Fonterra operates in 120 countries, has assets worth \$11 billion and employs 20,000 staff. It comprises approximately 100 companies and its main subsidiaries are NZMP, NZ Milk and the NZDB (Fonterra 2001a, 2001b).

NZMP is responsible for Fonterra's global ingredients business, including milk collection, manufacturing and logistics operations, and the marketing of ingredients (milk powders, milk proteins, cheese and cream products) (Fonterra 2001b; Wardle 2001). About 60% of net dairy export revenue comes from the ingredients business, with about a third of this from undifferentiated products (commodities/ingredients) and two-thirds from customised and specialty products (ingredients/specialty ingredients) (Fenwick 1995; Larsen 1997; Spring 1997; MAF 1999).

NZ Milk is Fonterra's consumer goods company, producing and marketing goods for the consumer and food service industries, including branded products such as Anchor, Anlene, Chesdale, Fern, Fernleaf, Mainland and Tararua (Fonterra 2001b; Wardle 2001). Approximately 40% of dairy revenue comes from these branded consumer products (consumer and food service products) (Fenwick 1995; Larsen 1997; Spring 1997; MAF 1999).

Fonterra has attempted to address some of the equity issues facing cooperatives (see Section 1.2.3.2) in their new structure (Fonterra 2001c, 2001d). Current suppliers were issued with shares in the company, and new suppliers or those with increasing milk volumes have to purchase shares in order to supply Fonterra. Peak rights notes have also been introduced to discourage increased production at the peak. Shares plus peak notes represent the value of a supplier's investment in Fonterra. Fair value or co-operative shares, valued at \$3.85 per kilogram milksolids when introduced on 15th December 2001, were issued to current suppliers based on their historic production (one share per kilogram of the annual milksolids supplied to Fonterra). This covers industry assets other than plant, half the investment in plant and the future potential of value of Fonterra's earnings discounted 5 years out (Moss 2002, *pers. comm.*).

Peak notes are calculated based on the supplier's highest 10-day production period, their annual production, and Fonterra's peak day equivalents (peak day equivalent = annual production divided by peak day production). These are worth \$30 per peak note (Fonterra 2001c), which equates to about \$1.03 per kilogram of annual milksolids production (Moss 2002, *pers. comm.*). This will vary between suppliers. Peak notes cover half of Fonterra's

investment in plant (Moss 2002, *pers. comm.*).

Each year new suppliers or those increasing production or peak production will be required to purchase shares and/or peak notes. Those decreasing production will be paid for their shares or peak notes. Alternatively, they can choose to accept supply redemption rights instead, which they can later exchange for shares e.g. accept redemption rights in a drought year when production is low and redeem them for shares the following year when it increases again. In addition there are also capital notes and redeemable preference shares (Fonterra 2001d). Capital notes are interest bearing notes. These can be taken in exchange for shares, supply redemption rights, peak notes or redeemable preference shares. Redeemable preference shares can be issued by the company in exchange for surrendered shares, supply redemption rights and peak notes. These must be paid out by the company within 3 years. However, these protect the company from some of the risk associated with a large number of suppliers selling out of Fonterra or changing companies and wanting to be paid out.

1.2.2 Milk payment system

The past milk payment system will be described. The recent amalgamation of the two companies and the NZDB means there will be less division between the marketing (NZDB), processing (companies) and producer (farmer) stages of the value system in the future. The implications of this will also be discussed.

1.2.2.1 NZDB to the Dairy Company

The NZDB used a cost model payment system to calculate payments to farmers in the past, as described by Larking (1989), Marshall (1989b) and Bates (1998). The NZDB pooled the returns from the various dairy products and calculated a single valuation for the milkfat and protein components based on the value of, and their use in, each of the various products. Standard cost models are used to estimate the production cost for each product (Bates 1998), including overhead costs (Marshall 1989b). The NZDB then paid the companies a common NZDB base price for the milkfat and protein components (which the companies used to pay their farmer suppliers with) plus the cost of producing their product mix (Bates 1998). The NZDB also had a range of incentive payments to encourage companies to process certain products but this was only a small part of the payment.

Dairy companies have become increasingly efficient at milk processing (Larsen 1997; Bates 1998), and often produced milk more efficiently than the NZDB cost models predicted. These cost savings, along with any profits from the domestic side of their business were passed onto

their farmer-suppliers as a bonus payment. In years where milk production was high these savings were also greater because their fixed costs were covered early on, although they continue to be paid in the cost model calculation (Larsen 1997). Therefore the payment farmers received for their milk included more than the raw milk price.

The cost model structure has generated highly efficient processing capacity in the New Zealand dairy industry. However, it has also encouraged high milk volumes, particularly in spring when pasture is plentiful and milk production costs are low (Larsen 1997; Bates 1998; Scrimgeour 1999; Eman and Gommans 2001). This increase in milk supply often ended up in commodity products, reducing the average milk price. Lockhart and Cartwright (1997) and Bates (1998) also note other disadvantages. Cost models are expensive to maintain. The cost model approach does not reward value to any extent i.e. a company will receive the same price for a product whether or not it has done anything to add value by meeting a customer's specifications, and regardless of the market that product is sold into. The same pooled rate for milkfat and protein is paid to a company regardless of their product mix. Therefore, the company may be more concerned with producing as much product as possible, as efficiently as possible, than with world market demand, because there is no incentive or disincentive to produce one product relative to another. As a result, the NZDB may not get the product mix they require.

The Business Development Project (BDP) was established to study means to better match product mix to market requirements by improving the way the NZDB and dairy companies interface (Bayliss 1998). Payment systems were modified from July 1998 (Bates 1998). NZDB returns were classified into four segments:

1. commodity products for which the NZDB paid processors a market related pooled price from sales of that product only;
2. NZDB value-added products where the NZDB retained the value-added component and the processor received the pooled price as in 1.
3. products which the NZDB and the processor added value to, where the pooled price again applied but the processor also received some of the value-added component; and
4. new and specialty products where the NZDB and the processor negotiated the price.

NZDB value-added returns were then distributed to the processors in a separate payment.

1.2.2.2 Dairy Company to the farmer

This has been discussed earlier (Sections 1.1.2 and 1.1.3.2 as well as above). As mentioned,

most farmers are paid for milkfat and protein production, with a deduction for milk yield, in the A+B-C system (Larking 1989). Although payments are made this way prices tend to be quoted in dollars per kilogram of milksolids (milkfat plus protein) based on an average milk composition. Farmers are paid monthly based on an estimated market price for the products made. Incremental additions to the initial payment announced may be made throughout the season. A final payment is made at the end of the season, reflecting the actual export returns and the processing company efficiencies (MAF 1999). The weighted average payment in 1999/2000 was \$3.78/kg milksolids, and the two largest dairy companies both paid \$5.00/kg for milksolids in 2000/2001 (the weighted average was \$5.01). The 2001/2002 payment is expected to be higher, and then decline over the next few years (MAF 2001).

Other components could be included in the payment system, but would require a quick, simple and inexpensive means of testing the component in milk (Marshall 1989a). Payments based on casein and whey components rather than protein have been suggested (Garrick and Lopez-Villalobos 1998), and payment was already made on casein rather than protein for milk supplied to the former Kaikoura cheese factory (Boland *et al.* 2000). As mentioned, the price paid to farmers for their milk, remains the same over the season, which has led to increasing volumes of milk particularly in the spring (Eman and Gommans 2001). Exceptions are town supply farms and some Northland farmers where a premium is paid for winter or shoulder milk.

A Fonterra supplier's returns will comprise the payout, plus the difference in the fair value share price (Fonterra 2001e). The payout has two components: the average milk return and the value-added component. The average milk return is the commodity price, less production and selling costs. The value-added component is the cash return from investment activities less the retention reinvested for growth. The investment in value-added includes brands, patents and intellectual property. Investment is high and can be risky, and the return on investment may take time, but returns can be high.

1.2.2.3 *Future milk valuation and payment possibilities*

Farmers are responsive to price signals (ADFF 1999; Eman and Gommans 2001). However, past payments from the company to the farmer may not have reflected either company or market milk requirements. Peak milk has a lower value than shoulder milk (Eman and Gommans 2001), and there has been concern for some years about the increase in peak milk (Paul 1982; 1985; McCombs 1986; Gray *et al.* 1994; Eman and Gommans 2001) which has been proportionally greater than the increase at other times of the year (Gray *et al.* 1994;

Townshend 1994). The establishment of peak notes is already a step on the way to ensuring equity between suppliers by paying the true value of milk over the year. Differential payments for peak and shoulder milk have been suggested by those mentioned above and it is likely that this will become standard practice in the future.

An Australian study commissioned by the Australian Dairy Farmers' Federation (ADFF 1999) identified issues similar to those facing the New Zealand dairy industry. Seasonal milk supply and differential milk component values have already been discussed. They also suggest improved price signals (i.e. differential milk values) in the future could be associated with location of supply (i.e. transport costs), milk volume (i.e. collection efficiencies) and adherence to planned production. Milk quality standards, farming practices and traceability are also likely to become more important in the future and could affect milk pricing (ADFF 1999; Campbell and Fitzgerald 2000). Opportunities also exist for price differentiation where value is added on farm e.g. milk for niche products.

Milk prices are currently bundled into one payout. The integration of the New Zealand dairy industry and the allocation of company shares provides the opportunity for milk returns to be unbundled in the future, with a milk payment, plus a dividend on the shares which could incorporate part of the value added returns (ADFF 1999). The milk payout would then represent the true value of the milk.

The integration of marketing (NZDB) and processing (companies) in the New Zealand dairy industry eliminates the need for payments from the NZDB and the companies, making it easier to ensure that the product mix made best matches customer requirements and specifications.

1.2.3 Value-added systems and vertical integration

1.2.3.1 Value-added systems and vertical integration

Agricultural production in the past has largely produced generic commodities for the feed, industrial and food markets (Street 1990; Boehlje *et al.* 1999). Agribusiness is evolving from fragmented commodity systems trading on the open market to more closely coordinated, market driven supply chains with a differentiated product focus (O'Keefe 1998a; Boehlje *et al.* 1999). Boehlje *et al.* (1999) suggest that agriculture in the 21st century will be characterised by: manufacturing processes in production as well as processing, a food supply chain approach to production and distribution, negotiated rather than market coordination, a

more important role for information and other soft assets, and increasing consolidation at all levels raising issues of market power and control. In the future value chains are likely to be competing with other value chains, both nationally and internationally, rather than with other firms (Nitschke and O'Keefe 1997).

The study of supply chains and vertical coordination is encompassed by a range of disciplines including industrial organisation economics, transaction cost economics (coordination mechanisms), agency theory (outcome uncertainty and risk, goals), political science (power relationships), law (contractual relationships), and more recently business strategy (trust) (Boehlje and Schrader 1998; O'Keefe 1998a, 1998b). Value-added systems or supply chains in the agricultural industries or food chain are broadly described in Street (1990), O'Keefe (1994), Boehlje and Schrader (1998), O'Keefe (1998a) and Boehlje *et al.* (1999).

Four strategies to supply end markets defined by Boehlje *et al.* (1999) were: blending commodities into a single product that meets a specified commodity standard, sorting raw materials based on various characteristics toward specific end use markets, acquiring only products that will meet specific requirements (e.g. by contracts), and separating commodities into components, then recombining these to meet specific end markets. Future trends will see a shift away from the first strategy towards the last strategy requiring more aligned food supply chains, although it is likely that there will be a place for all strategies in the market.

Low value commodities can be traded relatively cheaply with less integration assuming low asset levels (specificity), efficient information and communication systems or minimal information required, and adequate supplies (Boehlje and Schrader 1998; Scrimgeour 1999). More integrated vertical chains are relevant if enhanced customer value can be created, and although these can achieve cost efficiencies initially, their primary objective should be to create value (O'Keefe 1998a; Scrimgeour 1999). Scrimgeour (1999) commented in relation to the creation of differentiated products that: brands are expensive to develop and promote; product flows need to be linked with complementary product and people rewarded for their inputs; and promotion needs to be more sophisticated as some products end up as components of other products. These value-added products will have to be sold at a sum greater than the costs of adding value, for value-added returns to be realised (Lockhart and Cartwright 1997).

The food supply chain includes all the steps from producers to customers. The steps identified in the New Zealand dairy value chain (Lockhart and Cartwright 1997; Spring 1997) are:

1. milk producers;
2. primary processors (processing, manufacturing, packing);
3. shipping (exporters and importers);
4. secondary processors;
5. warehousing and distribution;
6. marketing, sales and customer service; and
7. customers.

Boehlje and Schrader (1998) and Shaw (2001) also identify suppliers of farm inputs in the supply chain, as farmers are increasingly purchasing more of their inputs off-farm e.g. stock, grazing, feed, transport, semen. Linkages in supply chains are changing (Boehlje and Schrader 1998). The number of linkages are increasing at the top end (more inputs into the farm system), while at the lower end functions performed by a number of firms are being internalised (e.g. wholesaling, retailing and distribution). The types of linkages are also changing e.g. spot markets to contracts. Those at the top end of the food chain (e.g. the producer) are often left with most of the risks while those at the bottom end enjoy most of the value-added opportunities e.g. through branding (Street 1990; ADFP 1999). Boundaries between firms range from free market to contracts, licences, strategic alliances, franchise agreements and complete vertical integration i.e. vertical ownership (Lockhart and Cartwright 1997; ADFP 1999; Boehlje *et al.* 1999). The better the co-ordination, the stronger the supply chain and the lower the risk (ADFP 1999).

Consumers in the Western world are now becoming more sophisticated in their requirements (“wants” rather than “needs”) (Street 1990), and are taking increased interest in quality issues such as taste, freshness, safety, origin and traceability, environmental issues, animal welfare, and production systems, as well as variety, price, convenience and availability (Street 1990; Boehlje *et al.* 1999; Christie 2000). These changing consumer expectations effect the whole supply chain. The demand for component specific rather than generic commodities by food and industrial markets (Boehlje *et al.* 1999) has led to increasing investment in value-added supply chain technology (Street 1990).

Factors contributing to the development of more closely aligned supply chains (Street 1990; Boehlje *et al.* 1999; Manhire 1999; Shaw 2001) include:

1. more discerning consumers demanding specific products, requiring higher levels of accurate and responsive messaging, and higher pay-offs;
2. government regulations and policies reducing subsidies and protection, imposing food safety regulations, and increasing privatisation;
3. globalisation, which has removed trade barriers making it easier for large retail chains wishing to optimise product supply to source internationally;
4. the shift in resources required to compete in global markets e.g. more sophisticated R&D, increased importance of information and knowledge, a skilled labour force and sophisticated technology, an efficient distribution channel and global access to all resources (including capital and finance);
5. attempts to reduce risk and cost (quality, volume, food safety, efficiency in production costs);
6. the development of food production and distribution technologies e.g. information technology (e.g. computer databases), biotechnology, monitoring and logistics technologies, environmental technologies, economies of scale and efficiencies of specialisation;
7. the potential of biotechnology to lead to the development of new or modified products that compete with traditional products, or improve productivity;
8. more differentiation across the chain rather than primarily in the manufacturing and marketing sectors, requiring better information flow;
9. more differentiation and specification resulting in more complex processing with the associated potential for errors, which are easier to control with a more integrated value chain; and
10. the increasing investment in sophisticated technologies which increases financial risks, therefore requiring a more reliable supply in quantity and/or quality.

The advantages of more closely aligned supply chains (Boehlje and Schrader 1998; Boehlje *et al.* 1999) include:

1. increased efficiency and lowered costs. Flow scheduling and volume control, specialist products and regulation compliance may need cooperation between different stages of the value chain.
2. management and allocation of risk. Coordination (e.g. contracts) can eliminate some of the price risk for both parties, as well as ensuring supply availability or consistent quality for those at the lower levels of the chain. Sources of food safety risk also have to be

maintained throughout the chain.

3. greater response to consumer demands.

Boehlje *et al.* (1999) described the critical dimensions of a value chain as including:

1. the explicit specification of the value creating activities in a production-distribution process, and provision of a structure for the linkages between these activities and processes i.e. identifying the activities necessary to create the products demanded by the consumer;
2. the specification of the *product flow* features i.e. transport and logistics of product flow;
3. the *financial or cash flow* between processes/participants and sharing of financial information;
4. the *information flow* across the chain;
5. the incentive system to reward performance and share risk; and
6. chain governance and coordination (e.g. from open market through to vertical ownership) which effects who has power and how risks are shared.

The degree of vertical integration is greater with high asset specificity, programmability and non-separability (Table 1.4) (O’Keeffe 1994; Boehlje and Schrader 1998; Boehlje *et al.* 1999). Asset specificity refers to the specialised nature of the assets required to complete a transaction. These can be site, physical, human, or dedicated assets. The greater the asset specificity, the greater the exposure to risk (Dorward 2001). Task programmability refers to the degree of specialisation and negotiation required to complete a task, and separability refers to the ease with which each party’s contribution can be identified and rewarded. If the threat of opportunistic behaviour within the chain is high a more vertically integrated structure may be adopted to reduce the risk (Boehlje *et al.* 1999; Dorward 2001). Dorward (2001) suggested that asset specificity and uncertainty (related to lack of information, bounded rationality and the scope for opportunism by another party in a transaction) are the key transaction characteristics that affect a firms exposure to risk and determine how different contractual arrangements can be used to reduce its transaction costs. The structure of a value chain is also likely to change over time (Boehlje and Schrader 1998).

Table 1.4: Predicting organisational forms of alternative business linkages (from Boehlje *et al.* 1999, p. 28).

Factors	Low programmability		High programmability	
	Low asset specificity	High asset specificity	Low asset specificity	High asset specificity
Low non-separability	Spot market	Long term contract	Spot market	Joint venture
High non-separability	Cooperation (strategic alliance)	Cooperation or vertical ownership	Inside contract (hybrid)	Vertical ownership

Important issues in supply chains relate to product differentiation and power, risk, information, and trust and relationships. Information exchange between stages occurs more rapidly in vertically integrated supply chains enabling them to respond more quickly to changing consumer demands, economic conditions or technological improvements (Boehlje *et al.* 1999). The higher the specification required in products, the higher the potential pay-off. The fewer the places where this differentiation can occur, the more important it is to have control over these stages because this is where the power to capture value lies.

The main source of the power in a supply chain is at the point that controls the least substitutable resource (Boehlje *et al.* 1999), and the owner of this point has the power to capture rents, transfer risk to others and affect what the chain does or does not do. The power in traditional commodity food chains is often held by those who generate the least cost, with capital and labour resources being important e.g. the processors. These resources become less important relative to accurate and unique information on what the consumer wants, and how to produce this (e.g. through genetics or processing) in the more differentiated food chains. Therefore, in differentiated chains the position of power moves from those with the capital and financial resources, to those with the “soft” assets e.g. information, R&D, new technology. This places the power at each end of the supply chain.

The power associated with producers of the raw materials depends on substitutability of their inputs (Boehlje *et al.* 1999). The genetic material is often the least substitutable, and those with the ability and knowledge to manipulate this (e.g. biotechnology companies) will increasingly hold more power, although processing technology can in some cases produce the same attributes at a lower cost.

Boehlje *et al.* (1999) surmises that in future the reduction in real differences between products will also see weakening brand loyalties, and an associated reduction in processors' power. Processors will rely more on time responsiveness and price to capture market share

with less differentiated products. Retailers' power will increase as consumers demand more unique and differentiated products i.e. retailers will have information on what the consumer wants.

Advantages accrue to those with the ability to understand and utilise the vast amount of information on chemical, biological and physical processes in agriculture, and who have a greater knowledge of processes in the food business and how to combine these in a total system i.e. food chain approach (Boehlje *et al.* 1999). Measuring and monitoring, such as in precision agriculture, become more important at the production level. Access to information, particularly at the production level, has historically come from public and external sources e.g. public sector research, suppliers of farm inputs and processors (Street 1990; Boehlje *et al.* 1999). In contrast, coordinated systems also access information from internal sources, often employing their own R&D staff. Information obtained from this source is proprietary and provides competitive advantage. The strategic value of information will see less free exchange of information in the future and intellectual property issues will become more important.

Research and development in coordinated chains also tends to focus on total system efficiency rather than on individual system components. This, along with the fact that they have the capacity to implement technological breakthroughs more quickly allows integrated supply chains to capture more of the innovator's profits compared to other structures. Greater monitoring and control in integrated supply chains also means adjustments can be made sooner in the case of defective technologies or deteriorating performance (Boehlje *et al.* 1999). An information intensive value-chain is more likely to regard short-term profitability and long-term market share as compatible goals. Sharing strategic information between the members of the value chain will shift the focus onto long term strategic objectives rather than short term opportunism (O'Keefe 1994).

The value captured from the production of differentiated products does not stay constant, and in fact often declines over time (Boehlje *et al.* 1999). Loss of intellectual property ownership, substitution or replacement, commodisation of a product as increasing numbers supply the product, and mitigation where buyers buy better products or similar products at a cheaper cost reduce the value of a product. Products are often designed for short life and obsolescence (Street 1990). Thus, continuing product development will be critical.

Increasing scale and investment in sophisticated technologies requires adequate volumes of

raw material, increasing financial exposure and risk (Street 1990). Consistent quantity and quality of raw material is required for some products, resulting in closer vertical integration to ensure this e.g. retailers entering into supply contracts with producers (Street 1990; Boehlje and Schrader 1998). This can also reduce the price risk for both parties compared to trading on the spot market. Food safety risk has become more important in recent years, not only for the firm responsible for the contamination but also those further down the supply chain (Boehlje and Schrader 1998).

Risks are not necessarily less with stronger vertical integration, but different (O’Keeffe 1998a). Price risk may be reduced but financial, marketing and relationship risks may increase. Risk management in the protection of brand investment can be a key force in developing more coordinated food chains (O’Keeffe 1998a). The production of market specific products will increase market risk because the product may be worth less in alternative markets than a non-specific commodity product (O’Keeffe 1998a). Risk may also be transferred to other sectors in the chain, with producers often being those most at risk (O’Keeffe 1998a).

Integration will not occur unless it is perceived that an economic advantage exists for both parties i.e. flexibility has value (Boehlje and Schrader 1998). Less integrated firms or producers have higher independence, but also often have higher price risk e.g. auction compared with contract (Nitschke and O’Keeffe 1997). As firms become more vertically integrated some independence is relinquished and interdependence is established between firms (O’Keeffe 1998b). Trust between the firms is critical in achieving effective vertical integration (O’Keeffe 1994, 1998b; Nitschke and O’Keeffe 1997).

O’Keeffe (1998b) found that relationships were more likely to be formed where there were compatible goals, alternatives were limited, there was information exchange and communication between firms, firms understood each other’s business, and firms believed the rewards were shared equitably. Relationships where size imbalance (e.g. between producers and processors) exists are not as effective as relationships between firms of similar size (Nitschke and O’Keeffe 1997; O’Keeffe 1998b). If one firm perceives that it is dependent on another then trust must be high for a firm to invest in the relationship (O’Keeffe 1994). Producers may increase scale by horizontal integration as well as vertical integration to share in value added activities (Street 1990). One firm in the chain may take control. This firm may take more of the risks and have a greater claim on profits (Boehlje *et al.* 1999). Further integration between firms at different levels in the chain is encouraged

when firms can not agree on equity.

There are two approaches to engineering trust in a supply chain. The first uses “monitoring” and penalties if criteria are not met. The second relies on “manipulation” with performance incentives and expectations of honesty i.e. guilt and satisfaction as motivators. This strategy works best where monitoring costs are high, communication costs low, the manager is persuasive, and performance is difficult to measure. This is more likely where intellectual skills are involved rather than manual skills e.g. service industries (Boehlje and Schrader 1998). The role of trust in contract coordination is important in agriculture because of the impossibility of writing a complete contract and the asset specificity associated with modern agricultural production (Boehlje and Schrader 1998).

1.2.3.2 Cooperatives

Primary producers are price-takers at the farm gate (Spring 1997). However, the cooperative structure of the New Zealand dairy industry allows dairy farmers to also capture the gains along the value-added chain. Cooperatives provide benefits to their owner-shareholders in processing scale, market access and bargaining power, the provision of an outlet that has to accept their produce (which is particularly advantageous with perishable agricultural produce), by providing security to their members by pooling returns and maintaining a market in times of adversity, and capturing marketplace margins through vertical integration that would otherwise go to middlemen (Spring 1997; Lynch 1998; Ling and Liebrand 1998; ADFP 1999).

The disadvantages can include payment of average returns to owner-shareholders with little or no differentiation between suppliers (e.g. on scale, quality, collection or processing efficiency of their milk), other firms can pick off the better suppliers thus reducing the average return to the cooperative, and there can be problems associated with common property rights e.g. new members may have the same rights as established members, life of the cooperative assets may exceed the time of a suppliers patronage of the cooperative (Spring 1997; Lynch 1998; Ling and Liebrand 1998; ADFP 1999). The Australian dairy is also seeing cooperatives taking a greater interest in equity issues (Langdon 2001; ADFP 1999).

Ling and Liebrand (1998) classified USA dairy cooperatives into six categories. These were bargaining (obtaining the best price for their producers milk), bargaining and balancing (selling milk and producing commodity products with surplus milk), undifferentiated hard-

product manufacturing, niche market, fluid processing and diversified dairy cooperatives (a combination of the others). The diversified cooperative definition best describes the New Zealand dairy industry structure. Diversified dairy cooperatives are the most vertically integrated. They tend to have large milk volumes, a system of plants that manufacture a variety of products, and can shift milk to the most profitable enterprises. It is anticipated these cooperatives will control most milk in the future (Ling and Liebrand 1998).

Future challenges for cooperatives identified by Ling and Liebrand (1998) include little or no government support, globalisation of the market and greater market access, increasing rules regarding food safety and the environment, and more discerning consumers. Management and business issues include: attracting quality employees, organisational strategies (maximising management competence and flexibility while maintaining producer control), establishing joint ventures and business alliances, meeting capital requirements which are likely to increase with further market integration yet still having to revolve equity to members, and retaining equity between more diverse farm units than in the past (Ling and Liebrand 1998). The New Zealand dairy industry already has little or no government support, and as an exporter will find increasing globalisation and market access an advantage. However, the other points identified also relate to the New Zealand dairy industry.

1.2.3.3 Vertical integration in the New Zealand dairy industry

The strength of the New Zealand dairy industry is its vertical integration (Spring 1997; Bates 1998). Dairy farmers own everything from production, processing, marketing, research and advisory services (Spring 1997; Holmes 1998). This cooperative structure ensures that the single industry objective is to create value for the New Zealand dairy farmer (Spring 1997; Holmes 1998). In contrast, separate ownership of the various stages of the value chain introduces different objectives and profit imperatives which can reduce customer focus and commitment to value creation throughout the chain (Spring 1997).

Added-value strategies by members of the supply chain create generative and distributive effects (Lockhart and Cartwright 1997). Generative effects are a result of increasing returns, by increasing the value of the goods, the volume of goods sold or by cost reductions. Distributive effects refer to the distribution of the value to various participants in the chain. Some of the value created by one party may accrue to another party because of asymmetrical bargaining power. The cooperative structure of the New Zealand dairy industry is such that the producers benefit from both generative effects (e.g. size and scale in marketing increases producer returns) and distributive effects (i.e. all returns accrue to producers) (Lockhart and

Cartwright 1997). However, management of the chain can detract from generative effects by encouraging manufacturers to produce low cost, high volume products (see Section 1.2.2.1), and partly as a result of continuing marginal production to maintain distributive effects in the cooperative. While the price signals and communication in the dairy industry are not ideal (Section 1.2.2), they may be greater than if a number of organisations were in the vertical supply chain. Holmes (1998) maintained that it is important to retain the industry's farmer control, integration of functions and services, and collective strength in the future. The further amalgamation of a number of the components of the New Zealand dairy industry in Fonterra is likely to result in a more highly integrated supply chain in the future.

Shaw (2001) noted that the New Zealand dairy industry is facing greater consolidation of food manufacturers and retailers generating leverage over producers in the supply chain, threats to our relative cost position, the change to knowledge and skills as the major source of competitive advantage rather than cost and availability of milk, and the potential for biotechnology to change the future e.g. new products and greater productivity. These two effects are likely to further the development of a more integrated dairy industry in the future.

1.2.4 Conclusion

The New Zealand dairy industry has undergone substantial change in recent years. The recent merger of the NZBD and the two largest companies means that 95% of the milk in New Zealand will be processed and marketed by one company, Fonterra Co-operative Group Ltd, which is owned by its farmer suppliers and overseen by a board of directors. This has brought changes to both the structure and the payment system of the industry. Further changes to the latter are expected in the future.

A strengths of the New Zealand dairy industry is the degree of vertical integration. The NZDB was the only exporter permitted to sell dairy products in the past. The NZDB was owned by the cooperative processing companies, which in turn were owned by their farmer suppliers. Therefore, all dairy industry profits ultimately accrued to New Zealand dairy farmers. The size of the NZDB gave it strength in the market place generating higher returns than the farmers as individuals could have achieved (i.e. farmers are price takers). Another advantage was farmers had a guaranteed buyer for their produce.

Price signals from processors to farmers in the past have led to increased milk production, particularly during peak supply, while the NZDB cost model payment system has led to the development of an extremely efficient processing industry. However, these factors have

contributed to the production of a product mix containing a high proportion of lower returning commodity products.

The dairy industry needs to increase the value added output of their business, and the integration of marketing and processing under the recent merger will make achieving this easier. Price signals for milk may better reflect the quantity, quality and timing of milk required and its true value under the new structure. Past returns to farmers have largely been average pooled returns. Farmers currently receive partial differential payments based on the composition of their milk (milk, milkfat and protein yields). The opportunity exists for farmers to receive further differential payments based on other milk production or quality aspects (e.g. spread of milk flow, collection efficiencies), better reflecting the true value of each suppliers' milk. The issue of shares and peak notes in the new structure will mean farmers who increase production, especially during the peak, have to pay toward the downstream costs associated with this. Payment to farmers for raw milk may also be differentiated from value added returns in the future. Suppliers producing milk that adds value on farm can be rewarded for doing so e.g. organics, niche markets. Some differentiation in milk returns may also be necessary to prevent competitors coming in and "picking off" the most efficient milk producers under the deregulated dairy industry structure. However, the continuation of the cooperative structure of the industry means some pooling of returns, particularly for milk processed into commodity products, will persist.

1.3 AGRICULTURAL SYSTEMS AND MODELLING

1.3.1 Systems

The systems approach is based on the argument put forward by Aristotle that the whole is more than the sum of the parts (Rountree 1977; Doyle 1990; Checkland 1999) i.e. they exhibit *holism* (Wilson and Morren 1990; Bawden 2000). Spedding (1988a, p. 18) described a system as: "a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks".

The attributes and components of a system as described by Rountree (1977), Dent and Blackie (1979), Spedding (1988a, 1988b), Doyle (1990), Wilson and Morren (1990), and Bawden (2000) include the following.

1. A set of identifiable components, with interactions and inter-relationships between the various components, all encompassed by a boundary that defines the limits of the system.

A system can maintain its identity and integrity under a range of conditions, exhibiting properties that emerge from their wholeness.

2. An environment that lies outside the boundary that affects the system. This may be the supra-system, as referred to in the next point. Outputs from the system to the environment do not affect the system i.e. it is not affected directly by its own outputs. All significant feedback is contained within the system boundary.
3. A hierarchical structure. It may be made up of a number of sub-systems, each of which may contain sub-systems. The system itself may be part of a supra-system. Each sub-system can be defined or extracted independently of the others. Interactions occur between the sub-systems within a system, as well as between the components within a system or sub-system.

A system is a human construct expressed in conceptual terms rather than a reality (Wilson and Morren 1990; Bawden 2000). The study of systems is an approach to, rather than a study of, a particular subject or set of phenomena and can be applied in most disciplines (Checkland 1999). A systems approach is “founded on the idea that it is necessary to identify and describe the system that one wishes to understand, whether in order to improve, repair or copy it, or to compare it with others in order to choose one” (Spedding 1988a, p. 18). Models play an important role in describing systems (Wilson and Morren 1990; Spedding 1994). Models are discussed later.

Spedding (1988a, 1988b, 1994) and Wilson and Morren (1990) suggest that the purpose of studying agriculture is the improvement of agricultural systems, either directly or indirectly. Spedding (1988a, 1994) describes the three main methods of improving agricultural systems, which he calls extension activities, as follows.

1. Offering advice on component changes, which should be related to the functioning of the system as a whole. A farmer may need to judge whether a component change would be beneficial based on knowledge of their farming system, as an advisor may not fully understand each individual’s farming system.
2. The adoption of an innovation, which may come from research and development (R&D), or from farmer innovation. This involves risk, and innovations are often trialled on some form of model. Models will vary and may depend on whether the objective is to operate, repair or invent new systems.
3. Copying what others are doing which requires a copier (i.e. the farmer) to determine whether the system to be copied is in fact better than that in place over a range of conditions, whether it is relevant to the copier’s system, and which components to copy.

The two questions Spedding (1988a, 1994) identifies as needing to be answered before the improvement process is implemented are:

1. What is the system to be improved? This requires some sort of model to describe the system. The components included in the model are determined by the objective of the model; this is considered in the second question.
2. What is an improvement? This is usually an improvement in some measure(s) of efficiency, which may be improved profitability; however, there is often more than one objective. Stability, risk-reduction, security, labour-reduction, environmental stability or improvement, and social objectives may be included.

A hard systems or a soft systems approach can be adopted. The nature of the problem is likely to determine the systems approach adopted. If the problem has clearly defined objectives and decision-making procedures, and quantifiable measures of performance are available a hard systems approach is appropriate. In contrast, a soft systems approach is applicable where there are poorly defined objectives, decision-making procedures are uncertain and measures of performance are unpredictable (Spedding 1988a; Checkland 1999). Hard systems approaches seek solutions to problems and commonly employ quantitative models and simulations, whereas soft systems approaches evolved to deal with situations where human perceptions and behaviour are dominant and involve a process of enquiry into a problematic situation. Hard systems approaches start by defining a systems model at the problem identification stage, whereas a soft systems approach includes on-going model development at a later stage of the process as understanding of the human activity system under study develops (Wilson and Morren 1990).

1.3.2 Models

Models can be defined as “representations of the real thing, simplified for some purpose: they include those features that are essential for the purpose and leave out those that are inessential” (Spedding 1988a, p. 19), or more specifically as “an abstraction and simplification of the real world, specified so as to capture the principle interactions and behaviour of the system under study and capable of experimental manipulation in order to project the consequences of changes in the determinants of the system’s behaviour” (Spedding 1988b, p. 4). Spedding (1988a), in discussing a hard systems modelling approach, notes that there needs to be a clear purpose in order to decide what is, and is not, essential to include in the model.

Agricultural systems are complex and multi-disciplinary, combining biological or physical, economic, management and social science components (Spedding 1976; Dent and Blackie 1979; Dent 1990). Consequently, it is impossible to develop a picture or model of an agricultural system that represents the entire system. Instead it is necessary to develop a model encompassing those aspects that are required to meet the objective or answer the question being asked (Spedding 1988a). Models can relate to whole systems or to sub-systems. Where a system is complex models of sub-systems can be developed and incorporated into the model as a whole with outputs from a sub-model acting as inputs to another sub-model (Spedding 1988a).

Wilson and Morren (1990) identified the uses of models as being to:

1. communicate complex interrelationships;
2. communicate concepts about the meaning of something;
3. search for new insights about how a system might be, might work, or might behave; and
4. evaluate alternative strategies or change.

As well as identifying the use of models to assist in the evaluation of new systems or assist in the decision making for existing systems, Ebersohn (1976), Dent and Blackie (1979) and Spedding (1988a) also noted that models could be used to identify where experimental studies may be needed (gaps in knowledge) as well as using and assessing the results of such studies. Model builders are also in a position to take an objective and critical review of knowledge concerning the system (Dent and Blackie 1979). A systems approach can cope with complex hypotheses, or hypotheses about complex systems, often expressed only as computer models (Spedding 1988a).

Models can range from mental models through to the more complex mathematical programming and simulation models. Dent and Blackie (1979), Spedding (1988a), Dent (1990), Doyle (1990), Wilson and Morren (1990) and Sorensen (1998) describe the various model types as follows.

1. Mental and verbal.
2. Physical, also known as scale or iconic models. Standard symbols may be used to represent the various system components e.g. Forrester's symbolic language.
3. Diagrammatic, including pictures and flow diagrams which often use recognised symbols. This is often a preliminary phase to the development of a mathematical model.

4. Mathematical programming models, such as linear programming models. These models are typically optimisation models for decision support (Dent and Blackie 1979; Sorensen 1998).
5. Simulation models, which do not include optimisation algorithms and are used to answer “what if?” questions (Sorensen 1998). These are discussed in more detail in the next section.

The last three categories are known as symbolic models, with categories 4 and 5 being mathematical models.

1.3.2.1 Simulation models

Simulation models were identified by Dent and Blackie (1979), Doyle (1990), Wilson and Morren (1990) and Sorensen (1998) as being useful in situations where:

1. real life experimentation is impossible or impractical because of time or cost factors, or the subject cannot be experimented on e.g. the economy, social innovations, ethical reasons;
2. real life experimentation would disrupt the system to an extent that the results were artificial;
3. situations that do not exist are to be evaluated;
4. the effects of time are to be included in an analysis;
5. stochasticity is to be included in the analysis to evaluate risk; and
6. people are being trained to operate in a real world situation.

Simulation models can be further categorised according to type. They are often described as being static or dynamic, deterministic or stochastic, and empirical or mechanistic (Sorensen 1998). Time is included as a variable in a dynamic model, whereas a static model remains constant over time. Some variables in stochastic models are described in terms of probability distributions whereas a deterministic models use a single value, such as a mean, for all variables. The outputs from a deterministic model given a set of inputs will always be the same, whereas with a stochastic model chance plays a part and outputs will vary. A mechanistic model has one or more sub-levels whereas an empirical model relates to input within the same hierarchy. Jones and Luyten (1998) describe models as being continuous or discrete. Variables change smoothly over time in a continuous model (described by equations) while the variables in discrete models take on integer values (e.g. dead or alive). Wilson and Morren (1990) also describe a number of other classifications.

1.3.2.2 Modelling process

Compartment models, where the main emphasis is on flow and storage of system variables (Jones and Luyten 1998), are useful in modelling agricultural systems (Ebersohn 1976). These are diagrammatic in the qualitative phase and use symbolic language and mathematical equations in the quantitative phase (Ebersohn 1976). The variable types in a model, or components of a compartment model, are described in different ways. Exogenous variables are those outside the system boundary that affect the system (Dent and Blackie 1979). These can be controllable or uncontrollable. Controllable variables can be fixed (represented by a constant) or can be systematically varied to assess their effect on the outcome. These inputs can also be known as driving variables where they refer to a rate or ratio, or a source where they refer to a resource (Ebersohn 1976; Wilson and Morren 1990). State variables are levels or amounts of material within the system and rate variables refer to flows of actions or materials within the system. Auxiliary variables are described as a mathematical function of other variables within the system. Flow lines show the movement of information or materials through the system. Outputs from the system to the environment, often the objective of the system, can be referred to as sinks. Components of the model that are considered to remain constant over time are represented by parameters or constants (Jones and Luyten 1998).

The modelling process has been described in a number of ways. The following description of the development of a simulation model is adapted from Dent and Blackie (1979), with input from Ebersohn (1976), Cooke (1998), Jones and Luyten (1998) and Sorensen (1998). The steps involved in the construction of a model are shown below.

1. Define the system and the modelling objectives. The reason for the model, the outputs and inputs, the degree of detail required, and the boundary are described. Cooke (1998) notes that the decision-maker needs to be identified, and further suggests that the decision-maker is usually both the person (or group) whose objectives are not being met and the resource provider. However, this may not necessarily be the situation, in which case both the decision-maker(s) and the resource provider will need to be involved in this step i.e. defining the objective and determining resources available to meet this objective. The statement of objectives should clearly define the intended users and the end product required (Jones and Luyten 1998). Considerations to be taken into account include the modelling resources available (e.g. expertise, time, finances) and any environmental constraints (Ebersohn 1976; Cooke 1998).

2. Analysis of the data relevant to the model. Information necessary to meet the requirements of the model objective is reviewed. A conceptual model is developed which is dependent on data available and/or the feasibility of data generation. The objectives and conceptual model are stated in word form or sketches (Ebersohn 1976; Cooke 1998).
3. Construct the model. First, decide whether a simulation model is appropriate, or whether a more simple model would suffice. A diagrammatic model showing the components of the system and their relationships with each other is then developed and a detailed data search is conducted to quantify the model components and relationships. The model construction process may be iterative as model restructuring, or data modification or manipulation, may be necessary where data or functions to describe relationships are limited. Data may not be available in the format required for the model and may require some modification. Subjective data may need to be estimated. Where data limitations mean a subsystem cannot be adequately represented within the system a component may need to be represented as an exogenous variable instead. Alternatively, data may be generated by experimental means. However, this may be costly in terms of resources e.g. time and money. A symbolic computer flow diagram may be developed. The final step is the development of the computer representation, using the selected programming language or software.
4. Validate the model. Model validation is concerned with ensuring the model mimics the “real” system sufficiently accurately to meet the model objectives (Spedding 1988a; Jones and Luyten 1998). The same inputs should result in the same outputs. Intermediate checks on accuracy as the model progresses are recommended (Cooke 1998). The model should be tested against data not used in its construction (Dent and Blackie 1979; Spedding 1988a; Sorensen 1998). However, this is not always possible. For example, a livestock system may require a fresh set of data from farms with the same production system measured over several years. In this case model output should be sufficient to enable it to be compared with reality, and model validation is achieved through application (Sorensen 1998). Further model modification and construction may be required.
5. Sensitivity analysis. This can be part of the validation stage (4) and model application (6). Sensitive model parameters or variables are identified. These should be clearly represented in the model. If there are doubts about the accuracy because data limitations may have led to modification of existing data or use of estimates in these areas, further

modification of the model may be required. If the model is believed to be a good representation of the system then this identifies the areas where close monitoring or control may be needed in the “real” system, or quantifies responses to change in a particular variable.

6. Model application. Documentation relating to model structure and code, as well as comprehensive user documentation needs to be provided (Jones and Luyten 1998). This should be sufficiently clear for users to understand the purpose of the model, and what the model can, and cannot do i.e. the model’s abilities and limitations.

1.3.3 Conclusion

This milk segregation study is an agricultural systems study using a hard systems approach. This section summarised the literature about agricultural systems approaches, with a description of modelling which is an important tool used in agricultural systems studies. The modelling discussion concentrated on simulation modelling which is the type of model that will be developed in this study. Inputs are adjusted in a simulation model to show the effect of differences in the management of a system i.e. inputs in a model of a dairy farm system can be altered to simulate different farms or management. A strength of simulation models is they can be used to assist in the analysis of the effects of changes over time. Consequently, this approach is applicable to this study. A model reflects the model-developer’s interpretation of the objective and approach to the problem, and given the same objective another modeller would develop a different, although possibly similar model. Unless a model is specifically designed and documented for other users, or is simple to understand, its use may be limited to the developer.

1.4 RISK

The nature of agriculture, with its reliance on external factors over which the farmer may have little control, makes it inherently risky (Fleisher 1990; Hardaker *et al.* 1997). Agriculture is affected by physical and biological factors, such as unpredictable weather or the uncertainty about the performance of crops or livestock e.g. from pests and diseases. Prices of farm inputs and outputs, which are dependent on markets and government policies, are variable and unpredictable. Deregulation of the New Zealand economy from 1984 onwards has left New Zealand farmers more exposed to market uncertainty (Martin 1994; Hardaker *et al.* 1997).

1.4.1 Decision making and risk

Farm managers make decisions on the allocation of limited land, labour and capital resources, often based on uncertain information, to meet the diverse goals and objectives of the farming family in an environment (e.g. physical, economic, social) which includes factors over which the farmer has little or no control (Kay and Edwards 1994). Decisions need to be made and revised as the environment or objectives change and as new information comes to light. Decision-making rules developed by economists that rely on objective functions that maximise profit, net present value or expected utility often fail to describe the actual decision-making process (Wilson *et al.* 1993). Most actions taken by a farm manager are subject to risk, therefore farm management studies need to place increasing emphasis on how to respond to risk (Jolly 1983). An individual decision maker's perception of risk will depend on their circumstances (Wilson *et al.* 1993), and management options chosen will have an acceptable balance between the exposure to risk and the risk-bearing ability of the business (Jolly 1983).

1.4.1.1 Risk and uncertainty

Decision making takes place under conditions of perfect knowledge, risk or uncertainty, and these have been variously defined. Under perfect knowledge there is only one outcome to an action, which is known with certainty (Sonka and Patrick 1984; Fleisher 1990). However, this situation rarely exists in the real world, particularly in agriculture. Hardaker *et al.* (1997) defined *risk* as imperfect knowledge where the probabilities of the possible outcomes are known, and *uncertainty* when these probabilities are not known. However, most probabilities are estimated subjectively rather than objectively (Anderson *et al.* 1977; Hardaker *et al.* 1997). Hardaker *et al.* (1997) therefore defined *uncertainty* as imperfect knowledge and *risk* as uncertain consequences. There is often little distinction in the use of the terms risk and uncertainty (Sonka and Patrick 1984).

1.4.1.2 Perceived riskiness of an action

Fleisher (1990) outlined six factors that affect the perceived riskiness of an action choice as:

1. the expected value of a distribution of outcomes i.e. the weighted value of likely outcomes multiplied by the likelihood that each will occur;
2. the spread of the outcomes i.e. range and distribution (e.g. variance, skewness);
3. the time interval;
4. the decision maker's situation;

5. the scope of the analysis i.e. a choice based on the decision maker's entire situation may appear more rational than considering that decision in a narrower context;
6. the aggregation of enterprises e.g. an enterprise that is riskier may be incorporated into a farm plan because it complements the other enterprises, with the overall farm plan being less risky than other alternatives.

The existence of variability does not necessarily create risk (Fleisher 1990). Stable price cycles that are more predictable can be used more accurately in planning. However, highly variable or unstable prices are less easy to predict, creating uncertainty. Estimation of probabilities can be difficult (Wilson *et al.* 1993; Hardaker *et al.* 1997). Variables may be correlated, distributions may not be normal, production distributions may be site-specific, technical changes may make historical data less relevant and distributions may be needed for new technologies where data are unknown (Jolly 1983). The description of distributions (e.g. probabilities, mean, mode) is subjective and will be influenced by an individual's knowledge and access to information, expectation of future trends or changes, past experiences and judgemental biases (Sonka and Patrick 1984; Barry *et al.* 1995; Hardaker *et al.* 1997). The perceived riskiness of any particular choice varies between individuals.

1.4.1.3 *Downside risk versus pure risk*

Pure risk is concerned about the variation about some representative measure of performance such as the mean (Hardaker *et al.* 1997). Downside risk refers to those outcomes with worse outcomes, while upside risk refers to better than normal outcomes (Fleisher 1990; Hardaker *et al.* 1997). When downside risk predominates, the norm is represented by the upper tail of the distribution (skewed distribution). Hardaker *et al.* (1997) argue that most technical risk in agriculture is downside risk, since significant deviations from plan are more likely to have adverse consequences e.g. large deviations in rainfall either way will reduce yields. It can also occur where there are non-linear interactions between variables. Managing response to low probability failures is an important element of routine farm management (Jolly 1983). Downside risk is discussed further in Hardaker *et al.* (1997).

1.4.2 **Farmer attitude to risk**

Farmers can be described as risk averse, risk neutral or risk preferring (Fleisher 1990; Barry *et al.* 1995; Hardaker *et al.* 1997). Risk averse individuals will forego some return for a reduction in risk, with a higher return expected from a more risky investment to compensate for the risk involved. Levels of risk aversion can vary between individuals, and for individuals over time as their circumstances alter. The increase in returns required for an

individual to accept a risk is called the risk premium. The longer the term of an investment the harder it is to predict future costs and prices, so the inclusion of a risk premium in investment analysis by using a higher discount rate is one way to allow for this (Kay and Edwards 1994).

A risk neutral person will accept a return based on the expected return, regardless of distribution. Risk preferrers will be prepared to accept a higher risk in order to get the maximum gains. Fleisher (1990) noted that early technology adopters tended to be risk preferrers, suggesting that the existence of upside risk may influence technology adoption.

Utility functions to measure risk attitudes are described in Hardaker *et al.* (1997). These integrate utility (an individual's preference) and probability (degree of belief) to provide a means of ranking risky options.

1.4.3 Risk decisions and techniques

The decision process involves: identifying the sources of risk, identifying possible outcomes or events such as ranges of variation in weather and prices, identifying alternative strategies, quantifying the consequences of each strategy incorporating the decision maker's beliefs about uncertainty, evaluating the trade-offs between returns and risk based on the decision maker's preferences, and selecting and implementing a strategy (which may be the status quo) (Sonka and Patrick 1984; Kay and Edwards 1994; Hardaker *et al.* 1997). In selecting risk management strategies farmers determine the degree to which risk is reduced by a strategy, and then place a value on the reduction in risk associated with that strategy (Fleisher 1990). A reduction in risk is likely to be associated with a reduction in profit, and may also require time and management skills.

Risk associated with many day-to-day decisions is often unimportant because the potential loss is small, and/or the probability of loss is low (Hardaker *et al.* 1997). Analysis of alternatives by farmers is often restricted to simple budgeting methods such as partial budgets, and cash flows to ensure debt servicing and living costs can be met (Jolly 1983). Risk assessment may be by the use of conservative assumptions, break-even analysis and sensitivity analyses. Wilson *et al.* (1993) note that managers may not calculate statistics to assist in decision making, selecting instead strategies that reduce uncertainty. The probabilities of success for each are unknown, with experience and perception used to assign weights to the alternatives.

More formal assessments of risk will have some cost associated with collecting and analysing the data required, so a problem will need to warrant this extra effort in order to be cost-effective. These may be appropriate for repeated risky decisions (e.g. mastitis treatment plans, or where an advisor is considering a plan than could be adopted by many farmers), or where a decision is important and there is a large gap between the best and worst outcome (e.g. a major investment decision) (Hardaker *et al.* 1997). Measures used in considering the outcomes of different alternatives can include averages, means (weighted by probability), range, standard deviations, coefficients of variation, cumulative probability distributions and decision trees (Kay and Edwards 1994). Decision trees draw out possible strategies, potential outcomes and their consequences. Measures such as range, standard deviation and coefficients of variation give the same weighting to higher returns as they do to lower returns, whereas in agriculture often only unfavourable returns are of concern (Kay and Edwards 1994) or are weighted more heavily (Wilson *et al.* 1993). Hardaker *et al.* (1997) describe more complex means of evaluating risk.

Decision rules used in selecting an option and described by Harsh *et al.* (1981), Fleisher (1990), Kay and Edwards (1994) and Hardaker *et al.* (1997) include selecting the strategy:

1. with the highest expected value, calculated using the outcomes for each option weighted by their probabilities (maximise expected value);
2. that is the best for the most likely outcome (one with the highest probability);
3. by comparing risk and returns;
4. with the best of the worst possible outcomes (maxi-min);
5. with the best of the best possible outcomes (maxi-max);
6. with the highest average for each option i.e. ignores probabilities;
7. with the highest return, where the minimum return exceeds a specified value for a specified proportion of the time (minimum return or safety first);
8. with the highest expected utility.

1.4.4 Types of risk

The types of risk as classified by Barry *et al.* (1995) and described by Sonka and Patrick (1984), Kay and Edwards (1994), Martin (1994, 1996), Barry *et al.* (1995) and Hardaker *et al.* (1997) are:

1. production and yield risks, also referred to as technical risk, which includes climatic factors, biological responses, and diseases and pests;
2. market and price risks. These can be variable and are affected by New Zealand and world markets;

3. risk of losses from severe casualties and disasters;
4. social and legal risks, also referred to as institutional risk or regulatory risk, include risk imposed on the system by government, local body and producer board laws and policies;
5. human risks associated with the labour and management including illness or death of staff or management, availability and ability of farm labour, and changes in the family situation;
6. risks of technological change and obsolescence;
7. financial risks include changes in interest rates, finance availability, ability to meet debt repayments and changes in value of collateral (e.g. land prices).

Business risk comprises risk categories 1 to 6, and these risks apply, regardless of the way the firm is financed (Hardaker *et al.* 1997). Financial risk is dependent on the way the firm is financed. A survey by Martin (1994, 1996) found New Zealand farmers identified market risk as very important. Production risk was less important, although rainfall variability was considered to be important by most farmers. Financial risk was seen as moderately important, as were regulatory risk and human risk. Production, marketing and financial risk occur on most farms and are inter-related and consequential (Kay and Edwards 1994).

1.4.5 Strategies to avoid risk

Strategies to avoid or reduce risk have been discussed in Sonka and Patrick (1984), Martin (1994, 1996), Barry *et al.* (1995) and Hardaker *et al.* (1997). Martin (1994) surveyed New Zealand farmers on the relative importance of some of these risks, and the strategies used to manage them. These strategies were broadly defined as those used to control risk exposure and those used to control the impact of risk on the farm business (Jolly 1983; Martin 1994). Controlling risk exposure involves manipulating the probability distributions facing the business so that variability is reduced. This can include strategies such as enterprise selection and diversification, marketing strategies, insurance, and scale of operation. Strategies that control the impact of risk on the business can include raising yields and prices so net income is higher, lowering leverages, matching debt repayments to income and maintaining cash or credit reserves.

Risk management strategies can be classified as production, marketing and financial and some of these identified by the above mentioned authors are described here. Production strategies included product diversification, informal insurance (e.g. spraying, drenching, feed reserves, irrigation and excess machinery), multiple production practices (e.g. several seed varieties or breeds), avoiding high-risk enterprises or very variable enterprises, and farming

in a more stable region. Marketing strategies were the selection of enterprises with low price variability, forward and future contracts, spreading sales and storing produce. Buying and selling on the same market is also a recognised marketing strategy. Financial strategies included matching debt repayment to income, increasing equity, having more liquid assets or off-farm investments, leasing rather than owning, and insurance. Strategies used by individual farmers will be dependent on their circumstances e.g. farm size, type location or ownership structure (Martin 1994), as well as factors such as farmer preference, ability, age, experience and opportunity (Sonka and Patrick 1984; Wilson *et al.* 1993).

Maintaining greater flexibility, while not directly reducing risk, allows a farmer to respond more quickly as new information becomes available over time i.e. as uncertainty is reduced (Barry *et al.* 1995). Hardaker *et al.* (1997, p. 240) defined flexibility as “the ease and economy with which the farming business can adjust to changed circumstances”. They went on to categorise these as asset flexibility (multiple use assets), product flexibility (products with more than one use), market flexibility (more than one market), cost flexibility (keeping fixed costs low) and time flexibility (speed at which changes can be made or the time frame of an enterprise).

Hardaker *et al.* (1997) and Fleisher (1990) both identified information collection as a risk reducing strategy. This reduces the distribution of outcomes associated with a certain alternative, as well as possibly shifting the distribution curve itself. Hardaker *et al.* (1997) identified postponing a decision to change until more information is available, the incorporation of strict safety standards until more is known (e.g. maxi-min or safety first decision rules), and the selection of a situation similar to the status quo as possible risk-avoidance strategies. The first two options tie in with timing and information availability. Strategies that allow learning as time progresses are reducing fixed costs relative to variable costs, using a more labour- relative to capital-intensive enterprise, using resources that are non-specific to the enterprise and delaying input use e.g. fertiliser (Sonka and Patrick 1984; Barry *et al.* 1995). These policies can also be associated with flexibility. Monitoring pasture supply as part of feed budgeting could also be described as a learning strategy to reduce risk.

Martin (1994, 1996) found the main risk strategies employed by New Zealand dairy farmers were spraying and drenching, feed reserves, keeping debt low, managed capital spending, maintaining flexibility (short- and long-term), financial reserves and insurance. Although dairy farmers ranked market risk as their greatest source of risk, the structure of the New Zealand dairy industry (single-seller) meant they could not influence milksolids price.

Diversification was also less important for dairy farmers, who face labour constraints making this a less practical option.

1.4.6 Risk and technology adoption

Farmers, advisors, commercial firms, agricultural research workers and policy makers all need to be concerned with risk in agriculture (Hardaker *et al.* 1997). Advisors need to be aware that the adoption of a technology may be risky for a farmer, particularly if it is untried commercially and involves capital investment. An adoption lag is likely to occur until the farmer has sufficient time to obtain and evaluate information before making a decision to adopt.

Hardaker *et al.* (1997) suggested that advisors and input suppliers could assist the adoption process by supplying information and organising demonstrations of the technology. Anderson *et al.* (1977) suggested that extension efforts could be focussed on farmers grouped according to the worst environmental conditions faced. Traders may increase the adoption rate by offering contracts and spreading the risk. Research workers need to recognise risk when identifying research opportunities and developing new technologies, and measure and report on variability, particularly downside risk, aspects as well as averages (Anderson *et al.* 1977; Hardaker *et al.* 1997). Policy makers need to consider the effect of risk-averse behaviour in supply models, and the impact policies affecting the riskiness of farming will have on the adoption of technologies (Hardaker *et al.* 1997). If adoption of a technology is in the national interest (e.g. production of a particular crop variety) a government insurance scheme, or price and income supports, that effectively truncate the lower tails of market price distribution, may enhance uptake by reducing risk (Anderson *et al.* 1977).

Martin (1994, 1996) identified that New Zealand pastoral farmers reduced production risk by maintaining feed reserves along with an adaptive ability to respond rapidly to changing circumstances, and suggested that research outcomes resulting in a reduction in flexibility are less likely to be adopted than those which enhance flexibility. Technology adoption will be discussed in Section 1.5.

1.4.7 Conclusion

Farmers take a number of objectives into account when making decisions. While profit maximisation is important, other objectives impact on the decision made including keeping risk at an “acceptable” level. This acceptable level will depend on the farmer’s circumstances and environment, and the risk profile of the farmer. A farmer considering adopting a new

technology or management practice will need to make their own evaluation of the riskiness of a proposition. A range of methods can be utilised. However, more formal evaluation will be required where a major change or large capital investment is required. Information is required for this evaluation. The less information available, the more risky an alternative may be perceived to be. A decision may be delayed until more information is available, and another option, which may be to retain the status quo, may be chosen in the meantime. Research and extension workers can assist in technology uptake by incorporating the effects of variability into technology development, testing and extension.

The references cited discuss some time-related aspects associated with risk. Short-term decisions can be less risky than longer-term decisions in that they may have less impact on the business. Decisions may be delayed or “safer” alternatives chosen to allow farmers time to gather more information or learn more about a particular alternative. Information gathering is considered to be a risk reducing strategy. More flexible strategies, while not directly reducing risk, allow farmers to adapt more quickly as information becomes available. A change that occurs over a long period of time may be risky because it is inflexible and possibly irreversible. Two other time-related aspects identified, but not specifically mentioned in the literature are as follows.

The expected average or most likely yield or price received may not remain constant over time. Therefore farmers not only have to predict the likely variation about the mean within a time period (e.g. a year), but also the trend the mean could take over time. That is, they will need to predict the average expected price or yield, and the change in the price or yield, over time. These values could increase, decrease, or remain constant over time. A probability distribution may be used to describe this change in the average expected value over time. For example, a farmer may not consider a crop yield to be sustainable over time under current practice, and will need to predict the likely size of the decrease in production over time. Similarly, the demand, and therefore price, for a particular product may be expected to decline or increase over time.

It is not only the potential variability within a season that can contribute to risk, but the distribution of this variability across time. If variation is evenly distributed across time an alternative is likely to be less risky than if it is not. Two or more bad years in succession could affect the farmer’s ability to meet debt commitments, whereas a number of “good” years may affect tax liability. Events occurring in one season are likely to affect the following year e.g. a poor year in terms of production because of low rainfall and therefore low pasture

growth rates, may affect production the following year because of low conception rates and reduced feed carried over. The converse may also apply.

1.5 TECHNOLOGY TRANSFER AND ADOPTION

Technology transfer is the process of moving knowledge, ideas, services, inventions and products from where they were developed to where they can be used (Guerin and Guerin 1994). The end product of this technology transfer process is technology adoption which is the implementation of this transferred knowledge about an innovation (Rogers 1983).

Participants at a dairy industry exchange forum defined technology transfer more specifically as:

“the (process of) passing of ideas from those that have them to those who are interested so they become aware of, or better understand them, and as a consequence be in a better position to decide whether or not adoption is appropriate or if further investigation is required” (Stantiall and Parker 1997, p. 1),

with technology defined as “an idea that can be applied to a system to achieve a defined purpose” (Stantiall and Parker 1997, p. 1).

The adoption of an innovation depends on its diffusion, described by Rogers (1983, p. 5) as “the process by which an *innovation* is *communicated* over *time* among the members of a *social system*”. An innovation is “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers 1983, p. 11). A technological innovation usually has an object component and an idea component, but may consist almost entirely of information (Rogers 1983; Guerin and Guerin 1994). Value adding may also be considered a technological innovation (Guerin and Guerin 1994).

Local research organisations are not the only source of useful farming technology, with other potential sources including local farmers (indigenous technical knowledge), and research organisations and farmers in other social systems (e.g. other countries) (Stroud and Kirkby 2000). Adaptive research can alter an innovation to make it more applicable to its users or the conditions it is to be used in (Arnon 1989). Reinvention occurs when an innovation is changed or modified by the user during its adoption and implementation (Rogers 1983).

1.5.1 The innovation-decision process

Rogers (1983) identified five stages in the innovation-decision process. These were:

1. the knowledge phase in which an individual becomes aware of a new idea and develops some understanding of it;
2. persuasion, in which an individual is persuaded by themselves or others and develop an attitude towards an innovation;
3. decision, in which an individual accepts or rejects a technology;
4. implementation is when the innovation is put into use;
5. confirmation, in which an individual questions their decision to adopt after the adoption decision has been made.

1.5.2 Time factors associated with technology adoption

The time factors Rogers (1983) associated with the adoption process are: the time taken for an individual to move from first knowledge of an innovation to its adoption or rejection, the time it takes for an individual to adopt a technology relative to others in the social system, and an innovation's rate of adoption in a social system. The time that is required to complete the adoption process and the maximum percentage of adoption achieved in a particular social system varies for different technologies. Rogers (1983) used an s-shaped curve to describe the rate of technology innovation (Figure 1.1). Factors associated with both the technology and the farmer affect the rate and level of technology uptake.

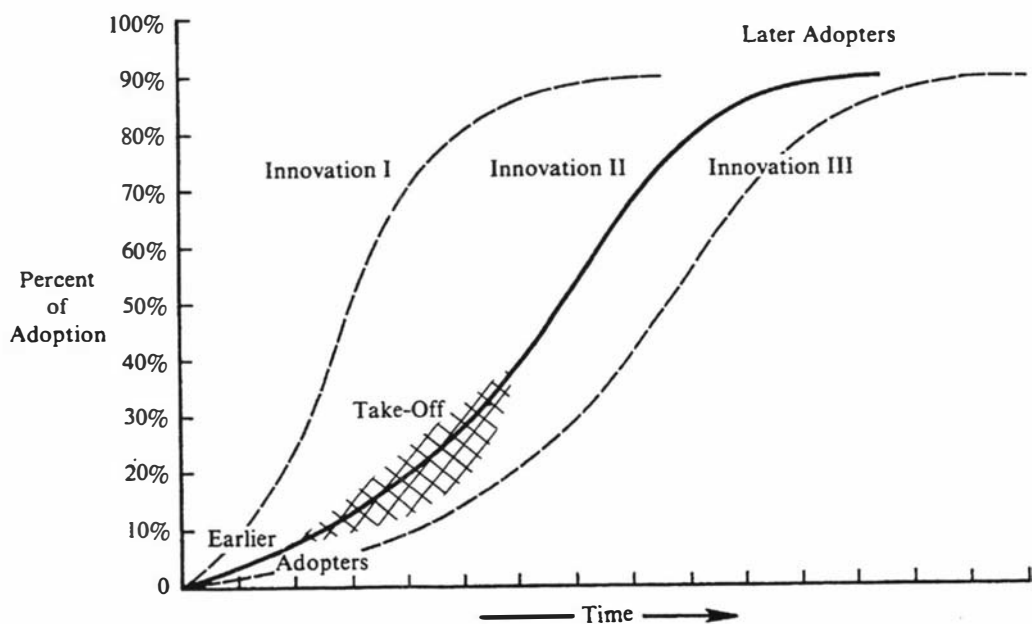


Figure 1.1: The s-shaped curve of technology adoption (from Rogers 1983, p. 11).

1.5.3 Farmer factors affecting technology adoption

Rogers (1983) categorised adopters according to their innovativeness i.e. the relative degree to which an adopter takes up new ideas earlier than other members of a social system. The five categories and the characteristics attributed to each are described below.

1. innovators are the first 2.5% of adopters. They seek new ideas, have a wide range of information sources, are financially able to take risks, and can understand and apply complex technical knowledge.
2. early adopters are the next 13.5%. They are well integrated into the local social system, with the highest degree of opinion leadership and respected by their peers.
3. early majority are the next 34%. They interact with their peers but seldom hold leadership roles.
4. late majority are the next 34%. They are cautious about adopting new technology and wait until most others adopt before adopting. Peer pressure often motivates adoption.
5. laggards are the last 16%. They have little opinion leadership, are often isolated in social networks and are very cautious in adopting new technology.

Adoption may level off with less than 100% adoption creating a further category of non-adopters (Arnon 1989). The laggard category has since been questioned, with the suggestion that non-adoption of a technology is often a deliberate decision not to adopt (Guerin and Guerin 1994; Frank 1997). Non-adopters are also often unable to adopt a technology because they lack the resources or finance, are unable to take risks (Arnon 1989; Reid *et al.* 1996; Frank 1997; Stroud and Kirkby 2000), or do not perceive the technology as benefiting them (Frank 1997) rather than being conservative. Access conditions to the technology (Audirac and Beaulieu 1986; cited by Guerin and Guerin 1994) can affect adoption. Access conditions include how knowledge-demanding and labour-saving the technology is, as well as distribution and promotion factors (Guerin and Guerin 1994). Institutional constraints and lack of skills can also influence technology adoption (Parminter and Parminter 1994; Stroud and Kirkby 2000). Discontinuance can also occur when a decision is to adopt and is then later reversed during the confirmation stage (Rogers 1983).

1.5.4 Technology factors affecting technology adoption

In a review of constraints to the adoption of innovations, Guerin and Guerin (1994) put the factors affecting adoption into two broad categories. These were the characteristics of the technology and the social and economic environment of the farmer, and farmer attributes

such as personality, education level and degree of motivation. Attributes of a technology that affect its uptake, identified by Rogers (1983) were:

1. relative advantage is the degree to which a technology is seen as being better than that which it replaces. This can be economic (e.g. profitability), safety or security, or social (e.g. status factors, self-esteem).
2. compatibility is the degree to which an innovation is seen as being consistent with existing values, past experiences and needs of potential adopters.
3. complexity is the degree to which an innovation is seen as being difficult to understand or use.
4. trialability is the degree to which an innovation can be experimented with on a limited basis.
5. observability is the degree to which results are visible to others.

Other studies have identified factors that affect the uptake of a technology. These include flexibility (Reid *et al.* 1996; Stantiall and Parker 1997), time-savings (Stantiall and Parker 1997), risk (Jedlicka 1979; cited by Guerin and Guerin 1994; Reid *et al.* 1996; Stantiall and Parker 1997; Marra *et al.* 2001), industry requirements (Stantiall and Parker 1997), expectations of future technological improvement (Rosenburg 1976; cited by Marra *et al.* 2001) and new technologies not performing on-farm as they did under research conditions (Armon 1989; Stroud and Kirkby 2000). Adoption is unlikely to occur unless a large economic gain is expected, presumably to compensate for the risk involved (Guerin and Guerin 1994). If the costs, benefits, and knowledge on how to use a technology are not clear or understood people will be more likely not to adopt in order to avoid risk (Jedlicka 1979 cited by Guerin and Guerin 1994). Anderson *et al.* (1977), noted that research planning and assessment of new technologies involving considerable changes in the use of resources needs to be done in the context of whole farm planning, whereas assessment on a practice-by-practice basis may be appropriate for more minor changes. This ties in with the easier adoption of more simple technologies, and suggests a different approach may be needed for more complex technologies.

1.5.5 The effect of social factors and farmer attitudes on technology adoption

While past research has aimed at maximising productivity and profitability this may not be the primary, or only, objective of those the technology is aimed at (Frank 1994). Frank (1994, p. 350) found cattlemen in North Queensland wanted to “maintain their satisfying lifestyle in a stable environment, rather than maximise their productivity”. Therefore, a decision on whether to adopt a technology or not, is made in context to the social, technical and economic

environment (Rogers 1983; Guerin and Guerin 1994; Frank 1997). Farmers select from a package of practices developed, those consistent with their needs, socioeconomic status and attitudes (Chamala 1987; cited by Guerin and Guerin 1994), with complementary technologies often promoted and adopted as packages rather than stand alone (Arnon 1989).

Farmers' attitudes and goals influence the decision to adopt a technology. Guerin and Guerin (1994) summarised the important attitudes as being a farmer's attitudes toward farming, the expectation of the economic future of farming, the gravity of the problem the technology addresses, risk and the technology itself. Bad experiences in the past may also discourage farmers from adopting new technologies. Rogers (1983) and Guerin and Guerin (1994) reviewed results attempting to relate farmer attributes to innovativeness. In general, the more innovative farmers were better educated, were more able to take risks, had access to credit, were more positive about change and had more social contacts. There was no clear relationship between innovativeness, and farm size or age.

1.5.6 Communication and technology adoption

For diffusion of an innovation to occur, communication is necessary. This can be via mass media or interpersonal (Rogers 1983). Mass media is important initially to spread information about a new technology, with interpersonal communication being more important in the persuasion stage. This interpersonal communication can be through opinion leaders who influence the opinions of others in informal ways (e.g. other farmers) or change agents (e.g. extension workers) who act as communicator links between two or more social systems. Communication is more likely to occur between individuals who are alike (Rogers 1983; Arnon 1989; Guerin and Guerin 1994). Hence, opinion leaders have a strong influence on technology adoption by others within their social groups. In contrast, change agents have an important role in transferring knowledge between social groups. Extension personnel need to follow through the entire adoption decision making process, including implementation and confirmation, to ensure that adoption is maintained (Guerin and Guerin 1994).

1.5.7 Identification of the decision makers

The decision on whether or not to adopt an innovation can be made independently by individuals within a social system (optional innovation-decisions), or collectively by the whole social system, either by consensus by group members (collective innovation-decisions) or by a few members in a system (authority innovation-decisions) (Rogers 1983). The fastest adoption rate results from authority decisions. Maher and Perkins (2000) point out that technology adoption that is advantageous for an industry may not necessarily be beneficial to

the individual companies that make up that industry. The reverse may also hold true. Where industry- and company-level issues arise, it is the individuals within companies that make technology adoption decisions, and it is important to identify these individuals, and take their views into consideration in research, development and extension (Maher and Perkins 2000).

1.5.8 Technology transfer models and approaches

The traditional transfer of technology (ToT) model for research and development is often described as a “top down” approach with knowledge flowing downwards from researchers to extension agents to farmers (from innovators down to laggards) (Reid 1996), although the convergent form of Rogers (1983) diffusion model suggests there is some two-way communication from farmers to scientists. In contrast, participatory approaches recognise more active involvement of farmers in research and extension, with a much greater two-way flow of information between farmers and researchers. These evolved in lesser-developed countries in the 1970’s (Reid 1996; Stroud and Kirkby 2000), but have also been effectively used in developed countries in more recent times (Hamilton 1998; Massey and Hurley 2001). Many forms of participatory approaches have been used and these are reviewed in Reid (1996) and Collinson (2000).

Participatory approaches recognise that the whole system, including socio-economic and environmental factors, needs to be taken into consideration in the development of relevant technologies, whereas in traditional research and development scientists have primarily been concerned with individual components of production developed under experimental conditions (Arnon 1989; Guerin and Guerin 1994; Stroud and Kirkby 2000). The two-way inclusion of farmers in the research and extension process is more likely to result in technology developed to meet the farmers’ needs or solve a particular problem, and is therefore more readily adopted (Arnon 1989; Guerin and Guerin 1994; Frank 1997).

Guerin and Guerin (1994) considered participatory action research as an extension of Rogers (1983) convergent diffusion model, where farmers, scientists and extension workers create and share information to help themselves reach an understanding of a problem. Reid (1996) suggested research into an issue or a problem cannot be clearly differentiated into a single model or approach, with the research approaches being a continuum from research carried out in isolation from the farming community, to research which is handed over to the community completely (from extreme ToT to highly participatory approaches). She comments that the approach chosen depends on the clarity with which the problem can be defined, the nature of the problem, researchers’ skills and resources available.

1.5.9 Conclusion

Technology will be more readily adopted if it has advantages over current practice (e.g. economic, time-savings, effect on environment or product quality), low cost, fits into the system, is flexible, low-risk or risk-reducing, simple and easy to use and adopt, trialable and observable, and is socially acceptable and fits in with the farmer's beliefs. Research and extension that includes both farmers with their knowledge of agricultural systems, and researchers with their technical expertise, is likely to result in the development of technologies that will be more readily adopted i.e. relevant and applicable. The inclusion of farmers and extension workers in the development of technologies is also likely to enhance adoption because an understanding of new technology is required before adoption will occur.

The decision makers required to implement a change may not be those that want the change e.g. the industry may want the change but the farmers need to adopt the technology. Technology uptake is likely to be enhanced if these farmer decision makers are included in the research and extension associated with the change required by industry (giving them some "ownership" of the problem), as well as providing them with an incentive to change.

CHAPTER TWO

OVERVIEW OF THE MODEL

A deterministic simulation model was developed to study on-farm milk segregation. This model was used to determine the break-even premium required to make it viable for a dairy farmer to segregate milk for a specific trait or processing characteristic on-farm. Changes required to alter a herd's milk composition can take time, often years, particularly if breeding is involved. The model therefore incorporated the changes over a 20-year time frame. A cost-benefit analysis using discounted cash flows was used to calculate the break even premium over periods of 10 and 20 years, and to infinity.

Figure 2.1 is a diagram of the segregated milk value system, showing the significant on-farm and off-farm components. This study modelled the on-farm and transport components. The two sub-components of the on-farm component of the system are milk composition and quantity. Together these make up the "on-farm milk production model". The milk transport sub-model is significant as the transportation of differentiated milk generates extra costs. These were included in the volume cost for differentiated milk in the segregated milk scenarios. Milk processing was also considered significant to the model, but the size of the study, and the unavailability of information which is largely in the industry domain and subject to confidentiality, made inclusion of this sub-model impractical. Marketing, transport and distribution, and customer/consumer are system components for which data were not available.

Figures 2.2 and 2.3 show some of the factors associated with milk production systems, many of which have been incorporated into the model in one way or another. Figure 2.2 shows some of the non-economic factors that impact directly on milk production and composition on the farm. Figure 2.3 shows the main factors that affect farm profitability, particularly milk income, and how milk yield and composition contribute to this. While some of these factors were not directly incorporated into the model, their influences on the system were represented by the model input variables.

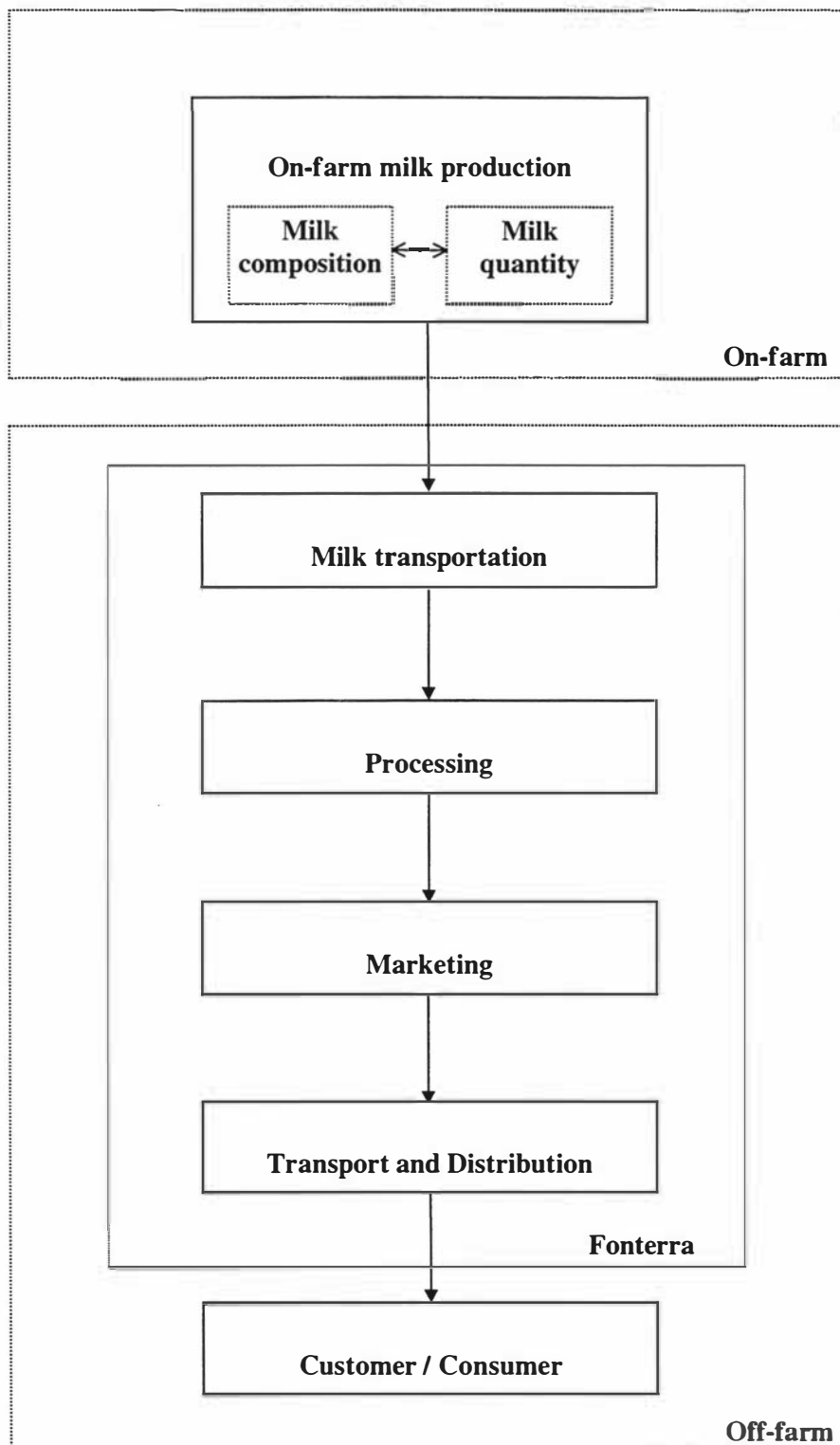


Figure 2.1: The segregated milk value-added chain.

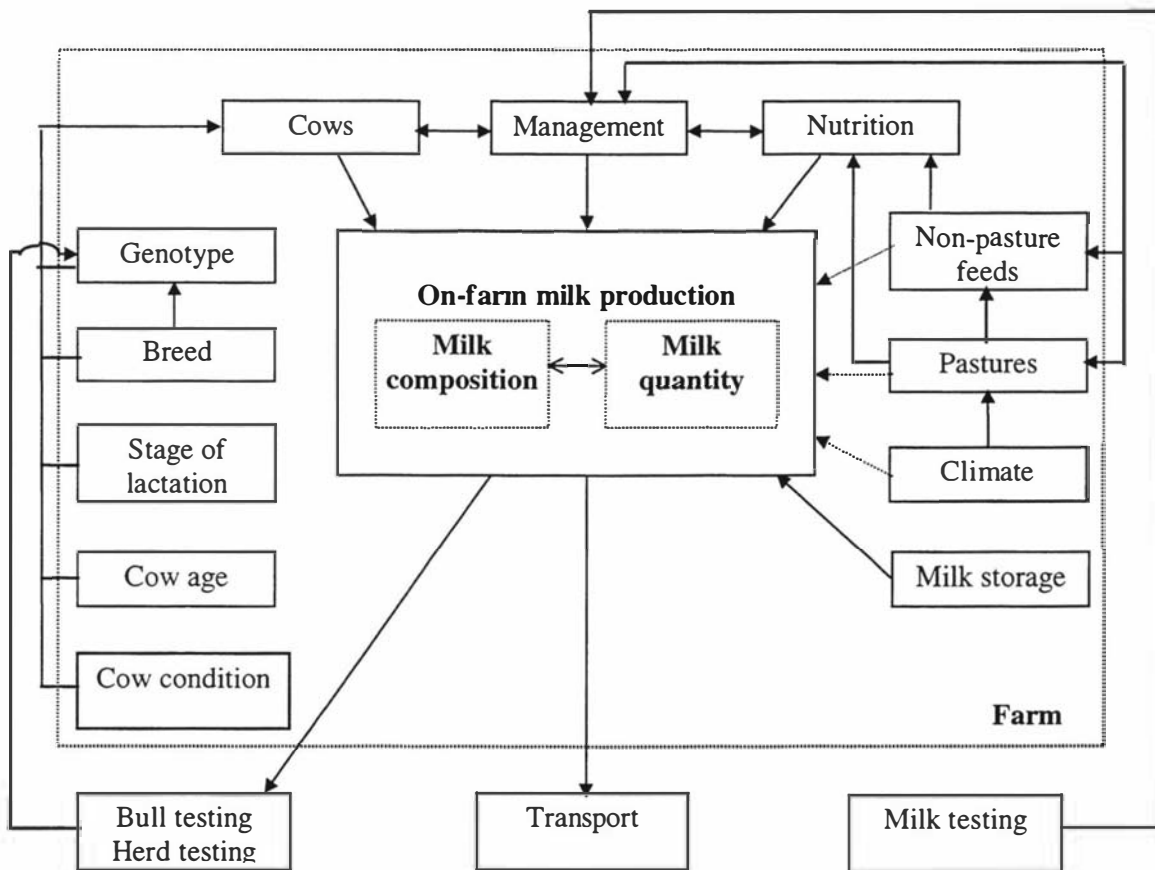


Figure 2.2: Some non-economic factors impacting on the milk production on-farm.

Figure 2.4 shows the model design and the main input-output flows between the sub-models. The model was developed as a series of sub-models, with the outputs from some sub-models providing the inputs for subsequent sub-models. Although milk processing was not modelled, this is shown diagrammatically to illustrate how it fits into the overall picture, and indicate the input and output variables between this and the other sub-models. All sub-models contribute variables to the overall model – the Farm Economic Model. This model is then used as the basis of a range of comparative scenarios, on which estimates of premiums are based.

The input and output variables associated with each of the farm sub-models can be found in Appendix 1. Intermediate variables are not described in the appendix, nor are all output variables from the sub-models, as some of these were written out for validation purposes only or were not discussed in this thesis.

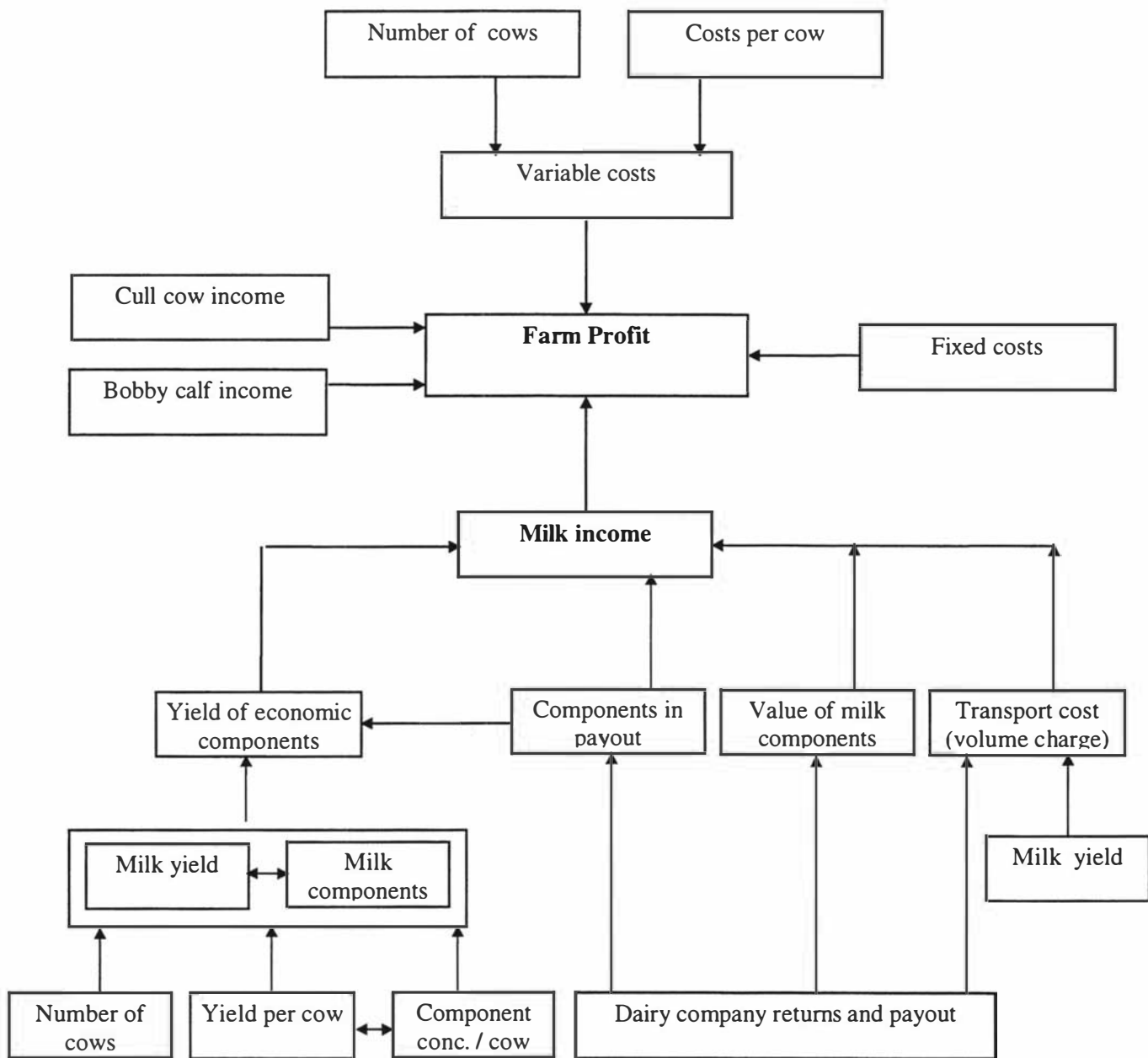


Figure 2.3: Factors that affect farm profitability, particularly milk income, and milk yield and composition.

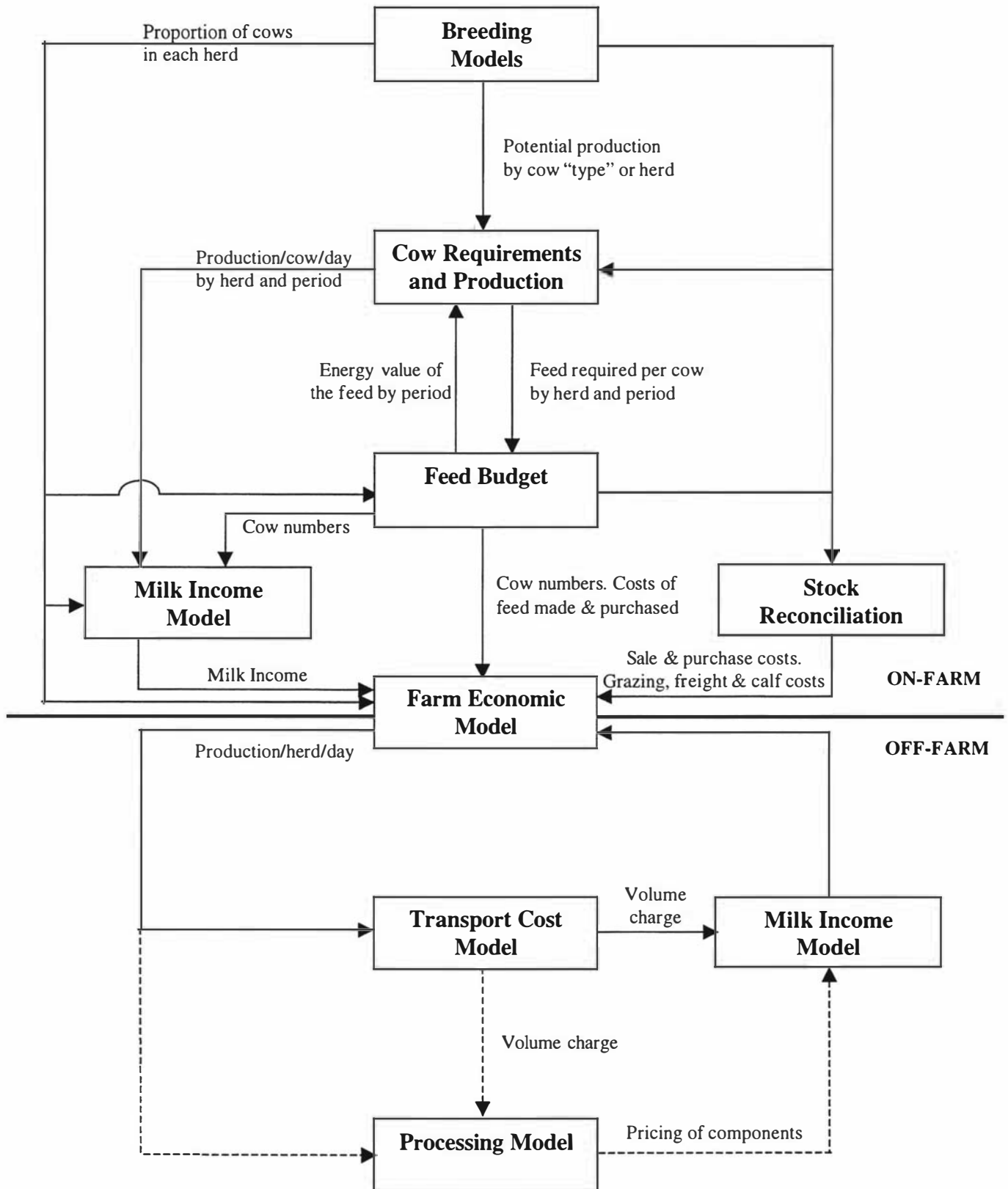


Figure 2.4: Model design and information flow.

CHAPTER THREE

BREEDING FOR A QUALITATIVE TRAIT: B HOMOZYGOUS β -LACTOGLOBULIN COWS

3.1 INTRODUCTION

Milk from cows of particular genotypes has been found to be superior for the manufacture of some dairy products relative to that of other genotypes. Ng-Kwai-Hang and Grosclaude (1992), Jakob (1994), Jakob and Puhan (1995), IDF (1997), Ng-Kwai-Hang (1998) reviewed the relationship between the genetic polymorphism of milk proteins and milk production, composition and processing properties. Benefits can include increased yields, functional or nutritional benefits, and processing benefits (Boland 1997). Thus, there is potential to breed and differentiate cows based on genotype to produce milk with processing advantages for the production of a particular product. A generic spreadsheet model was developed to calculate the potential production from cows bred for any specified qualitative trait. Outputs from this model can then be used in further sub-models to evaluate whether it is economically viable to identify and breed cows of a particular genotype to produce milk for a specific purpose.

The model example considered breeding cows with a BB β -lactoglobulin genotype. Milk from cows of this genotype is superior to milk from cows with AA or AB β -lactoglobulin genotypes for cheesemaking, milk powder production and UHT milk production. The polymorphism of β -lactoglobulin has been discussed in the references on milk protein polymorphism mentioned above, as well as being specifically reviewed by Hill *et al.* (1997). Cows of the BB β -lactoglobulin genotype have higher casein and lower whey protein production (including β -lactoglobulin), and in some trials higher fat concentration and production, lower total protein production and lower milk yields compared to AA β -lactoglobulin cows. Most research on processing attributes has related to cheesemaking, with milk from BB β -lactoglobulin cows giving higher cheese yields due to higher total solids, fat and casein content in milk of this type. After adjusting for milk composition Marziali and Ng-Kwai-Hang (1986), cited by Ng-Kwai-Hang (1998), still found higher cheese yields from the BB β -lactoglobulin milk. The example analysed in this Chapter focuses on the advantages of milk from BB β -lactoglobulin cows for cheesemaking.

There is interest in using qualitative trait loci as marker genes for QTLs (quantitative trait loci) (Sabour *et al.* 1996; Georges 1997; Spelman and Garrick 1997a; Freyer *et al.* 1999; Spelman *et al.* 1999). These marker genes could be included in a selection index, or for the identification of embryos to transfer, young bulls to progeny test or heifers to rear (Sabour *et al.* 1996). The simple Mendelian mode of inheritance of milk proteins makes them ideal marker genes (Ng-Kwai-Hang 1998). Milk protein genes can affect a milk production trait directly (i.e. act as a QTL), or be associated with QTL for the milk production trait (i.e. act as a marker gene) (Bovenhuis *et al.* 1992). The β -lactoglobulin locus has potential for use in marker assisted selection for protein percentage (Aggrey *et al.* 1998), fat percentage (Bovenhuis *et al.* 1992; Bovenhuis and Weller 1994), milk yield, protein yield (Bovenhuis and Weller 1994) and casein number (Lunden *et al.* 1997).

Four variants (A, B, C, and D) of β -lactoglobulin have been identified in the *Bos taurus* breeds, with B being the most common of these. The C variant is found at low frequencies in Jersey or related cattle and the rare D variant is found in some breeds in Europe (Ng-Kwai-Hang and Grosclaude 1992; Hill *et al.* 1997). Winkelman (1997) found the frequency of the C allele to be 0.071 in a predominantly Jersey population in New Zealand. Gene frequencies differ between breeds (Winkelman and Wickham 1996). Jakob (1994, 1995) indicated that the effect of a genotype might also differ between breeds if there are linked gene effects or mistyping of alleles. This has been observed in the casein variants, where there is close linkage between the casein loci. For example, κ -casein B is associated with a reduction in casein in Simmental or Brown Swiss cattle but an increase in Friesian cattle (Jakob 1995). Gene effects could also vary between families and populations. A particular genetic type may be carried by a superior sire in a population purely by chance, yet the gene effect could appear to be associated with a quantitative trait (Sabour *et al.* 1996). However, the effect of the β -lactoglobulin phenotypes is a direct gene effect i.e. it is the same for all breeds (Jakob 1995).

The genotypic frequency for each breed (line) can be predicted from the gene frequency using the Hardy-Weinberg law. However, this rule does not hold true for the overall population, with the drift towards an increase in homozygotes (Falconer 1960). However, population genotypes can be calculated from the genotypic frequencies for the lines (breeds) within the population. Breed distribution between regions in New Zealand also varies (LIC 1998), and therefore genotypic frequencies between regions are likely to differ as well. Advantage may be taken of these differences in gene frequencies between breeds and regions for the production of different milk-based products.

3.2 METHOD

A model to consider alternative herd breeding strategies for specific milk components was developed using Microsoft Excel software. The model details and breeding options are outlined in the ensuing sections. Three herd breeding scenarios were considered, where a “herd” could represent a single herd or a combination of herds (e.g. herds in a particular area, or of a particular breed or type). It was assumed that the semen used came from industry sources (e.g. Livestock Improvement Corporation (LIC), Ambreed), and that the sires available for the three genotypes were of similar genetic merit (based on breeding worth) i.e. B homozygous β -lactoglobulin bulls were of similar genetic merit to the AA and AB β -lactoglobulin bulls.

In the first two scenarios, only B homozygous β -lactoglobulin bulls were used for AI (artificial insemination). In the first scenario (TEST or T), cows and heifers were also tested to identify their genotype, and calves were selected based on genotype. Cow and calf genotypes were not identified in the second scenario (NOTEST or NT). The third scenario was status quo (SQ): the frequency of the B allele in the population was assumed to remain constant, and bulls representative of the industry sires were used. Each scenario was run over 20 years, to allow changes in the herd genotype to stabilise. Once genotype was known, it was assumed milk from cows with the desired genotype was kept separate from that of the remaining cows.

Breeding options may include combinations of these scenarios, or running the same scenario partway through the 20 years with a different set of inputs. The model population can be redefined during the 20 years, and run under a different scenario for the remaining years. Two possible options are:

1. selling non-BB β -lactoglobulin cows and purchasing B-homozygous cows once the herd reached a nominated threshold of BB cows. The frequency of the B allele could be set to 100% (or the actual frequencies of the different genotypes specified, if less than 100%), before running the subsequent years. If cows purchased altered the level of production, the base herd level would need to be redefined before running the remaining years.
2. running the model under the NOTEST scenario initially, and then at some point in time, testing cows and running the remaining years run under the TEST scenario.

Another alternative would be to sell and purchase cows in year 1 so that the frequency of the B allele in the initial cow population is 100%.

Model inputs described the herd structure, the selection of replacements, the base level of production and response to selection per year, and the frequency of the B allele in the initial population. Model outputs were the average potential milk, milkfat and protein yields, and cow liveweight, for each herd and genotype, and the proportion of cows in each herd and genotype, for each of the 20 years.

3.2.1 Genotypic frequencies

The proportion of AA, AB and BB genotype cows in the initial population (year 1) was calculated from the frequency of the B allele, and was assumed to be the same across all age groups. The frequency of the B allele used in the model was 0.684 (Winkelman and Wickham 1996, for Jersey cows), making the proportion of AA, AB and BB cows 0.10, 0.43 and 0.47, respectively. The proportions of cows in each age group, heifer replacement rate (calves retained per cow i.e. 2-year old heifers and mixed age cows) and AI heifer calves available per cow mated were specified, as well as whether or not yearling heifers were artificially inseminated.

For the TEST and NOTEST scenarios, the number of AI heifer calves born in each genotype (assuming B-homozygous bulls) was calculated as:

$$C_{AB} = \left(\sum_{i=3}^{i=10} ((D_{1i} + \frac{1}{2} D_{2i}) \times A_i) \right) \times I \quad \text{Equation 3.1}$$

$$C_{BB} = \left(\sum_{i=3}^{i=10} ((D_{3i} + \frac{1}{2} D_{2i}) \times A_i) \right) \times I \quad \text{Equation 3.2}$$

where:

C_{AB} = number of AI heifer calves (potential replacements) of genotype AB per cow;

C_{BB} = number of AI heifer calves (potential replacements) of genotype BB per cow;

D_{gi} = proportion of cows of genotype g in age group i;

g = 1 = genotype AA;

g = 2 = genotype AB;

g = 3 = genotype BB;

i = cow age (years);

A_i = proportion of cows in age group i;

I = proportion of AI heifer calves born.

If yearling heifers are artificially inseminated some of the heifer calves born to the 2-year-old cows will be available as replacements, and the cow age group range (i) in the above equation becomes 2 to 10, rather than 3 to 10. The number of AI heifer calves available from mating the yearlings was assumed to be the same as that for the cows (35 calves per 100 cows mated in the model example).

In the TEST scenario, replacements were selected from the BB genotype heifer calves and then, if there were insufficient of these, from the AB genotype calves. As all cows were tested to identify their genotype, the genotypes of their calves were known. Calves from AB genotype cows need to be tested to identify their genotypes (AB and BB) only if insufficient progeny are available from the BB genotype cows. The option to buy in extra B-homozygous calves, to ensure all calves retained are B-homozygous was also included in the model. Brought-in calves are assumed to be of the same genetic merit to those derived from the herd. This option would require testing of sufficient calves outside the herd to ensure enough replacements: in the example given this would be 2 to 3 calves tested for each calf purchased.

In the NOTEST scenario, the proportion of AB:BB calves retained is the same as the proportion available for replacements, as cow, and therefore calf, genotypes are unknown. In the SQ scenario, the proportions of AA, AB and BB genotype calves remained constant over time. Replacement calves became the rising-1-year-old heifers on hand at the beginning of the next year.

For each genotype, the proportion of cows in an age group became the proportion in the next age group in the following year. That is, D_{gi} in any year = $D_{g,i+1}$ in the following year, assuming the culling and death rates are the same across genotypes. In the TEST scenario (where cow genotype is known) a few cows could be culled on genotype. However, this would be at the expense of culling for production traits or temperament. An adaption of the TEST scenario (CULL), allows half the cows culled for being “unsuitable for dairying” (e.g. low production, temperament) in the 2- to 9-year age groups, to be culled on genotype. Within age groups, the AA cows were culled before AB cows.

The overall proportion of cows in each genotype in any given year, D_{gj} was:

$$D_{gj} = \sum_{i=2}^{i=10} (D_{gij} \times A_{ij}) \quad \text{Equation 3.3}$$

where:

D_{gij} = proportion of cows of genotype g in age group i in year j;

A_{ij} = proportion of cows in age group i in year j.

In the TEST and NOTEST scenarios bulls were assumed to be BB for β -lactoglobulin. The model was also altered to allow for both BB and AB bulls to be used i.e. in situations where the gene frequency is low and few BB bulls are available. The number of BB and AB bulls used in the examples related to the ratio of BB:AB bulls at the gene frequency shown e.g. at a gene frequency of 0.3 for the B allele the ratio of AA: AB: BB was 5:4:1, so 80% of bulls used are AB and 20% are BB.

3.2.2 Production

The model output for each breeding strategy is the average potential production per cow, per year, for the cows in each of the two herds (2 milk types). The first requirement was to establish the base production level and response to selection per year for each of the three genotypes for milk, milkfat and protein yields. The base level of production is the potential production of the oldest cow age group (10 years) as mature cows (5- to 8-year olds). The base level of production and the response to selection per year for each of the production traits were specified. The calculations described below are the same for all three production traits i.e. milk, milkfat and protein yield.

3.2.2.1 Calculation of base level of production and gain per year by genotype

Within the herd, the base level of production is likely to differ between cows of different genotypes. The relationship between the three genotypes was specified. For example, if AB cows produce 1.0% more than AA cows, and BB cows produce 1.3% more than AA cows, the yield relationship is defined as 1.000, 1.010 and 1.013 for the AA, AB and BB genotype cows, respectively.

The base level of production for each of the three genotypes was calculated as:

$$BL_g = \frac{R_g \times HBL}{\sum_{g=1}^{g=3} (P_g \times R_g)} \quad \text{Equation 3.4}$$

where:

BL_g = base level of production for genotype g;

$g = 1$ = genotype AA;

$g = 2$ = genotype AB;

$g = 3$ = genotype BB;

HBL = herd base level of production;

R_g = ratio for genotype g as described above;

P_g = proportion of cows in genotype g in the initial year.

The selection response for each of the three genotypes was calculated by putting the herd's response to selection into the above equation instead of the base population production value. For example, given the ratios above, genotypic frequencies of 0.100, 0.432 and 0.468 for AA, AB and BB genotypes, respectively, and a herd response to selection of 1.8 kg/milkfat/year, the corresponding response to selection for each of the three genotypes is 1.781, 1.799 and 1.805 kg milkfat/year. The proportion of cows in each genotype in the initial population was calculated from the frequency of the B allele in the population i.e. 0.684. These proportions can also be specified.

3.2.2.2 Calculation of production by genotype

The oldest cow age group (10-year old cows) was referred to as genetic year 0, with the next oldest age group (9-year old cows) being genetic year 1 and so forth. In the initial year (year 1), the milking herd consisted of cows from genetic years 0 to 8. Each group of cows retained its genetic year over time, even though year and age group change e.g. the following year (year 2) the 9-year-old cows remained in genetic year 1 although they were now in the 10-year age group.

Production was age-adjusted. Young cows produced less than older cows, with production increasing to a maximum for cows aged 5- to 8- years, then declining again. The age factor for milk yield was assumed to apply also to milkfat and protein yields. Although fat and protein concentration decline slightly with age (2 to 3 g/litre for fat, less so for protein (Holmes *et al.* 1984)), the greatest impact on fat and protein yield is due to differences in milk yield. If concentration was taken into account, the age factor for milkfat or protein yield would differ by 0 to 2.7% per cow age group, with the overall average production per cow differing by less than 1%. More importantly, this difference would have little impact on the results, with the relativity between herds and policies remaining similar. Table 3.1 shows the age structure (calculated from survivability percentages for 1996/97 (LIC 1998)) and the age adjustments used in the model example (Lopez-Villalobos *et al.* 2000).

Table 3.1: Herd age structure and age adjustments used in the model example.

Cow age (years)	2	3	4	5	6	7	8	9	10
Proportion of cows	0.219	0.183	0.155	0.130	0.105	0.081	0.060	0.041	0.026
Age adjustment	0.75	0.87	0.95	1.00	1.00	1.00	1.00	0.97	0.92

The average production for cows in each genotype for any given year was calculated as:

$$M_{gj} = \sum_{i=2}^{i=10} (BL_g + (G_g \times GY_{ij})) \times AF_i \times A_{ij} \quad \text{Equation 3.5}$$

where:

M_{gj} = average production by cows of genotype g in year j ;

BL_g = base level of production for genotype g ;

G_g = response to selection by cows of genotype g ;

GY_{ij} = genetic year of the cows in age group i in year j ;

AF_i = age factor for cows in age group i ;

A_{ij} = proportion of cows in age group i in year j .

It follows that:

$$AP_j = \sum_{g=1}^{g=3} (M_{gj} \times D_{gj}) \quad \text{Equation 3.6}$$

where:

AP_j = the average overall production per cow in year j .

For the TEST scenario, the milk from AA and AB β -lactoglobulin genotype cows (Herd 1) is likely to be kept separate from that of BB β -lactoglobulin cows (Herd 2). While average production per cow in Herd 2 will be the same as that for the BB genotype cows, the average production per cow in Herd 1 in year j was calculated as:

$$\frac{(M_{1j} \times D_{1j}) + (M_{2j} \times D_{2j})}{(D_{1j} + D_{2j})} \quad \text{Equation 3.7}$$

Milk from the two herds is likely to be kept separate, if differential prices for milk types justify this. If milk specifications permit, it may be possible to combine the milk from the two herds once the majority of the cows are in the second herd (B-homozygous). The proportion of B-homozygous cows at which the herds are combined, can be specified in the model. Once this level is reached all cows are assumed to be in Herd 2, with Herd 2 production equal to overall average production. For the NOTEST scenario all cows will be in the same herd (either Herd 1 or Herd 2). All cows remain in Herd 1 under the SQ scenario.

Liveweight was calculated in a manner similar to that for production traits, however the only age adjustment made was that for the 2-year and 3-year old cows (LIC 1997-2000; Garcia-

Muniz *et al.* 1998; Lopez-Villalobos *et al.* 2000). The proportion of the mature weight used was 0.8 and 0.92, for 2-year and 3-year old cows, respectively.

3.2.3 Breed Effect

The proportion of B-homozygous β -lactoglobulin cows in New Zealand, in total and within region, was calculated from the gene frequencies of the A and B alleles (Table 3.2) for the various breeds (Winkelman and Wickham 1996) and breed distributions in New Zealand (LIC 1998). Genotypic frequencies by breed were calculated using the Hardy-Weinberg law. These were then weighted by breed distribution at both national and regional levels to calculate national and regional genotype frequencies. The likely changes in genotypic frequencies over 20 years for each breed under the TEST and NOTEST scenarios were calculated using the initial (1997/98) genotypic frequencies.

Table 3.2: Gene and genotypic frequencies by breed.

	Ayrshire	Friesian	Jersey	FxJ Cross	Other
Gene Frequency (B)	0.703	0.513	0.684	0.603	0.569
AA cows	0.088	0.237	0.100	0.158	0.186
AB cows	0.418	0.500	0.432	0.479	0.490
BB cows	0.494	0.263	0.468	0.364	0.324

The allelic frequencies specified by Winkelman and Wickham (1996), which identified β -lactoglobulin variants as either A or B, were used in the model. The 0.684 gene frequency for the B variant of β -lactoglobulin in Jerseys suggests that the C variant was incorrectly identified as a B variant. Winkelman (1997) found allelic frequencies in a predominantly Jersey population of 0.31, 0.62 and 0.07 for the A, B and C variants, respectively. The C variant was considered to be equivalent to the B variant for Jersey cows because the frequency of the C allele is very low, the milk composition and processing qualities of C β -lactoglobulin milk more closely resemble B β -lactoglobulin milk than A β -lactoglobulin milk (Hill *et al.* 1997; Winkelman 1997), and information on the effects of the C allele is very limited.

3.2.4 Model Parameters

Some parameters used in the model are trait or breed specific (e.g. gene frequency), others are herd specific (e.g. herd age structure, replacements available, production levels). Table 3.3 shows the parameters used in the example. Base production level and genetic gain data were from unpublished data (Lopez-Villalobos 2000, *pers. comm.*). The initial frequency of the B β -lactoglobulin assumed in the model population was 0.684 (Winkelman and Wickham 1996).

The total production is the average production per cow per year for cows in that group i.e. genotype, herd or all cows (total). These values include age adjustments, and response to selection over time (i.e. the potential production from younger cows is greater than that of the older cows). The part production is the amount of the overall average production per cow per year contributed by cows in that group i.e. genotype or herd. For the cows in any given genotype, this is calculated as the actual production per cow per year for the cows in that genotype multiplied by the proportion of cows in that genotype.

As previously described, the base production level (Base) is the production per cow per year of the oldest cows (10-year olds) as mature cows (5- to 8-year olds) i.e. no age adjustment. Gain is the selection response per year for cows in that genotype. The average herd base production level and gain is the total of the production values for the cows in each genotype weighted by the proportion of cows in each genotype.

Table 3.3: Parameters used and first year production in selection for BB β -lactoglobulin cows.

YEAR 1						
Gene frequency (B)	0.684					
Cows (2- to 10-year old) by genotype						
AA cows	0.0999					
AB cows	0.4323					
BB cows	0.4679					
Replacements	Replacements/ Cow required	AI hfr calves /cow mated		Available replacements		
No yearling AI mating	.25	.35		.273		
Yearling AI mating	.25	.35		.350		
Production (production/cow/year)	Milk Yield (l)		Milkfat (kg)		Protein (kg)	
	Total¹	Part²	Total	Part	Total	Part
AA cows	2957	295	158.1	15.8	121.7	12.2
AB cows	2943	1272	159.7	69.0	121.1	52.3
BB cows	2919	1366	160.1	74.9	120.1	56.2
Herd 1 (AA and AB cows in Test option)	2945	1567	159.4	84.8	121.2	64.5
Herd 2 (BB cows in Test option)	2919	1366	160.1	74.9	120.1	56.2
Total		2933		159.7		120.7
Base production level (Base) and Selection Response per Year (Gain)	Milk Yield (l)		Milkfat (kg)		Protein (kg)	
	Base	Gain	Base	Gain	Base	Gain
AA cows	3090	30.25	164.3	1.78	122.0	2.22
AB cows	3074	30.10	165.9	1.80	121.4	2.21
BB cows	3049	29.86	166.4	1.81	120.4	2.19
Average	3064	30.0	166.0	1.80	121.0	2.20

¹ Total production/cow/year produced by cows in that group e.g.litres /cow/year.² Amount of the herd average production/cow/year that is contributed by cows in that group.

3.3 RESULTS

3.3.1 Genotypic and gene frequencies

The model was run over the 20 year time period for the three scenarios using the different selection policies. The change in the proportion of cows that are genotype BB over 20 years for the three policies (TEST, NOTEST and SQ) is shown in Figure 3.1.

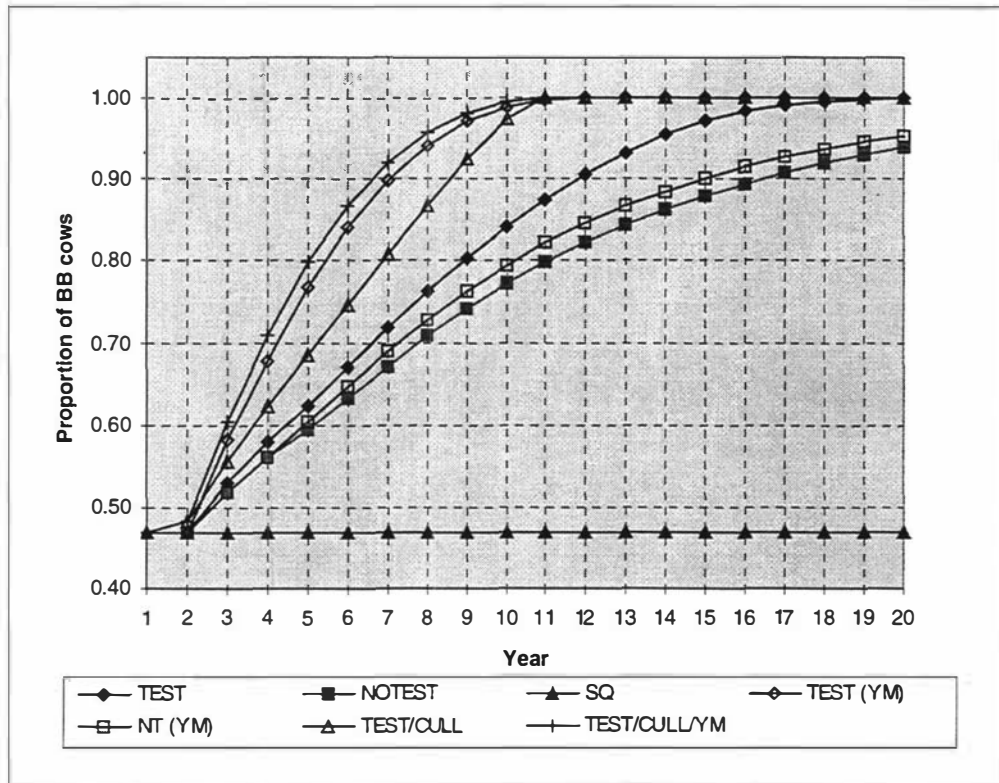


Figure 3.1: Proportion of BB cows over time using different selection policies (gene frequency of B = 0.684 in Year 1, i.e. BB = 0.468 in Year 1). YM = yearling mating with AI. CULL = culling on genotype.

At a gene frequency of 0.684 for the B allele with no yearling mating to AI, all calves selected in the tested herd will be genotype BB in year 11, and the whole herd will be BB genotype by year 20. Where half of the cows culled as being “unsuitable for dairying” are chosen on genotype (3.5% of the herd), all calves selected would be B-homozygous in year 9 rather than year 11, and all cows would be B-homozygous in year 12 rather than year 20. Where yearlings are AI mated, all calves selected in the tested herd will be genotype BB in year 3, and the whole herd will be BB genotype by year 13, assuming no culling on genotype. If there is no cow genotype testing (NOTEST), 93% of the herd will be B-homozygous by year 20, and it will take 35 years before 99% of the herd is B-homozygous cows. Yearling mating has

only a small impact on this scenario. Figures 3.2 and 3.3 show the frequency of the B allele in the population for the three scenarios over the 20 years, both with and without yearling AI mating.

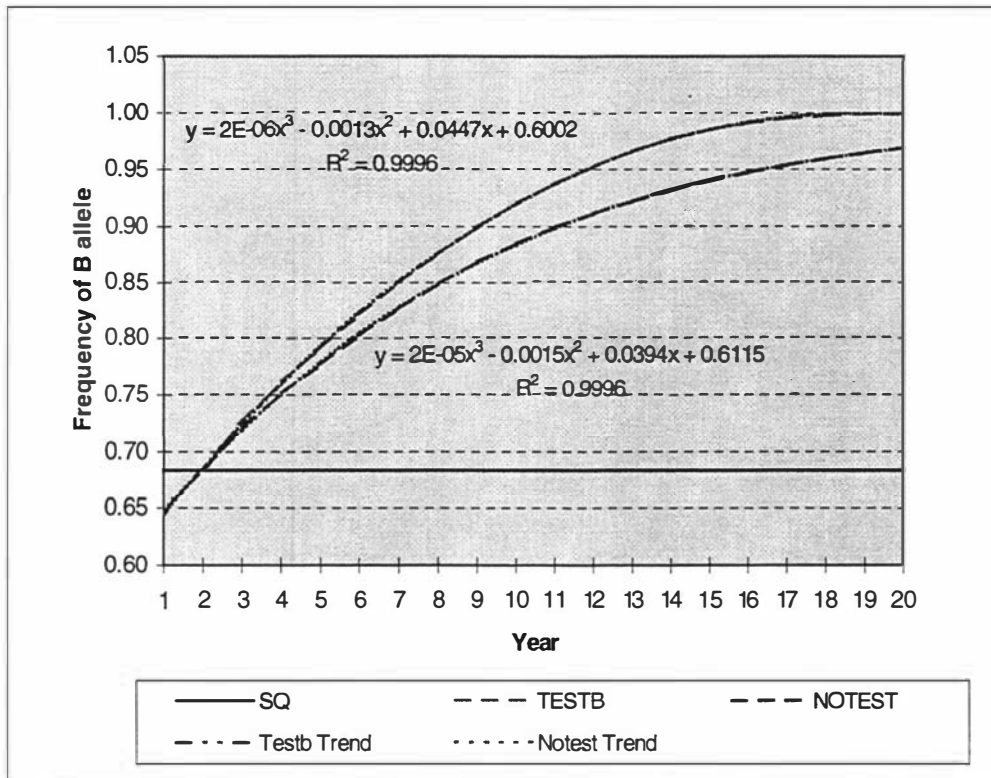


Figure 3.2: Frequency of the B allele over the 20 years for the three breeding scenarios (gene frequency of B = 0.684 in Year 1, No yearling AI).

The gene frequency remains constant for the first two years until the calves selected under the new policy enter the herd. From year 3, the frequency of the B allele for the three scenarios can be closely predicted. The high R^2 value (0.999) means the trend lines are superimposed on the actual frequency lines (Figures 3.2 and 3.3). Differences in the gene frequency (Figures 3.2 and 3.3) are similar to that for the genotypic frequency (Figure 3.1). More rapid progress is made under the testing scenario than the no testing scenario, with the difference between the policies being greater with yearling mating. Yearling mating has little impact on the no testing policy.

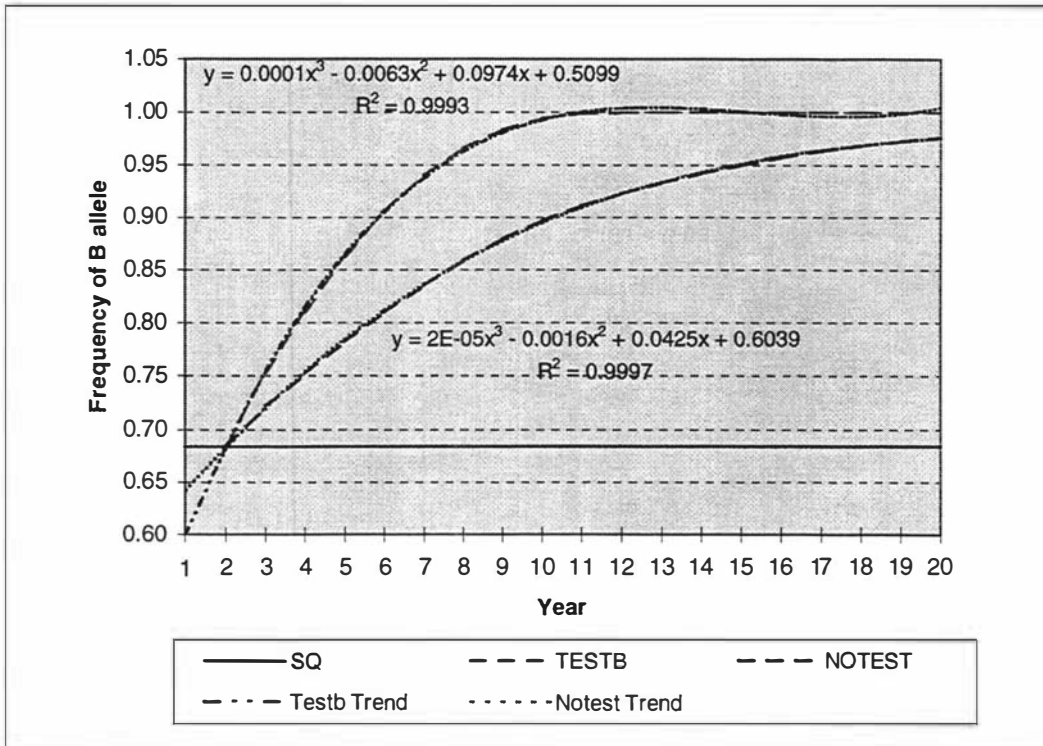


Figure 3.3: Frequency of the B allele over the 20 years for the three breeding scenarios (gene frequency of B = 0.684 in Year 1, Yearling AI).

3.3.2 Production

Potential production increases over the 20 years because of on-going genetic improvement are shown in Figures 3.4 and 3.5. Figure 3.4 shows the average protein production per cow per year, that is contributed by cows in each herd or sub-herd (i.e. average production/cow/year by cows in that herd multiplied by the proportion of cows in that herd). Herd 2 (H2) is comprised of the BB cows. The average herd production per cow under the status quo scenario, the no testing scenario, and the two testing scenarios (TEST and TEST/YM, combining Herd 1 (H1) and Herd 2 (H2) production), is similar.

All milk produced in the status quo option will be Herd 1-type milk, whereas milk produced in the no testing option will be either Herd 1- or Herd 2-type milk, with the change occurring once a certain proportion of cows reach the required genotype. In the testing option, milk from BB cows (Herd 2) can be kept separate from AB and AA cows (Herd 1), with the Herd 2 cow numbers, and therefore production, increasing over time as that of Herd 1 decreases. If yearling mating is practised, this change occurs at a faster rate.

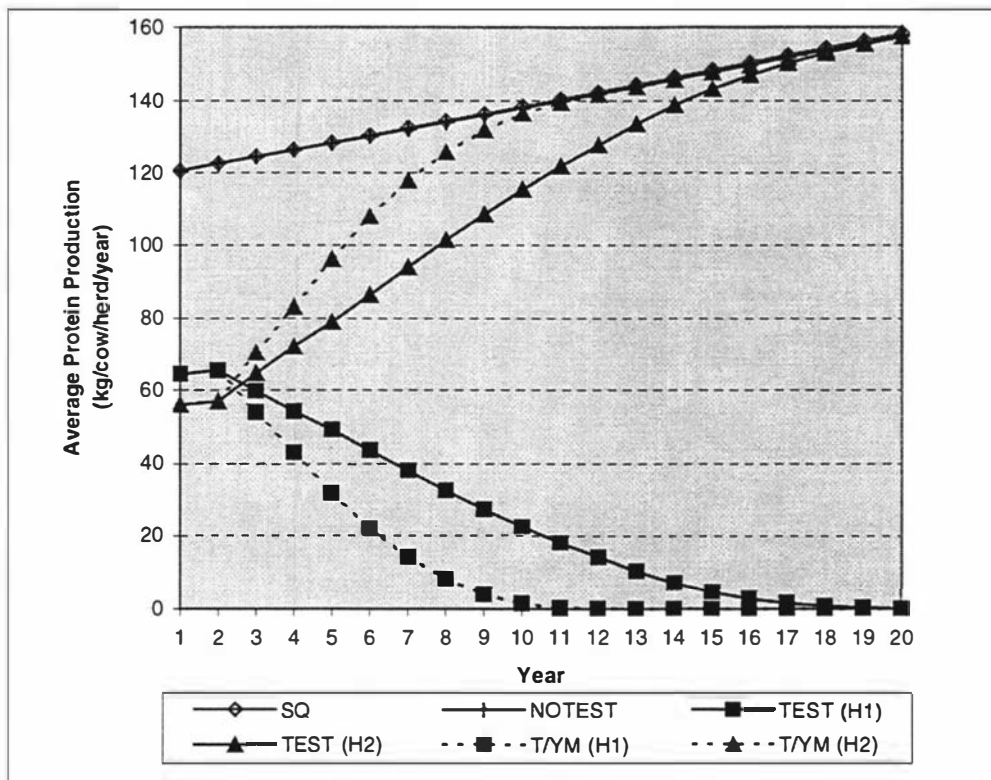


Figure 3.4: Average protein production per cow per herd per year over 20 years (gene frequency of B = 0.684 in Year 1).

The amounts of protein produced by Herd 2 cows (BB cows) and Herd 1 cows (AA and AB cows) for the testing and no testing options relative to their status quo counterparts remains the same for the first two years. Over the following five years, Herd 2 protein will increase by an average of 10.5% and 8.1% per year for the testing and no testing options, respectively, relative to the status quo BB cows, whereas Herd 1 protein will decrease by an average of 9.2% and 7.1% per year compared to that of the status quo AA and AB cows. Over the 20 years the average yearly increase in Herd 2 protein for the testing option relative to the status quo BB cows is 6.0%, while that for the no testing option is 5.2%.

There is a small difference in protein production between the genotypes, as can be seen by the comparison between the status quo production levels (Figure 3.5). As the gene frequency changes to generate all BB cows under the testing option, the average protein production of the different genotypes differs, primarily due to the age structure of the cows in the different genotype groups (i.e. younger cows make up a higher proportion of the BB herd, whereas older cows make up a higher proportion of the AA and AB cows) (Figure 3.5).

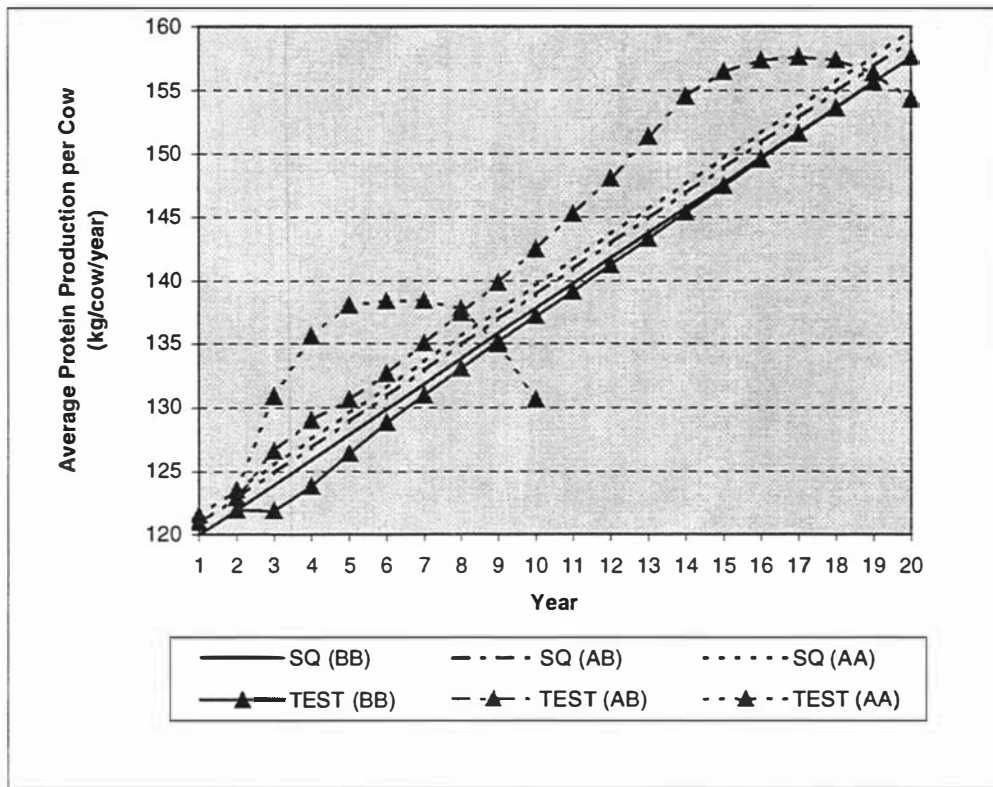


Figure 3.5: Average protein production per cow by the different genotypes over the 20 years (gene frequency of B = 0.684 in Year 1).

In year 5, Herd 1 cows (AA and AB – 37.6% of the cows) produce an average of 131.7 kg/cow/year compared to 126.6 kg/cow/year for the BB cows in Herd 2. In contrast, the difference between Herd 1 and Herd 2 cows in year 5, under the status quo is only 1.2 kg/cow/year. The greater difference under the testing option (5.1kg/cow/year) is because of the higher proportion of mature cows in this group. The average production of the AA genotype cows in the test option starts to decline after 5 years, as the average age of these cows increases and their production drops with age (Figure 3.5). After year 10, all cows in Herd 1 are genotype AB, and the higher production per cow in this herd up to year 19 is due to the higher average age of the cows in this herd.

However, the overall per cow production in the testing scenario is not greatly different from the status quo scenario as these higher producing AA and AB cows make up a progressively smaller proportion of the total herd over time. Once the whole herd is BB genotype, average per cow production is at the same level as the status quo BB cows. Trends for milk and milkfat yields are similar to protein yields, except milkfat production of BB cows is higher

that of AA or AB β -lactoglobulin cows. Production in year 20 for milk, milkfat and protein, with and without heifer AI, at initial gene frequencies of 0.684 (Tables A2.1 and A2.2) and 0.5 (Tables A2.4 and A2.5) are shown in Appendix 2. Differences in production are small.

3.3.3 Herd Structure

The impact of changing herd structure is twofold. As 2-year olds make up a higher proportion of the herd more calves are needed for replacements. However, unless yearling AB mating is practised fewer AI heifer calves are available as replacements, limiting selection. On the other hand, the B gene is bred into the herd at a faster rate with a higher replacement rate (more calves are selected, all of which will be either AB or BB genotype). Where cow and calf genotype are known, greater progress is made at a lower replacement rate once most of the herd is either AB or BB genotype, because more BB genotype AI heifer calves are available as replacements. Overall, replacement rate has little impact on the time taken for the whole herd to become B-homozygous.

For example, a comparison was made between replacement rates, one with 23.5% of the herd as 2-year old cows (above which insufficient replacements were generated) and the other with 19.9% 2-year old cows. The initial genotype frequency was 46.8% BB cows. In the no testing scenario, the difference in the proportion of BB cows between the two replacement rates ranged from 0 to 2.7% more at the higher replacement rate (74.1% c.f. 71.4% in year 9), over the 20 years. Where genotype was known (test option), slightly faster progress was made initially at the higher replacement rate (0.3% more BB cows in year 4), with no difference between replacement rates in year 7. After year 7 faster progress was made at the lower replacement rate, with the greatest difference at year 11 (2.2% more BB cows). Even at lower genotype frequencies (9% BB cows in year 1) the greatest difference in the proportion of BB cows between the two replacement rates over 20 years was 4.1% and 5.6% more BB cows at the higher replacement rate, for the testing and no testing options, respectively.

3.3.4 Initial gene frequency

The effect of altering the initial gene frequency on the frequency of the B allele over time is shown in Figure 3.6 for the test scenario. The rate of progress in introducing the B allele declines over time: this can also be seen in Figures 3.1, 3.2 and 3.3. Appendix tables show the gene frequencies and production in year 1 (Table A2.3) and year 20 (Tables A2.4 and 2.5) starting with a gene frequency of 0.5 in year 1. Gene frequencies are slightly lower after 20 years starting with a frequency of 0.5 (Tables A2.4 and A2.5) compared to 0.685 (Tables A2.1 and A2.2) with no testing, both with (95.7% versus 97.3%, respectively) and without heifer AI (94.5% versus 96.5%, respectively). Appendix Table A2.6 shows the time the herd takes to reach a range of gene frequencies, from an initial frequency of 0.5.

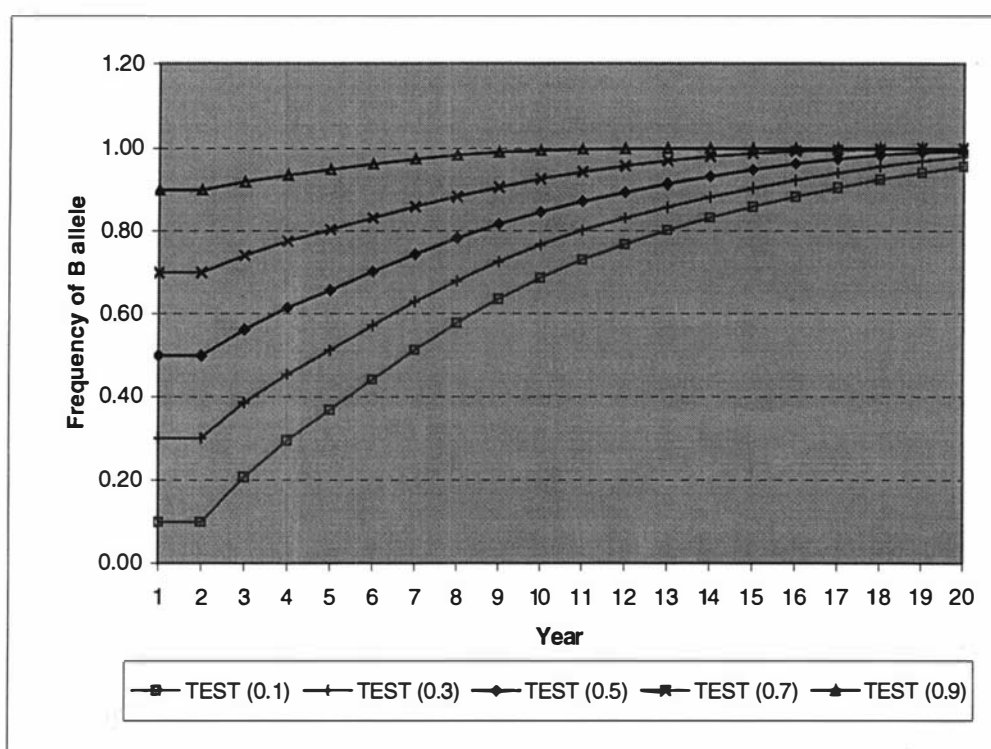


Figure 3.6: Frequency of the B allele over 20 years at initial frequencies of 0.1, 0.3, 0.5, 0.7 and 0.9 (testing for genotype, no yearling AB).

3.3.5 Using AB and BB β -lactoglobulin bulls

There may be insufficient BB β -lactoglobulin bulls at low gene frequencies to allow only BB bulls to be used. Table 3.4 shows the change in the proportion of AA, AB and BB cows in the herd after 20 years of selection at two gene frequencies, using either BB bulls or a combination of BB and AB bulls. Both testing and no testing scenarios are shown. The change is considerably slower where a combination of bulls is used.

Table 3.4: Cow gene and genotypic frequencies after 20 years of selection at 2 initial gene frequencies (0.2 and 0.3), using BB only or a combination of both AB and BB bulls (testing and no-testing for genotype, no yearling AB).

	Year 1	TEST		NOTEST	
		BB bulls only	AB&BB bulls	BB bulls only	AB&BB bulls
Initial gene frequency (B) = 0.3		Bull combination used¹ = 4 AB:1 BB, Freq(B) = 0.60			
Cows					
AA	0.49	0.000	0.076	0.000	0.187
AB	0.42	0.037	0.522	0.155	0.493
BB	0.09	0.963	0.401	0.845	0.320
Freq(B) ¹	0.30	0.982	0.663	0.923	0.567
Initial gene frequency (B) = 0.2		Bull combination used = 8 AB:1 BB, Freq(B) = 0.556			
Cows					
AA	0.64	0.000	0.127	0.000	0.233
AB	0.32	0.058	0.541	0.177	0.503
BB	0.04	0.942	0.332	0.823	0.265
Freq(B)	0.20	0.971	0.602	0.913	0.516

¹ Freq(B)=1 for the bulls, where BB bulls only are used.

3.3.6 Breed and Regional Effects

Genotype frequencies for the various breeds were calculated from the allelic frequencies derived by Winkelman and Wickham (1996) from a New Zealand trial (Table 3.2). The high frequency of the B allele in the Jersey population, and the low frequency of the B allele in the Friesian population, meant 46.8% of Jersey cows were B-homozygous compared to only 26.3% of Friesian cows. The distribution of breed within New Zealand and by region (LIC 1998) was used to estimate the frequency of the B allele nationally and by region (Table 3.5). The frequency of the B allele ranged from 0.59 in Taranaki, which has the highest proportion of Jersey cows, to 0.548 in the Bay of Plenty/East Coast region, which has the highest proportion of Friesian cows (Table 3.5).

A national gene frequency for B of 0.563 (as for New Zealand) under the Hardy-Weinberg law would give genotype frequencies of 0.191, 0.492 and 0.317 for AA, AB and BB genotypes, respectively. The calculated gene frequency differs from this, with a slight tendency toward homozygotes because the regional population data was calculated from the breed sub-populations.

Table 3.5: Gene and genotype frequencies by region.

Area	NZ	North-land	Auckland	BOP & East Coast	Taranaki	Wgtn & Hawkes Bay	South Island
Breed Propn							
Ayrshire (A)	0.01	0.02	0.01	0.01	0.02	0.01	0.02
Friesian (F)	0.58	0.56	0.59	0.70	0.38	0.65	0.64
Jersey (J)	0.16	0.16	0.15	0.11	0.28	0.14	0.12
FxJ cross (C)	0.19	0.20	0.19	0.12	0.22	0.14	0.17
Other (O)	0.06	0.06	0.06	0.06	0.10	0.06	0.05
Genotype Propn							
AA cows	0.196	0.193	0.197	0.208	0.173	0.202	0.202
AB cows	0.484	0.483	0.484	0.488	0.474	0.486	0.486
BB cows	0.321	0.324	0.319	0.304	0.353	0.312	0.312
Freq(B)	0.563	0.566	0.561	0.548	0.590	0.555	0.555

Figures 3.7 and 3.8 show the proportion of BB cows over time for the various breeds, under both the testing and no testing scenarios. As expected, Jerseys and Ayrshires progress faster toward a frequency of 1 compared to Friesians because of the higher initial frequency of the B allele.

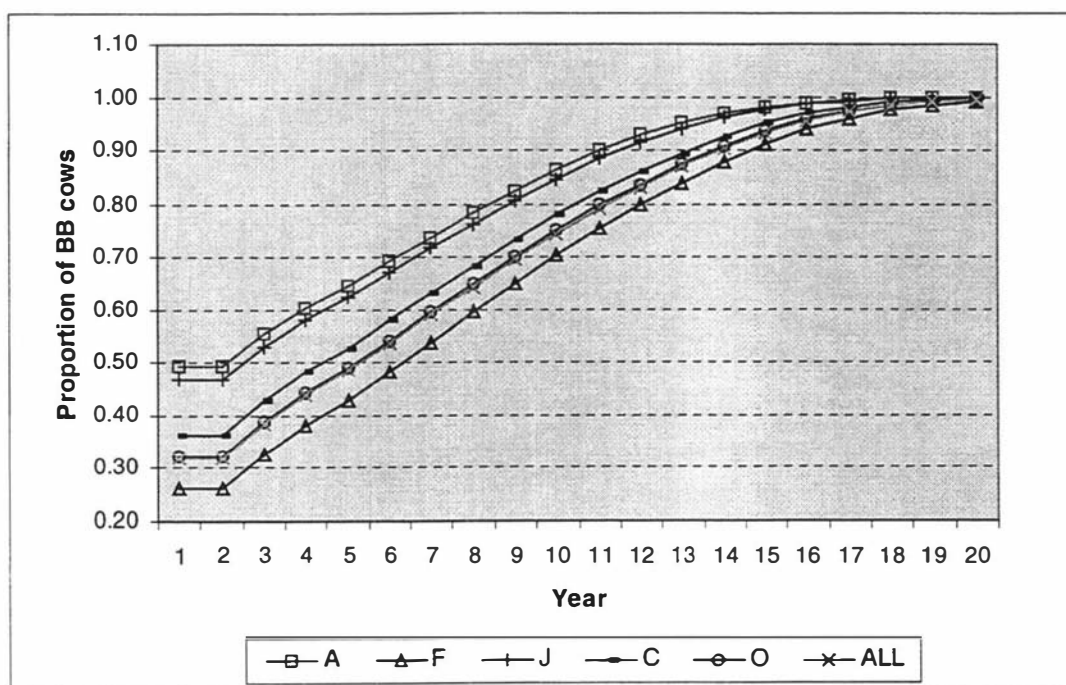


Figure 3.7: Proportion of BB cows by breed over time (testing scenario).

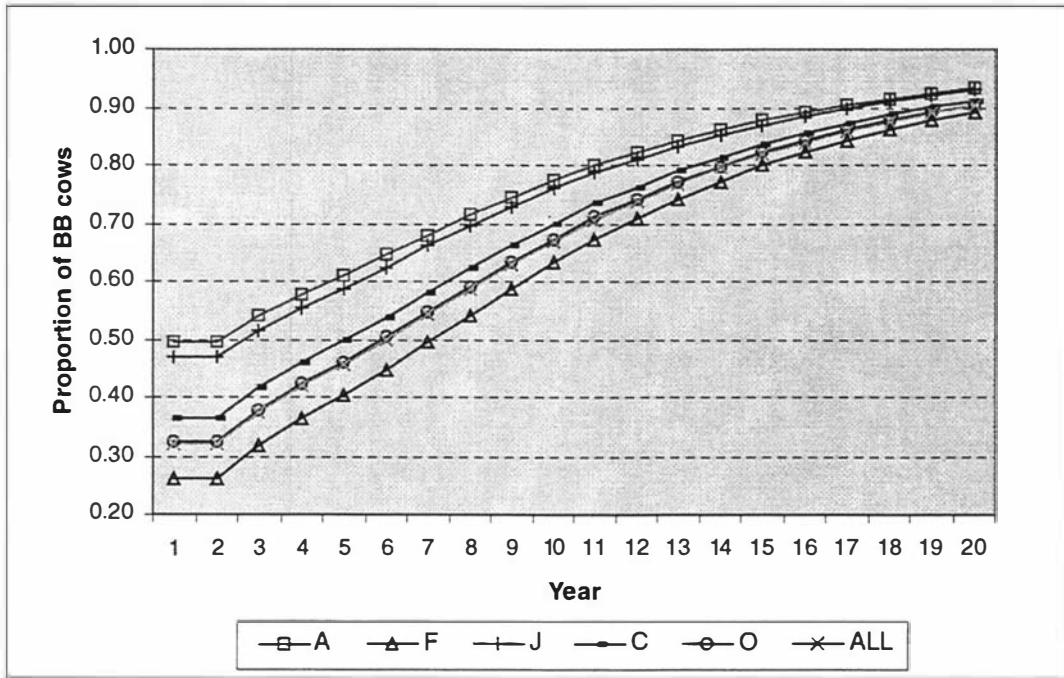


Figure 3.8: Proportion of BB cows by breed over time (no testing scenario).

3.4 DISCUSSION

The gene frequencies for all scenarios remained constant until year two (unless cows were culled on genotype), when the calves first selected under the new policy entered the milking herd. After year 2, a polynomial or binomial expression accurately described the change in gene frequency over time up to a gene frequency of close to one (Figures 3.2 and 3.3). A no testing policy generated a slower rate of change in gene frequency than a testing policy. A gene frequency close to one was reached only one to two years sooner with yearling mating, than without, for the no testing policy (Figure 3.1). Even though the rate of change was greater for the testing policy, it still took 20 years for all cows to be B-homozygous in the example given (i.e. starting with a gene frequency of 0.684). The time to reach this fixation was reduced to 12 to 13 years if culling on genotype, yearling mating or both were used along with testing cow genotype. Yearling mating had more impact than culling on the rate of change in gene frequency.

The rate of change in gene frequency is important in choosing between the breeding options. Clearly, the test option is better than the no-testing option where premium-attracting milk from BB cows is kept separate from that of other cows. In the example considered, 47% of cows were already identified as BB in year 1 with testing; with no testing the BB cows were unidentified, and it took 35 years before most (99%) cows were known to be BB. Unless the

cost of testing cows is prohibitively expensive, it would be advantageous to test all cows in year 1 (and get an immediate premium on some milk), than to adopt a no testing policy initially and then test cows partway through the breeding programme.

If a premium is paid on milk at a cut-off level of less than 100% BB cows, or on the frequency of the B allele in the herd (with all milk in one vat), the short-term rate of change is important in identifying the best option. As the cut-off frequency is lowered, the testing and no testing options converge, although the difference between the two options remains greater if yearling mating is practised (Figures 3.2 and 3.3 at an initial frequency of 0.684; Appendix Table A2.6 at an initial frequency of 0.5). For example, if only 70% of the herd was required to be B-homozygous before a premium was paid on all milk, the no testing option would take only one year longer than the testing option (8 c.f. 7 years) to reach this target, at 80% this gap would be 2 years and at 90%, 5 years (initial frequency of 0.684). However, with testing, a premium could be received on some milk over the whole time period for at least a portion of the herd where BB milk is segregated. If a premium is paid on the expected frequency of the B allele in the herd then clearly there is more rapid progress with testing. Nevertheless, this may not be the best option from an economic perspective once associated extra costs are allowed for.

Altering the structure of a herd generating its own replacements has only a small impact on the gene frequency. Increasing the replacement rate reduces overall production because the proportion of younger cows increases. Buying and selling cows is a more effective method of altering the frequency of the B allele in the herd, reflected by Figure 3.6. All cows in the herd, as well as any potential purchases, would need to be genotyped and cows with the requisite genotype may have a higher value than other cows. Buying and selling cows could be expensive, particularly where the frequency of the desired allele is initially low. This option will be least costly where the frequency of the allele is high, since only a small proportion of the herd will need to be replaced. As the rate of change is low at high gene frequencies this would also be the most effective method of increasing the gene frequency. At low gene frequencies, buying in calves in the earlier years to ensure all replacements are B-homozygous may be a cheaper option than replacing cows, and the expense can be spread over a number of years. However, with this option it will still take 11 years before the whole herd is B-homozygous i.e. when the first calves selected or purchased under the new policy are in the oldest cow age group.

The model assumes the cow population is in Hardy-Weinberg equilibrium. In New Zealand, the small number of bulls used in relation to the size of the cow population means that this

may not necessarily be the case, particularly within years. Similarly, individual herds may not be in Hardy-Weinberg equilibrium because of the small size of the population and the herd sires selected.

The genetic gain per year in production traits was assumed to be the same over the 20 years for the purposes of the analysis. However, this may not be the case, as selection and culling policies for both bulls and cows can impact on genetic gain. In general, the effect of selection on the cows to breed cows path is considered to be minimal (Bourdon 1997; Lopez-Villalobos *et al.* 2000) and as such, is sometimes ignored in calculating genetic gain. Differential cow selection and culling decisions may be made in the testing policy. B-homozygous replacements are more likely to come from the younger dams in the earlier years of the testing policy, as a higher proportion of these cows will be B-homozygous. This will lower the average age of the dams, and therefore the generation interval, increasing genetic gain: this will be intensified where yearling AB mated is practised. Conversely, culling on genotype, rather than production will reduce genetic gain in production traits, as well as reducing overall production. Selection of replacements from AB and BB dams only, reduces selection intensity slightly, and therefore genetic gain. The overall impact of these policies was considered to be small, and therefore they were not included in the model. Implications with respect to bull policies are discussed next.

All bulls were assumed to be of similar genetic merit for both the B β -lactoglobulin and the status quo scenarios, and sufficient B-homozygous bulls were taken to be available for the farms or regions wanting to make the change. Although β -lactoglobulin genotype would not necessarily be included as an economic trait in bull selection, the β -lactoglobulin genotype would need to be identified. LIC routinely do this for proven bulls (Rendel and Harris 1997). If a large number of farms decided to change, demand for BB β -lactoglobulin bull semen would increase, and breeding schemes would need to allow for this by taking β -lactoglobulin genotype into consideration in bull selection, in the selection index, the balance of genotypes or the number of bulls in the bull team. As a result, bull selection costs may increase, and high index bulls (non-BB β -lactoglobulin) may be discarded on genotype reducing the overall genetic gain in production traits. Reproductive technologies could also be used to increase the number of high breeding worth BB bulls in the bull team. These could include: cloning of high breeding worth BB bulls; transplanting BB β -lactoglobulin embryos from high breeding worth BB cows; modifying the cows to breed bulls population to include contract matings with more BB cows and the use of sexed semen to get more male offspring from these

matings. These technologies will increase bull selection costs, but are less likely to reduce the genetic gain in production traits and may in fact increase it.

Previous research on selection for a specific genotype has been from an industry, rather than a herd perspective. Gibson *et al.* (1991), Pederson (1991), Harris (1997), Rendel and Harris (1997), and Spelman and Garrick (1997a) investigated the implications of selection on a single locus at the breeding scheme level (bulls to breed bulls, cows to breed bulls, and bulls to breed cows pathways). Gibson *et al.* (1991) and Pederson (1991) considered κ -casein, Harris (1997) and Rendel and Harris (1997), β -lactoglobulin, and Spelman and Garrick (1997a) assumed a non-specific locus as a marker gene. The frequency of an allele was altered in the whole dairy cow population and economic benefits were assumed to be from the increased value of the milk to the industry. Comparisons included independent culling levels and a selection index incorporating the desired genotype. Index selection combining production traits and genotype gave the optimal economic outcome. Harris (1997) found that after 20 years of selection using BB bulls only, or index selection including β -lactoglobulin, approximately 90% of the population was BB β -lactoglobulin. To achieve this, all, or the majority, of bulls offered were BB β -lactoglobulin. The change in genotype frequency in the cow population determined by Spelman and Garrick (1997a) and Harris (1997) was comparable to that calculated in the current study using the no testing scenario with similar inputs (gene frequencies and bull genotypes).

The objective of these industry-based examples was to change the national population. Decision-making is predominantly at the bull breeding scheme level, with farmer selection on the bulls to breed cows pathway largely determined by the bulls made available by the breeding schemes. Several European countries, which predominantly produce cheese, already record and use genotype information (e.g. κ -casein) in their dairy breeding programmes (Puhan 1997; Kennelly and Glimm 1998). In New Zealand, the suppliers of the Kaikoura cheese factory use only BB β -lactoglobulin bulls (Davis, K. 1997). This industry-based selection may be inappropriate where selection is on a particular trait that may be beneficial in producing some products, but has a detrimental or unknown effect on the production of other products or even potential future products. The shift in the dairy industry from commodity-based dairy products to the development of a wider range of products suggests the inclusion of other traits in an industry-wide index needs to be treated with caution. A future possibility may be to offer a wider selection of bulls with a range of breeding values and indices, allowing farmers to select bulls based on their own breeding objectives. This may be particularly important with quantitative traits, which will be discussed later (Chapter 7).

Possible future selection may include casein and whey proteins in the index, rather than total protein. BB β -lactoglobulin cows tend to have higher amounts of casein, and lower amounts of whey and total protein than AA β -lactoglobulin cows with AB β -lactoglobulin cows intermediate between the two (Hill *et al.* 1997). If the relative economic values favour casein rather than whey, the index could favour BB β -lactoglobulin bulls, resulting in more BB β -lactoglobulin bulls in the bull teams anyway.

In situations where gene frequencies are low and there are insufficient B-homozygous bulls, AB as well as BB β -lactoglobulin bulls may be used. However, this markedly reduces the rate of change in the gene frequency (Table 3.4). This was also shown by Harris (1997). The example given assumed that the proportion of AB and BB bulls mated to each of the three cow genotypes was the same. The ratio of AA:AB:BB cows (genotypic frequency) could be altered by selectively mating the BB bulls to a particular cow genotype. Selectively mating the BB bulls to BB cows under the testing scenario will produce a higher proportion of homozygotes compared to mating BB bulls selectively to AA or AB cows (Dooley, unpublished results, 2000). The gene frequency will still change at the same rate with no selection. However, greater progress is made toward a BB herd by selectively mating the BB cows to the BB bulls, as the trend toward homozygotes means a higher proportion of cows will be in Herd 2 and a larger proportion of the calves not selected will be AA rather than AB. The change in genotype frequency with selective compared to non-selective mating is greater than the change in gene frequency.

The slower rate of change from using AB as well as BB bulls suggests it may be worthwhile obtaining BB bulls from alternative sources if insufficient industry bulls are available e.g. farmers could buy in or breed their own bulls. This is likely to be at the expense of some genetic gain in the production traits and would only be worthwhile if the greater rate of change in the qualitative trait and the higher value of the BB milk compensated for this. Screening-in cows of the required genotype to increase the initial gene frequency in the herd could be another option.

The Jersey and Ayrshire breeds, and the Taranaki region with its higher than average Jersey population, would have the advantage in breeding towards a high frequency of the β -lactoglobulin B allele because of their higher initial B β -lactoglobulin gene frequencies. Winkelman and Wickham (1996) also found differences between breeds in allelic frequencies for α_{s1} -, β - and κ -casein, as well as β -lactoglobulin. It is well known that breed differences

also exist in milk yields, and milkfat and protein concentrations and yields. The uneven breed distribution in New Zealand suggests that milk composition between regions in these components will also differ e.g. a higher milkfat concentration in milk from Taranaki, because of its higher Jersey population, and the reverse in the Bay of Plenty. This trend is in agreement with regional milk test statistics (LIC 1999). These differences, as well as the differences between breeds in genotypes, imply that milk from some breeds and regions in New Zealand could have processing advantages over others because of their different milk composition types.

However, choosing a particular breed to assist in selection towards a particular milk composition or component is unlikely to be straightforward because of the combination of effects that breed type has on milk composition. That is, just because Jersey breed has a higher proportion of AB and BB β -lactoglobulin phenotypes their milk may not be better for cheesemaking. However, it has also been found that they are higher than Friesians in the κ -casein B variant (Winkelman and Wickham 1996) which is also better for cheesemaking (Fitzgerald and Hill 1997). McLean *et al.* (1984) suggested the higher κ -casein in Jersey cows compared to Friesians “is consistent with the view held in the industry that Jersey milk is generally superior for cheesemaking”. Overseas studies comparing Friesian cows with that of other breeds, found Friesian milk to be inferior for cheesemaking (Macheboeuf *et al.* 1993; Malossini *et al.* 1996; Verdier-Metz *et al.* 1998). Although the protein and total solids content in Jersey milk is higher than that of Friesians, Jerseys have a lower protein:fat ratio which is a disadvantage in cheesemaking. This raises several questions, viz.: after standardisation (by excess fat removal), would milk from Jersey cows produce cheese of higher quality than that from Friesians? If so, is a higher return from this cheese possible? Similarly, how much more, or less, cheese per farm could be made from Jersey milk compared to Friesian milk, allowing for differences in β -lactoglobulin genotypes and per cow production? The model looks at changing milk from particular groups of cows e.g. cows within a herd, breed or region with specified initial milk compositions. In investigating answers to questions such as these separate model runs would need to be made for groups where initial milk composition differed, such as by breed.

Variation also exists in gene frequency between herds within a group (e.g. breed) (McLean *et al.* 1984), and it will be important to identify the cut-off point required before running the model i.e. the gene frequency input in the model. Alternatively, the model may be used in sensitivity analysis to identify the allelic frequency at which milk segregation becomes viable. For example, if the dairy company requires 30% of the milk to be of a particular type, then it

must be economically viable for herds with at least 30% of the cows to make the change. Those herds with milk composition closer to the required milk type will profit more from the change than those further from it, but there must be an incentive for the whole 30% to change. However, the milk received by the factory will be the average for this 30% of cows. This will be discussed further in Chapter 7.

In making economic comparisons between policies, the production per herd (BB and non-BB) or the proportion of BB milk is important. Initially, the proportion and age of the cows whose milk can be differentiated will have a greater bearing on production per herd than the genetic gain (Table 3.5). Differences in the level of production and genetic gain between genotypes become more important once all cows are in the same herd. However, differences between herds in overall production may be small, as for the scenarios given (Figure 3.4, Appendix Tables A2.1, A2.2, A2.4 and A2.5). For example, the milk and protein yields of the cows calculated for the SQ herd was only 0.5% more than that of the BB β -lactoglobulin cows.

The relative amount of BB protein, to AA and AB protein remains the same or similar under the testing options compared to the status quo option in the first 3 to 4 years. Segregation of milk at this stage will have little effect on the overall composition of the milk received at the factory unless BB cows are purchased from outside the factory region. The separation of BB milk in these initial years means the remaining bulk milk will have a higher proportion of AA and AB milk. This may affect the processibility of the bulk milk. Separation may still be viable from a processing perspective if the BB milk is required for the production of higher value products, with bulk milk used predominantly for commodity products. If the objective is to increase the B β -lactoglobulin levels in bulk milk i.e. no segregation of milk types, this is less likely to be an issue.

Systems that include genotype testing, buying and selling cows or calves to alter the gene frequency, yearling mating, and culling on genotype have additional costs, and may also impose other constraints on the system (extra labour, time delays in selection, herd management changes). The way in which the farmer is paid for the differential milk will also have an effect. For example, milk from B-homozygous cows may have to be kept separate from milk from non-B-homozygous cows. This would not be necessary where payment was based on the frequency of the B allele or the proportion of B-homozygous cows in the herd, either tested or expected. Another possibility is the inclusion of casein in milk payments, favouring BB β -lactoglobulin milk, as was considered by the Kaikoura cheese factory (Anon. 1997; Boland *et al.* 2000). Those systems with more rapid progress toward the desired

genotype will be more costly, requiring a greater return to farmers to compensate for this. Practical issues relating to milk storage and transport will need to be considered where milk is segregated. At high and low gene frequencies a disproportionate amount of milk will be of one type: combining all milk at low frequencies, and buying and selling cows at high frequencies may be required to overcome this. Differentiation is also likely to result in extra costs for dairy companies e.g. milk payment to farmers, and increased transport and milk storage costs if milk is kept separate. As a result, dairy companies will need a higher return from products manufactured from the differentiated milk. Although B β -lactoglobulin cows have a higher casein content than A β -lactoglobulin cows (giving higher cheese yields), they also have a lower whey protein content (Hill *et al.* 1997) so the relative returns from casein compared to whey proteins will have an impact. The value of the products produced and the extra costs involved, both on- and off-farm, will be deciding factors in determining not only whether differentiation is economically viable, but also which system is most economical. The output from this sub-model can be used in an economic analysis for this purpose (see Chapter 7 for a detailed discussion of the farm economic analysis).

CHAPTER FOUR

LOGISTICS OF TRANSPORTING TWO DIFFERENT MILK TYPES

4.1 INTRODUCTION

4.1.1 Transport issues

New Zealand dairy companies have a milk volume charge of about \$0.04 per litre which is deducted from farmers' payouts to cover costs associated with the transportation and storage (vats, silos) of bulk milk, and the removal of water at the factory (Larking 1989). Milk segregated at the farm is likely to increase this cost because of higher transport and milk storage costs. Separate milk collection, either as independent runs for the different milk types, or storage of distinct milk types in the truck and trailer units, is likely to increase the length of the trips and possibly the number of runs required. Extra vats and milk silos may be also required to segregate milk. Therefore the product produced from segregated milk must command a higher market value or a reduced processing cost, to offset any extra costs incurred on-farm and in transport and storage.

It can be argued that this increased transport cost should be borne by those farmers changing to a differentiated milk type, because their milk differentiation policy has increased overall transport costs and they will receive the price benefit from this change. To be economic for the farmer to produce a "more valuable" milk type (i.e. milk that will produce a higher value product) they will need to be compensated for associated incremental production and transport costs. The transport of segregated milk is evaluated in this Chapter. The increased storage costs for segregated milk are accounted for in the economic model described in Chapters 5 and 6.

Dairy companies, along with other transport companies, use transport-planning models to help with scheduling decisions. However, this software and related information is commercially sensitive and specific to a company's particular operation, and as a result is typically not in the public domain. Furthermore, current transport planning models for milk collection are likely to relate to the collection of one milk type only. A decision support model for planning the location of future factories, which included estimating milk tanker collection distances was developed by Mellalieu and Hall (1981). However, this related to the

collection of only one milk type and a formula was used to estimate distance travelled rather than calculating the actual distances travelled.

4.1.2 Transport routing problem

The travelling salesman problem (TSP) describes the problem of a travelling salesman who is required to find the shortest (minimum cost) route around a group of cities, visiting each city only once and returning to the original city (Hesse 1997). Problems like this are difficult to solve because there are a large number of possible routes/solutions. Identifying the minimum cost milk tanker collection route is a variation of the TSP, with the added complication that load size is limiting so the tanker will need to make a number of trips to get around all the farms, returning to base each time the load is full. The number of possible sort order solutions in the problem to be modelled, with a combination of 30 farms and 2 stops at each farm assumed, is 8.3×10^{81} . Where there is only one milk collection per farm (30 stops) the number of possible orders is 2.7×10^{32} . While the majority of these sort orders are unlikely to provide a sensible solution, even a very small proportion of sensible solutions could still provide a large number of possible answers, even though some of the solutions will be a variation of the same sort order (e.g. 6 lots of runs in a sort order can be expressed 120 (5!) different ways).

A greedy heuristic or nearest neighbour approach can be used to solve a TSP, but will not necessarily come up with an optimal solution. This method involves travelling from the first stop to its nearest neighbour and from there to the closest stop which has not already been visited, continuing in this manner until all stops have been visited (Hesse 1997). This approach can be used in association with other search methods such as genetic algorithms (GA) to generate starting solutions (Merz and Freisleban 1999).

4.1.3 Genetic algorithms

Genetic algorithms were developed by Holland (1975), and apply concepts from biological systems, specifically population genetics, to a mathematical context. Broad descriptive overviews of GA can be found in South *et al.* (1993), Flack (1998) and Mayer *et al.* (1999). The advantage of GA over other search methods is their ability to search a wide search space. GA optimise the trade-off between exploiting the information discovered so far and exploring new points in a search space (Buckles and Petry 1992). In contrast, hill climbing methods (e.g. calculus-based search methods) are likely to find a local optimum rather than the global optimum, whereas random search methods are inefficient (Flack 1998). GA can also handle non-linear problems (Palisade Corporation 1998). These advantages make GA an effective tool for solving real life problems where there are a large number of input variable

combinations and consequent possible solutions. GA are ideally suited to solving the TSP with its lack of a deterministic solution strategy and a large number of possible solutions (South *et al.* 1993).

The way GA work is briefly outlined here. Buckles and Petry (1992), Grefenstette (1992), South *et al.* (1993), Flack (1998) and Palisade Corporation (1998) describe the procedure in more depth. A set of input variables is represented as a string of numbers or a *chromosome*, with each of the input variables or *genes* represented by a number (or combination of numbers, depending on the number of possible values or *alleles* that an input variable can take). The allele (or number coding) for each of the variables is found at a set position or *locus* on the chromosome. A *population of organisms* (or individuals) is randomly created, with each organism represented by one chromosome.

Each organism in the initial population is randomly generated as a binary string, with a 50% probability of each number in the string being either a 1 or a 0. More than one number may be needed in the string for a particular gene, to allow for all possible alleles for that gene. Each individual is then evaluated with a fitness function. This measures each individual's value as a potential solution to the problem at hand (South *et al.* 1993). An individual's fitness determines the likelihood of it being selected as a parent for the next generation. Those individuals with the highest fitness have a greater chance of being selected to be a parent of the next generation. All or some of the individuals in the current generation are then replaced by new individuals, formed by the reproduction (selection, crossover and mutation) of individuals in the current generation. Crossover and mutation are the means by which variability is maintained in the population. Reproduction continues until some termination condition is met e.g. set number of evaluations or generations completed, best value has remained constant or there has been little change for a set number of evaluations. The optimum value found is an optimum value in the search space, but may not necessarily be the global optimum.

4.1.3.1 Crossover

Those individuals selected as parents, based on the fitness function are randomly paired off. Each pair of individuals is then crossed by selecting an integer place in the string and exchanging the tail, thus creating individuals that bear resemblance to both parents (Flack 1998). In some applications the probability of crossover occurring between two strings in the mating population is less than one (South *et al.* 1993; Flack 1998). The crossover rate determines the likelihood that future organisms will contain a mix of information from the previous parent generation. Crossover can be single point, multiple point or uniform (random

choice for each bit value) (Flack 1998). If the crossover rate is too high, high-performance individuals can be discarded faster than improvements can be made. If it is too low the search may stagnate due to low exploration (Grefenstette 1992).

4.1.3.2 *Mutation*

Random mutation changes an allele value from one value to another i.e. from a 1 to a 0, and vice-versa in a binary string (Buckles and Petrie 1992). This prevents loss of genetic material by reintroducing genes that may have been lost (Mayer *et al.* 1999) and compensating for sampling error (South *et al.* 1993). Values can range from 0 (no mutation) to 1 (all random values) (Palisade Corporation 1998).

4.1.3.3 *Proportion of population replaced and individuals replaced*

Some or all of the parent population can be replaced. In the simplest case the whole population is replaced every generation. However, to speed up computational requirements per generation only some of the population may be replaced (South *et al.* 1993). If only some of the parent population is to be replaced a decision has to be made as to which ones. This can be at random, at the risk of losing good individuals. Alternatively, the worst performing organisms in the parent population can be replaced. An elitism strategy is often used, where the best solution found so far is retained in the next generation

4.1.3.4 *Population size*

The population size needs to be large enough to contain a diverse range of individuals for cross breeding to be effective (Mayer *et al.* 1999). If the population is too low the GA search will perform poorly (Grefenstette 1992). A large population reduces the chance of premature convergence but computational requirements are higher, hence convergence can be slow.

4.1.4 Description of Evolver: a genetic algorithm software package

Evolver, a genetic algorithm solver, was developed by Palisade Corporation (1998) to run on Microsoft Excel spreadsheets. The methods used in the Evolver GA solver are described here (Palisade Corporation 1998). A steady state approach is used which means only one organism is replaced at a time. Parents are selected on a rank-based system, which gives a smoother selection probability curve and prevents good organisms from dominating at an early point. Each new individual generated replaces the worst performing organism in the current population.

Uniform crossover (South *et al.* 1993; Flack 1998), rather than single point, is used i.e. a given proportion of the two organisms, selected at random, is crossed rather than crossing at a set point. The ordering crossover method, as used in the TSP, uses a different approach to avoid replicating values on the string. Items are randomly selected in one parent, their place is then located in the second parent, and the remaining items are copied into the second parent in the same order they appear in the first parent. Mutation in the order solving method consists of exchanging the position of some of the variables in the individual (Buckles and Petrie 1992). Default crossover and mutation rates are included but can be altered. These are 0.5 and 0.06 for crossover and mutation, respectively, for the order solving method. Population size is specified, as is the stopping criteria.

4.1.5 Recommendations for genetic algorithm parameters

The parameters found to be effective in solving problems using GA in past trials are summarised in Table 4.1 (adapted from Barioni 1997).

Table 4.1: Operational parameters recommended for genetic algorithms.

Source	Population size	Crossover rate	Mutation probability	Generation gap	Elitism
Davis (1991)	50	0.65	0.008		
South <i>et al.</i> (1993)					
Standard	50	0.60	0.001	1	Yes
Quick	30	0.95	0.01	1	Yes
Comprehensive	80	0.45	0.01	1	Yes
Mayer <i>et al.</i> (1995)	40	0.60	0.001	1	Yes
Grefenstette (1992)					
On-line	30	0.95	0.01	1	Yes
Off-line	80	0.45	0.01	0.9	No
Mayer <i>et al.</i> (1999)	50	0.50	0.01, 0.001	0.98	Yes

4.1.6 Problem description

In order to quantify the increased transportation cost associated with milk changing from one type to another, milk collection was modelled where none, 25%, 50% and all farms changed to another milk type over a 20-year period. Two contrasting regions with different farm sizes and roading networks (collection areas) were modelled, at two stages of lactation. The model was developed using Microsoft Excel spreadsheets, and the Evolver genetic algorithm software (Palisade Corporation 1998) to search for the order of the farm milk collection pickups (hereafter termed "stops") which gave an optimal, least cost solution for milk collection for each prescribed set of inputs.

4.2 METHOD

A hypothetical block of 30 farms was defined for the North and the South Islands, respectively, based on actual farm milk production data supplied by New Zealand Dairy Group of Companies (NZDG). The North Island block represented an area of smaller dairy farms (average = 177 cows per farm) in Central Waikato situated relatively close to the factory, whereas the South Island farms had larger herds (from an area where the average number of cows is over 500 cows per farm, LIC 1999) and were physically further apart. Each farm produced one or two types of milk with the collection of each milk type defined as a separate stop, giving 60 possible milk collection stops. The number of stops and the milk volumes collected varied over the 20 years depending on the number of farms changing from type one to type two milk, the rate of change between milk types within farms, and the adoption of milk segregation policies on the farms.

Four scenarios of farms changing from one type of milk to the other (from type 1 to type 2) were explored: none, 25% (8 farms), 50% (15 farms) and all farms. For each scenario, farms were randomly allocated to the two groups (changing or not). The initial percentage of type 2 milk on farms that were changing from one type to the other averaged 36%, and ranged from 26% to 47%. This was based on the results from the qualitative breeding scenario, with initial gene frequencies ranging from 51% to 68% (Chapter 3). Farms were randomly allocated to five different gene frequencies, with their associated production of type 2 milk over time. Once 95% or more of the milk was type 2, it was assumed all milk was type 2, as it is unlikely a separate stop would be made for 5% of the herd's production. Further, at this level of production farmers are likely to have sold the few remaining type 1 cows and replaced them with type 2 cows. The time taken to change from one particular type of milk to another took about 14 years, depending on the initial amount of type 2 milk (Chapter 3).

For the 25% of herds changing option, the adoption uptake of the technology by farmers was assumed to be three herds in year 1, four herds in year 2, and one herd in year 3. At 50% this ratio was assumed to be 5:8:2. While some farmers may change policies over the course of the 20 years, in this case it was assumed for simplicity that all would commit to one policy or another in the first three years. Farms changing were randomly allocated to an initial year of change. Where all herds changed it was assumed this policy decision was made by all farmers in consultation with the factory or dairy company and that all farms changed in the first year.

A bridging point enroute to the collection area, at the edge of the collection area closest to the dairy factory was selected. As a result, only the distances within an area needed to be recorded (between farms, and between farms and the bridging point). A similar approach was adopted by Mellalieu and Hall (1981) in modelling a milk transport planning model. The distance between this point and the farms was measured, as well as the distances between the farms. A grid was then set up with the distances between each of the farms, and between each of the farms and the factory. The distance between a farm and the bridging point was added to the distance between the bridging point and the factory to give the total distance between the factory and the farm. This bridging distance between the dairy factory and the bridging point was assumed to be 25 km for the North Island and 85 km for the South Island.

Production for each farm in year 1 was based on actual production data for the farms in 1997/98 (North Island) and 1998/99 (South Island). Milk collection was simulated for two lactation days: the peak lactation day for both the North and South Islands, and the first late lactation day when all farms were on every second day pick up for the North Island, representing two points on the seasonal supply milk volume curve. The average amount of milk for the herds in year 1 at peak lactation was 3094 litres per day ($\sigma = 1544$) for the North Island and 11577 ($\sigma = 3629$) for the South Island. In late lactation this value was 1920 litres every second day ($\sigma = 1036$) for the North Island. A late lactation scenario was not run for the South Island, as the amount collected on the first day of every second day collection in late lactation was similar to daily pick up in peak lactation. This was because the South Island herds have a flatter lactation curve than their North Island counterparts. Also every second day collection occurred sooner in the South Island (185 days after peak collection) than the North Island (205 days). Milk yield per farm was assumed to increase, based on the historic average, by 1.5% per hectare per year (LIC 1999).

Tanker capacity was assumed to be 11,300 litres in the truck unit and 17,500 litres in the trailer unit (12,000 and 18,000 litres respectively, at approximately 95% loading), or a total of 28,800 litres (Spooner 2000, *pers. comm.*). If only one type of milk could be collected in a run, the model allowed for this by assuming the full amount (28,800 litres) was collected in one unit with none collected in the other, the unit in this case being the truck and trailer combined. For each year, the total amounts of type 1 and type 2 milk to be collected were checked, and if the tanker was empty the type with the larger amount was allocated first to the trailer unit which carries more than the truck unit.

Costs can be calculated by differentiating them into running (per kilometre costs) and hourly costs, however information used to estimate costs was not readily available in this format, therefore a flat per kilometre cost was used. These costs were estimated to be \$3.45 per km for the North Island and \$1.75 per km for the South Island, with the higher cost occurring in the North Island due to overheads being spread over the shorter distance travelled.

Farms were sorted into an initial sort order based on a greedy heuristic (Hesse 1997), by taking the stop nearest the factory and moving to the next closest point and so on until all points had been visited. A number of sort orders were generated from this initial sort order as described below. A given order from the factory to a set of farms and back will be the same distance whether it is travelled clockwise or anticlockwise, so it can be assumed the tanker will travel in the most efficient direction in terms of loading i.e. to the furthestmost point on the route first to ensure the load is at a minimum for as long as possible. Consequently, loading was not taken into consideration.

Order 1: A1, A2, B1, B2, C1, C2 ... Z1, Z2

Order 2: A1, B1, C1 ... Z1, Z2, Y2, X2 ... A2

Order 3: Z1, Y1, X1 ... A1, A2, B2, C2 ... Z2

where:

A, B, C ... Z = farm numbers;

1, 2 = milk type.

Orders 4 to 6 are the reverse of the three orders described above. Further sort orders were generated by running these six sort orders through a program that collected milk from the stops specified in the initial specified sort order. However, once it reached a stop that was unable to be collected (e.g. wrong milk type, too much milk volume) it jumped that stop and went to the next one, working its way through all the stops. The remaining stops were then worked through starting at the top again. This procedure was repeated until all milk was collected. This ensured the tanker was as full as possible before returning to the factory, but increased the distance travelled per run.

The model inputs required are:

1. a grid with distances between each stop and the factory, and between each of the stops.
2. a table with the amount of milk at each stop on a given day (in either peak or late lactation), for each of the 20 years.
3. the amount of milk that can be carried in the truck and trailer units.

4. costs per hour and per kilometre, time spent unloading at the factory, time per stop and the average tanker speed. The latter three are used in calculating the time taken for the trip.
5. the initial sort order for the stops. To set up a run, the number of stops with milk to be collected is counted. These stops are then sorted into one of 12 pre-defined orders.

The calculation process for each sort order evaluated under Evolver is:

1. Go from the factory to the first stop.
2. Check the amount and type of milk at that stop.
3. Check the truck and trailer units.

Are both units empty, or is it carrying that type of milk?

If YES, can the volume of milk at that stop be fitted into the truck or trailer unit(s) carrying that type of milk? (Note: It may be carrying that type in one or the other of the units, in both, or one unit may contain that type of milk and the other may be empty so it can take the milk.)

If YES, collect the milk and go to the next stop.

If NO, return to the factory and empty the load, then go to the next stop.

If NO, is it allowed to carry two different types of milk?

If YES, does it have an empty truck and/or trailer unit that will contain the volume of milk at that stop?

If YES, collect the milk and go to the next stop.

If NO, return to the factory and empty the load, then go to the next stop.

If NO, return to the factory and empty the load, then go to the next stop.

4. Go to 2, and repeat processes 2 to 4 until all milk is collected.
5. Once all milk is collected return to the factory with the remaining milk in the tanker (possibly not a full load).

Microsoft Excel lookup tables and functions, and user-defined functions were employed to model this process. The Evolver software was set to minimise the cost for each run.

Model outputs include:

1. the cost of milk collection.
2. the number of stops.
3. the number of runs.

4. the distance travelled.
5. the time taken.
6. the volumes of type 1 and type 2 milk.
7. the order of the stops, highlighting when the tanker returned to the factory.

Evolver parameters were set at 0.06 for the mutation rate, 0.5 for the crossover rate and a population size of 1000. A random seed was used to generate the sort orders evaluated by Evolver. Evolver stopped processing when there was less than 0.5% change in the last 1000 trials. Initial trials were run to establish the most efficient parameters to use in Evolver, with both a randomly generated set of 20 farms (50% changing, giving 30 stops), and with the North Island set. To enable comparisons, runs were made with a range of specified seed values, years and initial sorts. Combinations of the following parameters were tested as follows:

Crossover rates: 0.8, 0.7, 0.5, 0.4, 0.3, 0.1

Mutation rates: 0.001, 0.06, 0.1, 0.15, 0.2, 0.4, auto

Population size: 30, 80, 50, 100, 200, 500, 1000, 2000

The best mutation and crossover rates were also the default values for the order solving method (Palisade Corporation 1998). Ranking farms in one of the pre-defined sort orders, rather than in ID order, milk amount order or random order also produced better results.

Evolver can be run individually for each set of inputs. However, for ease of use a macro was developed to run the years automatically. Evolver was run five times for each of the 20 years for the North Island; this was reduced to three times for the South Island because of time constraints. The optimum output (least cost scenario) for each year was then written to a summary output page. The macro was run for a range of stage of lactation, number of farms changing, tanker-trailer amount and Island combinations, for each of the pre-defined sort orders. For each combination and year, the overall optimum was considered to be the optimum value (least cost run) from all of the pre-defined sort order runs. The scenarios investigated are summarised in Table 4.2.

The genetic algorithm search method used in the transport model finds an optimum value, which is not necessarily the actual unknown optimum value. Therefore, a direct comparison between two scenarios in a particular year cannot be made definitively, as the optimum value identified for one scenario may be closer to its actual optimum value than the other. However, if it is assumed that over the 20 years the average deviation of these values from their actual

optimum is similar for all scenarios then this search method is likely to be effective in comparing trends over time between the various scenarios.

Table 4.2: Transport model scenarios run.

Island	Stage of lactation	Collection Type	% farms changing
North	Peak	Daily, 2 types per run	None, 25%, 50%, All
North	Late	Every 2 nd day, 2 types per run	None, 25%, 50%
North	Peak	Every 2 nd day, 2 types per run	25%, 50%
South	Peak	Daily, 2 types per run	None, 25%, 50%
South	Peak	Daily, 1 type per run	None, 25%, 50%

"No farms changing" was considered to be the "status quo" (SQ) option for comparing between policies within island, stage of lactation and collection type. The average cost per kilolitre was calculated annually for each scenario. Type 2 milk was then assumed to carry the extra cost associated with collecting segregated milk. The cost per kilolitre for collecting type 1 milk was assumed to be the same as the SQ milk collection cost. The collection cost for type 2 milk was calculated for each year as the total cost of milk collection on that day, less the cost per kilolitre of the SQ milk multiplied by kilolitres of type 1 milk, all divided by the kilolitres of type 2 milk.

As the percentage difference in the cost of collecting type 2 milk in relation to type 1 milk varied over the years, it may be more convenient to take a longer term view and charge the extra cost of type 2 milk collection at a constant rate over time in relation to type 1 milk. Therefore, the Excel goal seek function was used to find the percentage over and above the cost per kilolitre for type 1 milk that would need to be charged for type 2 milk over the 20 years. This occurred at the point where the discounted cost over the 20 years for type 2 milk collection, priced relative to the type 1 milk collection cost, was equal to the unadjusted discounted collection cost for type 2 milk over the 20 years. That is, for each year, type 2 milk collection cost per kilolitre was the type 1 milk collection cost per kilolitre multiplied by $(1+p)$, where p is the extra proportion of cost, and p is constant for all years. Collection costs were discounted to account for the time factor. Discount rates of 7% and 10% were applied. For example, in one scenario the cost of type 2 milk collection (\$/litre) ranged from 4.6% to 79.2% more than type 1 milk over the 20 years. By adjusting type 2 milk collection to a constant 22.3% more than for type 1 milk collection over the 20 years, the total discounted

cost of type 2 milk collection remained the same. The cost for type 1 milk collection still varied over the years.

In order to even out the cost variation over time due to fluctuations in the volumes of milk collected and tanker fill, a similar approach was then adopted to calculate the collection cost of the SQ milk (with the collection cost of the type 1 milk being the same as SQ milk). The Excel goal seek function was used to find a set per kilolitre collection cost for SQ milk for all 20 years, which returned the same discounted cost for SQ milk collection as the unadjusted discounted collection cost for SQ milk over the 20 years. As a result the cost of collecting type 1 milk in the other options was altered, therefore the cost for type 2 milk collection was recalculated so that the total discounted cost for milk collection in these options remained the same. The proportional difference in the cost per kilolitre for type 2 milk was recalculated as described above. The actual per kilolitre cost for both type 1 and type 2 milk was the same over the 20 years. This is similar to the example above, except the type 1 milk collection cost is adjusted to a constant value over the 20 years (\$7.56), and therefore the type 2 milk collection cost is also a constant value over the 20 years (\$9.23 or 22.0% more than type 1).

Milk collection can be viewed from the farmers' or the dairy company's perspective when calculating collection costs. The extra costs associated with milk collection were calculated for a North Island farm and a South Island farm. The North Island farm was assumed to produce 574,884 litres per annum, the average for the data set. Production for the South Island in the first year was assumed to be 2,097,676, the average for the Hurunui district (LIC 1999).

Costs were calculated for 25% and 50% of farms changing, with both types of milk able to be collected in a run. Farms were assumed to start differentiating milk in year 1. The New Zealand average gene frequency was used (Chapter 3). Three different collection costs per litre were assumed, as described in the scenarios above i.e. actual calculated collection costs, type 2 milk collection cost at a constant percentage above type 1 milk and type 1 and 2 milk remaining at a constant cost over the 20 years. Dairy company collection costs over the 20 years were equated to a 7% discount rate. Peak milk collection costs only were used for the South Island. For the North Island, with a much more pronounced seasonal milk supply curve, both peak and late lactation costs, and the average of these were used to estimate costs.

The time taken to collect and return all the milk to the factory was derived, even though this value was not used directly for calculating milk collection costs. Time taken was estimated to be half an hour for the turn around at the factory and 0.2 hours (12 minutes) per stop. Average tanker speed was estimated to be 70 km/hour in the North Island and 80 km/hour in the South

Island. Travelling time was calculated as kilometres travelled divided by speed. The proportional increase in the number of tankers required to collect all the milk was the difference between a scenario and its associated SQ option, assuming all milk must be collected within a set time period e.g. every 24 hours during peak lactation.

4.3 RESULTS AND DISCUSSION

4.3.1 Model inputs used in the transport model scenarios

The total milk volume per day for the two collection areas and the percentage of type 2 over the 20 years are shown in Tables 4.3 and 4.4, respectively. The percentage of type 2 milk over time was largely influenced by the number of farms changing to this genotype, and the number of stops required in that year (affected by the farm adoption rate) (see Appendix Tables A3.1, A3.2, A3.3 and A3.4 for this information, for the policies described in Table 4.2). The percentage of milk that has changed to type 2 stabilises in the last few years, about year 17 (Table 4.4).

Table 4.3: Total milk volumes collected per day (litres) for each of the 20 years.

Year	North Island		South Island
	Peak Lactation	Late Lactation	Peak Lactation
1	92,819	57,601	347,297
2	94,211	58,465	352,506
3	95,604	59,329	357,716
4	96,996	60,193	362,925
5	98,388	60,157	368,135
6	99,780	61,921	373,344
7	101,173	62,785	378,554
8	102,565	63,649	383,763
9	103,957	64,513	388,973
10	105,350	65,377	394,182
11	106,742	66,241	399,392
12	108,134	67,105	404,601
13	109,526	67,969	409,810
14	110,919	68,833	415,020
15	112,311	69,697	420,229
16	113,703	70,561	425,439
17	115,096	71,425	430,648
18	116,488	72,289	435,858
19	117,880	73,153	441,067
20	119,272	74,017	446,277

Table 4.4: Percentage of the total milk supply that changed to Type 2 over the 20 years for different rates of farm adoption.

Year	North Island					South Island	
	Peak Lactation			Late Lactation		Peak Lactation	
	25%	50%	100%	25%	50%	25%	50%
1	5.99	6.73	36.41	5.08	7.74	3.04	5.48
2	11.79	19.48	36.41	12.20	21.00	7.66	15.51
3	13.06	21.88	42.82	13.26	23.36	10.97	20.53
4	14.66	24.68	48.17	14.91	26.31	12.33	23.13
5	16.08	27.27	52.70	16.36	28.99	13.83	25.91
6	17.45	29.66	57.79	17.71	31.49	15.21	28.43
7	18.87	32.17	63.01	19.14	34.11	16.63	31.05
8	20.28	34.69	68.09	20.56	36.74	18.10	33.74
9	21.64	37.14	73.03	21.93	39.28	19.53	36.37
10	22.94	39.48	77.72	23.23	41.71	20.91	38.91
11	24.16	41.68	82.12	24.46	44.00	22.22	41.32
12	25.23	43.67	85.77	25.54	46.04	23.41	43.52
13	26.17	45.37	89.24	26.48	47.80	24.48	45.44
14	26.97	46.89	92.27	27.28	49.35	25.44	47.18
15	27.69	48.32	95.18	28.00	50.82	26.27	48.77
16	28.59	49.54	97.28	28.91	52.14	27.01	50.17
17	28.72	50.52	99.26	29.03	52.99	27.80	51.29
18	28.91	50.76	100.00	29.21	53.23	28.31	52.33
19	28.96	50.90	100.00	29.25	53.35	28.31	52.45
20	28.96	50.90	100.00	29.25	53.35	28.31	52.45
Over 20 years	22.34	38.48	76.50	22.58	40.62	20.53	38.19

4.3.2 Average milk collection cost

4.3.2.1 Comparison with the SQ (0% of farms changing)

The average cost per kilolitre for milk collection in the North Island during peak and late lactation, and in the South Island during peak lactation for 0%, 25%, 50% and 100% (North island, peak) farms changing are shown in Figures 4.1, 4.3 and 4.5 for every alternate year (Figures 4.2, 4.4 and 4.6 will be referred to later but are on the same page as their counterparts for comparative purposes). The difference in the average collection costs between the SQ and other scenarios for all years ranged from 4.48% less to 25.2% more where there were two milk types than for the SQ scenario (Appendix Table A3.5). Differences between the SQ and the other options were more variable for the North Island peak lactation option than for the South Island peak lactation or for the North Island late lactation options.

4.3.2.2 Stage of lactation comparison

Costs per kilolitre for the North Island were greater at late lactation than at peak lactation, because of longer distances travelled to collect an equivalent volume of milk. However, the

total cost of collection is greater at peak lactation than late lactation because of the larger volume of milk. Although not investigated, costs per kilolitre may be greater still at the end of lactation, or prior to all farms going on to every second day collection, as the volume of milk collected per stop will be lower at these times than for the situation modelled for late lactation. Modelling the final stages of lactation would be complex as not all farms go on to every second day collection at once, nor are all herds dried off on the same day.

Average milk collection costs per year ranged from 1% to 23% more per kilolitre in late lactation than peak lactation and this variation could be explained almost entirely by the number of trips required to collect all of the milk. Costs were 12% to 23% more per kilolitre for late lactation milk where only one more trip was required to collect milk in peak lactation compared to late lactation. Once the collection of peak lactation milk became less efficient (two extra trips for peak lactation milk collection) the difference was reduced to only 1% to 2% more. Average collection costs per kilolitre over the 20 years were 16.4%, 14.7% and 14.1% more in late than peak lactation for SQ, 25% and 50% of farms changing to type 2 milk, respectively.

Late lactation costs were not calculated for the South Island. The average daily production on the first day of every second day collection in late lactation was about 50% of that at peak lactation in the South Island (185 days after peak lactation), thus collection costs per kilolitre would have been similar to peak lactation. In contrast, in the North Island production was about 31% of peak lactation once all farms were on every second day collection (203 days after peak lactation). Factors other than milk volume in relation to that at peak lactation may influence the change to every second day milk collection. Changing to two milk types may mean a farm moves to every second day collection sooner, particularly during the transition years, when the volumes of one or both milk types would be less than for the SQ situation.

4.3.2.3 *Variation in average milk collection costs over the years*

Within each of the scenarios, milk collection costs varied over time (Figures 4.7, 4.8 and 4.9 Note: these are the similar to Figures 4.1, 4.3 and 4.5. However, their perspective better demonstrates a between year comparison). The cost per kilolitre increased sharply once an extra run was required to collect the milk (Figures 4.10 and 4.11, Appendix Tables A3.1, A3.2 and A3.3), then declined gradually as the tanker loads approached capacity volumes, thus spreading costs over a greater volume of milk (Figures 4.10 and 4.11). This was more obvious for the North than South Island, because the incremental increase in milk over time in the North Island was smaller. The smaller amounts collected per farm in the North Island may also mean that it is easier to fill the tanker as close to capacity as possible. As the number of

farms changing to type 2 milk increased, the likelihood of having partial loads of one or the other milk types increased, resulting in greater variation in the collection costs over time.

The number of tanker runs had the greatest impact on milk collection costs because most of distance travelled was getting to and from the milk collection area, rather than collecting milk from the farms within the area. For example, in the peak lactation SQ scenario for year 1, and assuming a flat per kilometre cost, 91.6% and 86.0% of the collection cost for the North and South Islands, respectively, were for travelling to and from the collection area. Thus, the first priority in determining the order of the stops for milk collection is to ensure the loads are as close to capacity as possible. The distance travelled around the stops within a collection area is of secondary importance.

Another factor affecting variation in the transition years when farms are changing from one milk type to another is the balance of milk types, as this can affect the number of runs required. This is clearly shown by year 16 in the North Island, peak lactation scenario with 50% of farms changing to type 2 (Figure 4.11). Here type 1 and type 2 milk volumes are similar and the milk can all be carried in 4 trips, whereas in years 15 and 17 the slightly greater amount of either milk type means an extra trip is required, with consequent cost increases.

This variation in collection costs affected the difference between the SQ and "farms changing" options. Some of the more extreme differences in collection costs between the SQ and other options occurred in years where the average cost was decreasing for the SQ option but increasing for the other option. This is illustrated by the North Island peak lactation costs for years 15 and 16 in the 25% option, 14 and 15 in the 50% option, and 12 to 16 in the 100% option. In most of these cases the cost per kilolitre exceeded the SQ cost by more than 20% in that year (Appendix Table A3.5).

In general, average costs for milk segregation were greater than the SQ in the middle to later years (Appendix Table A3.5), once most of the farms had changed to type 2 (Table 4.4). North Island late lactation results did not show this to the same extent, probably because the number of trips remained the same (3) for all scenarios over the 20 years (Appendix Table A3.2). The South Island early lactation results are not as marked as those for the North Island and in some instances the collection of two milk types in the South Island was more efficient than the SQ scenario because the smaller lot sizes allowed the tanker to carry closer to capacity volumes (e.g. year 13, for 25% of the farms changing to type 2 milk fewer trips were required than in the SQ scenario (Appendix Table A3.3)).

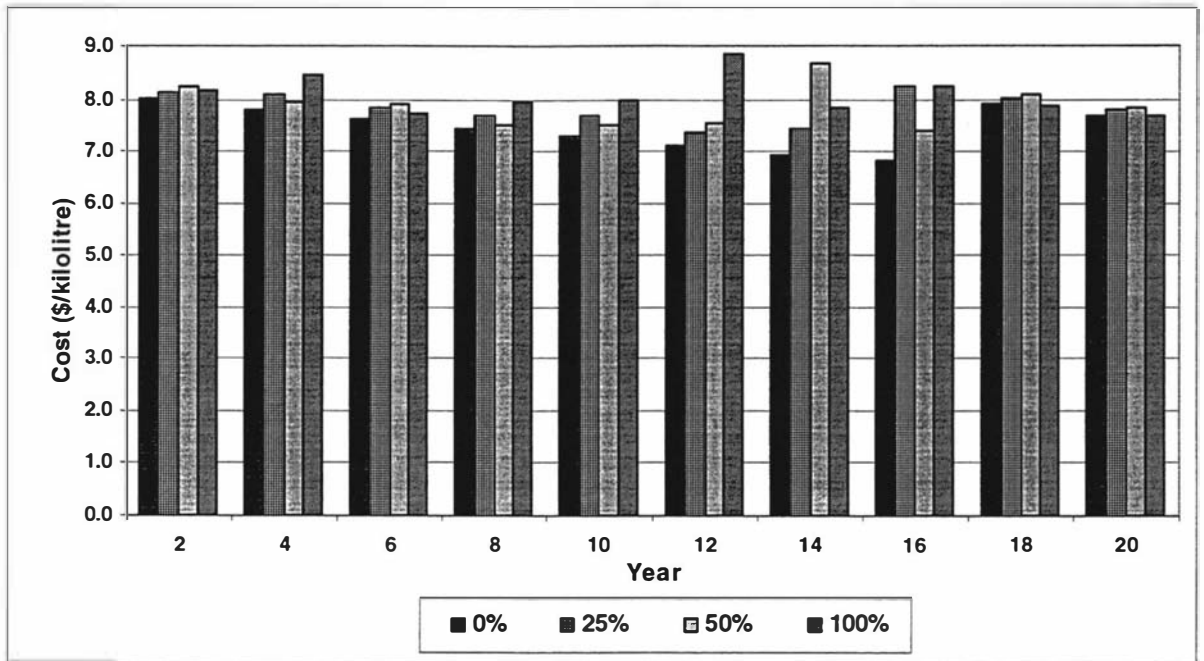


Figure 4.1: Average milk collection cost for the North Island farm set at peak lactation, with two types of milk able to be collected per run for 0, 25%, 50% and 100% of farms changing to type 2 milk.

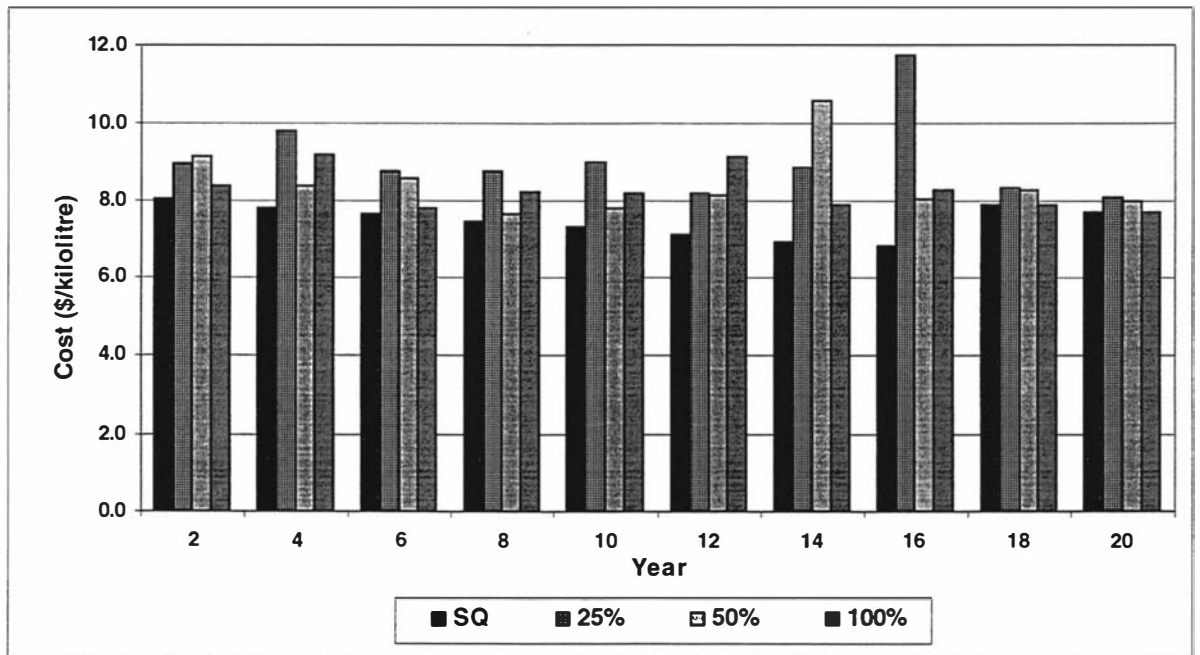


Figure 4.2: Cost of status quo (equals type 1) and type 2 milk collection for the North Island farm set at peak lactation, with two types of milk able to be collected per run for 25%, 50% and 100% of farms changing to type 2 milk.

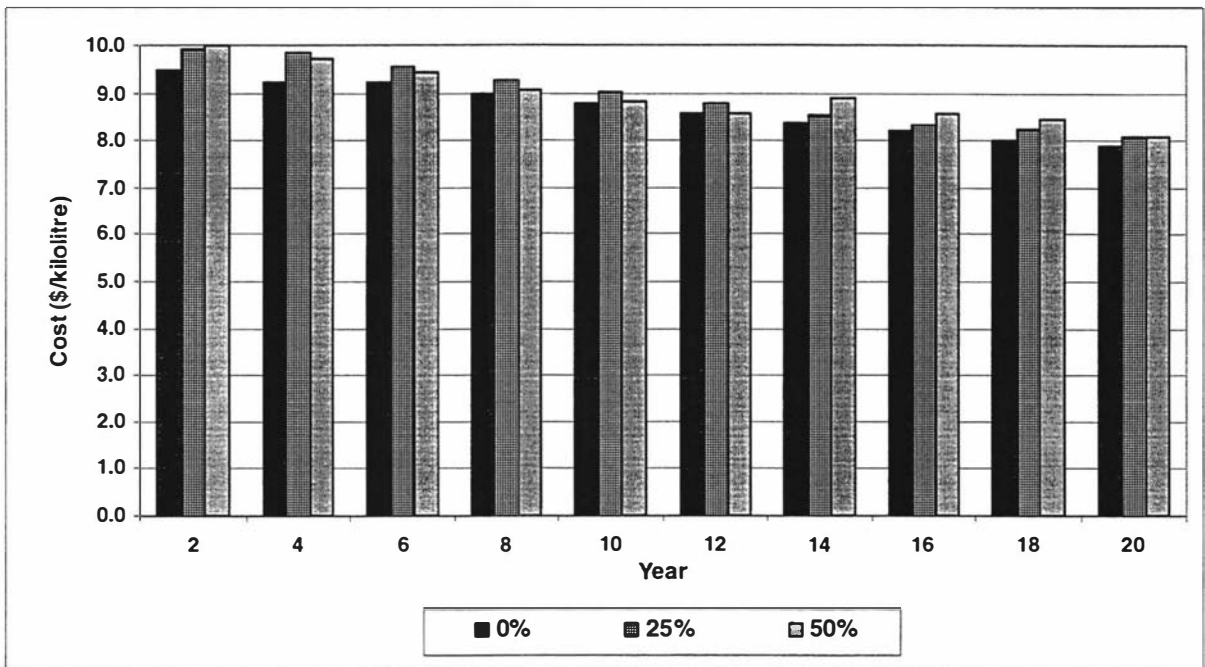


Figure 4.3: Average cost of milk collection for the North Island farm set in late lactation, with two types of milk able to be collected per run for 0%, 25% and 50% of farms changing to type 2 milk.

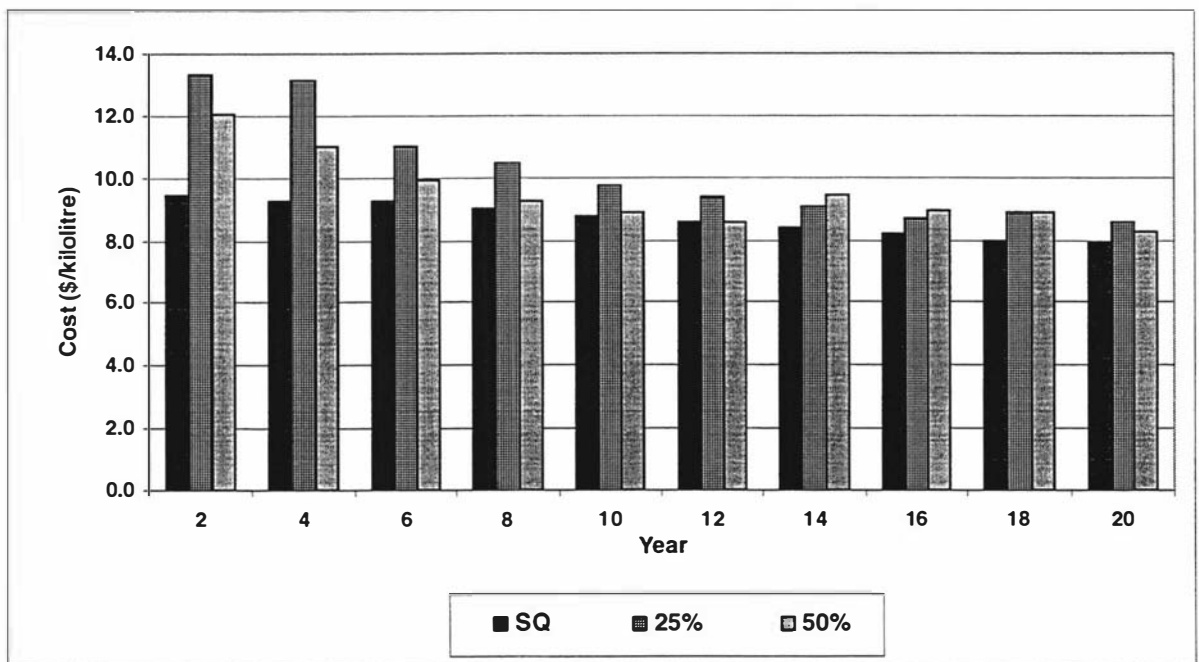


Figure 4.4: Cost of status quo (equals type 1) and type 2 milk collection for the North Island farm set in late lactation, with two types of milk able to be collected per run for 25% and 50% of farms changing to type 2 milk.

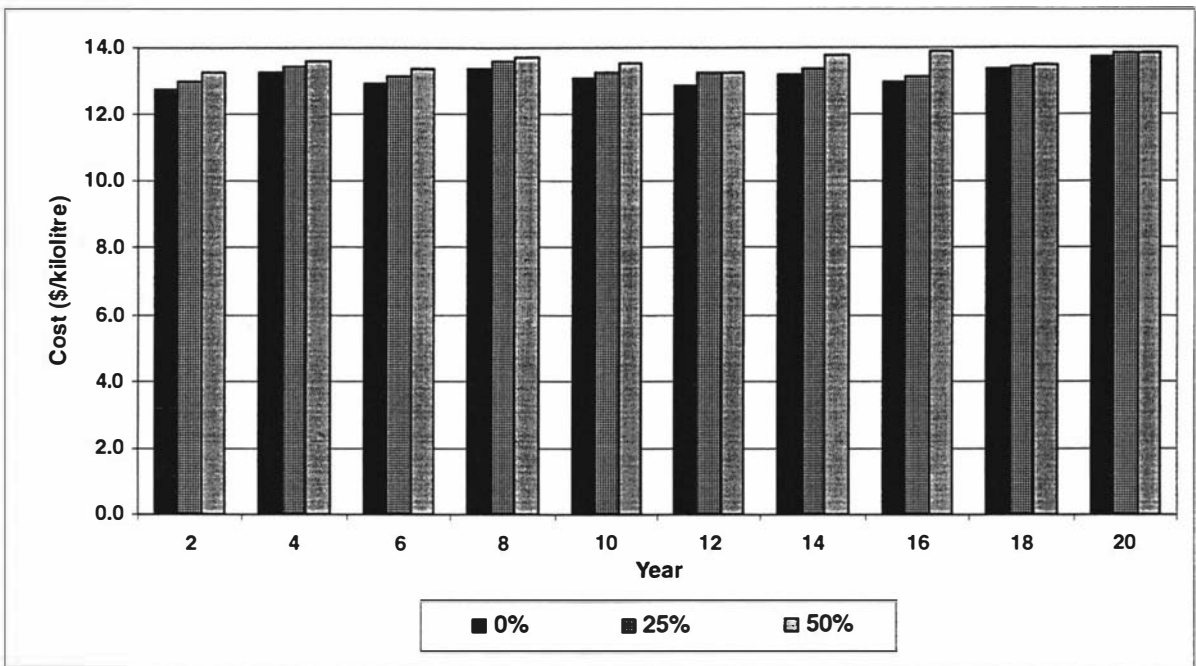


Figure 4.5: Average cost of milk collection for the South Island farm set at peak lactation, with two types of milk able to be collected per run for 0%, 25% and 50% of farms changing to type 2 milk.

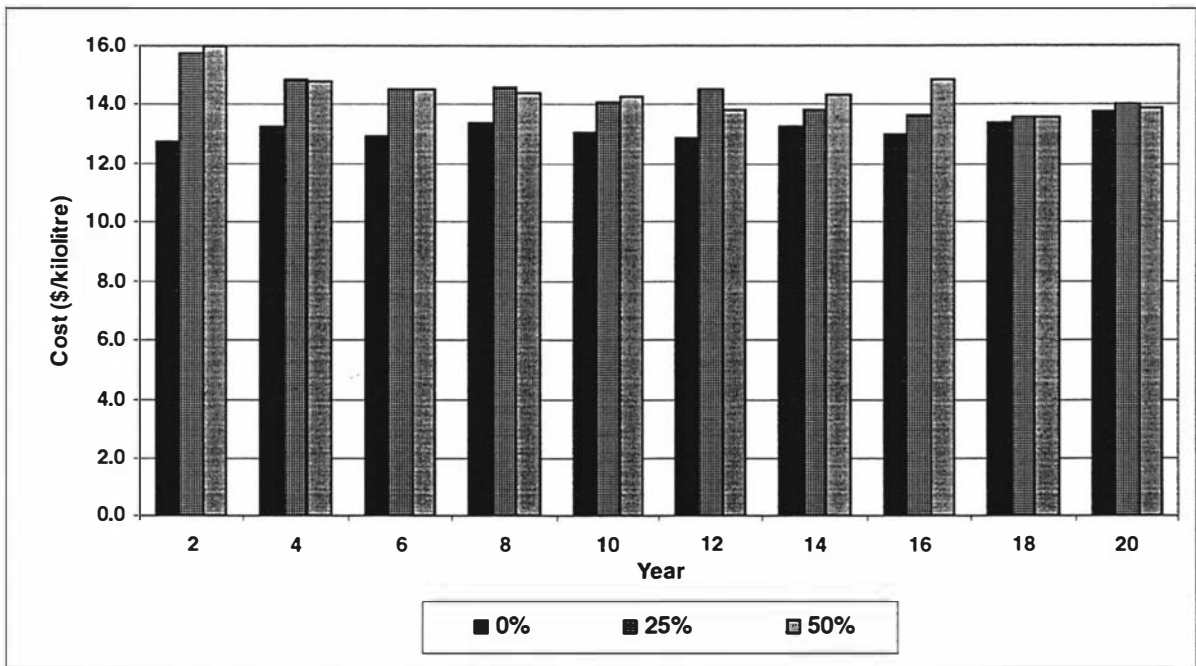


Figure 4.6: Cost of status quo (equals type 1) and type 2 milk collection for the South Island farm set at peak lactation, with two types of milk able to be collected per run for 25% and 50% of farms changing to type 2 milk.

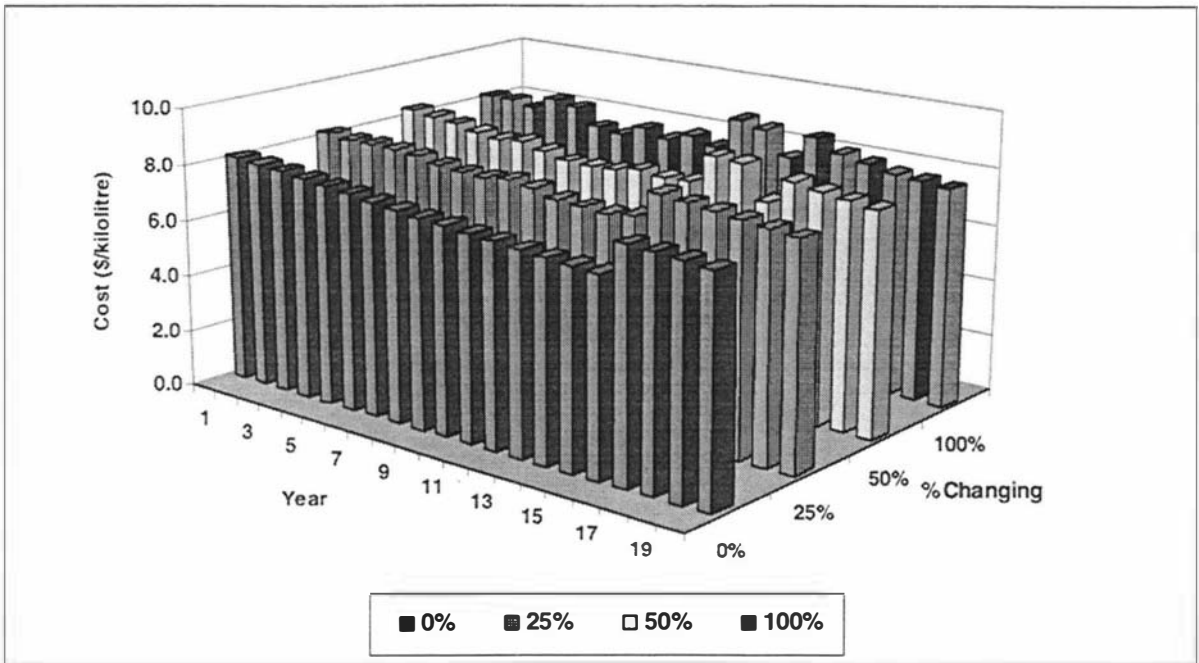


Figure 4.7: Average cost of milk collection for the North Island farm set at peak lactation, with two types of milk able to be collected per run for 0, 25%, 50% and 100% of farms changing to type 2 milk.

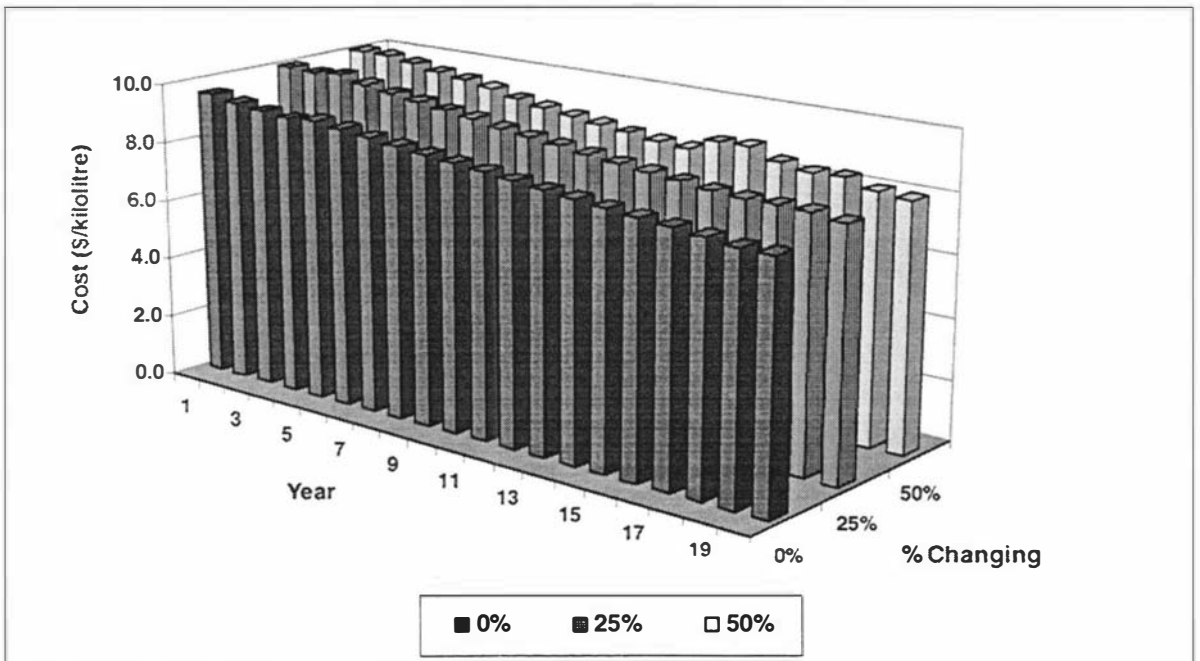


Figure 4.8: Average cost of milk collection for the North Island farm set in late lactation, with two types of milk able to be collected per run for 0, 25% and 50% of farms changing to type 2 milk.

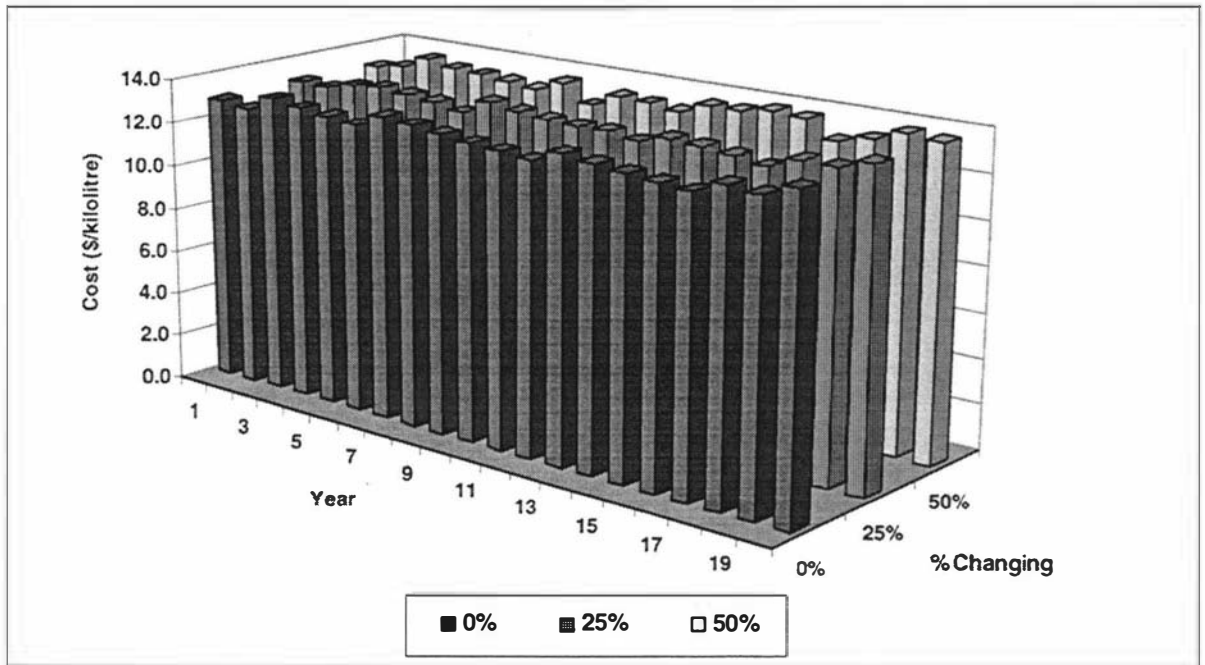


Figure 4.9: Average cost of milk collection for the South Island farm set at peak lactation, with two types of milk able to be collected per run for 25%, and 50% of farms changing to type 2 milk.

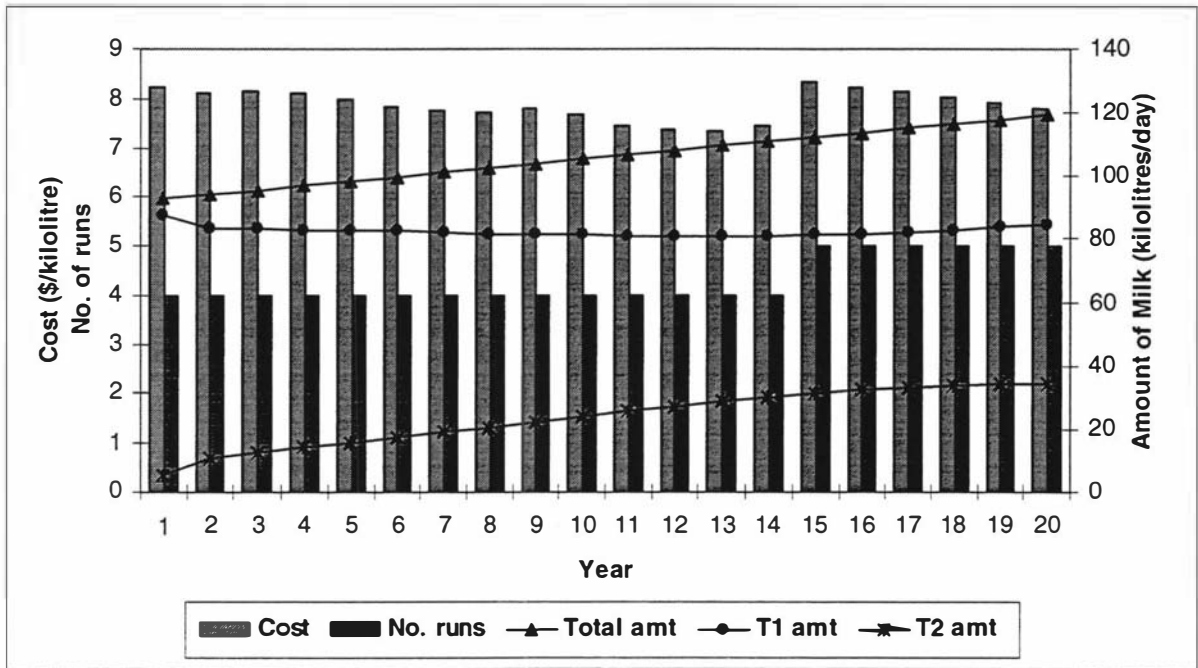


Figure 4.10: Average milk collection cost, number of tanker runs and volume of milk collected for the North Island farm set at peak lactation, with two types of milk collected per run and 25% of farms changing to type 2 milk.

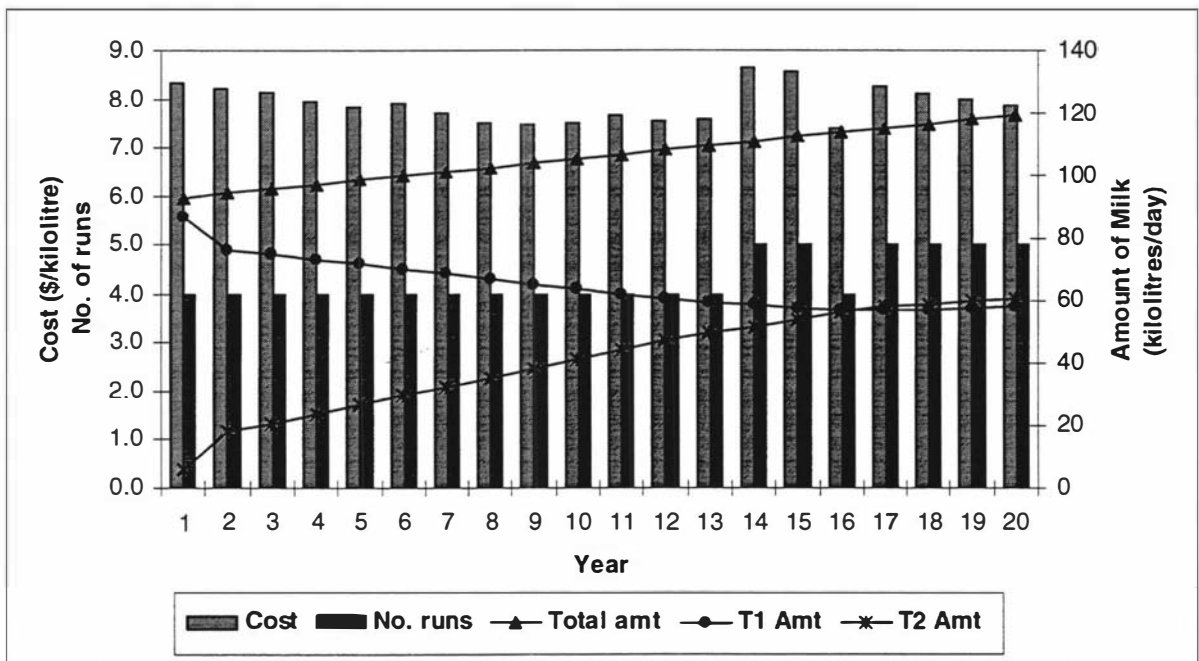


Figure 4.11: Average milk collection cost, number of tanker runs and volume of milk collected for the North Island farm set at peak lactation, with two types of milk collected per run and 50% of farms changing to type 2 milk.

4.3.3 Technology adoption time frame

The model assumed all farms changed to type 2 over a 20-year period through selection, with a three-year technology adoption time frame. These assumptions simplify reality. Farmers could, for example, adopt a number of policies to move toward producing a different milk type. As well as changing the herd over time through breeding, they could also: buy and sell cows to accelerate the change to one milk type (reducing or eliminating transition years), maintain split herds as a policy to spread risk, or adopt a combination of policies. The farmers changing to type 2 milk production are likely to adopt a range of management policies and this will impact on the rate of technology adoption which may be spread over a longer time frame than that modelled. The model is capable of modelling any combination of transitional management policies and technology uptake time frames over a 20-year period and these could be explored if necessary.

Factors other than farmer policy may affect the situation modelled. A dairy company may pay on the level of a component in the milk rather than segregating the milk so that all type 2 milk would be collected together from the start (i.e. no transitional years). Alternatively, where transitional years apply the initial amount of type 2 milk may differ from that modelled e.g. selected on a qualitative trait with a higher or lower gene frequency. In these situations the output from the model may still give some indication of milk costs e.g. if there are no transitional years and those farms changing have all type 2 milk in their first year, then the output for the last two to three years should give some indication. Similarly, for a higher proportion of type 2 milk a comparison can be made from the year that starts with that proportion. However, in this situation the first few years may be inaccurate, as the rate of technology adoption will not have been taken into consideration.

4.3.4 Average minimum load size

The small number of farms in each set (30 farms and up to 60 tanker stops) means the variable pattern of milk collection costs is probably greater than it would be for a larger sample of farms. Usually, there was at least one run where the load was not close to full (often the last run, and possibly another run where the last of a particular type of milk was collected). This can affect the results especially where the number of runs is small, such as in the North Island where only 4 or 5 runs were required at peak lactation, and 3 runs in late lactation e.g. 1 out of 4 (25%) of loads could be considerably lower than full capacity. The impact was less in the South Island where more runs were required (13 to 18). However, the greater amount of milk per farm in the South Island means the “full” loads may not be as close to the tanker unit capacity as in the North Island.

The average minimum load in the North and South Islands was compared for years 11 to 20 at peak lactation with 25% of the farms changing to type 2 milk. The North Island average minimum load was less than for the South Island (average minimum load was 54.4% of capacity for the North Island compared to 71.3% for the South Island). However, the average capacity of the remaining loads was slightly greater for the North than the South Island i.e. 94.3% and 92.6% for the North and South Islands, respectively. These results gave an overall average tanker load of 86.0% and 91.3% of capacity, for the North and South Islands, respectively. The better South Island loading rate reflected the greater number of runs required to collect all the milk, most of which were near to full capacity.

A larger set of farms for the analysis may have fine-tuned the results but not changed the overall findings. The number of farms (30) meant consistent comparisons could be made for the different scenarios within an acceptable computing time frame. Simulations involving larger sets of farms could be carried out with the model, but would be time consuming to run.

4.3.5 Farm and herd size

The 30 farms were assumed to remain the same size over the 20 years, whereas current trends suggest that both farm size and herd size are increasing (LIC 1999). Farm amalgamations are therefore likely to occur over the 20 years. While this would reduce the number of stops and increase the amount of milk per stop and farm, the total milk collected from the geographic area incorporating these 30 farms in the North Island may not differ greatly from that predicted, assuming the increase in per hectare production remains similar. Fewer farms would, however, affect the milk collection pattern with possibly 2 to 3 farm stops per run in the North Island rather than 5 or 6 as modelled, giving a farm distribution and milk collection cost pattern similar to that of South Island. South Island milk production within a given area is likely to increase through farm conversions to dairying. This would reduce collection costs per kilolitre slightly because the tanker will travel shorter distances within a set geographic area to collect a full load of milk.

4.3.6 Time taken for milk collection and tanker requirements

There was little difference between the scenarios in the time taken to collect the milk over the last 2 to 3 years (Appendix Table A3.10), when all farms produced milk of one type or another (0 to 5% more time than the SQ). The difference in time taken between the SQ and associated scenarios tended to increase as the number of farms changing to type 2 increased. The overall average difference in collection times between the SQ and the other scenarios at peak lactation in the North Island for 25%, 50% and 100% of farms changing was 12.7%,

23.0% and 45.0%, respectively. The greatest difference between the SQ and the other scenarios for 25%, 50% and 100% of farms changing was 23.2%, 38.4% and 65.2%, respectively. In the South Island the difference in most cases was less than 10% (averages of 4.0% and 7.5%, maximums of 9.5% and 13.3%, respectively, for 25% and 50% of farms changing). As for costs, a direct time comparison between scenarios within years cannot easily be made because time taken is not solely affected by the number of runs, and because the year(s) that the number of runs changed on over the years within a scenario was not consistent between the scenarios.

As all milk has to be collected within a certain period (daily or every second day depending on the time of year), the milk collection time will affect the number of tankers required. The time spent at each stop and average travelling speed was estimated. Nevertheless, the results still give some indication of the time required to collect the milk (Appendix Table A3.10). Once all milk has changed from one type to the other, the tanker requirement will be similar to the status quo i.e. up to 5% more tankers will be required. The greater the number of farms changing (and therefore stops required), the longer the milk collection will take, particularly in the transition years, increasing requirements for tankers over this period. This may be up to 65% more than the SQ requirement, for 100% of farms changing in the North Island (year 12, peak lactation). The extra time required to collect milk in the South Island is less than that for the North Island e.g. at peak lactation the greatest increase in time with 25% of farms changing was 23.2% and 5.3% for the North and South Islands, respectively. North Island values may be overestimated, as the small number of runs required means the average tanker volume may have been less than if a larger number of farms had been modelled. Costs associated with the provision of tankers are included in the overhead costs, and basing the collection costs on a flat per kilometre rate may not have fully allowed for this i.e. the increase in time required tends to be larger than the average increase in costs calculated.

The extra time required for more stops where farms are changing to another milk type may also not be fully accounted for when a flat cost per kilometre is used to derive trip costs. In particular, costs may be under-estimated where farms are in the initial years of changing to another milk type. Conversely, as the distance travelled increases, fixed overheads are spread over a greater distance reducing the per kilometre cost. As the distance travelled increases slightly where there are two milk types, the cost per kilometre may be lower than that used and therefore the total cost may be slightly overestimated. Information was not available to calculate costs at this level of detail. These two effects, however, should counter each other to some extent in the estimate of the per kilometre cost (assumed to be constant within Islands for all scenarios).

4.3.7 Milk collection cost with type 1 milk collection at SQ cost

The difference in average collection costs per kilolitre for SQ milk compared to the scenarios with farms changing to type 2 milk varied over the years. The greatest overall difference in costs usually occurred in the middle years of the transition (Figures 4.1, 4.3 and 4.5), while differences in the final years were usually small. These comparisons indicate the difference in costs to a dairy company. In contrast, Figures 4.2, 4.4 and 4.6 are more representative of the difference in costs likely to be faced by a farmer changing policies. In these comparisons, all extra costs are imposed on the type 2 milk only, with type 1 milk collection costs per kilolitre being equal to the SQ cost for that year. The SQ value (i.e. type 1 collection cost) is included for comparative purposes. Every second year has been shown, but values for all years are included in Appendix Table A3.6. When all extra costs are incurred by the type 2 milk, the difference between the collection costs for type 2 milk compared to type 1 milk are in most instances greater and more varied than when they are spread across all milk. The additional per kilolitre costs for type 2 milk compared to type 1 milk tended to be higher in the initial years when the volume of type 2 milk is small, or in the mid to later years when the volume of type 1 milk on these farms is low.

The cost per kilolitre of the SQ milk collection affects the type 2 milk collection cost, as the type 1 milk cost is assumed to equal the SQ cost, with extra costs above that being carried by the type 2 milk. In years where the SQ cost is efficient, the type 1 milk cost is reduced thereby increasing costs for type 2 milk collection. The cost of type 2 milk collection can also be greater in years where the total cost of milk collection is high for the farms changing milk type scenarios e.g. where an extra run is required to collect all the milk. These points are demonstrated by year 16 for the North Island, peak lactation with 25% of farms changing scenario. The total SQ milk collection cost is low in this year, and at the same time an extra run is required to collect the milk associated with 25% of farms changing to type 2. Consequently, the cost of type 2 milk collection is considerably greater than the SQ (and type 1 milk collection cost) in year 16 (Figure 4.2). Thus direct comparisons between years are difficult, and instead, for exercises such as these the comparison needs to be made over an extended period.

The proportional difference in the cost of type 2 milk collection, assuming type 1 equalled the SQ cost, varied considerably, particularly in the years where 2 milk types were produced by some farms. Differences in costs ranged from 26.93% less to 95.6% more for type 2 milk (Appendix Table A3.6). In the final years, when all farms had only one type of milk the difference between type 1 and type 2 collection costs was less than for the preceding years. In the middle to later years per kilolitre costs were high because of the higher average milk

collection costs, whereas for the earlier years they were high because the extra costs were spread over a low milk volume. As previously discussed, the distance travelled and the number of runs required for both the SQ and changing scenarios would have contributed to this variation. The largest variation in average costs was for the North Island at peak lactation.

4.3.8 Discounted cost of milk collection

4.3.8.1 *Type 1 milk at SQ cost*

Dairy companies are unlikely to pass actual extra costs on to farmers changing milk type policy at rates that vary markedly from year to year. It was for this reason that a consistent percentage above status quo for all years was calculated at discount rates of 7% and 10%, to determine the extra costs to pass on to the farmers who were changing policy (Tables 4.5 and 4.6). While the total discounted cost over the 20 years is not important in itself, it does allow comparisons between policies. The overall difference in collection costs between the SQ and other policies within scenarios ranged from 0.8% to 7.0% at a 7% discount rate, and 0.8 to 6.5% at a 10% discount rate.

The difference was greater for the North Island and, in most cases, was also greater where a higher proportion of farms changed to type 2 milk (the exception to this was for the South Island, two types per run option). However, when the extra collection costs were absorbed by type 2 milk only, the 25% options had proportionally higher collection costs for type 2 milk, in most cases because the increased cost was spread over a smaller amount of milk than the 50% and 100% farms changing scenarios, even though the total cost may have been less.

The extra costs for type 2 milk over type 1 milk ranged from 4.5% to 22.3% at a 7% discount rate, and 4.7% to 22.0% at a 10% discount rate. The proportion of the cost associated with transporting type 1 milk was slightly greater than the proportion of type 1 milk (Table 4.4), whereas the proportion of the total cost attributed to the type 2 milk was slightly less than the proportion of type 2 milk. This was because more type 1 milk was transported in the earlier years at a less discounted cost, while most of the type 2 milk was produced in the later years when costs have been discounted more even though the cost per kilolitre for type 2 milk is greater than type 1 at these times.

Table 4.5: Total net present value of the extra cost incurred in transporting type 2 milk over 20 years (at a discount rate of 7%) at a day in either peak or late lactation.

	Total cost (\$)	Difference from SQ (%)	Type 1 cost (\$)	Type 2 cost (\$)	% increase in T2 milk cost
North Island – Peak (2 types/run)					
SQ	8253		8253		
25%	8613	+4.36%	6638 (77.1) ¹	1975 (22.9)	22.29% (22.44) ²
50%	8644	+4.74%	5500 (63.6)	3144 (36.4)	14.22% (15.35)
100%	8829	+6.98%	2701 (30.6)	6128 (69.4)	10.37% (10.25)
North Island – Late (2 types/run)					
SQ	6018		6018		
25%	6246	+3.79%	4837 (77.4)	1409 (22.6)	19.31% (21.29)
50%	6230	+3.52%	3909 (62.7)	2321 (37.3)	10.03% (12.95)
South Island – Peak (2 types/run)					
SQ	53669		53669		
25%	54095	+0.79%	44134 (81.6)	9961 (18.4)	4.47% (5.67)
50%	55110	+2.69%	35890 (65.1)	19221 (34.9)	8.11% (8.76)
South Island – Peak (1 type/run)					
SQ	53669		53669		
25%	55442	+3.31%	44134 (79.6)	11311 (20.4)	18.64% (27.75)
50%	55872	+4.10%	35890 (64.2)	19982 (35.8)	12.39% (13.94)

¹ Percentage of the total cost is shown in brackets.

² Raw average over the 20 years is shown in brackets.

As there was little difference in values between the 7% and the 10% discount rate in comparing how much extra it would cost to transport type 2 milk, further discussion relates only to the 7% discount rate values. In the North Island the percentage over the SQ value for type 2 milk collection was slightly higher at peak lactation than in late lactation (22.3% cf. 19.3% for 25% of farms changing, and 14.2% cf. 10.0% for 50% of farms changing, at peak and late lactation, respectively). The actual collection costs for late lactation exceeded those at peak lactation though (Appendix Tables A3.1 and A3.2). Collection costs for type 2 milk decreased as the number of farms changing to a new milk type increased, although they were still greater than the SQ costs e.g. values for the North Island peak lactation were 22.3%, 14.4% and 10.4% more for 25%, 50% and 100% of farms changing, respectively.

Table 4.6: Total net present value of the extra cost incurred in transporting type 2 milk over 20 years (at a discount rate of 10%) at a day in either peak or late lactation.

	Total cost (\$)	Difference from SQ (%)	Type 1 cost (\$)	Type 2 cost (\$)	% increase in T2 milk cost
North Island – Peak (2 types/run)					
SQ	6590		6590		
25%	6859	+4.08%	5368 (78.3) ¹	1491 (21.7)	22.03%
50%	6880	+4.39%	4518 (65.7)	2362 (34.3)	13.98%
100%	7019	+6.51%	2379 (33.9)	4640 (66.1)	10.20%
North Island – Late (2 types/run)					
SQ	4825		4825		
25%	5016	+3.96%	3927 (78.3)	1088 (21.7)	21.29%
50%	4999	+3.62%	3226 (64.5)	1773 (35.5)	10.94%
South Island – Peak (2 types/run)					
SQ	42631		42631		
25%	42963	+0.78%	35534 (82.7)	7429 (17.3)	4.69%
50%	43741	+2.61%	29382 (67.2)	14359 (32.8)	8.38%
South Island – Peak (1 type/run)					
SQ	42631		42631		
25%	44047	+3.32%	35534 (80.7)	8512 (19.3)	19.95%
50%	44330	+3.99%	29382 (66.3)	14947 (33.7)	12.83%

¹ Percentage of the total cost is shown in brackets.

The difference in the South Island values for type 2 milk collection was less than for the North Island values. Peak lactation with only one type of milk collected per run was 18.6% and 12.4% more for 25% and 50% of farms changing, respectively. Where 2 types of milk could be carried by the tanker this was 8.1% more for 50% of farms changing which was similar to the other values for 50% of farms changing. However, the value for 25% of farms changing was low (4.5%), possibly because the number of trips required to transport milk did not exceed the SQ value for any of the years. In fact, the runs required were less than the SQ in three of the years, possibly because the smaller milk lots enabled the loads to be filled closer to capacity. In these years milk collection costs were less than the SQ value, and this would have contributed to the small difference between type 1 and type 2 milk.

4.3.8.2 *SQ cost constant over the years*

By discounting, as discussed in the previous section the type 2 milk cost was kept to a constant percentage above the type 1 cost for all years. However, as farmers producing SQ or type 1 milk are also unlikely to be charged at a fluctuating rate over time the SQ was also adjusted to a constant over the 20 years at a 7% discount rate (Table 4.7). The proportional extra cost to farmers changing milk types was similar for both calculation methods (less than a 0.4% difference) (Tables 4.5 and 4.7). Thus, the differences in the collection costs for type 1 and 2 milk varied similarly over the years i.e. they were not all higher in either the earlier or later years: this is borne out by the raw results (Appendix Table A3.6).

Table 4.7: Total extra cost of transporting type 2 milk at a discount rate of 7% over 20 years with the status quo cost adjusted to a constant value over time.

	Total cost (\$)	Type 1 cost (\$)	Type 2 cost (\$)	% increase in T2 milk cost	Cost Type 2 (\$/kilolitre)
North Island – Peak (2 types/run)					
SQ	8253				\$7.56
25%	8613	6617	1996	22.01%	\$9.23
50%	8644	5462	3182	14.03%	\$8.62
100%	8829	2637	6192	10.25%	\$8.34
North Island – Late (2 types/run)					
SQ	6018				\$8.89
25%	6246	4813	1432	18.93%	\$10.57
50%	6229	3837	2365	9.82%	\$9.76
South Island – Peak (2 types/run)					
SQ	53669				\$13.14
25%	54095	44153	9942	4.48%	\$13.73
50%	55110	35924	19186	8.12%	\$14.21
South Island – Peak (1 type/run)					
SQ	53669				\$13.14
25%	55446	44153	11292	18.67%	\$15.60
50%	55872	35924	19948	12.41%	\$14.78

Where the SQ value was adjusted to a constant over the 20 years the percentage increase over the SQ value difference for farms changing (Table 4.7) was similar to the values given in Table 4.5. The SQ cost per kilolitre for late lactation milk collection was 17.5 % more than for peak lactation (\$7.56 cf. \$8.89 for peak and late lactation, respectively). South Island milk

collection costs were 73.8% more than for the North Island at peak lactation (\$7.56/kilolitre cf. \$13.14/kilolitre for the North Island and the South Island, respectively).

The extra costs associated with type 2 milk collection at peak lactation and late lactation were almost the same in the North Island with 25% of farms changing (Table 4.7) i.e. $9.23 - 7.56 = \$1.67/\text{kilolitre}$ and $10.57 - 8.89 = \$1.68/\text{kilolitre}$. The difference with 50% of farms changing was less in late lactation than in peak lactation i.e. \$0.87 versus \$1.06/kilolitre respectively. The difference in costs between the SQ and 50% of farms changing was the same for the North and South Islands (\$1.06/kilolitre) at peak lactation. However, the extra costs associated with 25% of farms changing in the South Island was low (\$0.59/kilolitre) at peak lactation. Extra costs of type 2 milk collection are therefore not necessarily different between Islands or stage of lactation.

All farms in the last two to three years produced either type 1 or type 2 milk (Table 4.4). Costs per kilolitre were also lower in relation to SQ costs in these years (Table 4.7 and Appendix Table A3.6). This is particularly noticeable for all three North Island, peak lactation scenarios, where the difference between the average overall percentage (Table 4.7) and the average percentage for the last three years (Appendix Table A3.6) ranged from 9.7 to 16.8 e.g. for 25% of farms changing the difference was $22.0\% - 5.2\% = 16.8\%$. Therefore, it may not be appropriate to spread the difference in costs over the entire 20 years at the same rate. Rather, it may be better to spread these costs over fewer years, or alternatively, once the extra costs have been recouped over the 20 years, to review the extra transport costs attributable to type 2 milk. Also should farms producing two milk types (in transition or as a policy) pay more in collection costs than those producing only type 2 milk? Although this would pose practical difficulties, due to farmers using a range of policies and adoption rates, it would better reflect a "user-pays" approach.

4.3.9 Average milk collection cost: one milk type per run and every second day collection

Total average collection costs for two other policies were also compared. A situation where only one milk type could be collected per run (rather than two) was modelled for the South Island at peak lactation for 25% and 50% of farms changing (Figure 4.12). Every second day collection, rather than daily collection, was modelled for the North Island at peak lactation (Figure 4.13). Results for all years are presented in Appendix Table A3.4. In summary, collecting a single milk type per run increased costs. However, if milk was collected every

second day in the North Island during peak lactation collection costs are likely to be less than for daily collection.

4.3.9.1 *One milk type collected per run*

Where only one milk type is collected per run, collection costs were the same or greater than collection of two types per run for all but one year, where costs were less (Appendix Tables A3.3 and A3.4). The lower costs for one milk type per run (50% changing, year 13) was the result of a more efficient search and could apply equally to either option i.e. in reality, one type per run would not be more efficient. In most years the difference between one and two types per run was either nil or very small (Figure 4.12).

The SQ scenario for collecting one or two milk types per run was the same i.e. collecting all type 1 milk. For the 50% of farms changing scenario, the percentage increase over the SQ was 12.4% with one milk type per run compared to 8.1% for two milk types per run, which equates to a difference of \$0.56/kilolitre or 0.006 cents/litre (Tables 4.5 and 4.7, discounted comparison). The percentage increase over the SQ with 25% of farms changing was 18.6% for one milk type per run compared to 4.5% for two milk types per run. However, as previously discussed the South Island value for 25% of farms changing with two milk types per run was particularly low. The 18.6% for 25% of farms changing is comparable with the North Island, where the values for 25% of farms changing tend to be greater than those for 50% of farms changing. The number of runs required in the South Island means the difference between one or two milk types carried may not be great i.e. an increase of one run where there are 13 to 18 runs will not have a large effect.

4.3.9.2 *Milk collected every second day*

Every second day milk collection (peak lactation, North Island) was more economical than every day milk collection (Figure 4.13, Appendix Tables A3.1 and A3.4). Discounted (7%) total costs for every second day collection were 8.40% and 4.23% less overall than their daily milk collection counterparts for 25% and 50% of farms changing, respectively. Only one of the years for 25% of farms changing (and three of the years for 50% changing) was more costly than their daily collection equivalent. Furthermore, every second day collection for 25% of farms changing was 4.41% less than the SQ daily milk collection, while the discounted cost of every second day collection was almost the same as daily SQ collection (0.31% more).

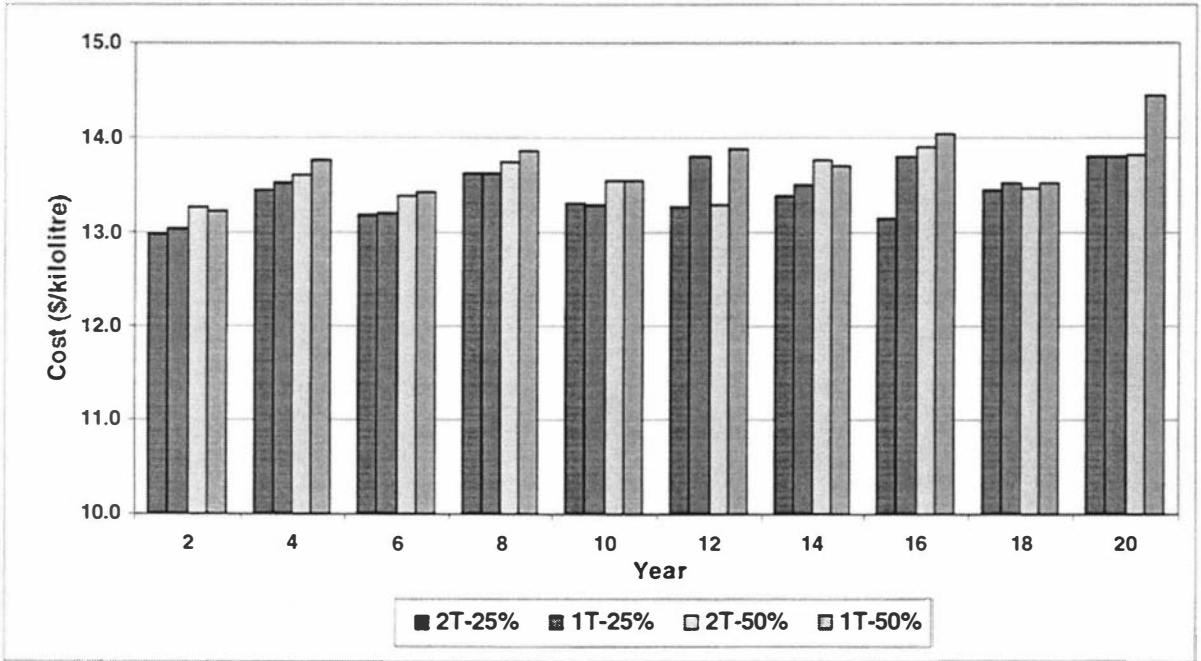


Figure 4.12: Average cost of milk collection for the South Island farm set at peak lactation, with both (2T) or only one (1T) type of milk able to be collected per run, and 25% and 50% of farms changing to type 2 milk.

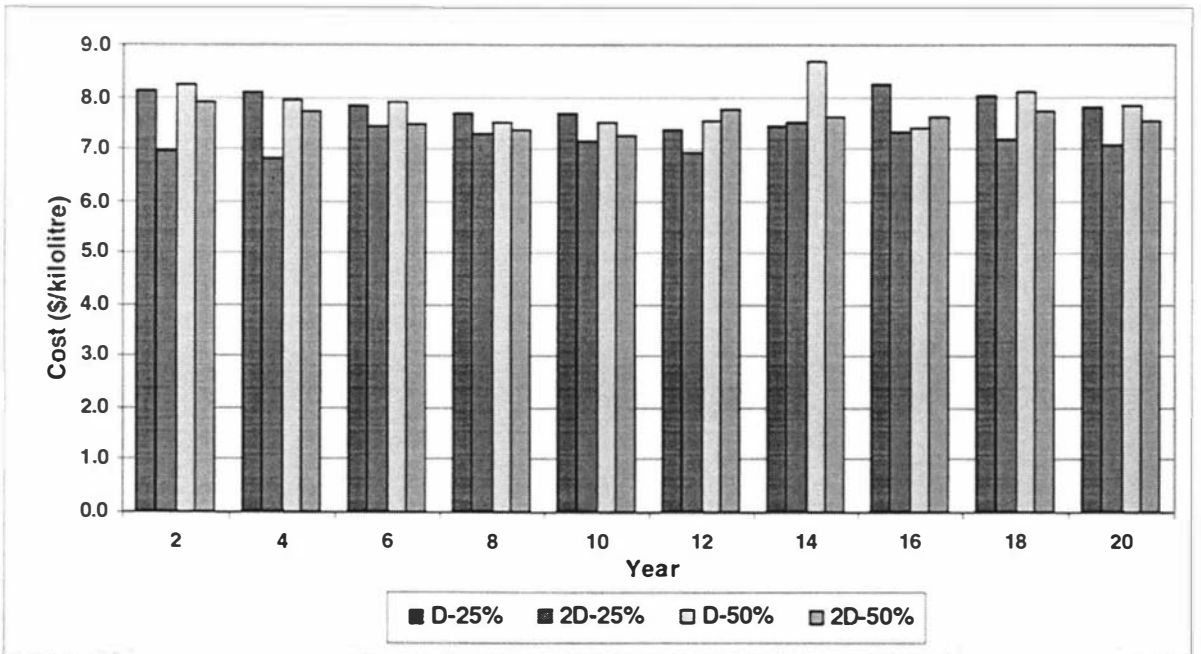


Figure 4.13: Average cost of milk collection for the North Island farm set at peak lactation, with two types of milk able to be collected per run, and milk collected daily (D) or every second day (2D), for 25%, and 50% of farms changing to type 2 milk.

Milk collection every second day during peak lactation could be used to counter the increased collection costs associated with two milk types. For milk processing purposes it may also be more convenient to have all the milk of a particular type collected on the same day. Every second day collection during peak lactation may therefore be particularly useful during the transitional years, particularly for the lower volume milk type. Type 2 milk could be collected every second day in earlier years and possibly type 1 in later years, although the tactics for the collection of type 1 milk may be less of an issue as the non-changing farmers will be producing type 1 milk as well. Every second day collection at peak lactation may be more applicable in the North Island where milk production per farm is lower, rather than the South Island, except perhaps for collecting low volumes of type 2 milk in the early years. Milk quality issues may need to be considered when changing to every second day collection, although this is standard policy in late lactation when ambient temperatures are often warmer than in late spring. A larger vat or an extra vat would also be required on the farm to store two days milk.

4.3.10 Extra costs to a farmer over the 20 years

The milk collection issues discussed so far consider the situation from the dairy company perspective. As the extra costs are likely to be passed-on to the farmers changing milk types, the magnitude of these need to be known in order to determine the premia for various milk types.

The extra collection costs for a North Island and a South Island farm over the 20 years are demonstrated in Table 4.8. These results are based on the third costing method i.e. the costs remain constant for both type 1 and type 2 milk over the 20 years. As a result costs increase over time as more type 2 milk is produced. Costs for 25% of farms changing are \$8.224/kilolitre for type 1 milk and \$9.908/kilolitre for type 2 milk in the North Island, and \$13.144/kilolitre for type 1 milk and \$13.733/kilolitre for type 2 milk in the South Island. Where 50% of farms are changing these costs are \$8.224/kilolitre for type 1 milk and \$9.205/kilolitre for type 2 milk in the North Island, and \$13.144/kilolitre for type 1 milk and \$14.212/kilolitre for type 2 milk in the South Island. A more complete set of results can be found in Appendix Tables A3.7, A3.8 and A3.9.

Assuming a farm size of 65 hectares in the North Island and 212 hectares in the South Island (LIC 1999) the total increased cost in year 20 will be \$19.14/ha and \$11.15/ha in the North Island, and \$7.49/ha and \$13.58/ha in the South Island for 25% and 50% of farms changing, respectively. This not a particularly large cost in terms of farm expenditure. Another way to consider this is in terms of milksolids price: at 8% milksolids concentration an extra 1.25

cents per kilogram of milksolids would be required for every extra \$1.00/kilolitre (0.1 cents per litre) in collection costs. The extra cost per kilolitre required for type 2 milk ranges from \$0.59 to \$1.69, equating to an extra 0.73 to 2.11 cents per kilogram milksolids over the season's lactation.

Table 4.8: The extra cost per year to a North Island and a South Island farmer for milk collection, and the proportional increase over a non-differentiated milk policy.

Year	% type 2 milk	North Island (average of peak and late lactation cost)						South Island (peak lactation cost)					
		Litres per yr	25% changing		50% changing		Litres per yr	25% changing		50% changing			
			\$	%	\$	%		\$	%	\$	%		
1	31.7%	574884	307	6.49%	179	3.78%	2097676	392	1.42%	710	2.57%		
2	31.7%	583507	311	6.49%	181	3.78%	2129141	398	1.42%	721	2.57%		
3	38.2%	592131	381	7.83%	222	4.56%	2160606	487	1.71%	882	3.11%		
4	43.7%	600754	442	8.95%	258	5.21%	2192071	564	1.96%	1023	3.55%		
5	48.3%	609377	496	9.89%	289	5.76%	2223537	633	2.17%	1147	3.93%		
6	53.6%	618000	558	10.97%	325	6.39%	2255002	712	2.40%	1290	4.35%		
7	59.0%	626624	623	12.08%	363	7.04%	2286467	795	2.65%	1441	4.80%		
8	64.4%	635247	688	13.18%	401	7.68%	2317932	879	2.89%	1593	5.23%		
9	69.6%	643870	754	14.24%	439	8.30%	2349397	963	3.12%	1745	5.65%		
10	74.6%	652493	819	15.26%	477	8.89%	2380862	1046	3.34%	1895	6.06%		
11	79.2%	661117	882	16.22%	514	9.45%	2412327	1126	3.55%	2041	6.44%		
12	83.2%	669740	938	17.03%	546	9.92%	2443793	1197	3.73%	2170	6.76%		
13	87.0%	678363	993	17.81%	579	10.37%	2475258	1268	3.90%	2299	7.07%		
14	90.5%	686986	1047	18.52%	610	10.79%	2506723	1336	4.06%	2422	7.35%		
15	93.4%	695610	1094	19.13%	637	11.14%	2538188	1397	4.19%	2532	7.59%		
16	95.6%	704233	1134	19.58%	661	11.41%	2569653	1448	4.29%	2624	7.77%		
17	100.0%	712856	1200	20.47%	699	11.93%	2601118	1533	4.48%	2777	8.12%		
18	100.0%	721479	1215	20.47%	708	11.93%	2632583	1551	4.48%	2811	8.12%		
19	100.0%	730103	1229	20.47%	716	11.93%	2664049	1570	4.48%	2845	8.12%		
20	100.0%	738726	1244	20.47%	725	11.93%	2695514	1588	4.48%	2878	8.12%		

However, as previously discussed, once all milk is one type or the other (years 18 to 20) costs may be even lower. Costs calculated using the raw data values (Appendix Tables A3.7 to A3.9) show a far more variable pattern of costs over the years. It may perhaps be more realistic to spread costs more evenly over the years, although the farmers will be better able to meet costs associated with type 2 milk once greater quantities of this are produced, assuming a premium on type 2 milk. South Island costs are calculated using the extra cost associated with peak lactation, but as the North Island results show, those for late lactation are similar to those incurred during peak lactation. These costs also assume the milk is differentiated over the whole year, which may not be the case in practice. Extra transport costs would only apply to the time when it was differentiated, as would any premium received.

4.3.11 Other factors

The transport system used for milk collection may be affected by other factors. If two milk types are collected it may be important to avoid cross contamination of the milk types, either from sharing a pump or from human error. It may also be more convenient for unloading and processing purposes to have the milk types collected separately. Allowing only one milk type to be collected per run as was modelled for the South Island at peak lactation would be a possible solution for this issue. Efficiency in milk collection may be improved by every second day collection during peak lactation, as already occurs in late lactation, with one type per run to avoid cross contamination. This system was modelled for the North Island at peak lactation (Appendix Table A3.4). Another alternative would be to have two pumps on the tanker, one each for the truck and trailer, which would reduce the volume of milk that could be carried (because of the extra weight of the pump) and as a result transport costs would increase. This system was not modelled.

Other milk collection factors that need to be considered are the provision of milk vats on the farm and possibly extra silos at the factory. Farmers changing milk types will need at least one other vat if they are changing milk types gradually and depending on vat size, may require a further vat once production of each milk type is at about 50%. Costs associated with the provision of an extra vat would be allocated to the farmer in the year of change (Chapters 5 and 6). The dairy company may require an extra milk silo or silos to receive the different milk types. Alternatively, low volumes of a particular milk type may be able to be collected less frequently to reduce the need for storage at the factory. While this would eliminate the need for an extra silo, it would increase on farm milk storage costs (vats and cooling costs). Water removal costs at the factory should not increase with two milk types because the combined milk volume should be similar for both scenarios.

4.4 CONCLUSION

The increased transport costs associated with the collection of two milk types are not high. A small market premium for type 2 milk would be required to cover these costs. In general, the fewer the farms changing to type 2 milk production, the greater the increase in costs per kilolitre of type 2 milk. The actual milk collection cost is not large relative to milk income, with the SQ cost for milk collection being less than \$9.61/kilolitre (1.0 cents/litre) for the North Island farm set and less than \$13.53/kilolitre (1.4 cents/litre) for the South Island farm set. Therefore, a large proportional difference in milk collection costs for type 2 milk relative to type 1 or SQ milk, will not be large in actual dollar terms. For example, the 22% increase

in milk collection costs for type 2 milk calculated for the North Island at peak lactation with 25% of farms changing, gave a discounted collection cost for type 2 milk of \$9.23 per kilolitre (0.923 cents/litre) compared to \$7.56 per kilolitre (0.756 cents/litre) for type 1 milk, a difference of \$1.67 per kilolitre (0.167 cents/litre). The extra cost to an average-size farm changing systems, compared to an average size SQ farm, would be between \$307 and \$1244 per year, or \$172 to \$3526 per year if raw values were used. An extra vat will be needed on farm and this initial cost may be of more significance to a farmer planning to change milk types.

Dairy companies will need to consider other factors in planning their transport management. An extra silo at the processing site may be needed and extra tankers are likely to be required particularly if farms are changing milk types gradually over time. Cross-contamination between milk types may be an issue and it may also be more convenient from a processing perspective to have milk of a particular type delivered on the same day. Transport management strategies, some of which have been evaluated using the model described in this Chapter, can be cost-effectively adopted to allow for these factors.

Therefore transport costs are unlikely to be an impediment when deciding whether it is economical to segregate milk into two types.

CHAPTER FIVE

DESCRIPTION OF THE MODELS

5.1 DESCRIPTION OF THE QUANTITATIVE BREEDING MODEL

A model was developed to look at the implications of segregating and breeding cows on milkfat colour. Milk from cows with a "lighter milkfat colour", based on a set criterion (i.e. a specified cut-off value), is segregated from that of the remaining cows. This milk can then be used to produce naturally lighter coloured dairy products, for which it is assumed a premium is paid.

The milk segregation model was developed using Microsoft Excel software and was run for a 20 year period. Model inputs include: the base production and milkfat colour level, age adjustments, phenotypic correlations and standard deviations, changes in genetic gain over time and the cut-off criterion. Outputs for each of the 20 years include: the actual cut-off value to meet the criterion, the proportion of the cows in each herd, the average milk, milkfat and protein production, and milkfat colour for each herd. A macro runs the calculations and writes out the outputs on a year by year basis.

As milkfat colour varies over lactation, the cut-off criterion and actual cut-off values referred to the average milkfat colour over the lactation. At the beginning of each lactation cows were sorted into two herds: those matching the criteria and the remaining cows. For ease of management, cows were assumed to remain in their allocated herd for the entire lactation.

The process for segregating cows on milk colour is outlined below.

1. Define the genetic gains.
2. Determine either the required mean for the segregating trait in one of the herds or the cut-off value.
3. Calculate the mean value for the segregating trait in each of the two herds.
4. Predict the expected performance for the other traits in each of the two herds.

Calculations are described in the next two sections and are run for each year.

5.1.1 Base level of production and change in genetic gain over time

The level of production for each of the traits is calculated for each age group within a year, and the average production per cow in the overall herd is calculated from this. The base production (not adjusted for age) which is the production of the oldest generation of cows in year one (year 0 cows) is specified, as in the qualitative breeding model (Chapter 3). The increase in production for the subsequent generations of cows is attributed to genetic gain.

The genetic gains per year for each of the traits were specified. These were calculated using a model developed by Lopez-Villalobos (Lopez-Villalobos *et al.* 2000; Lopez-Villalobos 2000, *pers. comm.*). The first ten generations (i.e. the base population of cows) differ from later generations as this base population has been selected on the standard industry selection index. The breeding population and selection index subsequently changed to include the new trait (e.g. milkfat colour) in the index, and as a consequence the genetic gain for all traits changed. The genetic gain for each generation is calculated in a lookup table as the cumulative genetic gain from the previous generation (year_{n-1}) plus the genetic gain in that year (year_n). For each generation, the cumulative genetic gain for the generations currently in the herd is read from the table using the lookup function. The level of production, colour and liveweight for a given generation, unadjusted for age, is the base level of production plus the cumulative genetic gain for that generation.

The model defines three trait types.

1. The selected trait is the trait on which milk segregation is to be made on e.g. milkfat colour.
2. The production traits are milk volume, milkfat, protein and liveweight.
3. The correlated trait is the trait that is correlated with the selected and the production traits. Sufficient information must be available on the relationship between this trait and the selected and production traits. The correlated trait could be the selected trait or a production trait, in which case the correlation between the trait and itself as a selected or production trait is 1. Ideally, the correlated trait would be the selected trait.

Age adjustment factors are entered for each trait group (i.e. the selected trait, the correlated trait and the production traits) for all years. Age adjustment factors for liveweight are entered for 2- and 3-year old cows. The selected trait, production traits and liveweight for an age group in a given year is the unadjusted production expected for that generation multiplied by the age adjustment factor. The overall average production is then calculated as the sum of the production for each age group weighted by the proportion of the herd in each age group.

5.1.2 Change in the selected trait and herd segregation

The model can segregate the cows into two herds according to their selected trait values in two different ways as described below.

1. A cut-off value is specified, with the cows below this value going into one herd, and those above it into the other herd. Over time, one herd will get progressively further from the cut-off value while the other herd approaches it. For example, if the objective is to reduce milkfat colour (i.e. negative genetic gain in milkfat colour), the milkfat colour in the herd with the desired colour will move further below this cut-off value over time, with increasing numbers of cows in this herd, while the other herd approaches the cut-off value until all cows are at or below the cut-off value.
2. An acceptable value in the selected trait for one of the herds is specified. Cows are then selected up to (or down to) a cut-off value that ensures that the milk in one of the herds matches this specified value. The objective can be to move a herd progressively down toward or below this value, or up to or above this value. If the selected trait is being moved downwards, all cows below the specified value go into the "selected herd", along with those cows above and closest to this specified value until the average value for the trait in the "selected herd" equals the value specified. The cut-off value is the value below or above that which the cows are selected at.

The value specified is either the actual cut-off value used (method 1), or the required value of the selected trait in one of the herds (method 2). If method 2, then the GOALSEEK function determines the required cut-off value for the colour trait, for either herd 1 or herd 2, depending on whether the selected trait is decreasing or increasing. The method used to determine the required cut-off value or the level of the selected trait in each herd follows that used to measure selection intensity (Van Vleck *et al.* 1987).

The calculations described here are done for each age group. The required cut-off value is the cut-off value (above which records are selected as shown on Figure 5.1), divided by the age adjustment for the selected trait for that age group. This allows cows who might not otherwise be included in the selected herd because they exceed the cut-off value to be included. These cows may actually meet the criteria in some years once the milk is adjusted for age factors e.g. if the cut-off value = 20 units and the age adjustment at 2 years = .75, then the required cut-off value for 2-year-old cows based on their expected mature production = $20/.75 = 26.7$ units at maturity, as those cows that will be achieving this level at maturity will

only be doing 20 units at 2 years and so can be included in the selected herd at this age. These cows will be in the herd that meets the criteria for some, but not all of their lives.

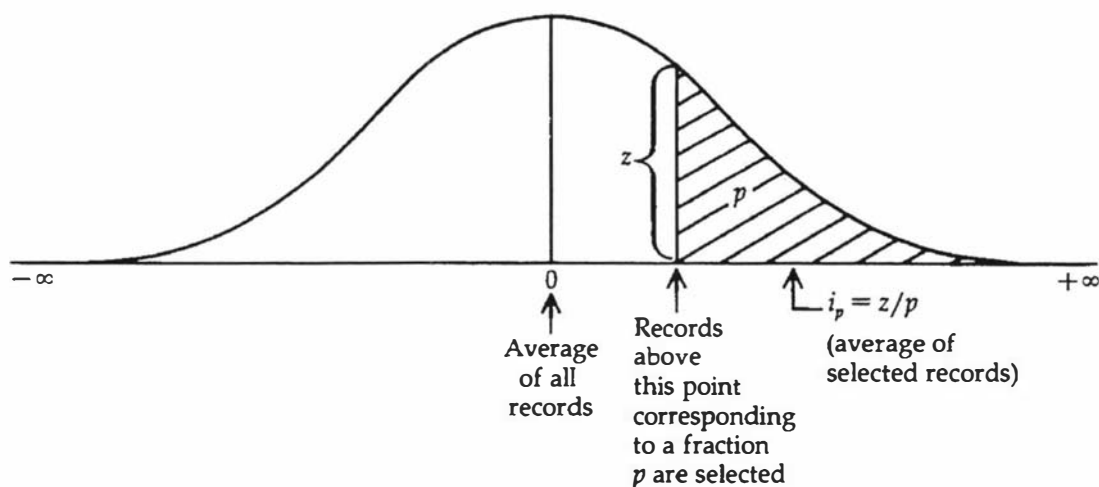


Figure 5.1: Average of selected records, i_p , from a standardised normal distribution (average = 0, and variance of 1) when a fraction p of the best records are selected (from Van Vleck *et al.* 1987 p. 298).

The Microsoft excel NORMSDIST function specifies the proportion (p) on the left hand side (LHS) of the normal distribution curve up to a specified truncation value, this value being the cut-off value. The shape of the curve is described by the mean (unadjusted for age) and the phenotypic standard deviation for the age group. The proportion on the right-hand side (RHS) of the truncation point on the normal curve is 1 minus the proportion on the LHS (left-hand side).

5.1.2.1 *Calculations relating to the RHS of cut-off value on the normal distribution curve*

The average value of the cows on the RHS of the cut-off value (I), is equal to the ordinate height of the normal distribution curve at the cut-off value (z) divided by the proportion of the cows on the RHS (p) of the normal distribution curve.

The difference between the cut-off value (age adjusted) and the mean, is calculated in standard deviations. The symmetrical nature of the normal distribution curve means the ordinate height will be the same, regardless of whether the value is negative or positive. The ordinate height (z) is then calculated using the excel NORMDIST function to return the height of the ordinate f for the standard normal distribution curve (mean=0, standard deviation=1) at

the number of standard deviations between the cut-off value and the mean. The selection intensity (I) is then calculated as z divided by p (in standard deviation units). The mean value of the cows on the RHS can then be calculated as the mean, plus the selection intensity multiplied by the phenotypic standard deviation. This value is then multiplied by the age adjustment for that trait and age group, to give the actual mean of the cows in the RHS herd i.e. the herd with the higher mean value for the selected trait.

5.1.2.2 *Calculations relating to the LHS of cut-off value on the normal distribution curve*

The mean value of the cows on the LHS of the normal distribution curve (i.e. the herd with the lower mean value for the selected trait) is calculated as the overall mean, less the mean on the RHS multiplied by the proportion of the cows in this age group on the RHS, all divided by the proportion of the cows in this age group on the LHS. The adjusted mean is this value multiplied by the age factor.

5.1.2.3 *Average production in the selected trait for each of the herds*

The proportion of all the cows for each age group and herd combination, is the proportion of cows in the total herd in that age group multiplied by the proportion of the cows in that age group in that herd. The average per cow production for each herd is calculated as the sum of the production for each age group in a herd weighted by the proportion of the total herd in each age group. If the selected trait is a concentration e.g. milkfat colour is weighted by milkfat yield because younger cows tend to produce less than older cows.

5.1.3 Production in the correlated and production traits for each herd

If there is sufficient information on the relationship between the selected trait and the production traits, then the correlated trait is the selected trait, and the correlation between the selected and correlated traits is 1. However, there may be little information on the phenotypic correlations between the selected trait and all other traits. Therefore a trait which is correlated with the selected trait, and which also has known correlations with the other traits is used to predict the production and liveweight e.g. in segregating herds on milk colour, fat yield is used as the correlated trait, because the parameters between fat yield and the other production traits are well researched, whereas the information on the relationship between milkfat colour and other traits is minimal.

The production in the correlated trait is calculated based on its phenotypic regression with the selected trait. Then the production of the remaining traits is calculated based on their

phenotypic regressions with the correlated trait. The correlated trait may be the selected trait or one of the production traits, in which case the correlation between the trait as a correlated trait and as the selected trait or a production trait is 1. Calculations are made for each age group, within each herd are described below with reference to Figure 5.2. In predicting the production level of the correlated trait, trait 1 (T1) is the selected trait and trait 2 (T2) is the correlated trait. For the remaining calculations T1 is the correlated trait and T2 is a production trait or liveweight.

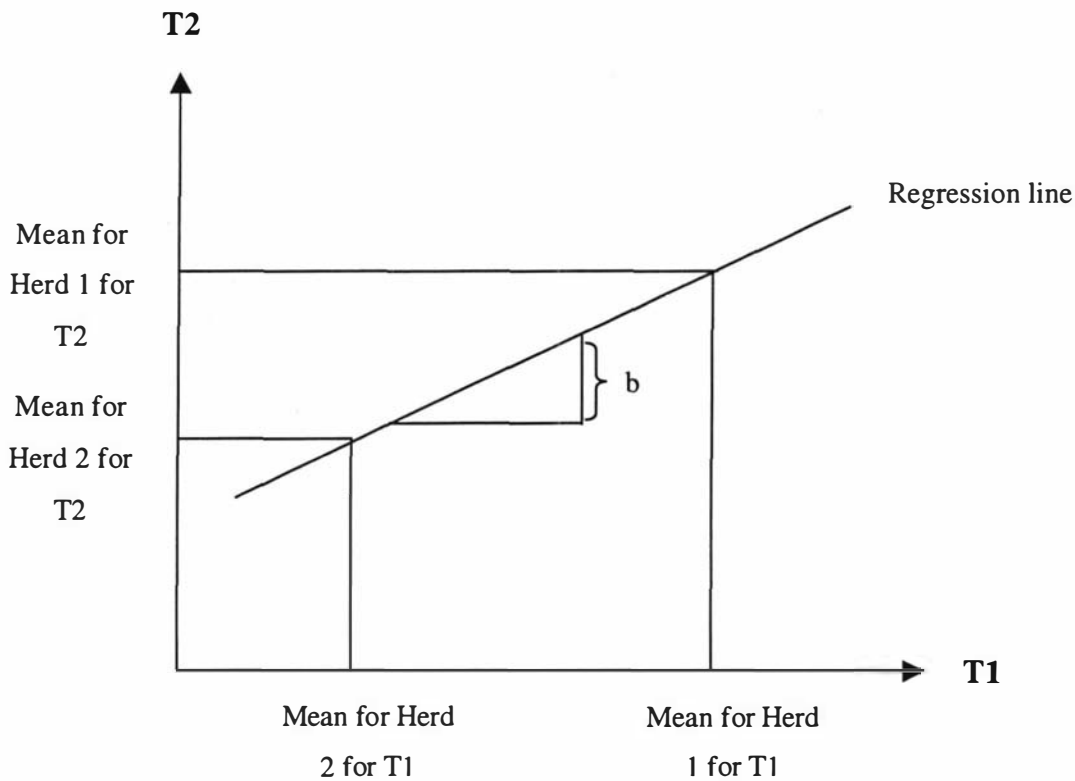


Figure 5.2: Regression line showing the relationship between T1 and T2

The regression (b) from Figure 5.2 is:

$$b = \frac{r \times \sigma_2}{\sigma_1} \quad \text{Equation 5.1}$$

where:

r = the correlation between T1 and T2;

σ_1 = phenotypic standard deviation for T1 and

σ_2 = phenotypic standard deviation for T2.

For each age group, the mean for T2 is calculated for each herd as:

$$\mu_{2h} = \mu_2 + (b \times (\mu_{1h} - \mu_1)) \quad \text{Equation 5.2}$$

where:

μ_{1h} = mean for T1 in herd h, and

h = 1 = the herd below the cut-off value and

h = 2 = the herd above the cut-off value.

μ_{2h} = mean for T2 in herd h;

μ_1 = overall mean for T1 and

μ_2 = overall mean for T2.

The mean for T2 is then age adjusted (multiplied by the age factor for that age and trait group). As for the selected trait, the average per cow production for each herd is calculated as the sum of the production for each age group in a herd weighted by the proportion of the total herd in each age group.

The production calculated as described above, using only one trait to predict the other traits would differ if an alternative trait was used as the correlated trait. However, the difference in the average production per cow for the two herds calculated using either milkfat or protein, as the correlated trait is less than 1%. This method also ensures that for all traits, the combined production for the two herds for any trait equals the average production for that trait.

DESCRIPTION OF THE FEED MODELS

Herd feed requirements were calculated using two sub-models. The first of these models calculated feed requirements on a per cow basis for the average cow in the herd. This model also calculated the average per cow milk, milkfat and protein production over the year. The second model was a feed budget that used cow requirements and feed inputs to calculate stocking rate. Both models were developed using Microsoft Excel software. They were required to generate results, quickly and easily for a number of runs, with 20 years in each run. This made the use of models such as UDDER (Larcombe 1990; cited by Uribe *et al.* 1996) impractical as setting up each of the 20 years for each run, would have been time consuming and restricted the number of runs that could be made. The average change in fat colour per annum was calculated using the quantitative breeding model (Section 5.1). Fat colour will also change over the lactation, and the prediction of this change was incorporated into the cow requirements model.

5.2 DESCRIPTION OF THE COW REQUIREMENTS MODEL

The feed requirements and production of a single cow over a year, divided into 24 periods, was modelled. The original model was developed by Dr Ian Brookes (Brookes *et al.* 1993), and is described in Appendix 4. This model was modified to represent the “average” cow in the herd, allowing for the younger, lower producing cows who are still growing out. The original model was also altered to allow for changing milk composition over the year. Culling and spread of lactation were then accounted for in predicting herd feed requirements and production over the year. Finally, a macro was added so the model to run the model automatically for two herds, over a 20-year period.

5.2.1 Allowance for younger cows growing out

Average cow liveweight at condition score 5 was assumed to be 4% higher at the end of the year than at the beginning of the year. The typical herd is 20% to 22% 2-year-olds and these 2-year-olds are 81.4% of their mature liveweight at the beginning of the year (Garcia-Muniz *et al.* 1998). The increase in average cow liveweight over the year ranged between 3.8% and 4.2%, depending on the input values used. Therefore, a value of 4.0% was considered to be sufficiently accurate, considering a difference of 0.2% in liveweight equated to a difference of only 0.08% in animal feed intake (approximately 4 kg DM per cow per year). Overall, feed requirements for growing out 2 year old heifers, increased annual feed requirements for the herd by less than 2%.

The liveweight increase for cows growing out was assumed to occur at a constant rate between post-peak lactation and calving. The calculation of metabolisable energy (ME) requirements for growth was the same as that for liveweight gain associated with increasing condition score (Appendix 4). The ME requirement for liveweight gain was included in calculating feed (kg DM/day) requirements, and in the calculation of cow liveweight and maintenance requirements.

5.2.2 Energy requirements for milk, allowing for changes in milk composition

Equations relating to milk production were calculated for the mid-day of each of the 24 periods in the year. Changes in milk composition were calculated using the Wood equation (Wood 1967). The net energy in the milk was then calculated using the equation of Tyrrell and Reid (1965) as recommended by AFRC (1993). This value was then used in Dr Brookes original model to calculate the ME requirements for lactation.

Tyrrell and Reid's equation (Tyrrell and Reid 1965; cited by AFRC 1993) calculates the net energy in a kilogram of milk as follows:

$$NE_M = ((0.0376 \times MF) + (0.0209 \times P) + 0.948) \quad \text{Equation 5.3}$$

where:

- NE_M = net energy in a kg of milk (MJ ME);
- MF = milkfat content of the milk (g/kg) = $MFC \times 10$;
- P = protein content of the milk (g/kg) = $PC \times 10$;
- MFC = milkfat concentration in the milk (%);
- PC = protein concentration in the milk (%).

The energy secreted in the milk each day was then calculated as:

$$E_1 = MY \times NE_M \times 1.03 \quad \text{Equation 5.4}$$

- E_1 = net energy secreted as milk per day (MJ/d);
- MY = milk yield (l/d).

The net energy in a kilogram of milk was converted into net energy in a litre of milk by multiplying by 1.03 i.e. 1 litre of milk weighs 1.03 kg (Goff and Hill 1993).

This E_1 value was then used in Dr Brooke's model to calculate the ME for lactation (Appendix 4).

In order to calculate the net energy in the milk, the milk production and the milkfat and protein concentration over the lactation needed to be determined. The Wood equation (Wood 1967) was used to predict yields (milk, milkfat or protein) and concentrations (milkfat or protein) in the milk over the lactation as:

$$Y_n = an^b e^{-cn} \quad \text{Equation 5.5}$$

and the shape of the curve is a function of time such that

$$F(n) = n^b e^{-cn} \quad \text{Equation 5.6}$$

where:

Y_n = the production or concentration measured at time n of lactation;

n = time of lactation (weeks);

e = base of natural logarithms.

a , b and c are coefficients measuring the lactation curve. The b and c coefficients are used to predict the shape of the curve and are related since the week of peak lactation = b/c . The a coefficient is a scaling factor associated with the average daily yield at the start of lactation. Henderson and Pringle (1982) found the Wood equation accurately predicted the lactation curve of cows under New Zealand grassland management.

The b and c coefficients for Friesian, Jersey and Friesian-Jersey cross cows for milk, milkfat and protein yields can either be calculated or read from a look-up table programmed into the spreadsheet. Calculated b and c coefficients are used if they exist, otherwise the look-up coefficients are used. The coefficients in the look-up table for Friesians and Jerseys are those calculated by Wood (1980), with Friesian-Jersey cross cows being intermediate between the two parent breeds. These coefficients are weighted for age i.e. the coefficients for the first, second, third, and fourth or greater lactations are weighted by the proportion in each class. The b and c coefficients can also be calculated as (Wood 1979):

$$c = Mq/(P_w - M) \quad \text{Equation 5.7}$$

L = length of lactation (weeks);

P_w = week of peak yield;

M = week of lactation midway between L and P_w where $M = (P_w + (L - P_w))/2$;

q = average rate of decline at week M (proportion per week).

and

$$b = Pc \quad \text{Equation 5.8}$$

To calculate the coefficients L , P , M and q need to be specified. The expected annual production based on a particular lactation length for each of the 20 years is input into the feeding model from the breeding model (Chapter 3 and Section 5.1). The length of lactation value (L) relates to the annual production it was based on. The week of peak yield (P) is

specified in the feeding model, as is the average rate of decline at week M (q). The week midway between P and L (M) is calculated.

Since the production of fat is the product of the yield of milk and the milkfat concentration, the exponents of the milk yield and milkfat percentages curves can be added to give the coefficient of the fat production curve (Wood 1976). Hence, the b coefficient for milkfat concentration is the b coefficient for milkfat yield less the b coefficient for milk yield. The c value for milkfat concentration, and the b and c values for protein concentration are calculated similarly.

The a values are calculated from the expected yields, the b and c coefficients, and the lactation length. The mid-day value for each of the 24 periods of the year is calculated, as the number of weeks from the start of lactation (i.e. the n value for the Wood equation). The daily production is calculated using the Wood equation, for each of these days where the n value is less than the lactation length. The total production is the total daily production for each of the periods multiplied by 15.21, the number of days in each period. The a values for the yields are calculated using the Microsoft Excel “goalseek what-if analysis” tool and by specifying what the total production values should be. The a values for the concentrations are the a value for milkfat or protein yield divided by the a value for milk yield.

The potential production values increase over time because of improved genetics and it is assumed these increases are realised. However, actual production may differ from potential production because of the effect a particular diet may have on milk composition e.g. feeding concentrates may alter milk production or concentration compared to a pasture-based diet (Holmes *et al.* 1984; Sutton and Morant 1989). The variation in lactation length can also affect production, although the shape and size of the lactation curves remain the same as the potential production curve. The average daily milk production and milkfat and protein concentrations for each of the 24 periods are calculated using the Wood equation for the periods where the n value is less than the actual lactation length, as described above. The previously calculated a, b, and c values, and the n values associated with the mid-day in each period are used in the Wood equation. The milk yield and concentration values calculated are multiplied by a user-defined multiplier, which allows any dietary effects to be imposed on production. The default value is one i.e. no dietary effect. The energy value of the milk per day for each of the periods is calculated using the Equations 5.3 and 5.4; this value is then read into Dr Brooke’s cow requirements model (Appendix 4).

The model does not assume to deal effectively with the differentiation of feed into pregnancy, maintenance, lactation and growth. Growth changes remain the same regardless of diet composition i.e. cows gain or lose a specified amount of weight dependent in association with changes in condition score (Appendix 4), or in the case of young cows, whether they are growing out. However, even ignoring carryover effects, the predicted feed required over the year will remain similar as the model assumes cows start and end the year at the same specified condition score.

The effect of different diets on milk composition can be varied. The model requires sensible user input in predicting the effect of diet on milk production and milk composition, and may also need to allow for any carryover effects. The model assumes the feed requirements for any extra production occur at the time of the extra production. However, intake may actually be higher in an earlier period and lower in a later period than that predicted by the model, due to a carryover effect. As a result, total feed may also be slightly under-estimated as the pathway from feed to body fat to milk is less efficient than feed directly used for milk production (AFRC 1993).

5.2.3 Calculation of calving spread

The user specifies the month of calving and whether calving starts in the first or second half of the month i.e. 1 or 2. Calving can be spread over up to two months i.e. 4 periods. A beta distribution describes the calving pattern. The median and final calving days (day 1 = beginning of calving), and the variance are specified by the user. The proportion of cows calving in each of the periods is then calculated. The calving spread can differ for each of the two herds.

The Microsoft Excel BETADIST function calculates the proportion calved in the first three periods. This function calculates the cumulative beta probability density, and requires the day to calculate the probability density for, the minimum and maximum calving days, and two input parameters (c and d) to describe the distribution. The mean, variance, minimum and maximum are needed to calculate these two parameters. GOALSEEK uses the BETAINV function to find the mean at which the two parameters calculated return a beta distribution function where the 50th percentile is the same as the median specified by the user. The calculation of the c and d parameters in the beta distribution function is described by Anderson *et al.* (1977) as follows:

$$m^* = (\text{mean} - \text{minimum}) / (\text{maximum} - \text{minimum})$$

Equation 5.9

$$v^* = \text{variance}/(\text{maximum} - \text{minimum})^2 \quad \text{Equation 5.10}$$

$$c + d = (m^* \times (1 - m^*)/v^*) - 1 \quad \text{Equation 5.11}$$

$$c = (c + d) \times m^* \quad \text{Equation 5.12}$$

$$d = (c + d) - c \quad \text{Equation 5.13}$$

For the first three periods, the Microsoft Excel BETADIST function calculates the proportion calved, as the proportion that has calved by the mid-day of that period (day 7.6, 22.8 or 38.0), less the proportion calved in previous periods. The remaining cows are assumed to calve in the last period. The minimum day is 1, the maximum day is user-defined and the c and d values calculated as described above. While the proportion calved on the mid-day of the period may not be the average proportion calved during that period, it provides a close estimate.

5.2.4 Culling

The proportion of the herd present for each of the periods over the year is specified. This is likely to be 1.0 in the period specified for the start of calving, and 0.75 to 0.85 in the final period, as cows are assumed to enter the herd as 2-year-olds at the start of calving.

5.2.5 Calculation of overall feed requirements and production over the year

The feed required per cow, and the milk, milkfat and protein production per cow, for each of the 24 periods in the year, is calculated by the model for the cows in each of the four calving periods. The overall average feed required, and the production, for each of these 24 periods is then calculated as the sum of the feed required (or the production) by the cows in each calving period weighted by the proportion of cows in that calving period. These average values are multiplied by the proportion of cows present at calving still in the herd to allow for culling. The final value is in units per cow present at calving, and as such, can be multiplied by the initial stocking rate or number of cows to give overall feed requirements or production. A macro enables these calculations to be automatically run for both herds, for each of the 20 years.

Staggering the calving spread may mean that the production is very low in the final milk production period of the year as the small proportion of cows in the final calving group are

the only ones still lactating, their herd mates having all been dried off earlier. In reality, however, the earlier calving cows may have a longer average lactation length than their later calving counterparts. The culling rate is assumed to be the same over time for all four groups, although in practice this may not necessarily be the case. The overall effect of these differences in comparing between policies is inconsequential.

5.2.6 Calculation of milk fat colour over the year

Fat colour (FC) is measured as milligrams of β -carotene per kilogram of milkfat. β -carotene yield (BCY) and fat colour (FC) were both measured by Winkelman *et al.* (1999) over the lactation for first and second calving cows (Friesian and Jersey). Fat yield (FY) for these cows was estimated using the BCY and FC values, and was lower, and had lower persistency than other lactation curves measured in New Zealand (Hendersen and Pringle 1982; Lopez-Villalobos *et al.* 2001), and lower than the default fat yield lactation curve value assumed (Wood 1980). The BCY curves measured by Winkelman *et al.* (1999) were highest at the start of lactation and flattened out toward the end of lactation (approximately 200 days), whereas FC was at its highest at the beginning of lactation, flattened out in mid-lactation and increased again in late lactation when FY was dropping at a greater rate than BCY. Jerseys were higher than Friesians at all stages of lactation for both FC and BCY, and the FC curve was flatter for Friesians than for Jerseys (Figures 5.3 and 5.4).

The FC curve recorded by Winkelman *et al.* (1999) was similar in shape to FC curves recorded in New Zealand bulk milk over the lactation (McDowell and McDowell 1953; Thompson *et al.* 1964; Keen 1986; Keen and Wilson 1993), although the actual FC and curves varied considerably between trials and years, possibly also reflecting breed and feeding effects. Therefore, the FC curve measured by Winkelman *et al.* (1999) was used to predict the change in FC over lactation. The percentage of the day one FC value was calculated from the graph shown by Winkelman *et al.* (1999), and a regression curve was fitted through these points for both the Jersey and Friesian curves. This was then used to predict the percentage of the day one value for the mid-point of each period. The FC over lactation was calculated for a number of initial values, for both Jerseys and Friesians to check the shape of the curve. The BCY was calculated as FC multiplied by FY, using the default FY curve in the cow requirements model. The higher persistency of the default FY curve compared to that of Winkelman *et al.* (1999) tended to increase BCY toward the end of lactation for Jerseys. The FC percentage value for Jerseys was adjusted slightly downwards at the end of lactation so that BCY flattened out rather than increased, maintaining the BCY

curve shape measured by Winkelman *et al.* (1999) as BCY is believed to be independent of milk or fat yield (Jensen *et al.* 1999).

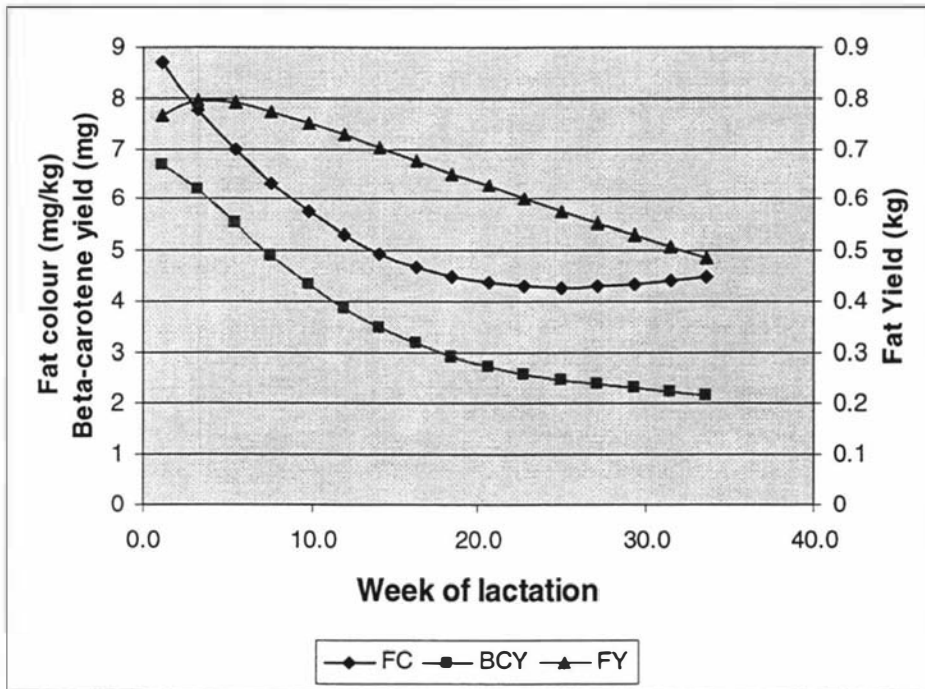


Figure 5.3: Change in fat colour, β -carotene yield and fat yield over lactation for a Friesian cow.

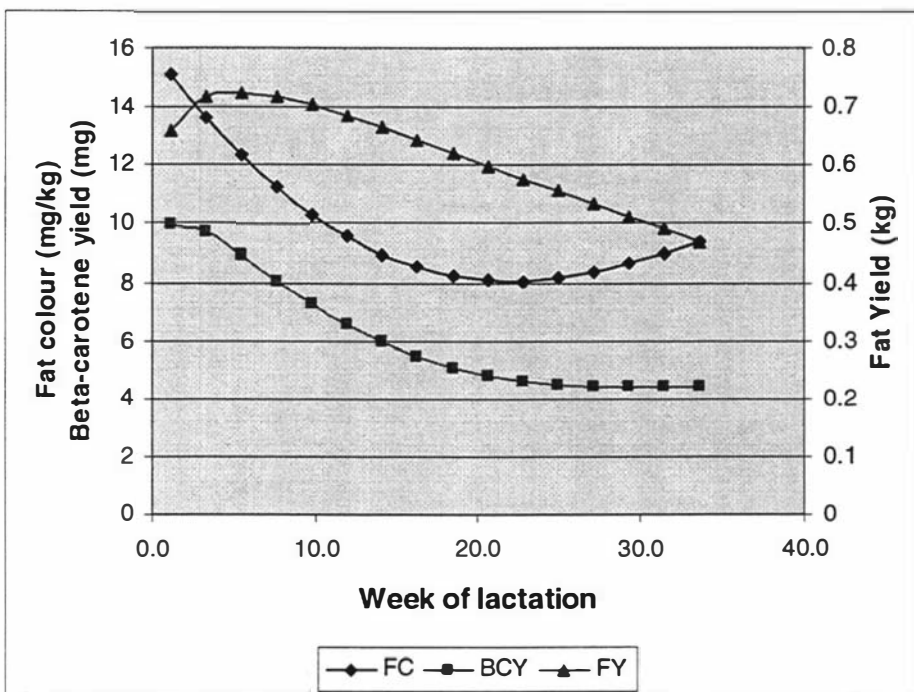


Figure 5.4: Change in fat colour, β -carotene yield and fat yield over lactation for a Jersey cow.

The prediction of FC over lactation as a proportion of the initial value was effective in predicting a flatter curve for cows with a lower initial FC value e.g. Friesian cows compared to Jersey cows. The change in FC over lactation predicted for a range of initial values for both Jerseys and Friesians was comparable to the FC curves found in other trials (McDowell and McDowell 1953; Thompson *et al.* 1964; Keen 1986; Keen and Wilson 1993).

The average FC is read in from the breeding model, and the FC is calculated over the lactation as described earlier for the other yield traits i.e. using the GOALSEEK function in excel. The FC for each period is a function of the FC at the beginning of lactation. BCY for each period is calculated (FC multiplied by fat yield). This initial FC value is adjusted until average FC (the total BCY over the lactation divided by the total fat yield) is the same as that specified. As for the other traits, the actual lactation length may differ from the lactation length these average values are based on. Consequently, the actual average FC may differ if the lactation lengths are different. FC is also multiplied by a value to allow for the effect of feed on the intensity of fat colour (default is one), in a manner similar to that described for the yield traits.

The BCY values are then adjusted for calving spread and culling, and the results for FC written out for each of the 24 periods over the 20 years as described in Section 5.2.5. BCY is used in making these adjustments rather than FC as it is simpler to deal with a yield than a concentration. FC is then calculated for each period (BCY divided by fat yield) and this value is written out to the results, as milk differentiation will be based on FC rather than BCY.

5.3 DESCRIPTION OF THE FEED BUDGET MODEL

The feed budget model differs from some used for feed budgeting in that it calculates the stocking rate that can be run, rather than having the number of animals (or stocking rate) as an input variable. Stocking rate is predicted for the milking herd, as it is assumed young stock are to be grazed off or run on a separate area of the property. Production per herd (allowing two herds per farm), and per farm is then calculated. As for the cow requirements model, the year is divided into 24 periods.

Herd inputs specified include the composition of the diet and the energy value of the components, intake per cow (based on production), and the proportion of cows in each herd. The main farm inputs include pasture growth rates and utilisation; maximum and minimum covers allowed over the year; effective area of the milking platform; area in, and production

of crops; and pasture grown from nitrogen applied. Combined, the farm inputs define the herd's feed supply.

5.3.1 Feed requirements

The proportions of the diet provided by pasture or grass silage, maize silage, hay, crop and concentrates, and the energy value of these components, are specified. The average energy value of the diet is calculated as the energy value of each of these components multiplied by the proportion of each diet component. The energy value of the grass silage is assumed to be the same as pasture at the time it is fed out, which is usually when pasture is at its lowest energy value for the year. The average energy value of the diet is also used in the cow requirements model to calculate the intake per cow (kgDM/cow/day) (Appendix 4). Diet composition can differ for the two herds, as this may be altered specifically to change milk composition in one of the herds.

The feed requirement per cow, per day, for the cows in each of the two herds and for each of the 24 periods is transferred into the farm systems feeding model from the feed requirements model, as are the production values (milk, milkfat, protein and milksolids). The proportion of cows in each herd, for each of the 20 years, is transferred in from the breeding model (Chapter 3 and Section 5.1) and is assumed to remain constant throughout each year. To allow for grazing off, the proportion of cows in each herd that are currently on the farm is specified. Those on- and off-farm are assumed to have the same feed requirement i.e. the per cow feed requirement value transferred from the feed requirement model which is an average value allowing for both dry and lactating cows. This is likely to be true if cows are grazed off in the winter, however, if cows dried off earlier are grazed off, the feed requirement for those on farm will be greater. The net effect of the latter on the herd's production, however, is minor.

The average feed requirement per cow, for both herds combined is calculated for inclusion in the feed budget. Initially this is calculated for each of the components as:

$$F_{tnx} = \sum_{h=1}^{h=2} H_{th} \times C_{nh} \times R_{tnh} \times P_{nhx} \quad \text{Equation 5.14}$$

where:

F_{tnx} = amount of feed x required (kgDM/cow/day), in year t, period n, where

x_1 = maize silage

x_2 = hay

x_3 = crop

x_4 = concentrates or other

x_5 = pasture or grass silage;

H_{th} = proportion of the cows in herd h, in year t;

C_{nh} = proportion of the cows on the farm in period n, herd h;

R_{tnh} = total feed required (kgDM/cow/day) by the cows in herd h, in year t, period n;

P_{nhx} = proportion of the diet contributed by feed x in period n, herd h.

The total feed required in a particular year and period is the sum of the maize silage, hay, crop, concentrates, and pasture and grass silage required in that year and period.

The total amount pasture and grass silage, hay (if made) and crop required are needed for the feed budget as these are produced on-farm. The amount of hay (x_2) and crop (x_3) required by the cows is calculated as:

$$I_{tx} = \sum_{n=1}^{n=24} F_{tnx} \times SR_t \times A \times 15.208 \quad \text{Equation 5.15}$$

where:

I_{tx} = total amount of feed x required (kgDM/cow/day), in year t;

SR_t = stocking rate in year t;

A = area of the farm (ha);

15.208 = days per period = 365 days/24 periods per year.

Quantities of maize silage (x_1) and concentrates (x_4) are calculated similarly. As it is assumed that these inputs will be purchased they are not required for the feed budget, but are needed in the economic model to calculate costs. The same applies to hay if it is purchased. Although these do not directly affect the feed budget, the demand for the other diet components (e.g. pasture or grass silage) will be reduced in periods where these are fed.

5.3.2 Calculation of stocking rate

As per cow production and therefore intake per cow is set in the model, the highest production per hectare will occur at the highest stocking rate. This stocking rate occurs when the supplements made are lowest, as this minimises the losses in the system. Therefore, as cow production and intake increase over time, stocking rate will be reduced (assuming a constant pasture growth rate and utilisation). Supplements made are also likely to increase as stocking rate decreases.

The stocking rate in the feed budget is calculated with the “SOLVER” tool in Microsoft Excel. Solver finds the maximum stocking rate by adjusting the stocking rate and opening pasture balance (at the beginning of July), subject to the constraints that final pasture cover must equal opening pasture cover and grass silage made must equal grass silage eaten plus losses. Grass silage fed out is 0.8 times that made to allow for losses in the stack and in making silage (Brookes 2000, *pers. comm.*). Losses in feeding out (utilisation) are allowed for in calculating the amount of silage made or fed out, as described later.

Maximum and minimum pasture cover allowed, and kilograms of dry matter grown from nitrogen applied are specified for each of the 24 periods in the year. The amount of crop consumed (kg DM) per hectare is also specified, as is the proportion of any cropped area unavailable for grazing in any of the 24 periods. Consequently the pasture growth on the cropped area can be adjusted until the land is returned to regular grazing. While the crop is growing, the proportion of crop unavailable for grazing is one. The area cropped is the total amount of crop required for the year (ha) divided by the amount of crop available to the cows (kgDM/ha).

Other inputs include the effective area (of the milking platform) and whether hay is made or purchased. If hay is made, it is assumed to be made in December with half made in each half. The amount of pasture used to make hay is calculated as 1.5 times the amount of hay required, to allow for losses. The area available for pasture production (ha) in any time period is the effective area of the farm, less the area in crop (ha) multiplied by the proportion of cropped area out of pasture in that area and time period.

The intake of grass or grass silage per cow per day for each period are those calculated in Equation 5.14. The average pasture growth rate (PGR) and utilisation is specified for each of the 24 periods for year one. The percentage increase per year, based on the year one value, for pasture growth rate and utilisation are also specified. Pasture growth is then calculated as:

$$PGR_{tn} = PGR_{1n} \times (1 + ((t-1) \times I)) \quad \text{Equation 5.16}$$

where:

PGR_{tn} = pasture growth rate in year t, period n;

PGR_{1n} = pasture growth rate in year 1, period n;

I = percentage increase in pasture growth rate per year.

Utilisation is calculated similarly. The opening cover in any period is the final cover in the previous period. Pasture cover, excluding grass silage made or consumed is then calculated as:

$$PC_{tn} = \frac{\left((OC_{tn} \times A) + (PGR_{tn} \times 15.208 \times PA_{tn}) - H_{tn} + N_{tn} - \left(\frac{F_{tn5}}{U_{tn}} \times A \times SR_t \times 15.208 \right) \right)}{A}$$

Equation 5.17

where:

PC_{tn} = pasture cover excluding silage made/eaten in year t, period n (kg DM/ha);

OC_{tn} = opening pasture cover in year t, period n (kg DM/ha);

A = area of the farm (ha);

PGR_{tn} = pasture growth rate in year t, period n (kg DM/ha/day);

PA_{tn} = area of the farm in pasture in year t, period n (ha);

H_{tn} = hay made in year t, period n (kg DM);

N_{tn} = pasture grown in year t, period n from N applied (kg DM);

$F_{tn5} = F_{tnx}$ = amount of feed x required (kgDM/cow/day), in year t, period n, where x = 5 (grass or grass silage) (kg DM/cow/day);

U_{tn} = pasture utilisation in year t, period n (proportion);

SR_t = stocking rate in year t;

15.208 = 365 days/24 periods per year.

Silage acts as a buffer in ensuring pasture cover levels on farm stay between the maximum and the minimum. If the pasture cover value lies between the maximum and minimum specified, grass silage is neither made nor fed out. If the value is going to fall below the specified minimum, the final cover is the minimum value and the amount of silage fed out is the farm area multiplied by the minimum pasture cover less the calculated expected pasture cover. If the pasture cover value is above the specified maximum, the final cover is the maximum value and silage made is the farm area multiplied by the calculated pasture cover less the maximum pasture cover. Most silage is made in November, as cover is allowed to build up until then. Also, in November the maximum cover is reduced to 2000 kg DM/ha.

While this model effectively calculates the highest stocking rate and lowest supplement combination, the minimum and maximum cover constraints mean the model output produced

has a low opening pasture cover in June (opening month), and most silage is fed out in late winter-early spring with pasture covers at a minimum thereafter for a number of months over the calving and early lactation period. This is typical of pastoral systems where soil conditions or the availability of a feed pad allow late winter-spring supplementation. The calculated stocking rate can also be fed into a similar feed model specifying the proportion of silage fed in each period (allowing more to be fed in summer and autumn). This allows a higher opening cover to be calculated by iteration, and the cover may match the minimum level in only one month. The amount of silage made and fed remains the same, even though for the later analysis an optimal solution could not be found with SOLVER.

5.3.3 Production per cow, herd and hectare

Production values (milk, milkfat, protein and milksolids yields) per cow per day for each period and cow production per year are entered from the cow requirements for each herd. Total production of milk components and production per herd, per hectare and per farm are calculated on a monthly and a yearly basis using the per cow production, the proportion of cows in each herd, stocking rate and farm size.

5.3.4 Model outputs

Model outputs for each of the 20 years include: stocking rate and number of cows, opening cover, grass silage fed and made, hay fed and made, hay, silage and concentrates purchased, hectares of crop grown, pasture production /ha/year and milk production as described above.

DESCRIPTION OF THE ECONOMIC MODEL

The final model developed was the economic model. This model incorporates inputs from the earlier models, along with costs and prices to determine if segregation based on milk type is economically viable. The components of the economic model and the inputs used to evaluate scenarios are described in this chapter. Results from the model runs are in Chapter 6, and the discussion of the model results will be included in Chapter 7.

The economic model comprises four integrated Microsoft Excel spreadsheets, and as for the other models is run for a 20 year period. The spreadsheet models include: a Stock Reconciliation for calculating stock sales and purchases along with their associated income and expenditure, and the capital value of the stock; a Milk Income calculation model; and an overall Economic model which incorporates the outputs from the other spreadsheets with the per cow costs to generate the cost-benefit analysis. Feed component costs for the economic

model are incorporated in the Feed model, but are described here as their outputs are used in the economic model. Each of these spreadsheet sub-models will be described here.

5.4 DESCRIPTION OF FEED COMPONENT COSTS AND GRAZING OFF

The calculation of the feed quantity made, required or purchased for each of the 20 years is described in Section 5.3. The cost per unit for each of the feed components is entered for each year, and the total cost associated with each of the feed components is calculated for each of the 20 years as described below. These total feed costs are transferred to the overall economic model. The calculation for grazing periods per cow for each of the 20 years, used in the derivation of grazing and freight costs are also described below.

5.4.1 Hay

The amount of hay eaten in total kilogram of dry matter (kg DM) is read from the feed output file. The amount of hay baled is set at 1.17 times the amount eaten to allow for losses after baling (Holmes *et al.* 1984). The cost per kg DM baled is used as this applies whether the hay is made or purchased. Total cost is the amount of hay baled (kg DM) multiplied by the cost per kg DM.

5.4.2 Maize silage purchased

Calculations are similar to those for hay. To allow for losses, the amount in the stack is assumed to be 1.5 times the amount eaten. The cost per kg DM is for silage in the stack, including freight.

5.4.3 Concentrates purchased

For concentrates the amount purchased is assumed to be 1.05 times the amount eaten, to allow for wastage. The cost per kg DM includes freight to the farm.

5.4.4 Nitrogen

The amount of pasture grown from nitrogen applied is read in from the Feed budget calculation, and the cost per kilogram of nitrogen is entered. The total cost is then derived assuming an average response rate of 10 kg DM grown per kilogram of nitrogen applied (Lincoln University 1996) i.e pasture grown divided by 10, multiplied by the cost per kilogram of nitrogen.

5.4.5 Crop

The area (hectares) of crop grown is read in from the feed budget calculation, and the cost per hectare associated with growing the crop (including any regrassing costs) is entered. Total crop costs are calculated as hectares grown multiplied by per hectare costs.

5.4.6 Grass silage

The amount of pasture harvested (kg DM) to make silage is read in (the difference between that harvested and that eaten i.e. losses, has already been accounted for in the feeding model). The cost of making silage is entered.

5.4.7 Grazing

The number of periods that each cow is grazed off-farm and the maximum proportion of the herd grazed off-farm at any period of the year are calculated separately for the two herds. The model currently assumes the grazing off policy remains the same over the 20 years.

The culling factor (number of the opening cows not culled at that time) multiplied by the proportion of cows grazed off-farm (1 minus the proportion of the live cows on the farm) is calculated for each of the 24 periods. The number of periods (2.17 weeks) that each cow, based on opening cow numbers, is grazed off-farm is calculated as the sum of these values. This is transferred to the stock reconciliation model for the calculation of grazing costs.

The proportion of cows in the herd grazed off-farm for each period of the year is calculated, based on opening numbers. The maximum proportion grazed off-farm at any time is then transferred to the stock reconciliation model to derive the cost of freighting cows to and from grazing.

5.5 DESCRIPTION OF THE STOCK RECONCILIATION

The stock reconciliation is designed to estimate the numbers of replacement stock (heifers and breeding bulls) which need to be retained to support the number of cows required to be in milk, and the number of cull stock available for sale after deaths and losses.

5.5.1 Stock reconciliation calculations

The numbers of animals sold, purchased, and on-hand at the beginning of each farming year (1 July) are calculated with a template in a series of stock reconciliations with the previous year's closing stock numbers (30 June) being the current year's opening stock numbers. The

stock classes are heifer calves, rising 1-year-old heifers (R 1 yr heifers), rising 2-year-old heifers (R 2 yr heifers), mixed-age cows (MA cows), bull calves, rising 1-year-old bulls (R 1 yr bulls) and breeding bulls as shown in the example given in Table 5.1 for years one and two. All stock numbers are rounded to the nearest whole number.

The columns across Table 5.1 are: year; stock class; opening number; natural increase; specified purchases; balance of purchases; sales of culls or surplus animals; other sales; balance of sales; deads, killers or missing (DKM); closing numbers; the proportion of dead, killers and missing animals in that class; the proportion of culls in that class; and the proportion of the herd in that class in relation to the closing number of cows. These are described in more detail below.

5.5.1.1 *Opening and closing stock numbers*

The total number of cows (both herds combined) is transferred from the feed model (opening number for year 1 and closing number for all years) to the stock reconciliation template. The opening numbers for year 1 are calculated based on the opening number of MA cows and herd structure.

Herd structure is specified for MA cows, R 2 yr heifers, R 1 yr bulls and older bulls for all years, as the proportion in that class in relation to the total number of cows in the herd (MA cows and R 2 yr heifers). The number in each of these classes is calculated as the proportion in that class multiplied by the total number of cows. The number of R 1 yr heifers is calculated similarly: however, the proportion is calculated rather than specified as the proportion of R 2 year old heifers, plus the proportion of the R 2 yr heifers culled and dead multiplied by the proportion of R 2 yr heifers, plus an adjustment factor. A small adjustment factor can be included for fine tuning, to increase the closing number of R 1 yr heifers and reduce the number of calves sold in a year by 1, thereby avoiding having to purchase a single R 1 yr heifer the following year. The proportion of R 1 yr heifers is only slightly greater than for R 2 yr heifers e.g. a 3% difference in the example shown, including a 0.4% adjustment factor.

Table 5.1: Stock reconciliation calculation table for years 1 and 2. Read-in (or entered) values are in italics and calculated values are in regular font.

YEAR	CLASS	Open. No.	Natural Incr.	Purch. (Spec.)	Purch. (Bal.)	Sales Culls	Sales Other	Sales (Bal.)	DKM	Closing No.		DKM %	CULL %	HS %
	COWS		97.0%	Calving						209	Cows			0.4%
1	Heifer calves		102	0			0	39	11			11.0%		
1	R 1 yr heifers	53		0	0	5	0	1	1	52		2.0%	10.0%	25.0%
1	R 2 yr heifers	46		0		7	0		2	46		5.0%	15.0%	22.0%
1	MA cows	164		0	0	25	0	5	8	163		5.0%	15.0%	78.0%
	BULLS													
1	Bull Calves		102	0				96	6			6.0%		
1	R 1 yr Bulls	0				0			0	0		2.0%	0.0%	0.0%
1	Bulls	4			2	2		0	0	4		2.0%	50.0%	2.0%

	COWS		97.0%	Calving						207	Cows			0.4%
2	Heifer calves		101	0			0	38	11			11.0%		
2	R 1 yr heifers	52		0	0	5	0	0	1	52		2.0%	10.0%	25.0%
2	R 2 yr heifers	46		0		7	0		2	46		5.0%	15.0%	22.0%
2	MA cows	163		0	0	24	0	7	8	161		5.0%	15.0%	78.0%
	BULLS													
2	Bull Calves		101	0				95	6			6.0%		
2	R 1 yr Bulls	0				0			0	0		2.0%	0.0%	0.0%
2	Bulls	4			2	2		0	0	4		2.0%	50.0%	2.0%

5.5.1.2 Natural increase

The calving percentage is specified for each of the 20 years and is read into the stock reconciliation e.g. 97% in the example shown. The number of calves born is the calving percentage multiplied the number of cows (R 2 yr heifers and MA cows) at opening. Half the calves are assumed to be heifers and half bulls.

5.5.1.3 Numbers of specified sales and purchases

The number of specified sales (sales - other) and purchases (purchases - specified) are defined for each of the 20 years for calves, heifers and cows, and are read into the stock reconciliation. In most years this would be none. However, if cows were purchased and sold

based on the level of a milk trait in a particular year the numbers sold or purchased can be specified here. These sales and purchases are kept separate from culls and other purchases, as these animals are likely to be traded between herds, and the prices associated with their sale or purchase are likely to differ from the culls or herd replacements.

5.5.1.4 *Numbers of culls, and deads, killers and missings*

The number of culls, and losses i.e. deads, killers and missings (DKM) are specified for each of the 20 years, and are read into the stock reconciliation. It is assumed calves are not culled. The number in each class culled or DKM is the opening number in that class multiplied by the proportion specified.

5.5.1.5 *Numbers of sales and purchases*

The stock reconciliation is balanced by adjusting the number of sales and purchases. The only purchases of bull and heifer calves are assumed to be the specified purchases. The sales for these classes are calculated in the sales - balance column and are assumed to be bobby calves. Calf sales are calculated as the natural increase plus purchases, less DKM, sales - other and R 1 yr on hand at closing.

The difference required to balance the stock reconciliation for the R 1 yr heifers, the MA cows and the older breeding bulls is calculated, and this value is read into either the sales - balance, or the purchases - balance, column. The balance is calculated as the closing balance for the next age class plus cull sales, other sales and DKM, less the opening balance and specified purchases. If the balance is positive, the value is entered into the purchases - balance column, otherwise it is entered into the sales - balance column. Sales balance figures are added to the cull sales figures later for the income from stock sales calculation.

The closing balance for the R 2 yr heifers is calculated for the stock that are R 1 yr heifers during the year, while the calves become R 1 yr heifer values. For MA cows it is assumed any extra sales are MA cows rather than R 2 yr heifers. The closing balance value is that for the MA cows, and the other values are those for both the R 2 yr heifers and the MA cows. The bulls are similar in that the closing balance is that for the older bulls, and the other values are those for both the R 2 yr bulls and the older bulls. There are no specified purchases or other sales for the bulls.

5.5.1.6 Outputs

The number of sales and purchases for the stock classes listed below, for of the 20 years is written to an output file. The balance of sales are included in the cull sales total. Specified sales and purchases are separate from cull (and bobby calf) sales and other purchases.

Purchases	Specific Purchases	Sales	Specific Sales
R 1 yr heifers	Heifer Calves	Heifer Calves	Heifer Calves
MA cows	R 1 yr heifers	R 1 yr heifers	R 1 yr heifers
Bulls	R 2 yr heifers	R 2 yr heifers	R 2 yr heifers
	MA cows	MA cows	MA cows
	Bull Calves	Bull Calves	
		R 1 yr Bulls	
		Bulls	

5.5.2 Stock income and expenditure

The price received or paid for each of the classes for which stock is purchased or sold is entered for each of the 20 years, and the income received for the purchases and sales of each class is calculated. Total income from stock purchases and sales is then calculated for each year.

5.5.3 Capital value of stock on hand

The opening number of R 1 yr heifers, R 2 yr heifers, MA cows, R 1 yr bulls and breeding bulls is read from the output. The capital values of the heifers and cows in the two herds are calculated separately to allow for possible differences between herds in the value of animals of the same class. The proportion of the cows in herd 1 for each of the 20 years is input from the feed model (Section 5.3), with the remainder being in herd 2. The capital value per animal for the R 1 yr heifers, R 2 yr heifers and MA cows in each of the herds is entered, as is the capital value of the R 1 yr bulls and breeding bulls.

The capital value for the R 1 yr heifers, R 2 yr heifers and MA cows in each herd is the number of animals in that class multiplied by the capital value per animal for that class and herd multiplied by the proportion of cows in that herd. While the proportions of these classes in each herd may differ slightly within a year, this makes only a small (less than 2%) difference to the overall capital value. The capital value of the bulls is the number of animals in that class multiplied by the capital value per animal for that class.

5.5.4 Grazing, calf rearing and stock freight costs

The opening number of R 1 yr heifers, R 1 yr bulls and older bulls is read in for each year from the stock reconciliation calculation. The closing number of R 1 yr heifers and bulls is read in for each year to calculate calf grazing costs. The proportion of the heifer calves, R 1 yr heifers, bull calves, R 1 yr bulls and older bulls grazed off, the number of weeks these classes are grazed off and the grazing cost per head per week are entered. Calves are often grazed off-farm most of the year, whereas the R 1 yr heifers are often away the whole year, returning as R2 yr heifers prior to calving. The number of animals, proportion grazed off, number of weeks grazed off and cost per head per week are multiplied to give the grazing costs for each of these classes.

The opening number of R2 yr heifers and MA cows is read in from the stock reconciliation to calculate the cow grazing costs. The proportion of the cows in herd 1 for each of the 20 years is input from the feed model (Section 5.3), with the remainder being in herd 2. The number of periods each cow is grazed off (based on opening number of R 2 yr heifers and MA cows) in each of the herds is entered from the feed model. The number of cow weeks grazing required for each herd is the number of cows (R2 yr heifers and MA cows at opening) multiplied by the proportion of cows in that herd, the number of periods each cow is grazed off, and the number of weeks per period (2.1726). The number of cow weeks per herd is then multiplied by the cost per cow per week for grazing to give the cow grazing costs for each herd. Total grazing costs are the sum of the grazing costs for all stock classes.

The freight costs for the calves, the R 1 yr animals and the bulls is the number in each class multiplied by the proportion grazed off in that class and the freight cost for that class, which is specified. Freight is calculated on the basis of one way for calves and/or R 1 yrs as these often leave the farm as calves and return as R 2 yr olds. The maximum proportion of cows off-farm (based on opening number of R 2 yr heifers and MA cows), in each of the herds is entered from the feed model. The freight cost for each herd is the number of cows multiplied by the maximum proportion of cows grazed off in each herd and the return freight cost per cow. Total freight costs are the sum of the freight costs for all stock classes.

Calf rearing costs per replacement calf are entered. Total calf rearing costs are the cost per calf multiplied by the number of heifer and bull calves reared. Calf rearing costs for animals that die after rearing but prior to the end of the year (i.e. as a R 1 yr old at closing) are not accounted for but these costs are likely to be minimal in relation to total costs, and will affect both the with and without model comparison in the cost-benefit analysis.

5.6 DESCRIPTION OF THE MILK INCOME MODEL

This worksheet calculates the annual milk income from a farm over the 20 year period taking both milk payment system and time factors into consideration. Time factors are accounted for within the milk payment systems. Three factors impact the milk payment system: there can be two herds on the farm producing segregated milk; the prices may differ depending on whether the milk is above or below a set criterion e.g. based on fat colour; and the prices may differ for peak and off-peak milk. Combined, these give eight possible sets of price inputs (i.e. 2 herds, above and below criterion groups, and on- or off-peak production groups).

The inputs for some of these price groups may be the same. For example, for the status quo there is only one herd, and the prices, whether the milk is above or below the criterion, are the same i.e. criterion is irrelevant. Similarly, for the herd producing the standard milk where there are two herds, one producing niche-market milk and the other producing standard milk. Prices are entered for milk yield (\$/litre), milkfat (\$/kilogram), protein (\$/kilogram) and another trait if required. Prices and production for the “other” trait will be 0, but this allows inclusion of an economic value for another trait should it be required at some future date. It should be noted that the price for a component is negative where this is a cost e.g. milk yield volume charge, which includes the transport cost.

The price-related time inputs include:

1. whether the off-peak or the peak milk price applies for each month, and each herd;
2. the number and proportions of cows in each of the 2 herds for each of the 20 years;
3. the cut off value for each of the 20 years, for differentiating whether the milk is sold at a premium or not, with a premium paid for milk either above or below the cut off. This cut off value may differ from that specified in the breeding model and may be set so milk from a herd receives a premium over the whole year or for some part of it;
4. up to three changes in milk component prices over the 20 years can be allowed for within each of the 8 possible payment groups.

Other inputs include the discount rate and farm size (effective hectares). The production per cow for each of the 24 periods in the year, for each herd, is read in from the cow requirements model.

A macro was designed to carry out the calculations on a year by year basis for each of the 20 years in the model, and to write out the outputs. The year is divided into 24 periods. The calculations run for each year are described below.

The number of cows in a herd is calculated as the total number of cows multiplied by the proportion of cows in that herd. The production of each milk component (milk yield, milkfat, protein and other), for each period and each herd is calculated as:

$$P_{thc} = DP_{thc} \times N_h \times 15.208 \quad \text{Equation 5.18}$$

where:

P_{thc} = the total production of component c, for herd h, in period t;

DP_{thc} = the daily production per cow of component c, for herd h, in period t;

N_h = the number of cows in herd h;

15.208 = the number of days in a period.

The price for each component in each period is read from one of the 8 lookup tables, identified by a user-defined macro. Five variables are specified in the macro to identify the lookup table to read the prices from. These are the herd (1 or 2), a value (0 or 1) identifying whether milk is off-peak or peak in that month, the cut off value, the price of the component on which the milk is segregated for that period, and the trait. Herd and trait are specified, while the other values are read from the input tables. The Excel LOOKUP function then reads the price for that component and year from the appropriate table.

A multiplier is specified for each trait and each herd. The default value is 1. The multiplier enables the price of a component trait in one or both of the herds to be increased or decreased. This can be used in a break-even analysis if required, to identify the minimum price a component (or components) would need to realise before changing to an alternative scenario would be worthwhile.

Using P_{thc} from Equation 5.18, the income associated with each component, within herd and period is calculated as:

$$I_{thc} = P_{thc} \times V_{thc} \times M_{hc} \quad \text{Equation 5.19}$$

where:

I_{thc} = the total milk income from component c, for herd h, in period t;

V_{thc} = the price of component c, for herd h, in period t;

M_{hc} = the multiplier value for component c in herd h.

The annual income for each herd is the sum of the income from all components for all periods in that herd. The Excel SUMIF function determines the income from components in periods where the value of the criterion trait is above, below or equal to, the specified cut off value. Similarly the COUNTIF function counts the periods where the value of the criterion trait is above, below or equal to the specified cut off value (ignoring periods where production is zero). The Excel SUMIF function is also used to determine the quantity of each component where the value of the criterion trait is above, below or equal to, the specified cut off value.

Outputs for each herd are written to the output file after each year's calculations have been run. For each of the herds these include: total income; income from milk above, and below, the cut off value; the number of periods in the year in which milk is above and below the cut off; and the amounts of milk, milkfat, protein, milksolids, and other above and below the cut off value. The total outputs for the farm are then calculated as the sum of the outputs from the two herds. The present value, total and by herd, are calculated for each of the 20 years, and the net present value is calculated for the 20 years.

The present value of the milk income for both herds and the overall total for each year is calculated as:

$$PV_t = \frac{I_t}{(1 + DR)^t} \quad \text{Equation 5.20}$$

where:

PV_t = the present value of the income in year t ;

I_t = the income in year t ;

DR = the discount rate;

t = the year (i.e. 1 to 20).

The net present value is calculated as the sum of the present values for the 20 years.

5.7 DESCRIPTION OF THE OVERALL ECONOMIC MODEL

The overall economic model spreadsheet calculates the difference in the costs and benefits for the "with" minus the "without" change in milk type. The status quo herd is the "without"

scenario, and all cows in this scenario are likely to be in one herd. The "with" scenario may have two herds in all or some years. Income, cow-related variable costs and capital costs are calculated for each of the herds. All other costs are assumed to remain constant between scenarios. A cost-benefit analysis calculates the difference between the "with" and the "without" scenarios, the present value (PV) of the income less costs for each year and the net present value (NPV) over 10 years, 20 years and infinity (20+ years).

Some inputs are read in from the other economic sub-models, while others are entered by the user. Cow numbers, the proportion of cows in herd 1 and stock income (sales less purchases) are read from the stock reconciliation spreadsheet for each scenario. Grazing costs, freight to grazing, cow feed and calf feed costs are read from the feed spreadsheet for each scenario. Milk income is read directly from the milk calculation spreadsheet for each herd. Stock capital values can be read from the stock reconciliation spreadsheet if required.

Wages (total) and contracting costs are entered for each scenario, for each year. The cost per cow for animal health, breeding expenses, herd expenses, shed expenses and power are entered for each herd in each scenario, for each year. The per cow cost for each of these variables in each scenario is the cost per cow in each herd weighted by the proportion of cows in each herd, with the proportion of cows in herd 2 being 1 minus the proportion in herd 1. The total cost associated with these inputs for each year are then calculated as the weighted cost per cow multiplied by the number of cows in that year. The costs for any extra vats, plant and other costs associated with the "with" scenario are entered in the years these costs are incurred. The discount rate is specified. Farm expenses that remain the same between the status quo and associated scenarios are ignored (with minus without equals zero). The outputs are pre-tax, since tax is peculiar to an individual's circumstances. Further, tax considerations alone, should not drive an investment decision to adopt a segregated milk strategy.

The income components for the whole farm are milk and stock income. Variable expenses include wages, contracting, animal health, breeding expenses, herd expenses, shed expenses, electricity, cow and calf feed, grazing and freight. Capital expenses can include vats, plant and others. The "with" minus "without" value for each of these is calculated for each year. The net difference in income (or expenditure) for each year is derived from these parameters with the PV calculated as described in Equation 5.20. The NPV is the sum of the PV's, and is calculated over 10 years, 20 years and infinity (20+). The year 20 value was converted to an annuity (year 20 value divided by the discount rate) and then discounted at this period in time to calculate the NPV to infinity representing the likely net income stream (present values)

from year 21 to infinity. This assumes the difference between the status quo and the scenario in year 20 remains constant beyond year 20 i.e. does not diverge.

If the life of a scheme is limited (e.g. 10 years) salvage values are usually allowed for in the final year. If these relate to capital items their resale value (if any) in the final year is entered in this year. The value of stock-on-hand could also be included if this differed between the scenario and the status quo. This could be calculated as the incremental gain or loss in stock values between the two policies for each year over the period or the total difference in stock values between the policies in the final year. Both would add to the same value, however discounting would affect the associated NPV. As it was assumed the value of the stock in the "with" and "without" scenarios was similar their salvage value was not included.

5.8 MODEL INPUTS

An on-farm cost-benefit analysis was conducted for a quantitative trait and a qualitative trait. The quantitative trait analysis compared the production of "white" milk with the status quo. Cows were segregated into differentiated herds based on milk colour in the "with" change scenario. Assumptions relating to the quantitative breeding model, cow requirements and feeding, and economic model inputs for this comparison are described. Assumptions that differ between the "with" scenario and "without" (or status quo) scenarios are described separately in Section 5.8.6. The qualitative breeding analysis considered breeding BB β -lactoglobulin cows. The output from the qualitative breeding model described in Chapter 3 was used in the comparison. The economic assumptions relating to this model can be found in Section 5.8.6.4.

5.8.1 Quantitative Breeding Model

The herd was assumed to be Friesian cows, which have a less concentrated milkfat colour than Jerseys (Keen and Wilson 1993). The cut-off level considered suitable for making products from white milkfat products was assumed to be 4.5 mg beta-carotene per kilogram of milkfat (MacGibbon 2001, *pers. comm.*). The required cut off value for fat colour in one of the herds for the production of "white milkfat products" is 4.5 mg beta-carotene/kg milkfat (MacGibbon 2001, *pers. comm.*).

The genetic gain per year for each trait for the cows in the initial 10 cow age groups selected under the current industry selection criteria (Lopez-Villalobos 2000, *pers. comm.*) was

calculated using a model developed at Massey University (Lopez-Villalobos *et al.* 2000) (Table 5.2). The gain was assumed to be the same for all years under the status quo scenario.

Age adjustments for fat, milk and protein yield are 0.75, 0.87, 0.95, 1.00, 1.00, 1.00, 1.00, 0.97 and 0.92 of mature cow production for 1st to 9th lactation cows (LIC 1997). There are no age adjustments for fat colour as there was no information on this. Age adjustments for liveweight are 0.8 and 0.92 of mature weight for 2- and 3-year-old cows, estimated from Garcia-Muniz *et al.* (1998), Lopez-Villalobos *et al.* (2000) and LIC (1997-2000). The proportion of cows in each age group is 0.219, 0.183, 0.155, 0.130, 0.105, 0.081, 0.060, 0.041, 0.026 for 2- to 10-year-old cows (LIC 1999; Lopez-Villalobos *et al.* 2000).

Year 1 average herd production is the 5-year average production for Friesians in (LIC 1996-2000). The base year values (oldest cows in year 1) have been calculated allowing for the genetic gains under current industry selection, the year 1 average production, the proportion of cow in each age group and age adjustments (Table 5.2).

The correlation between fat colour and fat yield is -0.09 (Winkelman *et al.* 1999). The correlations between fat yield and the other four traits are given in Table 5.2 (Winkelman *et al.* 1999). Standard deviations are also shown in the Table 5.2 (Winkelman *et al.* 1999).

Table 5.2: Traits and trait parameters used in the quantitative breeding model.

Trait	Selected Trait	Correlated Trait	Trait 1	Trait 2	Trait 3	Liveweight
	Fat Colour	Fat Yield	Milk Yield	Fat Yield	Protein Yield	Liveweight
Genetic Gain/Yr	-0.032	1.5	24.0	1.5	1.8	0.1
Base Year	8.174	170.6	3948	170.6	130.9	506
Year 1 Average	8.000	162.5	3709	162.5	127.8	477
Standard Devn	1.48	22.6	519.5	22.6	16.6	33.2
Correlation		-0.09	0.80	1.00	0.90	0.18

5.8.2 Cow Requirements Model

The parameters for the two sub-herds (the herd meeting the criteria and the one that does not) within the herd are assumed to be the same. The breed for the quantitative breeding model was Friesian i.e. breed=1.

It was assumed there were no effects on milk composition associated with the diet i.e. a special diet which affected milk composition was not fed, therefore the feed multiplier is 1 for

all milk composition traits. The assumptions relating to the energy value of the diet are included in the feed model assumptions (Table 5.6), as are the culling pattern assumptions.

Calving is assumed to start in the first period in August, and the median and final calving days are assumed to be 21 and 100 days from the start of calving respectively. The variance is assumed to be 300 days. This gives a calving pattern similar to those described in Holmes *et al.* (1984, 1996), Massey University (1997, 1998).

The lactation length assumed in predicting the milk composition is 215 days (Table 5.3) and is that associated with the yields assumed in the breeding model (LIC 2000, from the herd testing statistics). However, the actual lactation length in calculating production is assumed to be 37 weeks (LIC 2000, from the industry statistics). Condition scores at four times of the year, used in calculating liveweight changes, are those assumed by Dr Brookes for this model (Table 5.3).

Table 5.3: Condition score at four periods of the year.

	Days after calving	Condition Score
Calving	0	5.0
Peak milk yield	42	4.5
Drying off	215	4.3
Next calving	365	5.0

The "b" and "c" Wood equation values used in predicting milk composition over the lactation for the three breeds are given in Table 5.4 (Wood 1980), although the breed in the colour differentiation comparison is Friesian.

Table 5.4: Wood equation parameter values.

	B	C
Milk Yield		
Friesian	0.2040	-0.0328
Jersey	0.1506	-0.0287
Jersey x Friesian	0.1773	-0.0308
Fat Yield		
Friesian	0.0800	-0.0224
Jersey	0.1190	-0.0229
Jersey x Friesian	0.0995	-0.0227
Protein Yield		
Friesian	0.0741	-0.0219
Jersey	0.0632	-0.0197
Jersey x Friesian	0.0687	-0.0208

Table 5.5 shows the proportion of the first lactation day fat colour value associated with the mid-day in each of the 24 periods in the year, as described in Section 5.2.6. This describes the shape of the fat colour curve.

Table 5.5: The proportion of the day 1 fat colour value associated with the mid-day in each period. Period 1 is the beginning of the lactation.

Period	Friesian	Jersey	F x J	Period	Friesian	Jersey	F x J
1	0.9516	0.9382	0.9449	13	0.4696	0.5195	0.4945
2	0.8500	0.8467	0.8484	14	0.4748	0.5391	0.5070
3	0.7631	0.7671	0.7651	15	0.4823	0.5605	0.5214
4	0.6897	0.6988	0.6943	16	0.4908	0.5834	0.5371
5	0.6290	0.6415	0.6352	17	0.4993	0.6076	0.5535
6	0.5797	0.5946	0.5872	18	0.5068	0.6332	0.5700
7	0.5409	0.5578	0.5493	19	0.5124	0.6602	0.5863
8	0.5115	0.5304	0.5210	20	0.5147	0.6885	0.6016
9	0.4905	0.5121	0.5013	21	0.5130	0.7183	0.6156
10	0.4769	0.5023	0.4896	22	0.5061	0.7495	0.6278
11	0.4695	0.5006	0.4850	23	0.4930	0.7824	0.6377
12	0.4674	0.5065	0.4869	24	0.4726	0.8168	0.6447

5.8.3 Feed Model

Farm size is assumed to be the 93 hectares, the average NZ dairy farm size in 1999/2000 (LIC 2000).

Although the model allows for feeding of hay, purchased silage, crop and other feeds e.g. concentrates it was assumed for simplicity that the diet was pasture and grass silage only, with grass silage made in times of surplus. Pasture growth rates (PGR) shown in Table 5.6 are the net pasture growth rates for Manawatu (Massey University farm) (Lincoln University 1996). These have been multiplied by 1.176 as a utilisation of 85% is assumed, bringing the PGR back to their net values in the calculations. This utilisation value is also used in allowing for some of the losses in silage-making. PGR are assumed to increase by 1% of year 1 values per year, allowing for improvement in management and pasture species. The maximum and minimum covers are shown in Table 5.6 (Gray and Parker 1990).

44640 kg DM from nitrogen applied is available in Spring and 29760 kg DM in Autumn. This equates to 80 kg N/ha (Rogers 2001, *pers. comm.*) at an average response rate of 10 kg DM/kg N applied. This remains constant over the 20 years.

The energy value of the feed is shown in Table 5.6. This is based on a pasture and grass silage diet and as such, is the energy value of the pasture, as assumed by Dr Brookes for this model. These values are high, but reflect the high standard of management that is assumed.

It is assumed all cows are wintered on-farm. All replacements are grazed off, with heifers brought back to the farm at the end of June, a month before calving starts. The culling factor (Table 5.6) is the proportion of cows at opening (stock reconciliation values at 1 July) on-farm over time (Gray and Parker 1990).

Costs and prices associated with this model will be discussed under the economic model.

Table 5.6: Pasture values used in the Feed Model.

MONTH	PGR (kg DM/ha/d)	MAXIMUM COVER	MINIMUM COVER	MJME/ Kg DM	CULLING FACTOR
JULY (1)	23.5	2500	1500	11.3	1.00
JULY (2)	23.5	2500	1500	11.4	1.00
AUG (1)	35.3	2500	1800	11.4	1.00
AUG (2)	35.3	2500	1800	11.4	1.00
SEP (1)	52.9	3500	1800	11.3	0.98
SEP (2)	52.9	3500	1800	11.3	0.98
OCT (1)	70.6	3500	1800	11.2	0.96
OCT (2)	70.6	3500	1800	11.2	0.96
NOV (1)	76.5	2000	1800	11.1	0.96
NOV (2)	76.5	2000	1800	11.1	0.96
DEC (1)	52.9	2500	1800	11.0	0.96
DEC (2)	52.9	2500	1800	11.0	0.96
JAN (1)	41.2	2500	1500	10.9	0.96
JAN (2)	41.2	2500	1500	10.9	0.96
FEB (1)	35.3	2500	1500	10.8	0.96
FEB (2)	35.3	2500	1500	10.8	0.96
MARCH (1)	23.5	2500	1500	10.9	0.90
MARCH (2)	23.5	2500	1500	10.9	0.90
APRIL (1)	35.3	2500	1500	11.0	0.90
APRIL (2)	35.3	2500	1500	11.1	0.90
MAY (1)	29.4	2500	1500	11.1	0.78
MAY (2)	29.4	2500	1500	11.2	0.78
JUNE (1)	29.4	2500	1500	11.2	0.78
JUNE (2)	29.4	2500	1500	11.3	0.78

5.8.4 Stock Reconciliation Model

A 97% calving percentage is assumed. The number of heifer calves retained is calculated to ensure sufficient replacements to maintain herd structure allowing for culls and deaths as specified (Table 5.7). The number of cull cow sales is automatically adjusted and is slightly higher than the culling percentage specified to maintain herd structure.

Costs and prices associated with this model will be discussed under the economic model.

Table 5.7: Herd structure, losses and culls percentages.

Stock Class	Herd Structure	Losses %	Culls %
Heifer Calves		11.0%	
R 1 year heifers		2.0%	10.0%
R 2 year heifers	22.0%	5.0%	15.0%
MA cows	78.0%	5.0%	15.0%
Bull Calves		6.0%	
R 1 year Bulls		2.0%	
Bulls	2.0%	2.0%	50.0%

5.8.5 Economic Model

5.8.5.1 Feed Model

Grass silage and nitrogen are the only feed costs in the base model. These costs are assumed to be \$0.10/kgDM for making grass silage and \$0.80/kgN applied for nitrogen (Lincoln University 1996; Massey University 1997, 1998; Lincoln University 2000).

5.8.5.2 Stock Reconciliation Model

Grazing costs for calves are assumed to be \$3.00/head/week for calves and \$5.00/head/week for heifers (Lincoln University 2000). Freight is assumed to be \$6.00/head for calves to grazing and \$8.50/head for heifers from grazing back to the farm. Calf rearing costs are assumed to be \$100/calf (Lincoln University 2000).

National average market values (1999) are used for calculating the capital value of the stock (Lincoln University 2000). These are \$314 for rising one-year heifers, \$647 for rising two-year heifers, \$769 for mixed-age cows and \$863 for breeding bulls. These values may be higher for a specialist herd and where this has been assumed it has been stated in the assumptions for that model run.

Sales prices are estimated based on a range of sources including Lincoln University (1996), Massey University (1997, 1998) and Lincoln University (1996-2000). Where available prices are based on the last 5 years and actual farm data. The livestock sales and purchases are a small part of dairy farm income, and in comparing two systems the "with" minus "without" situation will only differ if the stocking rate is different. Differences in stocking rate were assumed to be small. Therefore sensitivity to these prices is not likely to be great, and they are considered to be of little consequence to the analyses.

Sale prices assumed are (stock class at opening, but may in next stock class at sale):

Calves \$40

Rising-1 year heifers \$370

Rising-2 year heifers and MA cows \$410

Bulls \$800

Purchase prices assumed are:

Rising-1 year heifers \$645

Bulls \$1000

5.8.5.3 Milk Model

The base milk price assumed was the average New Zealand Dairy Company (NZDG) for three seasons (Table 5.8) (Moss 2001, *pers. comm.*). This price was assumed to remain the same for peak and off-peak milk, unless otherwise stated.

Table 5.8: Milk component prices for 3 years.

Year	Milkfat	Protein	Milk
1999/2000	\$2.6149	\$5.5635	-\$0.0415
2000/2001	\$2.7317	\$5.9384	-\$0.0435
2001/2002	\$3.3366	\$7.2209	-\$0.0396
Average	\$2.89440	\$6.24092	-\$0.04153

The required cut off value for fat colour in the herd producing differentiated milk for the production of "white milkfat products" is the same as in the breeding model i.e. 4.5 mg beta-carotene/kg milkfat (MacGibbon 2001, *pers. comm.*). In early lactation when milk is more yellow, it will exceed this value and will not be able to be used for "white" products. However in later lactation, milk may be "whiter" than the cut-off, and may therefore be diluted with yellow milk and still meet the criteria.

5.8.5.4 Economic Model

Cow numbers and the proportion of cows in Herd 1, milk income, sales less purchases income, stock capital values, grazing costs and freight to grazing, and cow and calf feed costs are read in from the other spreadsheet sub-models for the "with" and "without" (status quo) scenarios.

Values for the other variable costs (Table 5.9) are those for the MAF farm monitoring national dairy budget 2000/2001 forecast (MAF 2000). These costs are assumed to be the

same for the "status quo" herd and both herds in the "with" scenario unless stated otherwise. All other costs are assumed to remain the same between scenarios so are not included as will not impact on the net present value (NPV). Costs remain the same for all years at year 1 values.

Table 5.9: Variable costs used in the Economic Model.

	Cost
Total Costs (\$)	
Wages and ACC	23242
Contracting	0
Per cow costs (\$)	
Animal Health	44.93
Breeding expenses	25.00
Herd testing expenses	10.00
Dairy expenses	15.07
Power	24.76

The discount rate is assumed to be 7%.

5.8.6 Assumptions that differ in the with and without scenario

Assumptions that differ between the "with" scenario and the "without" (or status quo) scenario are described here.

5.8.6.1 *Quantitative breeding model*

The status quo model assumed genetic gain under current industry selection as described in Section 5.8.1. Four scenarios with selection on fat colour were compared. Genetic gains were based on a small breeding scheme model (Lopez-Villalobos 2000, *pers. comm.*). The selection pressure and the genetic gain associated with each of the traits for two of the scenarios, and for the status quo, are shown in Table 5.10. The status quo scenario is included for comparison. The third scenario is similar to that for scenario 1, but the herd is assumed to have low milk colour in year 1 (i.e. 6.0 mg beta-carotene/kg milkfat compared to 8.0 mg beta-carotene/kg milkfat). The fourth scenario is the same as Scenario 1 for the first 10 years, then reverts back to status quo values for the remaining 10 years. The gain for the first 10 years (the base herd) in all four scenarios is that for the status quo.

Table 5.10: Weightings and genetic gains used in the quantitative breeding model.

	Fat Colour	Fat Yield	Milk Yield	Protein Yield	Liveweight
Scenario 1					
Selection weighting	-1	0	0	0	0
Genetic Gain/Year	-0.265	0.6	-8.0	0.06	-0.03
Scenario 2					
Selection weighting	-10	1	0	0	0
Genetic Gain/Year	-0.216	1.8	13.4	0.67	0.81
Status Quo					
Selection weighting	0	0.80	-0.047	3.35	-0.47
Genetic Gain/Year	-0.032	1.5	24.0	1.8	0.1

5.8.6.2 *Qualitative breeding model*

Two scenarios were compared, both requiring the testing of cows for genotype and the use of BB bulls (nominated sires). In the first scenario all cows in the herd were tested in year 1 and the whole herd changed to BB genotype over time through breeding. In the second scenario it was assumed that cows in herds of similar genetic merit and production were also tested and cows were brought and sold in year 1 so that the initial herd was all BB genotype. The status quo assumed that the frequency of the B allele remained constant in the herd.

5.8.6.3 *Economic model - Quantitative trait*

Milk from the "white" milk production herd was purchased at standard status quo milk prices when the colour criterion was exceeded (Section 5.8.5.3). A premium was received on the milkfat at those times when the milk met the colour criterion, as it is the whiteness of the milkfat that allows higher value products to be produced. The extra price per kilogram of milkfat was specified. As well as the premium on milkfat, a further premium is allowed for milk that is below the specified colour, based on the amount of milkfat and the beta-carotene concentration. For every unit of beta-carotene concentration below the specified value, the premium value divided by 3.5 (the difference between the average beta-carotene concentration (8.0) and the criterion beta-carotene concentration (4.5)), is paid for every kilogram of milkfat of that concentration. This allows low colour milkfat to be diluted with more "yellow" milk to give a greater volume of milkfat that meets the criterion. For example, if the milkfat premium is \$1.00/kg milkfat, and the beta-carotene concentration is 3.5 mg beta-carotene/kg milkfat (1 mg below the criterion), an extra \$0.286/kg milkfat is paid as 0.78 kg of milkfat can be made up to one kilogram by adding 0.22 kg of 8.0 mg beta-carotene/kg milkfat (which has no premium on it). This creates an incentive for farmers to produce at below criterion values, while holding the adjusted milkfat volume premium at \$1.00/kg milkfat for 4.5 mg beta-carotene/kg milkfat. In the fourth scenario, the premium price was

applied for the first 10 years then all milk reverted to standard milk (i.e. light coloured milk was no longer considered more valuable) at status quo prices.

The protein price received for differentiated milk was the same as for the status quo milk at all times i.e. colour is unlikely to affect protein products. The milk volume charge¹ for differentiated ("white" milk) was assumed to be 1 cent/litre more than the standard charge, to allow for extra transport costs (Chapter 4).

Herd testing, and breeding costs were assumed to be higher in the differentiated milk scenarios for both herds. Breeding costs were assumed to be \$5 per cow more than the status quo cost (the difference between premier sires and nominated sire services) (Ramshaw 2001, *pers. comm.*). Herd testing was assumed to cost \$2 more per cow, allowing for another herd testing trait (colour) to be measured.

The cost of installing an extra milk vat on the farm in year 1 in the "with" scenarios was assumed to be \$5000 (Johnston 2001, *pers. comm.*). The salvage value associated with the vat purchased was considered to be negligible in years 10 and 20, and was assumed to be zero. If, after 10 years the vat was valued at \$1500, assuming 7% straight line depreciation (Lincoln University 2000) the discounted value would be \$763, which has little or no impact on the premium required. Alternatively, it could be valued as scrap metal. Salvage value by year 20 was zero. In some scenarios by year 10 and in most scenarios by year 20, all milk was the differentiated type and vat requirements would be similar to the status quo (because of similar milk production).

The salvage value of the cows is only relevant if the scheme has a limited life i.e. the life of the investment if differentiated milk is no longer required, as represented by the 10 and 20 year time periods. In the calculation to infinity the value of the cows is represented by their potential production and therefore no salvage value is used. The number of cows differs between the status quo and some scenarios. This difference in cow numbers was because the cows at the higher stocking rate had lower per cow production. If differentiated milk is no longer required, the cows bred for differentiated milk will have a lower breeding worth based on a standard index than the status quo cows (which is the relevant one to use if valuing the cows after obsolescence), and therefore the value per cow will be less. It is assumed that this difference in value between the status quo and the scenario cows will be similar to the

¹ There may have been an over-estimation in the transport charge. See Appendix 4: Note on transport related costs.

difference in potential production. Therefore, the value of the status quo and scenario herds at the end of the scheme will be similar, and hence the salvage value for the two herds was assumed to be the same. The difference in salvage value required for the two herds for this to be equal is considered in the results.

The premium that was required for milkfat to give a NPV of zero over a 10-year period, a 20-year period and infinity (20+) was determined. It is assumed that the farmer will be indifferent to the choice of scenario at the breakeven NPV.

5.8.6.4 *Economic model - Qualitative trait*

Milk from the AA and AB genotype cow herd was purchased at status quo milk prices. The extra price per kilogram of milksolids (milkfat and protein) for the BB cow herd can be altered by changing the multiplier value for milkfat and protein, thus altering the status quo price of these components by the multiplier for milk from this herd. To maintain relativity, the same multiplier value was used for milkfat and protein.

As for the quantitative (white milk) model, the milk volume charge¹ for the differentiated milk (from the BB herd) was assumed to be 1 cent/litre more than the standard charge, to allow for extra transport costs (Chapter 4).

Breeding costs were assumed to be \$5 per cow more than the status quo cost for both herds in the differentiated milk scenarios allowing for the use of nominated sire services. An extra milk vat was installed on the farm in year 1 in the "with" scenarios at a cost of \$5000 (Johnston 2001, *pers. comm.*). In year 1 the whole herd was tested to identify genotype at a cost of \$20.00 per test for genotyping (A2 Corporation 2001) and \$4.50 for blood sampling per cow (Lincoln University 2000), with 1.25 blood tests taken per cow to allow for the cost of testing the cows and replacements. Each year that there were insufficient heifer replacements from the BB cows, the heifer progeny of the AB cows were tested to identify their BB calves at the same cost i.e. \$24.50 per calf.

The second scenario allowed for non-BB cows in the herd to be replaced by BB cows. As 46.8% of the herd are BB, the remaining 53.2% will need to be replaced. This proportion of the cows (MA cows and rising 2-year old heifers) and rising 1-year old heifers in the herd was replaced. A premium of \$200 for cows and \$150 for heifers was paid for those purchased compared to those sold (or exchanged) in order to acquire BB animals of similar breed and genetic merit. As well as testing the animals in the herd, 2.14 cows or heifers in outside herds (1/0.468) were tested for genotype for each cow or heifer replaced. All potential replacement

heifer calves were assumed to be tested for genotype in year 1 to ensure those retained were BB.

As described for the quantitative model, the salvage value of the vat over a 10 and 20 year period was assumed to be zero. The number of cows was the same, and the production per cow very similar, for the status quo and the scenarios, therefore the salvage value of the cows in the herds was the same. The premium required on milkfat and protein to give a NPV of zero over a 10-year period, a 20-year period and infinity (20+) was determined.

CHAPTER SIX

MODEL RESULTS

6.1 QUANTITATIVE TRAIT

The premium required for milkfat over and above the \$2.894/kg paid in the status quo scenario to give a net present value (NPV) of zero at a discount rate of 7% for alternative milk colour segregation strategies is shown in Table 6.1. This premium is paid on milkfat that is below the milkfat colour criterion while the status quo price is paid for milkfat above this criterion. Where the milkfat beta-carotene yield is less than 4.5 mg/kg milkfat (criterion value), an additional 28.6% of the premium value (the premium divided by 3.5) is also paid per kilogram for each one mg increment in colour below 4.5 mg/kg milkfat.

Table 6.1: Premium required per kilogram of milkfat for each scenario for the NPV to equal zero over periods of 10, 20 and 20+ years. The total milkfat price and percentage increase in milkfat price required compared to the status quo (SQ) are also shown in row 2.

Scenario (Quantitative)	10 years	20 years	20+ years
No. 1: Selection on colour only, initial colour 8.0	\$2.08 \$4.97 (71.9%)	\$1.11 \$4.00 (38.4%)	\$0.92 \$3.81 (31.8%)
No. 2: Selection on colour and milkfat yield, initial colour 8.0	\$2.10 \$4.99 (72.6%)	\$1.08 \$3.97 (37.3%)	\$0.87 \$3.76 (30.1%)
No. 3: Selection on colour only as for No. 1, but with initial colour 6.0	\$0.41 \$3.30 (14.2%)	\$0.46 \$3.35 (15.9%)	\$0.47 \$3.36 (16.2%)
No. 4: As for No. 1 for first 10 years, then reverting to SQ for genetic gain and prices received.	\$2.08 \$4.97 (71.9%)	\$5.62 \$8.51 (194.2%)	\$9.66 \$12.55 (333.8%)

The milkfat premium that is required for NPV to equal zero at a 7% discount rate is similar for scenarios 1 and 2 (\$2.08 and \$2.10 per kilogram, or a milkfat price of \$4.97 and \$4.99 per kilogram, respectively). The premium is considerably lower for scenario 3, where the initial colour is lower, than it is for the other scenarios. If the premium paid for scenario 3 milk was that for scenario 1 milk where NPV was zero, the NPV for scenario 3 would be \$291,107,

\$289,254 and \$375,440 for 10, 20 and 20+ years, respectively. As expected, the premium required for scenario 4, for 20 years and 20+ years, is high compared to scenario 1 because a premium is only paid on the low volumes of white milk produced in the first 10 years. This premium has to be high enough to compensate for the loss of production and extra per cow costs incurred through lost genetic gain, not only in these years but in the later years as there will be a long lag phase before the scenario production and cow number come close to the status quo.

The income and expenses associated with a NPV of zero for the four scenarios and three time periods are presented in Table 6.2. The net income is the closest NPV to zero at a premium rounded to the nearest cent (two decimal places)

Table 6.2: The discounted difference (\$) between each quantitative trait scenario for milk colour and the status quo in milk income, sales and purchases income (S&P), farm working expenses (FWE), capital expenses (CE) and net income total for the period specified, where NPV for the period equals zero (or the closest premium value to 2 decimal places).

	10 years	20 years	20+ years
Scenario 1			
Milk	22800	40401	64845
S&P	-599	-374	782
FWE	17509	35692	59215
CE	4673	4673	4673
Net Income	19	-338	1740
Scenario 2			
Milk	19877	29273	44271
S&P	-208	-515	-4293
FEW	14837	23805	33326
CE	4673	4673	4673
Net Income	159	280	1980
Scenario 3			
Milk	22902	41149	66461
S&P	-599	-374	782
FEW	17509	35693	59215
CE	4673	4673	4673
Net Income	121	410	3355
Scenario 4			
Milk	22801	31180	38932
S&P	-599	-80	3026
FEW	17509	26330	37130
CE	4673	4673	4673
Net Income	20	97	155

Capital expenditure of \$4673 for all the scenarios (Table 6.2) is the cost of another milk vat in year 1. Extra breeding and herd testing expenses are included in the farm working expenses. Farm working expenses also vary due to the differences between the status quo and the scenarios in cow numbers i.e. per cow expenses such as animal health, shed, power, freight and some feed expenses. The financial impact of carrying extra cows on the farm can be seen by comparing scenarios 1 and 3, both of which resulted in more cows being milked, with scenarios 2 and 4 (Tables 6.2 and 6.3). This had a relatively small impact on the difference in net income from sales and purchases. The change over time for all scenarios and time frames in income, expenses and present value is shown in Appendix Tables A5.22 to A5.27.

Figure 6.1 compares the NPV over a range of premium milkfat values for three quantitative scenarios. Once NPV is greater than or equal to zero, Scenario 3, in which more milk meets the criterion over time has a higher NPV over all three time frames, followed by scenario 1 then scenario 2. For all three scenarios the slope is greatest for 20+ years, followed by 20 years then 10 years i.e. total extra costs are greater for 20+ years giving the greatest negative value at a premium of zero: conversely, the greater amount of white milk over the time will give the highest total income at higher premiums.

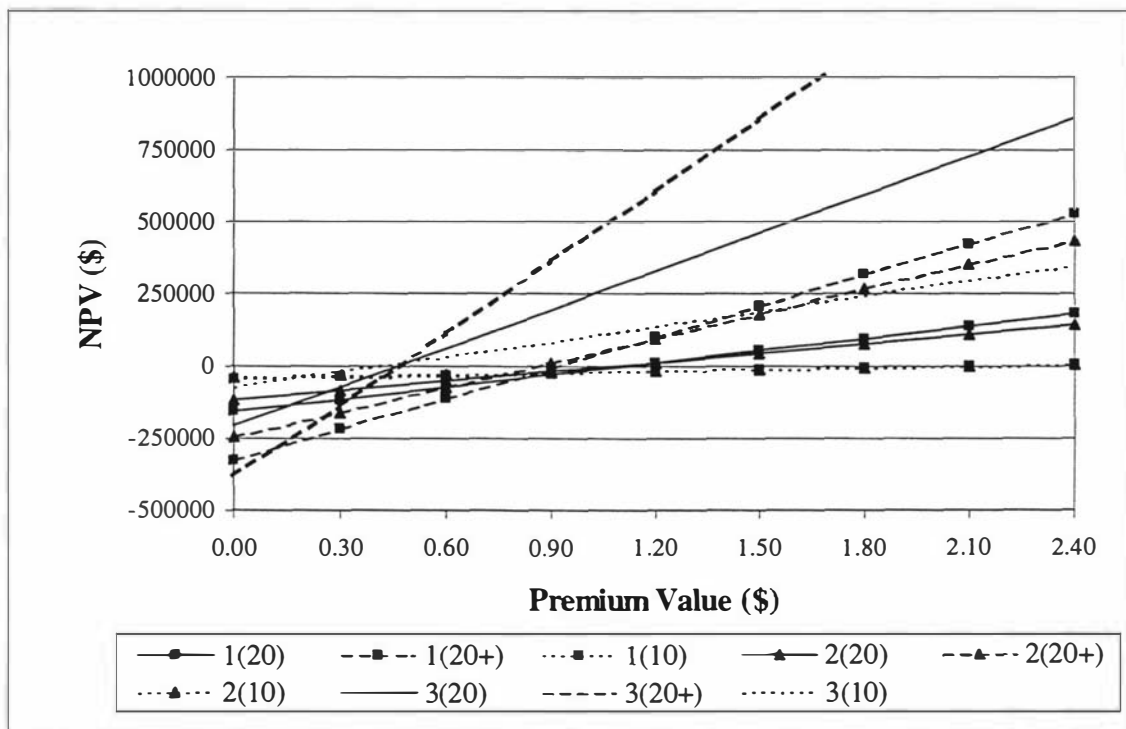


Figure 6.1: Net present value at a range of milkfat premium values for three scenarios (1, 2 or 3) over 20 (20), 20+ (20+) and 10 (10) years at a discount rate of 7%.

Figure 6.2 shows the percentage of milk attracting a premium over the 20 years for quantitative scenarios 1 to 3 (i.e. the white milk below the criterion in herd 1, Appendix Tables A5.16 to A5.18), and qualitative scenario 1 (see next section and Appendix Table A5.32). The fourth quantitative scenario is not included on Figure 6.2, however it is the same as scenario 1 for the first 10 years after which no milk attracts a premium (Appendix Table A5.19). All milk attracts a premium in the second qualitative scenario (Appendix Table A5.36). The curve flattens where the reason for the increase in the proportion of milk changes from an increasing number of cows with suitable milk entering the differentiated milk herd, to the differentiated milk being suitable for white milk products for more periods within a lactation. This change occurs when about 66% of the milk is suitable for white milk products. For example, in quantitative scenario 3 all milk that is sold is produced by the differentiated herd in year 11 and this is suitable for white products for 7 months. In year 12 the milk continues to remain suitable for white products for 7 months, therefore there is little increase in the proportion of milk attracting a premium (flat part of the curve). In year 13 the milk is now suitable for white products for 7.5 months reflecting the whiter colour on average of the new herd replacements, therefore the proportion attracting a premium increases again.

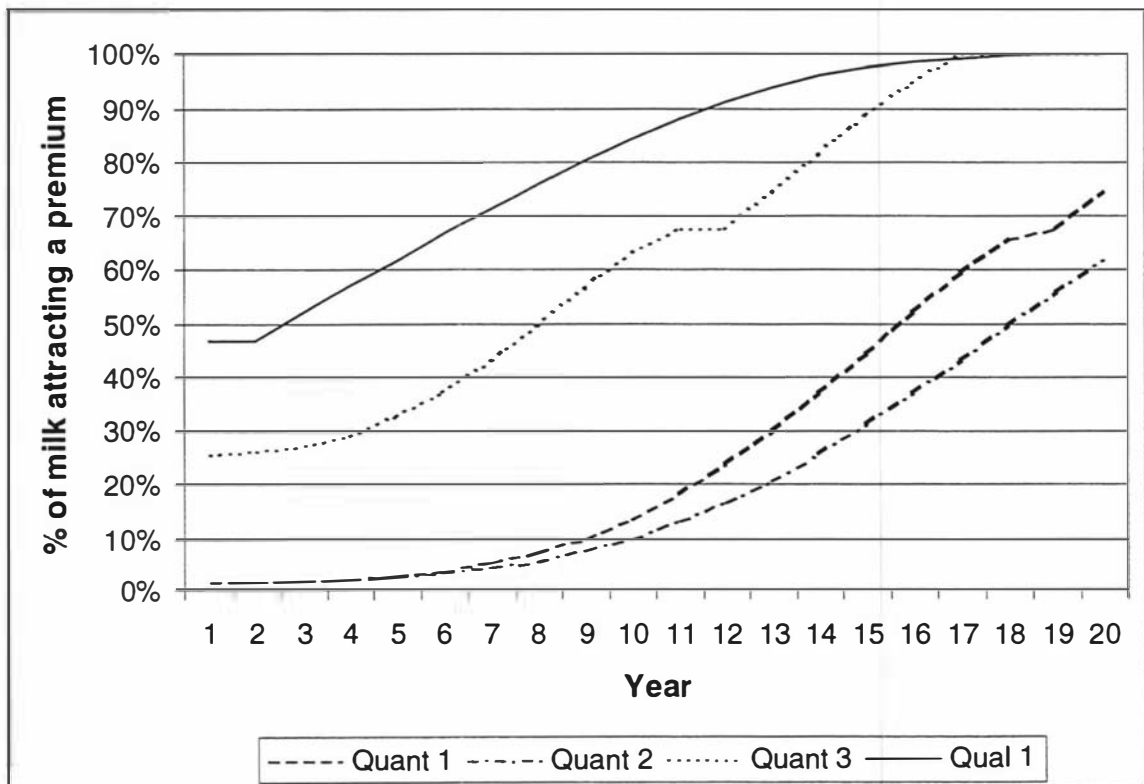


Figure 6.2: The percentage of milk attracting a premium over the 20 years for 3 quantitative scenarios and the first qualitative scenario.

The percentage of milk income from the differentiated herd (Appendix Table A5.20) is slightly higher than the percentage of milk attracting a premium (Figure 6.2) (up to 4% more for NPV=0 over 20 years) because of the higher price for this milk, with the exception of scenario 4 where the percentage of income is greater (up to 10% more) because of the very high premium.

Changes in cow numbers, and milksolids and milkfat production per cow and per hectare over the 20 years, and between the status quo and the other scenarios in year 20, are compared in Table 6.3. In year 1 all herds had 293 cows. Similarly, the milksolids production in year 1 for all options is 317.6 kg/cow and 1001 kg/hectare, with a protein to fat ratio of 0.7867. The milkfat production is 177.8 kg/cow and 560 kg/hectare in year 1.

Table 6.3: Cow numbers, and milksolids and milkfat production per cow and per hectare for year 20, and the percentage change in these attributes over the 20 years and between the status quo (SQ) and the other scenarios. See Appendix Tables A5.1 to A5.15 for an annual breakdown of changes in these attributes. Note: Scenario 3 is the same as scenario 1.

	SQ	Scenario 1	Scenario 2	Scenario 4
Cow Number				
Cow Number in Yr 20	319	336	320	331
Diff. over 20 yrs	+8.87%	+14.67%	+9.22%	+12.97%
Diff. from SQ in Yr 20		+5.33%	+0.31%	+3.76%
Milksolids (MS)				
Production/cow				
Kg MS cow in Yr 20	380.0	342.6	368.18	353.8
Diff. over 20 yrs	+19.65%	+7.87%	+15.93%	+11.40%
Diff. from SQ in Yr 20		-9.84%	-3.11%	-6.89%
Production/hectare				
Kg MS/ha in Yr 20	1304	1238	1267	1259
Diff. over 20 yrs	+30.27%	+23.68%	+26.57%	+25.77%
Diff. from SQ in Yr 20		-5.06%	-2.84%	-3.45%
Milkfat (MF)				
Production/cow				
Kg MF cow in Yr 20	206.1	193.4	210.4	197.2
Diff. over 20 yrs	+15.92%	+8.77%	+18.32%	+10.91%
Diff. from SQ in Yr 20		-6.16%	+2.09%	-4.32%
Production/hectare				
Kg MF/ha in Yr 20	707	699	724	702
Diff. over 20 yrs	+26.26%	+24.82%	+29.29%	+25.36%
Diff. from SQ in Yr 20		-1.13%	+2.40%	-0.70%
Protein:Fat ratio in Yr 20	.8437	.7716	.7503	.7942

Per cow production increased for all scenarios over time, but at a slower rate over time than for the status quo. The largest increase in herd size by year 20 (+17 cows) relative to the status quo in year 20 occurred where the smallest gains in production were achieved. However, the additional cows did not completely offset the lower per cow MS production, and the MS production per hectare was lowest where MS production per cow was lowest and stocking rate was greatest. The lowest MS production per hectare at year 20 occurred where herd replacement selection was entirely based on colour. The percentage change in production per farm will be the same as that per hectare.

Milkfat production decreased at a lesser rate compared to the status quo than milksolids production, and increased slightly per cow and per hectare compared to the status quo for scenario 2. The protein:milkfat ratio changed over the 20 years according to the breeding objective. The protein:milkfat ratio is greatest for the status quo scenario (0.8437) and lowest in scenario 2 (0.7502) where selection of replacements is based on colour and milkfat production. The protein:milkfat ratio decreased over the 20 years for scenarios 1 and 3 (from 0.7867 in year 1 to 0.7716 in year 20), whereas it increased to 0.8437 in the status quo scenario (Table 6.3 and Appendix Table A5.42).

The decreasing protein:milkfat ratio in the scenarios compared to the status quo means returns per kilogram of milksolids for the scenarios at status quo prices are lower than for the status quo i.e. 4.6 to 9.6 cents per kilogram of milksolids lower (Appendix Table A5.42). The increase in the milkfat returns is insufficient to compensate for the decrease in protein returns giving a net decrease in dollars received per kilogram milksolids. While the scenario milk is slightly more concentrated than the status quo milk, resulting in lower volume charges this difference is very small i.e. about 0.1 cents per kilogram milksolids (Appendix Table A5.42).

The difference in farm milk income between the status quo and the quantitative scenarios at status quo prices in year 20 is \$32,521, \$24,638 and \$21,993 less for scenarios 1, 2 and 4, respectively (Appendix Table A5.42). Most of this difference is due to the difference in production between the scenarios and the status quo. However, if it is assumed that the scenarios had the same milksolids production as the status quo these differences would be \$8,815, \$11,595 and \$5,971 less for scenarios 1, 2 and 4, respectively, largely because of the lower protein:milkfat ratios.

If the same salvage values used to value status quo stock, were used to value the stock in the four scenarios at the end of years 10 and 20, the net discounted salvage value would be positive because of greater cow numbers (Table 6.4). Table 6.4 also shows the reduction in

values required for the scenario stock to be valued at the same as the status quo (net salvage value equals zero). For comparison, the production of the scenario cows, as a proportion of status quo values is also included.

Table 6.4: The net discounted salvage value of the stock, the percentage of salvage values required for the net discounted salvage value to be zero, and milksolids production of scenario cows as a percentage of status quo (SQ) cows, for the four scenarios at the end of 10 and 20 years.

10 years	Quan 1	Quan 2	Quan 3	Quan 4
Discounted value (\$)	1242	199	1242	1242
Reduction in value (%)	98.2	99.7	98.2	98.2
MS per ha (% of SQ)	96.8	99.0	96.8	96.8
MS per cow (% of SQ)	98.3	99.0	98.3	98.3
20 years				
Discounted value (\$)	4247	447	4247	2757
Reduction in value (%)	94.2	99.4	94.2	96.2
MS per ha (% of SQ)	94.9	97.1	94.9	96.5
MS per cow (% of SQ)	90.2	96.9	90.2	93.1

6.2 QUALITATIVE TRAIT

Changes in cow numbers, and milksolids production per cow and per hectare over the 20 years are compared in Table 6.5. The initial cow number for all scenarios is 329. The milksolids production in year 1 for the status quo and scenario 1 is 307.4 kg/cow (307.2 kg/cow for scenario 2), and 1087 kg/hectare (all scenarios), with a protein to fat ratio of 0.7557 (0.7502 for scenario 2). At year 20 there is very little difference in production between the status quo and the scenarios, and no difference in cow numbers.

A 3.2% to 4.8% increase in the milkfat and protein price for scenario 1 and scenario 2, respectively, would be required for differentiated milk, for NPV to equal zero (Table 6.6). The multiplier value can be interpreted in percentage terms i.e. 1.048 equates to an extra 4.8%. The milksolids value changes over the 20 years as the protein:milkfat ratio alters, and the figures given in Table 6.6 are based on the year 10 protein:milkfat ratio (0.7952 for the status quo, 0.7907 for scenario 1 and 0.7893 for scenario 2). The milksolids value for year 20 at status quo prices is \$4.003/kilogram for both scenarios, compared to \$4.007/kilogram for the status quo i.e. there is very little difference (Appendix Table A5.42).

Table 6.5: Cow numbers, and milksolids production per cow and per hectare at year 20, and the percentage change in these attributes over the 20 years. See Appendices A5.28 to A5.36 for an annual breakdown of changes to these parameters.

	SQ	Scenario 1¹	Scenario 2²
Cow Number			
Cow Number in Yr 20	348	348	348
Diff. Over 20 yrs	+5.77%	+5.77%	+5.77%
Milksolids (MS)			
Production/cow			
Kg MS cow in Yr 20	383.2	382.9	382.9
Diff. Over 20 yrs	+24.66%	+24.56%	+24.64%
Production/hectare			
Kg MS/ha in Yr 20	1434	1433	1433
Diff. Over 20 yrs	+31.92%	+31.83%	+31.83%
Protein:milkfat ratio in Yr 20	0.8319	0.8258	0.8258

¹ Scenario 1 = changing to all BB cows over time by testing and selection.

² Scenario 2 = all cows BB in year 1 (buying and selling).

Table 6.6: The multiplier and milkfat, protein and milksolids values required for the differentiated milk in each scenario for the NPV to equal zero over periods of 10, 20 and 20+ years. Milksolids price inclusive of volume charges (above) and exclusive of volume charges (below) are given. The difference between the scenario and the status quo milksolids value is shown in brackets (in cents per kg).

Scenario	Multiplier	Milkfat value	Protein value	Milksolids value
Status Quo	1.00	2.894	6.241	3.959 4.377
10 years				
No. 1: To BB herd over time	1.039	3.007 (11.3)	6.484 (24.3)	4.026 (6.7) 4.542 (16.5)
No. 2: Herd all BB cows in year 1	1.048	3.033 (13.9)	6.540 (30.0)	4.064 (10.5) 4.580 (20.3)
20 years				
No. 1: To BB herd over time	1.034	2.993 (9.8)	6.453 (21.2)	4.004 (4.5) 4.520 (14.3)
No. 2: Herd all BB cows in year 1	1.041	3.013 (11.9)	6.497 (25.6)	4.033 (7.4) 4.550 (17.3)
20+ years				
No. 1: To BB herd over time	1.032	2.987 (9.3)	6.441 (20.0)	3.995 (3.6) 4.511 (13.4)
No. 2: Herd all BB cows in year 1	1.037	3.001 (10.7)	6.472 (23.1)	4.016 (5.7) 4.532 (15.5)

The milksolids payment required has been presented both inclusive and exclusive of volume charges deducted. Milksolids payments inclusive of volume charges deducted do not fully reflect the difference required in the milkfat and protein payments to cover the full costs, including extra transport costs, associated with differentiated milk. This is because transport charges can differ between the status quo and the scenarios, and the extra milkfat and protein income required has to be sufficient to cover this differential as well as other associated costs. For both scenarios, over all time frames, the extra cost required for milk transport makes up a greater proportion of the extra payment required. For example, for scenario 1 over 20 years an extra 14.3c/kg MS (excluding volume costs) is required between the status quo and the scenario to break even. After deducting transport from each scenario the difference drops to 4.5c/kg MS (31.5% of the difference). The remaining 9.8c/kg MS (68.5%) is associated with extra transport costs. This makes comparisons using milksolids less useful where extra income or costs are associated differently with the components of the milk payment system.

The premium that is required for NPV to equal zero is lower for scenario 1 than scenario 2 for all time periods e.g. 13.4 cents/kgMS for scenario 1 compared to 15.5 cents/kg MS for scenario 2 over 20+ years. Scenario 1 has a lower investment cost associated with changing to differentiated milk (Table 6.7), some of which is spread over the first few years and discounted. In contrast, all costs associated with the change in scenario 2 occur in year 1. As the length of the discounted periods increases, the required increase in payments for NPV to equal zero decreases because the present values are negative in the early years, or in year 1 only for scenario 2 (Appendix Tables A5.37 to A5.39). Hence the longer discounted periods have more positive present values to counter the negative year(s) e.g. 20.3 cents/kgMS for 10 years compared to 15.5 cents/kg MS over 20+ years for scenario 2.

The discounted difference between the qualitative scenarios and the status quo in milk income, net sales and purchases income, farm working expenses and initial investment expenses where NPV equals zero (or the closest multiplier to three decimal places) is shown in Table 6.7 for the three discounting periods. The change over time for all scenarios and time frames in income, expenses and present value is shown in Appendix Tables A5.37 to A5.39.

Farm working expenses for both scenarios consist of extra breeding expenses (for nominated sire service) as well as some per cow costs because of a difference in cow numbers in a few years. Cow numbers are similar for the status quo and the other scenarios, and hence the differences in the other per cow expenses are minimal. The investment expenditure associated with changing to BB milk production for both the qualitative scenarios is greater than that for

the quantitative scenarios, as it includes genotyping of cows. As for the quantitative scenarios, the capital cost of another milk vat in year 1 is included (\$5,000, not discounted). There is also an \$11,028 transition cost for scenario 1 for genotyping cows, heifers and calves in year 1. These costs reduce in years 2 to 12 to less than \$1,000 per year, decreasing over time, as fewer calves require testing. Investment expenditure for scenario 2 all occurs in year 1 and is very high. It includes genotype testing of all cows and young stock in the herd (\$12,206, not discounted), testing of potential replacement cows and heifers (\$11,447) and the extra \$200 per cow and \$150 per heifer paid for BB replacements over and above what is received for their AA or AB counterparts (\$41,550). If cow trading costs in scenario 2 were halved to \$100 per cow and \$75 per heifer an extra 4.3%, 3.7% and 3.4% would need to be paid for milkfat and protein for NPV to equal zero for 10, 20 and 20+ years, respectively (compared to 4.8%, 4.1% and 3.7%).

Table 6.7: The discounted difference (\$) between the qualitative scenarios and the status quo in milk income, sales and purchases income (S&P), farm working expenses (FWE), investment expenses (IE) and net income total for the period specified, where NPV for the period equals zero (or the closest multiplier value to 3 decimal places).

	10 years	20 years	20+ years
Scenario 1			
Milk	31558	40271	48952
S&P	409	342	342
FEW	12080	18258	24243
IE	19505	19762	19762
Net Income	382	2592	5289
Scenario 2			
Milk	77556	87821	93487
S&P	448	382	382
FEW	12215	18396	24380
IE	65675	65675	65675
Net Income	114	4133	3814

The two scenarios converge for all three time periods where just over 6% more is paid for milkfat and protein (Figure 6.3). If the milkfat and protein price is 6% more than the status quo price a NPV of \$43,468 and \$39,605 is achieved over 10 years for scenarios 1 and 2, respectively. Over 20 years the corresponding values are \$104,679 and \$103,822, and for infinity \$171,974 and \$171,102 for scenarios 1 and 2, respectively. The expenses in the two scenarios are the same from year 13 onwards (Appendix Tables A5.37 to A5.39). The 6.2% less milk income for scenario 1 in year 13 (at a 6% premium) declines to no difference in year 19 when all milk for both options receives a 6% premium. The difference in NPV between the

20 year and infinity time frames for the two scenarios is the difference in the PV for year 21 onwards. This difference is the same for both scenarios because it is based on the year 20 value, and the expenses and income are the same in both scenarios for year 20. Therefore, the premium required for the NPV to be equal for both scenarios will be the same for both the year 20 and infinity time frames, even though the NPV will differ.

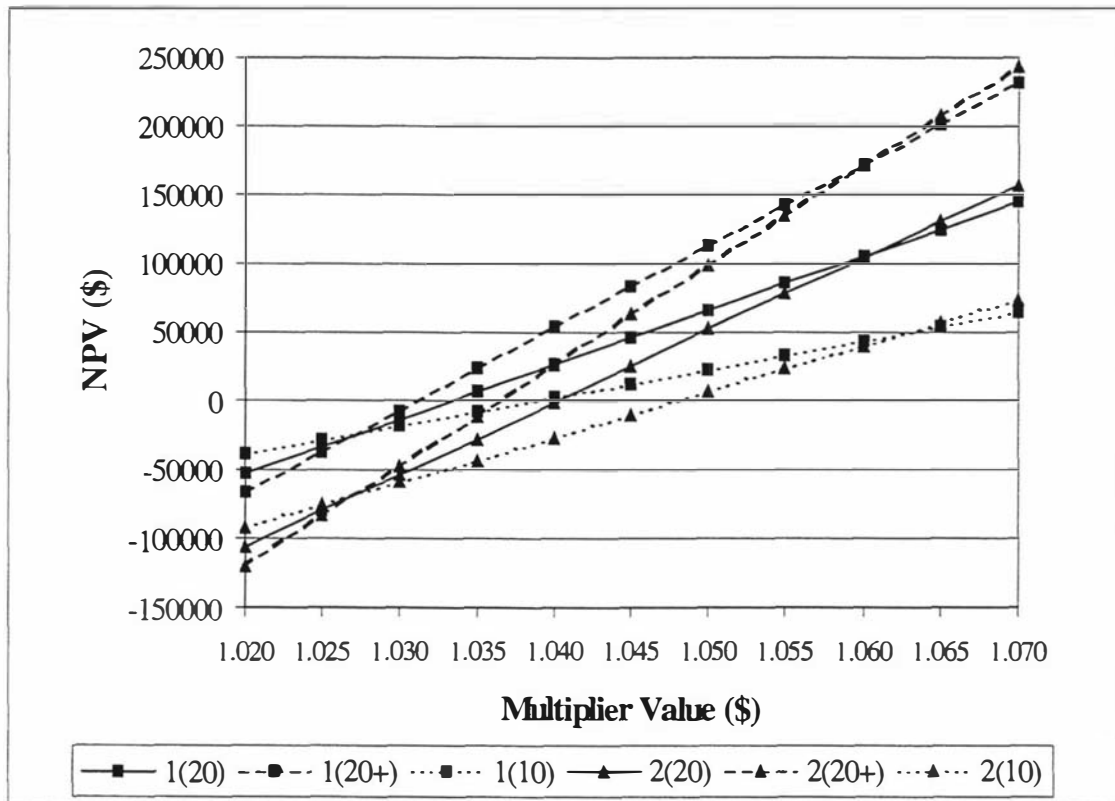


Figure 6.3: Net present value at a range of multiplier values for the two scenarios (1 or 2) over 20 (20), 20+ (20+) and 10 (10) years at a discount rate of 7%.

6.3 SENSITIVITY ANALYSES

Table 6.8 shows the milkfat premium required for quantitative scenarios 1 and 3, and the multiplier required for the two qualitative scenarios giving a NPV of zero over periods of 10, 20 and 20+ years at discount rates of 7%, 10% and 15%. Generally, an increasing premium is required as the discount rate increases. The quantitative 3 scenario shows the converse because most of the positive net income years occur sooner than for the other options, with the later years being negative whereas these are positive for the other options. Quantitative scenario 1 and the qualitative scenario 2 would require a premium increase of 24% and 27%, respectively, over 20+ years if the discount rate was raised from 7% to 15%. The remaining

differences are all below 20%. The change in the premium required as the discount rate changes is small for most of these comparisons.

Table 6.8: Milkfat premium (\$/kg milkfat) required for two quantitative scenarios and the premium (cents/kg milksolids) required for two qualitative scenarios for the NPV to equal zero over periods of 10, 20 and 20+ years at 3 discount rates.

	Discount rate		
	7%	10%	15%
Quantitative 1			
10 years	\$2.08	\$2.14	\$2.24
20 years	\$1.11	\$1.17	\$1.30
20+ years	\$0.92	\$0.99	\$1.14
Quantitative 3			
10 years	\$0.41	\$0.41	\$0.41
20 years	\$0.46	\$0.46	\$0.45
20+ years	\$0.47	\$0.46	\$0.45
Qualitative 1			
10 years	16.5	16.9	17.8
20 years	14.3	14.7	16.0
20+ years	13.4	14.3	15.6
Qualitative 2			
10 years	20.3	21.6	23.3
20 years	17.3	18.6	20.8
20+ years	15.5	17.2	19.9

Tables 6.9 and 6.10 show the change in the NPV associated with changes in the premium paid for the required milk type or a reduction in the collection costs of this milk type. These changes affect only the milk income and are linear. Extra transport costs are likely to range between 0.7 and 1.3 cents extra per litre (Chapter 4), so the NPV could change by plus or minus three times (plus or minus 0.3 cents, or 0.1 cent x 3) the value given because breakeven NPV is calculated where transport costs are 1 cent more per litre. Altering the premium has a greater effect. The larger impact on the two qualitative scenarios and quantitative 3 scenario reflects a greater amount of milk meeting the criterion. At higher discount rates the impact is lessened because the greater amounts of the desired milk produced in the later years is more heavily discounted.

At a 7% discount rate, for the 20+ year scenario, the sensitivity of a 1 cent /kg milksolids is \$6,371, \$14,818, \$13,622 and \$16,644 for quantitative scenarios 1 and 3, and qualitative scenarios 1 and 2, respectively (the quantitative scenarios have been calculated using the year 10 protein:milkfat ratio for the differentiated milk). The sensitivity to a 1 cent /kg milksolids

change in premium is very similar to the sensitivity to a 0.1 cent /litre change in transport costs for all scenarios i.e. there is about 10 litres to a kilogram of milksolids.

Table 6.9: The change in the NPV over 10, 20 and 20+ years associated with a \$0.10 increase in the milkfat premium for the desired milk type or a 0.1 cent per litre reduction in transport costs for two quantitative scenarios at three discount rates.

	Quantitative 1			Quantitative 3		
	10 years	20 years	20+ years	10 years	20 years	20+ years
7% discount rate						
Increased premium	\$2,070	\$14,043	\$35,615	\$17,424	\$44,438	\$82,686
Reduced transport cost	\$377	\$2,450	\$5,964	\$3,204	\$7,228	\$11,898
10% discount rate						
Increased premium	\$1,703	\$9,356	\$17,808	\$14,827	\$32,365	\$47,345
Reduced transport cost	\$310	\$3,015	\$1,639	\$2,729	\$5,365	\$7,194
15% discount rate						
Increased premium	\$1,259	\$5,035	\$7,250	\$11,597	\$20,467	\$24,394
Reduced transport cost	\$230	\$887	\$1,248	\$2,137	\$3,490	\$3,969

Table 6.10: The change in the NPV over 10, 20 and 20+ years associated with a 1% (of the status quo price) increase in milkfat and protein (i.e. 4.37c/kg milksolids) for the desired milk type or a 0.1 cent per litre reduction in transport costs for two qualitative scenarios at three discount rates.

	Qualitative 1			Qualitative 2		
	10 years	20 years	20+ years	10 years	20 years	20+ years
7% discount rate						
Increased premium	\$20,517	\$39,264	\$59,530	\$32,909	\$52,468	\$72,734
Reduced transport cost	\$4,789	\$9,006	\$13,490	\$7,710	\$12,113	\$16,597
10% discount rate						
Increased premium	\$17,598	\$29,957	\$37,895	\$28,683	\$41,619	\$49,556
Reduced transport cost	\$4,111	\$6,894	\$8,650	\$6,726	\$9,641	\$11,397
15% discount rate						
Increased premium	\$13,930	\$20,337	\$22,418	\$23,292	\$30,032	\$32,113
Reduced transport cost	\$3,260	\$4,704	\$5,164	\$5,471	\$6,991	\$7,451

6.4 REDISTRIBUTION OF THE PREMIUM PAID

The effect of redistributing the milk premium payments so farmers received a greater proportion in the earlier years was explored for the quantitative 1 and qualitative 2 scenarios. While the milk premium paid changed over time, the NPV was the same for all premium distributions i.e. zero at a 7% discount rate. Quantitative scenario 1 was selected because little of the desired milk type was produced in the first 10 years. Thus, little extra income was generated from this source in the earlier years. Qualitative 2 scenario was selected because almost all of the extra costs associated with this scenario occurred in year 1. The difference in the payments required, and the difference between the payments in the even and uneven distributions is shown in Tables 6.11 and 6.12. The effect on the present values over time for the 20 years can be found in Appendix Tables A5.40 and A5.41.

The payments received within the 10-year period to break even in the quantitative scenario would be the same for both uneven distributions (5 years at year 1 value, 5 years at 0.75 multiplied by the year 1 value). In all comparisons, the increased premium payment required for the first two periods is considerably greater than the reduction in the premium payment received for the milkfat in the last period compared to the even distribution value (Table 6.11). However, the reduction in the premium paid for each step ranges from 42 cents (20+ years, 2nd uneven distribution, 75 minus 43) to 64 cents (10 years, 48 plus 16). Redistributing the payment reduces the negative present values in the initial years, and the positive present values in the latter years, thus evening out the variation in the present values over time (Appendix Table A5.40).

As for the quantitative analysis, compared to the even distribution value, the increased milksolids price for the first period is considerably greater than the reduction in the price received for milksolids in the last period (Table 6.12). The drop in the premium paid for year 1 and the later years is from 50 cents for the first uneven distribution and 79 cents for the second uneven distribution. Redistributing the payment reduces the large negative present values in the first year, and decreases the positive present values in the later years for the first uneven distribution. In the second uneven distribution the first year is now negative allowing the considerable cost associated with changing to BB milk to be paid, but most of the remaining present values are now negative (Appendix Table A5.41).

Table 6.11: The premium required on white milkfat in quantitative scenario 1 for the NPV to equal zero at a 7% discount rate over three time periods, with the premium either evenly or unevenly distributed over the time period. The year value in brackets is the proportion of the year 1 value. The data value in brackets is the difference between that value and its associated even distribution value in cents.

	10 years	20 years	20+ years
Even – all years	\$2.08	\$1.11	\$0.92
Uneven			
Years 1 to 5	\$2.560 (+48)	\$2.033 (+92)	\$1.775 (+86)
Years 6 to 10 (0.75)	\$1.92 (-16)	\$1.525 (+42)	\$1.331 (+41)
Years 11 to 20 (0.50)		\$1.017 (-9)	\$0.888 (-3)
Uneven			
Years 1 to 5		\$1.770 (+66)	\$1.672 (+75)
Years 6 to 15 (0.75)		\$1.328 (+22)	\$1.254 (+33)
Years 16 to 20 (0.50)		\$0.885 (-22)	\$0.836 (-8)

Table 6.12: The payment required on BB milksolids (before transport cost deduction) in qualitative scenario 2 for the NPV to equal zero at a 7% discount rate over three time periods, with the premium either evenly or unevenly distributed over the time period. The year value in brackets is the proportion of the year 1 value. The data value in brackets is the difference between that value and its associated even distribution value in cents.

	10 years	20 years	20+ years
Values (\$)			
Even - all years	\$4.58	\$4.55	\$4.53
Uneven			
Years 1	\$5.02 (+44)	\$5.01 (+46)	\$5.00 (+47)
Years 2 to 20	\$4.52 (-6)	\$4.51 (-4)	\$4.50 (-3)
Uneven			
Years 1	\$5.27 (+69)	\$5.28 (+43)	\$5.28 (+73)
Years 2 to 20	\$4.48 (-10)	\$4.49 (-6)	\$4.49 (-6)

Figure 6.4 shows the cumulative present values over the 20 years for all scenarios, including the two redistributed premium scenarios (the first uneven distributions for each scenario) at the premium for each of these where NPV equals zero i.e. they are all zero or close to zero in year 20. The maximum negative cumulated present value is -\$23,139 for quantitative scenario 1 in year 13. When the premium is redistributed the maximum cumulated present value is

-\$14,067 (year 13). The maximum negative cumulated present value for the qualitative scenario is -\$60,834 (year 1), and this changes to -\$17,601 when the premium is redistributed. The other scenarios are also shown and will be discussed later in terms of the risk associated with the different options.

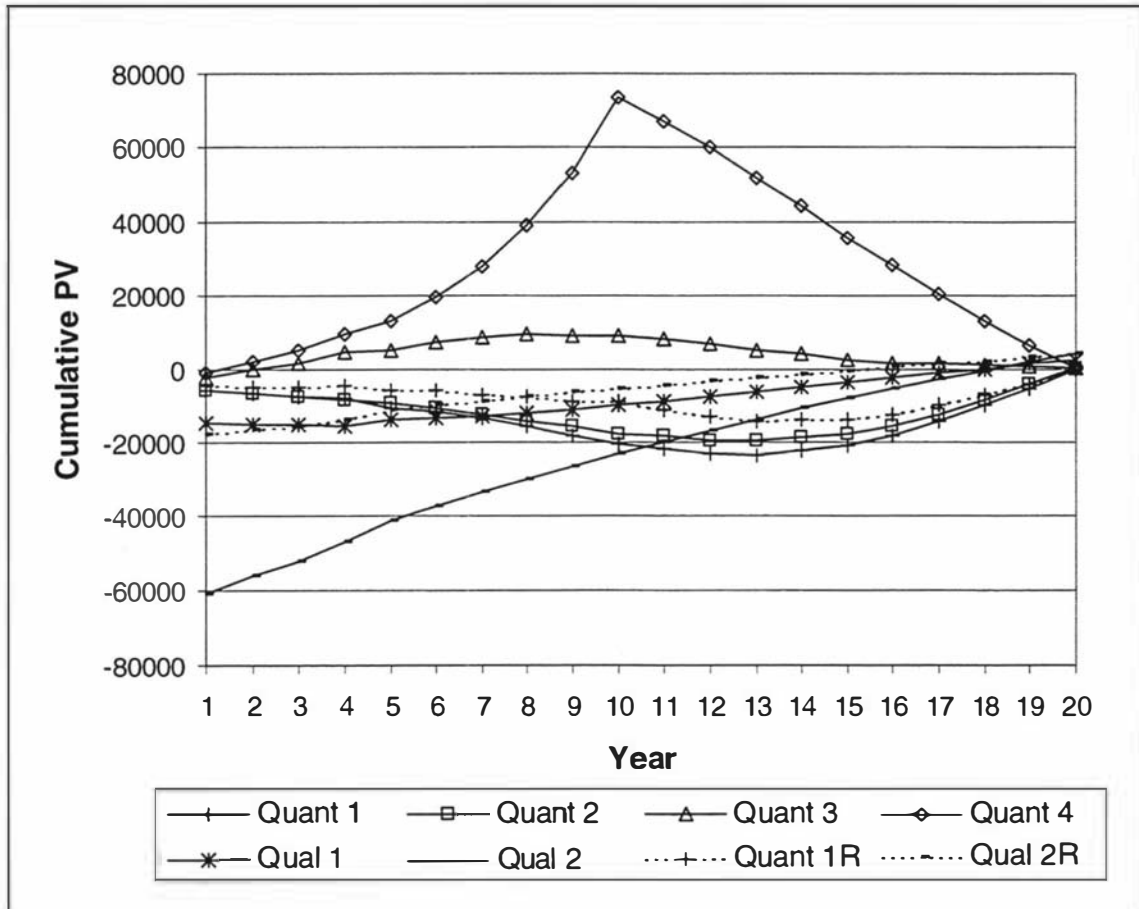


Figure 6.4: The cumulative present values over the 20 years for all scenarios, including the two redistributed premium scenarios, at the premium for each of these where NPV=0.

The qualitative scenario cumulative present values over the 20 years are plotted for a premium for milkfat and protein of 6.1% of the status quo value (Figure 6.5). At this value scenarios 1 and 2 are almost equal in year 20. The cumulative present values for qualitative scenario 2, with the premium redistributed so years 2 to 20 are 0.90 and 0.95 of the year 1 value are also presented. Clearly, qualitative scenario 1 has a lower initial negative present value (-\$9,410) than scenario 2 (-\$52,657), and the cumulative present value is positive by year 3 compared to year 6 for scenario 2. Redistributing the premium for scenario 2 reduces the year 1 present values to -\$8,953 and -\$31,690, and the cumulative present values are positive by years 2 and 5, for the 0.90 and 0.95 redistributions, respectively.

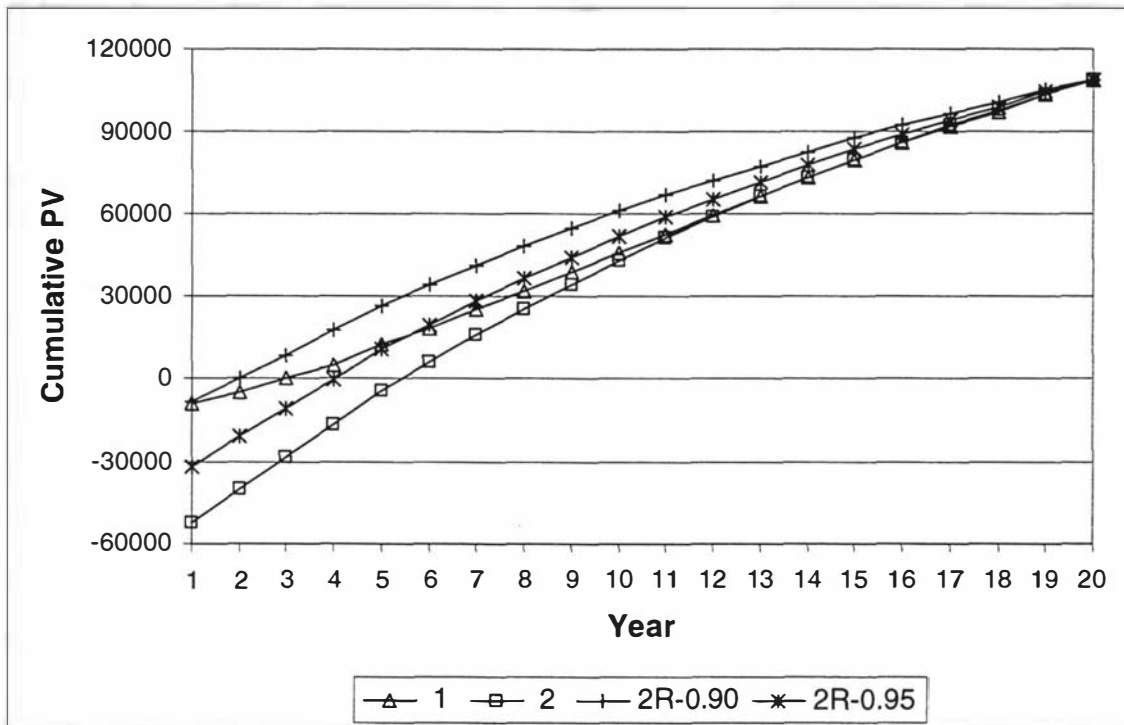


Figure 6.5: The cumulative present values over the 20 years for qualitative scenarios 1 and 2, and qualitative scenario 2 with the premium redistributed so years 2 to 20 are 0.90 and 0.95 of the year 1 value. The premium is for milkfat and protein is 6.1% of the status quo value.

CHAPTER SEVEN

GENERAL DISCUSSION

This discussion includes issues related to the overall analysis outputs (Chapter 6). Issues under consideration addressed include: what premium would be required for a farmer changing to a differentiated milk policy to break even; the factors that affect this premium value; possible milk differentiation strategies; and other implications of milk segregation at the farm level. The transport (Chapter 4) and qualitative breeding (Chapter 3) chapters also have stand-alone discussion sections related to their outputs. While some issues discussed there are also referred to here, they have been discussed in more depth in Chapters 3 and 4. Outputs from the quantitative breeding, and the cow requirements and feeding models, used in the economic model, and issues pertaining to all three sub-models, are discussed.

Both a quantitative trait (milkfat colour) and a qualitative trait (β -lactoglobulin) were considered in this milk segregation study. The scenarios for implementation of milk segregation are discussed in terms of these two traits, however the concepts associated with these can be generalised to any quantitative or qualitative trait. Some issues have been discussed in more depth in relation to either the qualitative or quantitative comparisons but could apply to either.

A large number of scenarios could have been modelled. The four quantitative scenarios and two qualitative scenarios considered were:

Quantitative scenarios

Scenario 1: Selection on colour only, with an initial colour of 8.0;

Scenario 2: Selection on colour and milkfat yield, with an initial colour of 8.0;

Scenario 3: Selection on colour only as for Scenario 1, but with an initial colour of 6.0;

Scenario 4: As for Scenario 1 for the first 10 years, then reverting to status quo values for genetic gain and prices received for the remaining years;

Qualitative scenarios

Scenario 1: Changing to a BB herd over time by breeding;

Scenario 2: Changing to a BB herd in year 1 by buying and selling cows.

This impact of some of the input variables on the outputs is discussed at the start of the Chapter. This has been done separately for the quantitative and qualitative breeding traits. Wider industry-related issues that affect milk segregation policies are then discussed. Most of these relate to both the farmer and the processor. These include technology uptake, risk, premium redistribution, price interpretation, other farm financial considerations, payment options, processing issues and possible breeding strategies. Finally the effectiveness of the model itself is discussed. While an attempt has been made to discuss these issues in a logical sequence, many of the issues are inter-related and apply to more than one section.

7.1 QUANTITATIVE SCENARIOS

7.1.1 Factors affecting selection for, and production of, differentiated milk

Increasing the number of traits in a breeding objective lowers the rate of likely genetic gain in each of the traits, compared to selecting entirely on one particular trait (Van Vleck *et al.* 1987). Negative correlations between selection traits will further slow the gain in the selected traits. Under quantitative scenario 1 all selection was on reducing milkfat colour in order to maximise the genetic gain in this trait. Although this trait has a high heritability ($h^2=0.49$), selecting only on milkfat colour still took an "average" (8 mg beta-carotene/kg milkfat) Friesian herd 18 years for all cows to meet the "white" milkfat criterion (4.5 mg beta-carotene/kg milkfat) (Appendix Table A5.2). In contrast, selection on milkfat production (i.e. index selection on milkfat and colour) was also included in scenario 2, as this was the component on which the premium was paid. A small negative correlation exists between these traits (-0.09, Winkelman *et al.* 1999). However, the associated reduction in the genetic gain for milkfat colour meant it took longer for the whole herd to produce "white" milkfat compared to scenario 1 (ca. 22 vs. 18 years) for scenario 1. Therefore, the time required to manipulate the level of a desired trait such as white milkfat colour through conventional animal breeding methods may limit the number of other traits in the selection objective, and reduce genetic gain in these traits. Once all cows are in the "white herd" for most or all of the year, the selection objective could be changed to hold milkfat colour at its current level (restricted trait) in order to place greater emphasis on production traits. Alternative animal breeding technologies could also be used to accelerate genetic gain, as discussed later.

The within-herd milk colour distribution and phenotypic standard deviation also affects the rate of selection progress. A normal distribution was assumed in calculating genetic gain and the number of cows in each herd (based on the phenotypic standard deviation). However, Winkelman *et al.* (1999) found the distribution for milkfat colour in first and second lactation

cows to be positively skewed, which suggests that under a normal distribution fewer cows may be calculated to be in the white herd than are actually available. In contrast, the milkfat colour data from 50 cows in a low colour pedigree Friesian herd in March (Keen 1986) showed a close to normal distribution (skewedness = -0.1787). The standard deviation for the trait also affects the progress made (Van Vleck *et al.* 1987). Milkfat colour has a relatively large phenotypic standard deviation (a phenotypic standard deviation coefficient of variation of 18.5% was used) enabling greater genetic progress than would be possible with traits of lesser variation. It is also unknown whether the genetic gain for milkfat colour is limited i.e. whether it will reach a plateau as milkfat gets whiter, although Keen (1986) found cows with milk colour as low as 1.8 mg beta-carotene/kg milkfat in March suggesting cows can be bred for very low milk colour.

The scenarios for the quantitative model were started from the same genetic base, and it was assumed that the potential genetic gain was realised over the 20 years modelled. Increasing selection on colour decreased the genetic gain in milk yield, milkfat and protein leading to lower production per cow over time compared to the status quo (industry objective), particularly in scenarios 1 and 3. This resulted in reduced feed requirements per cow and therefore a higher stocking rate e.g. at the end of the 20 years scenarios 1 and 3 supported 5.3% more cows than the status quo. Further, the higher stocking rate meant a greater proportion of the feed utilised was used for maintenance, pregnancy and liveweight gain requirements than production. Consequently, farm productivity was 5.1% less at the end of the 20 years where selection was based on colour (scenarios 1 and 3) than for the status quo (Table 6.3).

Genetic gain in the production traits also varies between scenarios at different rates, altering the milksolids concentration and protein:milkfat ratio between the status quo and the scenarios over time. The ratios of milk, milkfat and protein produced per cow and hectare therefore vary between the different scenarios. Milk composition also affects the price received per kilogram of milksolids. Milk concentration affects the volume charge, whereas the protein:milkfat ratio affects the proportion of milkfat and protein in a kilogram of milksolids and, as these are differentially priced, this affects the milksolids price and the profitability of a different strategy. This matter is further discussed later.

While a greater quantity of “white” milkfat was produced over the 20 years for scenario 1 than scenario 2 (Figure 6.2), the greater overall milksolids production per hectare (or farm) for the latter (fewer cows but higher production per cow, leading to an extra 4 kg protein and 25 kg milkfat per hectare) meant more milksolids was sold, even though more was sold at the

standard status quo price. Consequently, the premium that was required for the NPV to break even was very similar for both scenarios (scenario 1 required only 2 to 5 cents per kilogram of milkfat less than scenario 2). Therefore, any trade-off between increasing the genetic gain in a desired trait and selling more milk at a premium, and the lower production because of lower genetic gain in the production traits and the higher costs (associated with a higher stocking rate), has to be considered in deciding the approach to use in selecting for a particular milk characteristic. The greater number of cows in the quantitative scenarios compared to the status quo may also require more labour. This was not allowed for, and if included would marginally increase the breakeven premiums required for scenario 1.

7.1.2 Calculation to infinity

Differences in genetic gains in the production traits for the status quo, and the other scenarios, also meant that production per cow and farm diverged between the status quo and the other scenarios over time. Extra returns from white milkfat need to be sufficient to compensate for this increasing difference in production, as well as the extra costs associated with the change. For simplicity, the NPV calculated to infinity used year 20 to calculate returns for year 21 onwards. However, this value does not account for the on-going divergence in milk production and cow costs between the status quo and the other scenarios after year 20. Therefore, a slightly greater premium to break even than that calculated would be required in practice (Appendix Tables A5.24 and A5.25). Also, where scenarios have not yet stabilised year 20 will not yet represent a “typical year”. In scenario 2, for example, the herd has not yet stabilised to all cows in one herd, and in scenario 3 the values in the later years vary between the positive and negative, with year 20 being a negative year.

7.1.3 Initial milkfat colour in the base herd

The milkfat colour in the base herd had a large impact on the premium required for the NPV to break even, as can be seen by comparing scenarios 1 and 3. The premium required to break even for scenario 3, where a greater proportion of the cows and the milkfat produced met the criterion and therefore attracted a premium, was considerably lower than that required for scenario 1 (Table 6.1). The base production for the scenario 3 herd was assumed to be the same as that for the herd in scenario 1. While this could be incorrect, the difference in the base herds is unlikely to significantly impact on the relatively large difference between the breakeven premiums for the two scenarios e.g. \$1.11 for scenario 1 compared to \$0.46 for scenario 3 over a 20 year period.

After the first year, the present values for scenario 3 were positive for about 7 years, followed by a number of negative years (Appendix Tables A5.23, A5.25 and A5.27; Figure 6.4). This was because the low premium on the increasing amount of white milk did not fully compensate for the extra cow costs and lower production compared to the status quo scenario. Another effect was that the breakeven premium required was greater over longer time periods (Table 6.1). As most of the benefits from the change at this breakeven premium occur in the earlier years a farmer may regret changing systems after a few years as their returns decrease in contrast to their status quo neighbour. However, even if they wished to, and other things being equal, they will not be able to catch up to their status quo neighbour in terms of genetic potential for per cow production.

This difference in returns may encourage a farmer producing higher initial levels of white milkfat to consider alternative options after a few years. The dairy company could respond by having a lower premium in the earlier years and increase it in later years to encourage farmers to continue with white milk production, however, this will not encourage uptake initially. Premium redistribution will be discussed further later. The premium required could also be set at a level where the present value for most years are positive compared to the status quo. At a premium of \$0.52/kg white milkfat (a 10% increase on the breakeven premium required for 20+ years) for example, only the present value for the first year is negative and the NPV is \$21,030, \$31,516 and \$52,966 for periods of 10, 20 and 20+ years, respectively. This premium is only marginally greater than the breakeven premiums required (Table 6.1) and is still considerably lower than the premium required for scenario 1 (\$0.92/kg white milkfat for 21+ years).

A dairy company requiring differentiated milk will need to attract farmers with a range of base level white milkfat productions to adopt a differentiated milk policy. For example, in the white milk scenario they may be trying to encourage farmers with herds ranging from the base level of the scenario 1 herds up to that of scenario 3 herds. Accordingly, the premium will need to be set to attract lower level (scenario 1) farmers. The premium required for scenario 1 farmers to break even is considerably more than that required for the scenario 3 farmers. Scenario 3 farmers paid at the same rate as scenario 1 farmers would be financially better off to change with NPVs of \$291,107, \$289,254 and \$375,440 being achieved at 10, 20 and 20+ years, respectively. This is the likely situation if a company is trying to get sufficient “average” herds to change (as in scenario 1). This issue is further discussed later in relation to technology uptake.

A dairy company could identify white milk herds in year 1, and segregate their milk without informing the farmers or paying a premium. However, the whole herd would need to meet the criterion for some of the year. This is unlikely with white milkfat where few complete herds currently meet the criterion for part of, let alone the whole lactation, thus limiting existing volumes of suitable milk. This situation may be different for other traits, particularly where some component was being extracted from the milk. However, a dairy company then runs the risk of farmers using bulls that reduce the level of the desired component. For example, a Feilding Friesian herd producing white milk had primarily been using Canadian sires (Keen 1986). If this farmer was given no incentive to continue producing white milk he could change back to New Zealand sires and possibly reduce the whiteness of the milk. Also, a dairy company will not be able to increase the amount of a desired milk type without paying farmers an incentive to do this.

7.1.4 Low initial volumes of white milk and associated risk

In scenarios 1 and 2 where low volumes of the desired milk type are produced in the first few years (1.6% in year 1 up to 15.6% in year 10), the premium required for the NPV to break even decreases with time (Table 6.1), with the later years having the positive present values (Appendix Tables A5.22, A5.24 and A5.26; Figure 6.4). Farmers in this position would need to plan well ahead in making the change and anticipate receiving higher future returns. Their enterprise risk is increased because new technologies could make the selected technology obsolescent (e.g. a processing technique to produce whiter milkfat with no effects on flavour or processing properties could be discovered), there could be changes in consumer preferences (e.g. white milk products could be linked to a health issue) or the value of white milk products could be reduced because of an increase in these products on the world market, both from increases in New Zealand production and competition from overseas countries (e.g. as has happened in some European countries which now have a surplus of organic milk). The initial costs invested in this technology in cow testing and vat installation are largely non-recoverable or "sunk" costs should obsolescence, premium reduction or policy reversal occur. Similar risks may exist for other traits.

Scenario 4 considered the effect of adopting a scenario 1 policy for 10 years, after which no premium is paid for white milk. The premium required is considerably greater than that for scenario 1. Assuming that milk will attract a premium for over 20 years, a producer may be prepared to accept a \$0.92 premium/kg milkfat (scenario 1). However, if this premium ceases after only 10 years there is a net loss situation, as the premium required for the NPV to equal zero would be \$9.66/kg milkfat (scenario 4). The tenfold increase in the premium required makes the downside risk associated with this proposition high. Figure 6.4 shows this clearly,

with the very high premium leading to a high cumulative present value up to year 10 compared to the other scenarios, followed by a rapid decline. Putting status quo prices in scenario 1 from year 10 onwards requires a higher premium still (\$13.05/kg milkfat), however scenario 4 is more realistic in that farmers would likely revert to breeding for traditional production traits if there was no premium for colour. The gain in the production traits from year 11 onwards for scenario 4 would initially be slightly greater than that assumed in the model (i.e. status quo gains), and would approach status quo gains over time. As a result production from year 13 onwards will be slightly more than that predicted. Nevertheless, there would be a long lag phase before the herd's production (based on cow genetic potential) gets close to that of the status quo herds. Therefore, the premium required for the NPV to equal zero for the 20+ years will be marginally less than the \$9.66/kg milkfat calculated, because the underestimated production occurs in more heavily discounted years (i.e. year 13 on).

The later years in scenario 4 are predominantly negative financially at the breakeven premium (Appendix Tables A5.23, A5.25 and A5.27), and the premium required to break even increases as the time frame increases (Table 6.1). While the price paid for the milk components from year 11 onwards for scenario 4 and the status quo are the same, the lower genetic merit of the scenario 4 cows for the production traits, their lower per hectare production, and their lower protein:milkfat ratio, mean income is lower in scenario 4 than for the status quo for these years. This, along with increased cow costs (more cows) compared to the status quo scenario, contribute to these negative present values. A producer deciding to reduce the downside market and/or technological risk by requiring a premium that allows the NPV to break even over 10 years as a risk management strategy, still has some risk associated with the possibility of no premium after 10 years because of these later negative present value years in scenario 4. For example, at a premium of \$2.08/kg milkfat, both scenarios 1 and 4 break even over 10 years, however, over 20 years, scenario 1 has a NPV of \$135,875 while scenario 4 has a NPV of -\$73,178. The time frame selected for the premium payment to cover the risk will vary between producers.

Should white milk attract no premium after 10 or 20 years, a farmer could decide to sell the white milk herd and replace it with a status quo genetic merit herd. The higher breeding worth of the status quo herd relative to the white milk herd, based on the industry objective, means these cows are likely to be higher producing, more valuable cows, therefore fewer cows would need to be purchased than are sold. Consequently, it was assumed that the capital cost value of the scenario and status quo herds was the same, with the scenario livestock worth about 95% of status quo value i.e. the salvage value was zero. If buying and selling cows is an

option, the scenario 1 premium is the relevant one to use for 10 or 20 years rather than those for scenario 4, because production will be the same as a status quo herd after this period. However, this option requires both the availability of status quo cows and a market for white milk cows. Without a white milk premium the sale of these cows could be difficult if industry demand for cows is low.

The quantitative scenarios all assumed the change to a white milk herd occurred by breeding. The very low initial frequency of white milk cows in the herd in scenario 1 (2.3%) makes the possibility of testing cows and replacing the whole herd with white milk cows in year 1 difficult. That is, 44 cows would need to be tested for each white milk cow identified, or 12,740 cows to replace all 293 cows in the herd. Changing the whole herd to white milk cows could be advanced by 7 years (Appendix Table A5.2) if sufficient cows could be purchased to change 10% of the herd. Buying and selling cows to form white milk herds from average herds may be an option for a company, rather than an individual, because they could approach a number of their suppliers to test cows. Cows could also be bought and sold in the last year or two when most of the cows in the herd are white cows. If white milk cows are to be purchased and possibly managed under different conditions such as on another property, it would be important to consider the extent to which genetic or environmental effects influence white milk production in the herd these cows are sourced from.

7.1.5 Stage of lactation

The stage of lactation was assumed to affect milk colour in the quantitative scenario modelled. The high (8.0) initial colour white milk herd did not produce white milk over the whole lactation, although continued selection on colour once all the herd was producing white milk meant the milk then moved to being whiter for longer. However, the low (6.0) initial colour produced white milk all year after 20 years (Appendix Table A5.21). Milk was most yellow at peak lactation (Appendix Table A5.21) when it would be less convenient for a dairy company to process special lots anyway, than it was in mid- to late-lactation. It was assumed that all milk was processed as standard milk at this time. Differential pricing for both white milk and standard milk at peak production and shoulder production times could have been modelled. In general, differential pricing does not occur in the New Zealand dairy industry, but will in the future for standard milk because proportionately more peak milk is processed into lower value commodity products than at other times of supply (Gray *et al.* 1994; Hughes 2002). In reality, differentiated milk may, or may not, be processed into differentiated milk products all year round, and the pricing could reflect this. For either a qualitative, or a quantitative model where a component was being extracted from the milk, a premium could be received for all milk throughout the year, with the premium being paid on the level of the

desired component in the milk. Alternatively, differentiated milk could be processed along with the bulk milk at peak because of processing limitations and made into differentiated products at the shoulder, with peak and shoulder prices applying i.e. differentiated milk may only receive a premium at the shoulder. This would require a higher breakeven premium for milk segregation because the premium is paid on a lower volume of the season's production of milk.

The amount of milk produced by the white milk herd also depends on the milk colour cut-off value between the two herds specified in the quantitative breeding model. This is the average value for the year, and stage of lactation effects are then imposed on this. The farmer needs to consider the trade-off between the size of the differentiated herd and the number of months the milk meets the requirement. The model can be used to evaluate trade-off options involving time and volume of supply, feeding effects and margins of error in milk colour. The cut-off level in both the breeding and economic models was the same, however, this could be set lower in the breeding model, which would give fewer cows in the white herd, less white milk in total but more periods over the lactation when this milk is acceptable i.e. a higher proportion of the milk from this herd will be acceptable. This would also allow for a margin of error to ensure milk meets specification for most of the lactation. This margin may be needed because cows could have slightly more yellow milk than that assumed because of cow genetic effects, feeding or seasonal effects.

The model does not include the complexity of shifting cows between herds within a lactation. In reality, farmers could transfer cows between herds during lactation to take advantage of stage of lactation effects on the whiteness of the milk within herds. Allowing for the dilution factor in paying for white milk, as modelled, partly compensates for this in the analyses reported i.e. shifting cows to the white herd from the yellow herd at times of the year when milk is more white will increase the amount of milk but reduce the whiteness.

The model could be adapted to check the effect of split calving (Garcia and Holmes 1999) on colour, by combining the milk outputs from the "white" and "yellow" milk herds for each calving period. The return is likely to be the same as that calculated here for a seasonal calving herd because the scenario modelled allowed for the dilution effect possible with white milk below the criterion i.e. this milk receives a higher premium. Returns could differ for a trait where shoulder milk received a higher price than peak milk, or where combining milk from the two "white" herds at times altered whether it met the criterion or not i.e. combining milk from the split-calving white herds may produce more or fewer periods where milk met the cut-off criterion. Milk mixing could only occur for those periods where the colour

criterion could still be met. Split lactations with a white and a yellow herd (4 herds), or shifting cows between the two herds within a lactation would require additional management, and possibly more labour and associated higher costs.

7.2 QUALITATIVE MODEL

Many of the issues discussed in relation to the quantitative model also apply to the qualitative model. Two qualitative scenarios were run through the entire model: changing the frequency of the genotype by breeding and testing cows for genotype, and the buying and selling of cows to achieve a herd of BB genotype in year 1. A greater number of qualitative scenarios were explored in the breeding sub-model including testing the genotype of the cows versus no testing, yearling mating to increase the change in the gene frequency, the effect of the initial gene frequency in the herd, and the use of AB bulls as well as BB bulls if there are insufficient BB bulls. These were discussed in Chapter 3.

7.2.1 Factors affecting selection for, and production of, differentiated milk

As for the quantitative trait, the rate of genetic gain in the production traits can be affected by selecting on genotype for another trait, although the effect on production was minimal for the qualitative trait modelled (BB β -lactoglobulin). Differences in milk composition between genotypes were also minor. Consequently, the stocking rate and production under the qualitative trait scenarios and their associated status quo scenario remained similar over time. The initial level of the gene frequency, and therefore the amount of differentiated milk produced, in the qualitative scenarios was greater than that for the quantitative trait. Only a small increase in the premium for differentiated milk was required relative to the quantitative scenarios because of the greater volume of differentiated milk, and because the increased value applied to both the milkfat and protein components of the milk, rather than milkfat only as in the quantitative scenarios.

Genetic gains were derived from a model developed by Lopez-Villalobos (2000, *pers. comm*). These were assumed to be constant over time for each breeding objective for the purposes of the analysis. This may not be the case, as selection and culling policies for both bulls and cows can impact on the genetic gain, although the impact of the cows to breed cows pathway (cow selection within the herd) is considered to be minimal. Factors affecting this were presented in Chapter 3. This is also relevant in selecting for a quantitative trait

Over the period that a herd (within a scenario) was changing from bulk milk to differentiated milk production, the age distribution of the cows in the differentiated herds had a greater impact on production per cow and the proportion of differentiated milk produced than the genetic gain. The differentiated herd initially tended to have a higher proportion of younger, lower-producing cows while the older higher-producing cows remained in the other herd. Once most cows were in the differentiated herd the situation reversed with only a few older lower-producing cows in the bulk milk herd (Appendix Tables A5.29 to A5.30). This trend also occurred in the quantitative scenarios, but per cow production in each herd was confounded by a combination of age effects (proportion in each age group in each herd, with younger cows having lower production) and the correlation with the selected trait (within an age group the higher producing cows are more likely to be in one or the other of the herds depending on the correlation between the production trait and the "correlated" trait).

7.2.2 Breed distribution

The effect of breed differences in milk composition was explored in the qualitative breeding model (Chapter 3). The uneven distribution of breeds throughout New Zealand means that average milk composition varies between regions. This can be used to advantage in producing some types of differentiated milk. For example, the Taranaki region which has a high proportion of Jersey cows compared to other regions. As this breed has a higher frequency of B β -lactoglobulin cows, the milk from this region will be higher in B β -lactoglobulin as discussed in Chapter 3. In contrast, the milk from Friesian and Ayrshire cows tends to be whiter than that of Jerseys (Keen and Wilson 1993), so if a processor was to consider producing white milk products, as in the quantitative scenario modelled, it could source milk preferentially from the Bay of Plenty and East Coast, Wellington and Hawkes Bay and the South Island regions according to the breed distribution (LIC 1998).

7.2.3 Value of premium required

The premium required on the protein and milkfat for B β -lactoglobulin milk was calculated in the economic model as a percentage over the status quo (with the status quo based on the average for the previous 5 seasons). The status quo value may change over the years, so this percentage increase in value needs to be considered in terms of the absolute value i.e. actual price difference (Table 6.6). Only a small premium per kilogram milksolids (less than 16 cents) is required for the two qualitative scenarios to break even with current practice because much, or all, of the milk meets the criterion from year 1. The difference between the breakeven premiums for the two qualitative is small (less than 4 cents/kg milksolids) suggesting other factors are also likely to be important in choosing between the two policies.

7.2.4 Strategies used to alter herd genotype

Producers can use different strategies to achieve an end goal, according to their individual circumstances and aspirations. For example, a BB herd can be achieved by breeding only or by the sale and purchase of cows in year 1. In both of these scenarios the initial years, or year 1 only for scenario 2, have negative present values (Appendix Tables A5.37 to A5.39), and the premium required to break even decreases as the time frame increases (Table 6.6). According to the model, if the extra milksolids premium offered was less than 3.2% then it would be inadvisable to change, from 3.2% to just over 6.0% a change may be advantageous particularly for the first policy and if over 6%, the second policy will give a higher NPV than the first policy (Figure 6.3). The second policy is more risky than the first. If BB milk is no longer required after 5 years the farmer adopting the first policy would be \$15,286 worse off than if he had stayed with a status quo policy, whereas those with the second policy would be \$48,754 worse off because of the size and timing of the negative present value years (based on a 20+ year time period at the multiplier where these policies NPV equals zero) (Appendix Table A5.38). Therefore some farmers may choose the first policy over the second even at a higher premium i.e. over 6% extra.

The change in the cumulative present value over time was compared for scenarios 1 and 2 over a 20 year time period with a premium of 6.1% over the status quo (Figure 6.5). At this premium the NPV is almost the same over the 20 years for both policies. The cumulative present values remain higher for the first policy up to year 13, with the difference between the two policies being greatest in the earlier years, and policy 2 does not reach a positive cumulative PV until year 6 compared to year 3 for policy 1 (Figure 6.5). Therefore, the risk associated with technology obsolescence is greatest with the second policy, although the short time to break even and the NPV achieved in this example is likely to make the change worthwhile for both policies. Of course it could also be argued that should the premium increase over time (perhaps because of increasing demand for this milk type) the second policy would give better returns than the first. However, as farmers usually budget on conservative estimates (Jolly 1983) this is likely to have little impact on a decision made. Figure 6.5 also shows the effect of redistributing the premium, so a greater proportion is paid in year 1 (years 2 to 20 are paid at 0.90 and 0.95 of the year 1 value). This reduces the risk compared to paying an even premium over time for scenario 2, making it similar to the first policy in terms of either time to break even, or present values achieved over time. Premium redistribution is further discussed later.

The second qualitative scenario modelled was costly to implement (Table 6.7) but it assumed a differential of \$200 for cows and \$150 for heifers with the desired genotype. Actual market values could be greater or less, and will depend on the demand for BB genotype β -lactoglobulin cows and the incidence of these in the population. A lower differential would reduce the breakeven premium e.g. halving these differential values reduced the percentage increase required on protein and milkfat from 3.7% to 3.4% for 20+ years. This premium value is close to that required for the first strategy (i.e. 3.2%) therefore the price a farmer expects to pay for cows and heifers also impacts on their choice of segregation policy.

7.2.5 Comparisons with current industry applications

The qualitative analysis in this study considered the production of BB β -lactoglobulin milk for cheese-making. A current industry example of this approach in New Zealand is the Kaikoura Co-operative Dairy Company (Boland *et al.* 2000). This dairy company, which predominantly manufactures cheese, encouraged its suppliers to change the genotype of their herds to BB β -lactoglobulin cows, to produce milk with higher proportion of the protein as casein, improving the cheese-making properties of the milk. B homozygous bulls were identified and semen from these bulls made available to these processors. A simple test for casein was developed to permit regular testing of the milk for this component. While the milk was not segregated, this allowed payment to be made on casein, milkfat and milk yield rather than protein, milkfat and milk yield with whey protein assumed to have no value. The reasoning and strategy behind the Kaikoura Co-operative Dairy Company initiative has been described in Boland *et al.* (2000) and also discussed in Chapter 3.

A2 Corporation in New Zealand has recently developed an enterprise for the production of A₂ β -casein milk (A2 Corporation 2001), which is also similar to the example modelled. β -casein comes in two main variants, A₁ and A₂, with the incidence of pure A₂ β -casein cows in herds ranging between 20% to 45% (A2 Corporation 2001). Research has suggested a correlation between the consumption of A₁ β -casein milk and the incidence of diabetes and heart disease (Elliot *et al.* 1996, 1999; A2 Corporation 2001). While these findings are not conclusive and work continues in this area, A2 Corporation believes the evidence is sufficiently strong to offer the consumer the choice of A₂ β -casein milk. The A₁ β -casein milk is still suitable for butter (which contains little protein) or cheese products (where renneting alters the structure of the proteins). It is unclear what the effect on milk powder or other dairy products is, as the push for A₂ β -casein milk is aimed at the fresh milk market.

The incidence of the A_2 β -casein allele in the New Zealand population ranges from 0.510 (for Friesians) to 0.591 (for Jerseys) (Winkelman and Wickham 1996). An allelic frequency of 0.55 would mean 30.3% of New Zealand cows would be A_2A_2 genotype for β -casein milk. In contrast, the frequency of BB β -lactoglobulin cows was 46.8%. It would therefore take longer to change a herd or population producing A_2A_2 β -casein milk than the BB β -lactoglobulin example studied here. For the A_2A_2 β -casein case, it may be more economic to buy and sell some cows initially to increase the incidence of the A_2A_2 β -casein cows in the herd than to rely solely on genetic selection. The A_1 β -casein cows could be sold to herds that continue to supply milk for processing purposes.

It may be unnecessary in New Zealand to alter the whole cow population to produce A_2A_2 β -casein milk as the majority of New Zealand's milk is used for processing. The segregation of some of the A_2A_2 β -casein cows in select herds, and the use of A_2A_2 β -casein bulls in these segregated herds, could produce sufficient A_2A_2 β -casein milk to meet New Zealand's needs. Bulls could continue to be selected on production with these segregated herds choosing to use A_2A_2 β -casein bulls, rather than limiting the national bull selection to A_2A_2 β -casein bulls only. This would increase the A_2A_2 β -casein allele in the population, albeit more slowly, by increasing the A_2 β -casein allele in the selected herds without affecting national bull selection (by limiting bulls able to be selected, and therefore selection intensity). It is unlikely that a company would want to pay a premium to encourage farmers to produce A_2A_2 β -casein milk where a large proportion of the milk is processed. Genetic diversity will also be retained in the New Zealand cow population, as there may also be advantages associated with A_1 β -casein milk in the future. For example, current research suggests A_1 β -casein is associated with immune response and the component in milk that acts as a natural opiate (Pilkington 2001, *pers. comm.*). There is likely to be a greater advantage for the A_2 β -casein technology offshore, where a larger proportion of the milk supply is for the fresh milk market, than in New Zealand.

7.3 TECHNOLOGY UPTAKE

7.3.1 Industry perspective

The premium a dairy company can afford to offer farmers for differentiated milk will depend on the price received for the products made with this milk. This is dependent on the markets available for products made with this milk, and the supply and demand curves for these products. To meet market needs, or to develop products and markets, a company may require

a minimum amount of differentiated milk from year 1. The premium offered to farmers must therefore be large enough to encourage sufficient farmers to change to differentiated milk supply. It may, however, be physically impossible to supply the required volume of differentiated milk, or farmers may not be prepared to change supply at the premium offered (insufficient adopters). Therefore, differentiated milk products may be uneconomic because the premium required to encourage enough farmers to change policies may be too expensive. To achieve sufficient milk to meet and develop markets, the dairy company could initially offer a higher premium than may be economic initially and hope to recoup the extra expense once markets are developed. Alternatively, it may still be economic for a company to offer farmers a higher premium than initially planned by retaining a lower return for itself.

Suppliers of differentiated milk are likely to produce increasing amounts as the proportion of differentiated milk type cows increases. As differentiated milk supply increases, some milk may be processed into either lower value differentiated milk or standard milk products, depending on the size and availability of markets. Also, as more differentiated product is produced the average price received per tonne for products may decrease over time. Consequently, the return for the product and therefore the premium offered to farmers and/or the dairy company's profit (per tonne of product) may be reduced. Nevertheless, it could still be more economic for a dairy company to produce higher volumes of a differentiated product even with a reduction in price per tonne (and profit) over time than to continue to produce larger volumes of low margin commodity products from undifferentiated milk. The dairy company should ensure it can maintain the premium paid to farmers, or advise farmers that the premium may decline in the future. A reduction in the premium offered, as more differentiated milk than is required becomes available to the dairy company, might cause some farmers to cease its supply. Alternatively, milk quotas may be imposed for the production of differentiated milk. These could be given to those currently producing differentiated milk (keeping out new entrants), or to those producing larger volumes of differentiated milk thus reducing transport costs.

At a given premium it will only be cost-effective for some farmers to change to the production of differentiated milk. Therefore the premium offered will need to provide sufficient incentive for those at the lower end of the differentiated milk production level to change e.g. quantitative scenario 1 rather than quantitative 3 scenario. At this premium it will be financially profitable for those at the top end, such as scenario 3 with its high initial white colour herd, to change. Factors other than profit (discussed later) also affect farmers' decisions to adopt new technologies (Frank 1997), so the premium offered will need to be large enough to encourage more farmers than required to change supply. All suppliers, or a select group of

farmers such as those with milk composition closest to that required, could be targeted by a dairy company for change. As described above, a higher premium would be required if all farmers were targeted. However, if a select group, such as those with whiter milk were targeted, a lower premium could be offered but more effective extension would be required to achieve the necessary level of adoption amongst this group, than if all farmers were targeted.

When determining the premium and the group of farmers to target, a dairy company will need to consider a number of factors. In order to obtain sufficient milk initially they will need to know the distribution of herds with potential to produce differentiated milk. Either, a few herds producing significant amounts of differentiated milk or many herds producing only small amounts of differentiated milk could meet supply requirements. Testing the milk from their suppliers' herds over a season should assist in providing information about the likely distribution. The technology uptake will need to be estimated. Determining the adoption rate will be more difficult as factors influencing technology uptake are complex (Rogers 1983; Guerin and Guerin 1994). The rate of technology uptake, rather than the level of uptake only, will be important because the a dairy company may need a minimum volume of differentiated milk for processing in the first year, and to meet this the premium may need to be set higher than it would be if the rate of technology uptake was less critical.

Should it seem that too few farmers intend to adopt the technology in the first year to provide sufficient differentiated milk, an additional premium may be required. Initially, this could come from the company's research and development budget while differentiated products and markets are developed. Alternatively, early adopters may be offered an incentive to change e.g. a one-off bonus. These options may pose some risk for the dairy company and they will need to know the maximum affordable premium. A dairy company could also consider the possibility of owning (or leasing) their own herds. This would require testing a large number of cows. An above market price to purchase (or lease) suitable cows may need to be offered. If purchasing, the full cost of the cows would have to be paid rather than the difference between cows as in qualitative scenario 2. Properties to milk these cows on will need to be purchased or leased, and managers employed, or farmers could be contracted to milk the cows on their properties (reverse of sharemilking). If a significant volume of differentiated milk was required a lot of capital investment would be required, and all of the risk would be bestowed on the company.

7.3.2 Factors affecting technology uptake

So far the discussion has focussed on determining the premium required. In principle, the minimum premium required should be where the NPV equals zero for those herds producing

the lowest required initial volumes of differentiated milk. However, factors other than the economic impact (premium value) affect technology uptake (Rogers 1983; Guerin and Guerin 1994; Frank 1997), including both technology and farmer attributes. These include: relative advantage from an economic perspective (e.g. profitability, effect on debt and cash flow) and also social and environment aspects; the compatibility with the current system and the farmer's beliefs; simplicity and reversibility of the technology, implementation requirements, resource availability, and understanding of the technology; the trialability and observability of the technology; the riskiness and flexibility of the technology, and the risk averseness of the farmer; expectations of future technological change; and the availability of information about the technology (Rogers 1983; Guerin and Guerin 1994; Martin 1994, 1996; Reid *et al* 1996; Hardaker *et al.* 1997; Stantiall and Parker 1997; Marra *et al.* 2001).

Clearly, a differentiated milk policy is unlikely to be readily adopted as it is not simple, flexible, trialable and observable, and requires changes to the system rather than fitting into the current milk supply system. The risk associated with milk segregation is also likely to be a major factor affecting its uptake. The quantitative scenario demonstrates some of the risks, particularly the long time required to change through conventional animal breeding methods and low volumes of premium-attracting milk in the initial years. Technology obsolescence or a drop in demand for differentiated milk products may occur while herds are in the process of change. The premium may be lost under these circumstances (see quantitative scenario 1 compared to quantitative scenario 4, Section 7.1.4). The increasing production of white milk in later years may exceed that required to meet the market for white milk products and the premium may fall or farmers may have quotas imposed on them. These outcomes are likely to have the greatest impact on those who had the lowest amount of white milk initially and have therefore received the smallest return from the change up to this time. A company may increase adoption by spreading the risk between the farmer and the company e.g. contracts or guaranteed prices (Anderson *et al.* 1977). The reduction in genetic gain in the production traits compared to the status quo makes the policy irreversible within a herd, with white milk cows lagging behind the status quo cows for several generations in genetic merit for the production traits.

The increased labour and management input could also influence uptake, even if extra labour does not need to be employed. Cows may need to be managed in two, often unequal-sized herds, increased record keeping will be required with care being taken to ensure that cows are in the correct herds maximise white milk production or to realise the correct milk compositions, milk will have to be segregated and cross contamination possibly avoided, and differential feeding may be required. Dairy companies collecting colostrum found farmers

expected a higher price in the second year than they did in the first year because of the difficulties they initially experienced. Consequently, dairy companies had to pay a much higher price to get sufficient colostrum in the second year (Franks 2001, *pers. comm.*). The time required to implement the change in some herds may, in itself, deter farmers from adopting the technology. Capital will be required for policies such as qualitative scenario 2, where cows are bought and sold, therefore, access to finance will also affect the adoption of differentiated milk. This could incur financial risk.

Effective methods must be used to explain the underlying science of the technology because it is important to ensure the implications of the change are fully understood by those being targeted, to enable them to decide whether to change (Guerin and Guerin 1994). A lower premium along with effective research and extension activities focussed on the appropriate target group may be more effective than relying predominantly on premium pricing to encourage uptake. Joint involvement of farmers and dairy company staff in research and extension is likely to lead to the development of more effective strategies for a differentiated milk policy, and increase their understanding of the implications for each other. Consequently, the technology is more likely to be adopted (Guerin and Guerin 1994; Frank 1997). While the industry (i.e. processors and marketers) may wish to develop a differentiated milk policy, farmers are the key decision-makers in its initial implementation i.e. they provide the milk. Therefore, it is also important to include them in the research, development and extension associated with this policy (Maher and Perkins 2000). Extension activities may need to be continued through the implementation and confirmation phases to ensure adoption is maintained (Guerin and Guerin 1994).

7.3.3 Some experiences in extending proposed changes

Boland *et al.* (2000), Fearon and Mayne (2000), Henning *et al.* (2000) and Shanahan (2000) described the implementation of policies to alter milk composition. Boland *et al.* (2000) described a New Zealand project to increase the frequency of the B β -lactoglobulin gene in the population of cows supplying a cheese factory. The other three were Irish studies, two to increase protein through breeding, feeding and management (Henning *et al.* 2000; Shanahan 2000) and one to modify milkfat composition by feeding (Fearon and Mayne 2000). While these authors focussed on the more technical side of bringing about the change, they also highlight some of the aspects leading to the success of the policies in practice.

A Northern Ireland initiative for milk protein was introduced through a demonstration farm (Henning *et al.* 2000). Farmers were able to follow progress via field days, a web site and the

farming press. A further 8 demonstration farms throughout Northern Ireland followed. The other protein initiative came from a Kerry milk processor who wanted to increase the protein level in its suppliers' milk. (Shanahan 2000). The impact of breeding, feeding and management (calving date, lactation length) was demonstrated using 35 monitor farms, and associated discussion groups and seminars, to show farmers how protein could be increased under local conditions. At the same time payment was altered to more strongly favour protein, providing farmers with an incentive to change.

The milkfat initiative (Fearon and Mayne 2000), started after the processing company was approached by a buyer wanting to purchase soft butter. Groups of dairy industry processors, animal scientists, food scientists and feed manufacturers, each with their own objective, worked together to "transfer scientific technology into a commercial operation". The need for farmer involvement was recognised. An initial pilot study of 13 selected supplier farms (minimum processing milk volume) was trialled, followed by a trial involving 35 farms to generate enough butter for market assessment. A parallel research trial was conducted. The research groups worked closely together throughout the trial.

The New Zealand initiative (Boland *et al.* 2000) came from researchers at the New Zealand Dairy Research Institute, who had identified the production and processing benefits of BB β -lactoglobulin milk. They then approached a small cheese factory (Kaikoura Cheese Factory with 31 farms and 28 suppliers) suggesting they encourage their suppliers to use BB β -lactoglobulin bulls. LIC cooperated by ensuring semen from BB and some AB β -lactoglobulin bulls was identified and available to the suppliers. The payment was changed to include casein rather than protein to encourage farmers to change their breeding practices (BB β -lactoglobulin cows tend to have similar levels of protein, but higher levels of casein than their AA contemporaries). All but one of the suppliers participated.

In each of these examples the initiative came from industry (two from researchers, two from processors), the changes sought were within a factory supply area or a region (i.e. not large-scale or national level) and farmers were involved at the early stages of the project e.g. pilot trials, monitor farms. Advantages accrued to those involved (i.e. it was a win-win situation for the farmers involved and the company) whereas farmers who did not become involved or adopt the technology were no worse off than before. The authors suggest that these measures were effective in bringing about changes in milk composition, demonstrating that milk composition can be changed where the benefits accrue to, and are perceived as benefiting all parties e.g. consumers, retailers, processors and farmers.

7.4 RISK AND SENSITIVITY

Risk perception and management has already been alluded to in this discussion in relation to the successful adoption of a differentiated milk supply. The minimum premium required would need to at least enable the NPV to equal zero for either the longest (e.g. 20+ year) or shortest (e.g. 10 year) time period. This would allow for decreasing values compared to the status quo over time and/or technology obsolescence. If it was believed there was a chance of technology obsolescence occurring then the NPV could be calculated over the period this was expected to occur in, which may differ from the 10 years modelled in this example. In the case of technology obsolescence, the payment of the highest premiums calculated can still be risky because of the loss of genetic gain compared to the status quo, and a much higher premium may be required to compensate for this e.g. quantitative scenario 1 compared to quantitative scenario 4. However, this premium is probably greater than a dairy company will be willing to pay and the farmer will need to be prepared to take some, or most, of this risk. The premium required will still need to be over the breakeven value to encourage those farmers at this level of production to change e.g. quantitative scenario 1 value.

7.4.1 Effect of altering the discount rate

A higher discount rate may be used to calculate the NPV as a means of allowing for risk (Barry *et al.* 1995). A sensitivity analysis at three discount rates (7%, 10% and 15%) was calculated for quantitative scenarios 1 and 3, and both qualitative scenarios (Table 6.8). The increase in the premium required for NPV to equal zero was, in most cases small, both in value and percentage terms for quantitative scenario 1 (0.5% to 1.0%, for a 1% increase in discount rate), whereas for quantitative scenario 3 a reduction in premium was required at higher discount rates for NPV to equal zero. These results indicate the premium required is not very sensitive to discount rate, recognising that increasing the discount rate may not be the most effective way to account for risk. That is, the interest rate is not a material factor in choosing a milk segregation policy. Profitability in relation to other variables (e.g. prices, costs) should therefore be considered.

7.4.2 Sensitivity to transport collection cost and premium

The NPV is calculated from the difference between the status quo and the scenario for milk and cattle income less expenses. The premium paid and additional transport costs affect net milk income only. The change in the NPV in response to changes in the premium paid or transport costs is linear. Therefore, the greater the volume of differentiated milk produced in

earlier years and over the whole time period, the more sensitive the NPV is to changes in these variables (Tables 6.9 and 6.10). The sensitivity to a 1 cent per kilogram milksolids change in premium is very similar to the sensitivity of a 0.1 cent /litre change in transport costs for all scenarios. The NPV breakeven was calculated for an “average” transport cost of 1 cent/litre. If this were 1.3 cents/litre an extra 3 cents/kg milksolids premium, approximately, would be required for the four scenarios being compared to compensate for the extra cost.

The profitability of scenarios is most sensitive where the premium for NPV to break even is small, and larger volumes of differentiated milk occur. Under these circumstances it may be important to have the premium at higher than the breakeven premium to offset the farmer’s perception of risk. For example, if the transport cost was an extra 1.3 cents/litre, the NPV for qualitative 2 scenario over 20+ years would be -\$49,791 and an extra 2.99 cents/kg milksolids would be needed to counter this. The NPV would only be -\$17,892 for quantitative scenario 1 at a transport cost of 1.3 cents/litre, requiring an extra 2.81 cents/kg milksolids to break even. Although the negative NPV is considerably greater where a lower premium is required, the larger volumes of differentiated milk means the compensating premium may be similar.

7.5 PREMIUM REDISTRIBUTION

A larger premium can be paid in the earlier rather than later years of supply, to reduce the negative impact of initial set-up costs for the new system and smaller value of the incremental milk income relative to later years. Farmers may welcome the larger premium in the first few years but not the premium reduction later, despite being informed of this pricing strategy from the start. They may re-evaluate the policy if a premium reduction occurred and some may even withdraw from differentiated milk supply even though the net benefit is the same as that for a constant premium.

The effect of redistributing the premium over time was considered within two scenarios. In the quantitative 1 scenario a small quantity of milk was produced in the earlier years and payments were reduced in three steps. The premium paid in the first few years was considerably greater than a constant value payment would have been, whereas the payment in the last period was only a few cents less than the constant premium option (Table 6.11). However, even with an increased premium in the early years the difference in the present values between this scenario and status quo remained negative, although less so (Appendix Table A5.40). Any extra milk income received in the early years was small because of the low volumes supplied. In the example given, a decision to change policy once the premium drops (for example, after 5 years) meant a farmer would have been better off to stay with the status

quo, but this disadvantage was reduced if the premium was redistributed. The present value differences were -\$11,534, -\$7,079 and -\$7,634 between the scenario and the status quo over the first 5 years of a 20+ year time period for a constant premium and the two uneven distributions, respectively (Appendix Table A5.40). This meant that the dairy company would have paid the farmer dropping out \$4,455 and \$3,900 more for the two uneven distributions, respectively, than had they paid a constant premium. Figure 6.4 also shows that the cumulative present value over time does not drop as low for the “redistributed” as it does for the even premium scenario. Therefore, redistributing the premium reduces producer’s risk but increases processor’s risk. However, for the example given, a farmer would still be better to discontinue a white milk policy after 5 than after 15 years, as most of the first 15 years have negative present values, and even greater genetic gain would have been lost in the production traits by then. A farmer exiting the production of differentiated milk early may also recoup some of the negative difference by selling suitable cows to other differentiated milk suppliers at a price premium.

The second scenario considered for the redistribution of the premium was qualitative scenario 2 (Table 6.12). This scenario was in complete contrast to the first scenario and raised some interesting issues. All milk received a premium over all years, and the majority of costs associated with the change occurred in year 1 (cow testing and purchase) (Table 6.7). The present value differences were -\$48,754, -\$13,869 and \$6,449 between the scenario and status quo over the first 5 years of a 20+ year time period for a constant premium and the two uneven distributions, respectively (Appendix Table A5.41). A dairy company would have paid a farmer dropping out after 5 years \$34,885 and \$55,203 more for the two uneven distributions, respectively, than if they had they paid a constant premium. The very high initial cost here makes this option risky for a farmer e.g. the \$48,754 disadvantage compared to the status quo over the first 5 years. Spreading the premium and reducing the risk to the farmer (e.g. technology obsolescence) may provide farmers with some incentive to change. However, spreading the premium makes this risky for a dairy company, with the extra premium paid to farmers leaving after 5 years being greater than that in the previous example (quantitative scenario 1). The difference between the premium paid in the first and other years could be less than in the examples given though, reducing the cost to the company and leaving farmers to take more of the risk.

There is no risk for farmers producing differentiated milk with the second uneven premium distribution (qualitative scenario 2) compared to an even distribution, and they are in fact better off changing milk types again in the first few years before the difference in the return between the status quo and other scenario becomes negative. This second uneven premium

distribution is unlikely to be attractive to a dairy company as farmers could capture premiums and then discontinue milk segregation. To combat this the dairy company could insist on a contract with suppliers for an agreed term.

An uneven premium distribution shifts some of the risk of technology obsolescence or farmers changing policies to the company. However, a larger premium in the early years, with a reduction in later years as milk volume increases could also be a more realistic scenario from a dairy company perspective if the price received for white milk products is greater in the earlier years. In this case, any risk associated with a larger premium in the earlier years is reduced or may not exist as it will be paid out of current income from white milk products rather than anticipated future income or borrowings.

The redistribution of premium payments raises some questions in relation to policy implementation. To encourage potential producers of differentiated milk to switch it still has to be economic for later adopters to do so. If the premium remains constant over time this is not an issue, but if the premium offered reduces over time it becomes less economic for later adopters. Processors will need to assess the period of time it will take for sufficient producers to join and ensure it remains economic for them to do so over this period. They will need to determine whether a bonus payment or higher premium initially (assuming it is clear that this is the policy to reduce farmer risk and encourage early adoption) are sufficient incentive for farmers to adopt sooner.

The premium offered will need to be such that NPV equals zero for those adopting later, while earlier adopters benefit from adopting sooner. Relative to the ideal, this increases the cost to a dairy company. This can be demonstrated by using the quantitative scenario 1 example over 20+ years, with the first uneven distribution (an extra \$1.775/kg milkfat in year 1). If an extra 50% is paid (\$2.663/kg milkfat) for the first 5 years before going to \$1.775/kg milkfat for 5 years and so on, an early adopter (year 1) will get \$31,723 more. At an extra 20% (\$2.131/kg milkfat), this will be \$28,961 more and at an extra 10% (\$1.953/kg milkfat), \$28,041 more. Those adopting in year 6 receive a NPV of zero. This is not unreasonable in that early adopters often receive higher financial benefits if the technology adopted is a success. Farmers could be paid on a redistributed premium scale regardless of when they adopt (i.e. payment linked to the number of years a farmer has been supplying rather than the year of adoption) but this is unlikely to be practical.

7.6 FACTORS AFFECTING THE PRICE RECEIVED PER KILOGRAM OF MILKSOLIDS: MILK CONCENTRATION, PROTEIN: MILKFAT RATIO AND COMPONENT PRICES

Milk prices in New Zealand are commonly quoted in dollars per kilogram milksolids. Factors affecting the price received per kilogram milksolids are the protein and milkfat concentrations in the milk, the prices received for these two components, and the volume charge deducted (Larking 1989; Marshall 1989b). Therefore, the price received varies between farms. A standard milksolids price is usually used in comparing management systems even though this is unlikely to be the actual price received. However, in this model it is assumed that the initial milk composition, and component prices and volume charge are the same in the systems being compared.

In contrast, the price received per kilogram milksolids for the differentiated milk and the standard milk within a scenario, and the status quo milk will differ. In part, this is because of differences in the price paid for the milkfat and/or protein components and the volume charge, however differences in the concentration of milkfat and protein in the milk due to selection affects the overall milksolids price received. Since milk composition, and hence price of status quo and scenario milks, changes differently over time, the comparison of returns in terms of dollars per kilogram milksolids is less useful. Farmers considering changing to differentiated milk need to think in terms of component pricing (e.g. milk, milkfat and protein) and the effect this has on their returns.

Transport costs differ between status quo (and standard) and differentiated milk, and this too impacts on the price received per kilogram milksolids. This is demonstrated in Table 6.6, where the approximately 10 cents per kilogram difference in milksolids between the status quo and scenario milks is due to transport costs. Although this cost is currently deducted before the milksolids payout, it would be informative for farmers to realise the effect of the transport charges, as the premium needs to cover all incremental costs relative to the status quo including transport.

The premium required in a scenario for the NPV to equal zero has to be sufficient to compensate not only for additional costs associated with the change, but also the difference in milk income that could have been earned at status quo prices between the status quo and the other scenarios (Appendix Table A5.42). This revenue difference is also important should all or some of the milk revert to status quo prices after a period of time. Most of this is because

of differing amounts of milk produced between the scenario and the status quo, while some is due to milk composition and concentration differences.

The loss in milksolids earnings for the scenarios versus the status quo at status quo prices in year 20 is greater for the quantitative comparisons (\$21,994 to \$32,521 less) than the qualitative comparisons (\$1,009 to \$1,015 less) (Appendix Table A5.42). Changes in milk composition between scenarios over the 20 years (Table 6.3) contributed to this. If constant milksolids production for the scenarios and the status quo is assumed, 27% of this difference would be due to differences in milk composition for quantitative scenarios 1, 3 and 4, and 47% for scenario 2. The loss in protein income per kilogram of milksolids was more than twice the gain in milkfat income (Appendix Table A5.42). Milksolids concentration, which affected transport costs, had only a small effect on milksolids income.

The decline in the protein:milkfat ratio may affect the product mix, or the processing properties of the milk. A premium may be received on all, or only some, of the products made with the white milk. The white milk may be used to make white milkfat products only, with the protein component used for standard products such as casein or skim milk powder. Thus, the mix will be a combination of white and non-white products, with the protein valued at status quo prices and the milkfat at a premium. Therefore the relativity between these prices is important e.g. is white butter going to be more valuable than casein? In contrast, white milk may be used to make white milk powder or cheese products, with excess milkfat taken off and possibly also used for white milkfat products such as anhydrous milkfat, ghee and butter. If white milk powder or cheese commands a market premium, then the premium offered to farmers could incorporate both protein and milkfat components. However, because the yellow colour component in milk is stored in the milkfat, paying the premium only on the milkfat component may provide stronger incentive for farmers to change to "white milk". Further, extra protein could be provided from skim milk derived from status quo milk, in which case the value of protein from white milk would be similar to that of the status quo protein anyway. Therefore, the value of the product mix made with differentiated milk may change over time as the amounts of protein and milkfat produced (and protein:milkfat ratio) alter, to either a lower or higher returning mix, depending on the relative prices for the products in the product mix. A lower protein:milkfat ratio also has a processing disadvantage in the production of cheese and milk powder products, and a declining protein:milkfat ratio means more milkfat will need to be removed before producing these products. The declining protein:milkfat ratio will probably only have a small impact on the product mix made, and the returns received, particularly as protein product prices have in recent years been greater than those of milkfat. However, this declining protein:milkfat ratio will be more of an issue if

prices revert to status quo values, where the value of milkfat is considerably less than that of protein.

The status quo value of protein is greater than that of milkfat. If the value of the milkfat, including the premium, remains lower than that of the protein, then a reduction in the amount of protein produced or the protein:milkfat ratio will not be advantageous. Protein could be included in the breeding objective, however, this needs to be balanced against the moderating impact this will have on the rate of gain in the milkfat colour trait. The value of the differentiated milkfat at premium prices is still likely to outweigh any loss in protein production even at higher protein prices. However, protein could be included in the objective once most or all of the milk met the differentiated standard.

7.7 OTHER FINANCIAL CONSIDERATIONS

Other financial considerations in milk segregation include the effect on debt requirements and cash surpluses over time. In the cost-benefit analysis all costs and benefits were allowed for in the year they were incurred i.e. treated as an overdraft if costs exceeded benefits. Initial costs associated with a change are met by an increased overdraft, a loan, or a reduction in savings and interest earned on these savings. Interest was not included because discounting allows for the time value of money. A series of budgets would need to be prepared to determine the effect on cash flows and any extra debt commitments required before a farmer committed to a policy change. Any debt-related costs associated with a change should be able to be met over the time period specified if the appropriate discount rate is used in the NPV calculation i.e. interest rate associated with borrowing or savings was the same as the discount rate. The analysis did not include income tax effects as these vary from business to business. Tax implications would need to be assessed according to the circumstances of each farm business.

Some scenarios had only a relatively small negative partial budget value in year 1 e.g. quantitative scenario 1. These policies may be able to be implemented out of cash surpluses rather than debt. If so, the cash surplus for year 1 would be similar to that for the status quo plus the difference between the scenario and the status quo. The reduction in values compared to the status quo over the following years would also be similar to the difference in cash surpluses between the scenario and status quo i.e. no extra interest or principal repayments.

In contrast, qualitative scenario 2 would require a large investment in year 1, and this capital may need to be borrowed. If so, the difference in the cash situation between the status quo and the scenario would not be as great as the difference between the status quo and the scenario

values in the year of borrowing. Interest and principal repayments would need to be budgeted for, from the increased surpluses compared to the status quo in the following years. The loan is likely to be a term loan so a set amount of the actual non-discounted value (rather than present value) per year would need to be allowed for in making comparisons between options. The farmer's cash flow may be worse in some years than for the status quo. Having to borrow may also affect the producer's perception of exposure to financial risk.

The only capital item purchased to implement the change was a vat. Depreciation on this is tax deductible. This will be a small cost with little impact on the financial situation between the status quo and the scenario. Genotyping, as a farm working expense would be tax deductible, however this is already reflected in the difference in cash flow between the status quo and the scenarios. There could also be tax implications for policies where livestock numbers are increasing compared to the status quo e.g. quantitative scenario 1. The increase in the capital value of the stock is considered in calculating tax, and policies with more livestock than the status quo will have to pay a higher tax because of this, assuming livestock are valued equally between policies.

Interest, as well as directly affecting the cash surplus, is also a tax deductible expense and will, according to timing and differential tax rates, affect tax liability. These factors will therefore affect the cash difference between the status quo and the scenario e.g. quantitative scenario 2. The inclusion of tax in the NPV calculation would have required further assumptions about the amount of the investment funded by cash surpluses or a loan, the interest rate (discount rate) and the term of the loan. As indicated earlier, the economic model could be adapted to investigate these matters for an individual farm.

The NPV calculations were based on an average year. However, the cash surplus will need to be sufficient to repay debt even in years where the milk payout is lower (due either to the market or climatic conditions). The milk component premium used in the NPV calculation was consistent across all years. In reality, the premium may also be less in absolute (rather than percentage) terms in years when the payout is less than the long-term average. While the reverse could also occur, this brings an added element of downside risk to the adoption of a differentiated milk policy, as income will need to be sufficient to cover extra costs, including debt servicing, in years where the payout and the premium may be lower. If the lower payout years come soon after the change over, this may negatively affect profitability.

7.8 MILK SEGREGATION AND PAYMENT OPTIONS

If milk is being differentiated on a milk characteristic or component such as milkfat or protein that gives the milk a particular quality (e.g. colour, softness, flavour, health related or immune qualities) that affects the nature of the product(s) made, then the differentiated milk will need to be segregated from the remaining milk. The products will be speciality higher value products targeted to niche markets (Street 1990; Spring 1997; Boehlje *et al.* 1999). The premium paid for these products less any extra processing and marketing costs will be reflected in the milk payment to the suppliers of differentiated milk.

In contrast, if cows are bred to produce milk with a higher level of a particular compound for extraction (e.g. sphingiolipids) then this milk may or may not need to be kept separate at the farm. Where small amounts of very high value components are being extracted and a few herds are sufficient to provide this, it would be advantageous to keep the milk from these few select herds bred for high levels of these compounds separate, enabling higher processing yields from the same milk input. Where compounds are being extracted from large volumes of milk, the differentiated milk may not need to be kept separate, but farmers could be paid on the herd's level of the milk component. This may be the situation initially, whereas in later years there may be sufficient herds with high levels of the desired compounds to separately process lower volumes of the desired milk type.

If cows are bred to produce milk with improved processing qualities (e.g. BB β -lactoglobulin for improved cheese yields) this milk also may or may not need to be kept separate. Milk with improved processing capabilities could be kept separate if it is to be used for high quality products, or included with the standard milk to improve the overall quality. The overall quality of the milk would improve over time in parallel with the concentrations of the useful protein in the milk. If milk is not segregated farmers could be paid on the proportion of the desired protein in the milk. The proportion of AB as well as BB cows in the herd would contribute to the level of the B protein. If the BB milk were segregated farmers would be paid on the amount of differentiated milk (as discussed also in Chapter 3).

The value of the milk produced, and therefore the price received by farmers, should be based on the net value of the product derived from their milk (i.e. less associated processing, distribution and marketing costs for the product made with the milk), rather than a company paying an average return overall plus a premium for differentiated milk. Therefore, farmers

who produce a differentiated milk type should receive a raw milk price that reflects their product's market premium, while those that produce status quo milk or standard milk should receive a price reflecting returns from their milk (Scrimgeour 1999). This approach may affect the returns received by status quo farms, as their milk will be largely used for commodity and some ingredient products. If this reduced their returns, the price required for the differentiated milk herds to break even would be reduced, as it is the actual difference that between the status quo and the scenario that is used in calculating NPV. The prospect of a reduction in milk price for status quo herds would also act as an incentive for their owners to switch to differentiated milk.

Paradoxically, an increase in niche products from differentiated milk may, in time, slightly increase the price received for status quo milk. As more milk is used for niche products the volume available for commodity products will reduce and this may improve the market-weighted average return. Given New Zealand's increasing milk production and the rate of growth in world demand, this is unlikely to occur in the short term.

Keeping all the cows in one herd and paying for the concentration of a desired milk component has advantages for both the farmer and dairy company. Management will be easier, and possibly less labour intensive because separate herds will not be required. Alternatively, milking systems with two milk lines could be installed, however, this would require a greater investment. Cross-contamination between milk types may occur with two herds although this may not be of major significance with some milk types. Milk transport costs will also remain the same if all the milk is collected in one lot, benefiting both the dairy company and the farmer.

Owners of larger herds may find it easier to change to differentiated milk by breeding. There will be more cows in the differentiated herd initially, making it more worthwhile for a company to collect the milk as well as making herd management easier than for the owner of a smaller herd. Farmers may also choose to maintain two herds to spread the risk, rather than to supply only differentiated milk. Small herds may have an advantage where milk manipulation is by other means (e.g. injection to stimulate immunoglobulins, specialised diets, purchase of cows rather than breeding) as the farmers often know their cows better and may be better able to monitor these effects on herd health and milk production. Smaller herds are also likely to be managed by the owner who will probably have a greater interest in monitoring and adapting the system to ensure it works effectively, than a manager or an employee in a large herd situation.

Garrick and Lopez-Villalobos (2000) modelled the value of New Zealand milk (yield, protein and milkfat) and identified that in reality, the value of milk and milk components differed depending on the product mix made with that milk. They suggested that the economic weightings of the milk components could vary between farms in New Zealand to reflect the value of the value of the product mix made with the milk from each farm (Garrick and Lopez-Villalobos 2000; Lopez-Villalobos 2002, *pers. comm.*). Differential payment for milk components depending on the end use of that milk would involve redistribution of industry income, benefiting some and disadvantaging others. They noted that differential payments for milk between factories would encourage suppliers to provide milk to those manufacturing high value products at the expense of those producing a suite of lower value products, which could be a problem because high value markets are limited and low value (commodity) markets are also required as a buffer.

The traditionally cooperative nature of the New Zealand dairy industry (Spring 1997) ensures all suppliers within a company are paid the same for their milk components (milkfat, protein and yield). Fonterra, New Zealand's biggest dairy company, owns most dairy processing sites in New Zealand covering all but the West Coast region of the South Island (Fonterra 2001a, 2001b). Suppliers are likely to resist systems of differential payments between factories for essentially the same product (i.e. for similar milk) which leaves some farmers worse off than they were, particularly if the only reason for this is their misfortune to be farming in an area where their milk is directed into a low value product, or changes in component values make their milk less valuable than similar farmers in another area. There would be justification in farmers feeling this way as in the past all suppliers received the same price signals and selected bulls based on the same national index and relative economic weightings.

Even assuming the average return for milk could be kept the same between factories, altering the weighting between the components within factory supply areas, to reflect local milk component values, and send market signals to suppliers to change milk composition may also be unpopular. This would create inequity between farms producing similar milk types supplying different factories e.g. a farmer with supplying a butter and casein factory may receive a lower income than a farmer with similar milk supplying a milk powder factory, because of component value differences.

However, the future development of differentiated milk supply from select groups of farmers for specialised milks used in the production of value-added products could be acceptable. Premiums will come from the value added price component and will not detract from the remaining farmers' incomes. This premium will be required to compensate for the extra

investment, on-going costs, risk and management associated with segregated milk. Implementing changes within a whole factory supply area may also be possible if the milk payment increased to cover any extra costs associated with a proposed change, and the change was relatively straightforward e.g. milk suppliers in the Kaikoura area used BB β -lactoglobulin bulls (Boland *et al.* 2000). Processing advantages (e.g. higher yields or lower costs) or higher product returns would be expected to cover increased costs.

New Zealand's dairy mega-sites often produce a range of product mixes (e.g. skim milk powder and butter, or cheese and whey products). The opportunity clearly exists for processors to direct the milk from selected farms to different factories (either separately or within a mega-site) for the production of the various product mixes. This practice has no cost implications for farmers. Extra transport and possibly storage costs may be incurred at factory level, so advantages would need to be sufficient to cover this. Some of the increase in return over and above this could be returned to farmers supplying milk for that product, possibly by increasing the payment for the most valuable component. Farmers would not lose out (i.e. there would be no decrease in component values) and any component increases will send market signals to farmers to help direct their breeding and management decisions. Processors are also more likely to direct a farmer's milk to the mix it is most suited for, and which is therefore most likely to increase the marginal value of a farmer's milk.

7.9 INDUSTRY STRUCTURE, AND TRANSPORT AND PROCESSING ISSUES AND STRATEGIES

The 2001 merger of New Zealand's two largest dairy companies, New Zealand Dairy Group and Kiwi, along with the Dairy Board and the Dairy Research Institute means the New Zealand dairy industry is now dominated by one major dairy company, Fonterra (Fonterra 2001a, 2001b). Therefore the priority Fonterra puts on the development of niche product opportunities will have a large impact on the prospects for differentiated milk in New Zealand. Companies comprising Fonterra have shown interest in developing niche products, and markets for these, over recent years, some of which require milk differentiation at farm level e.g. organic milk, colostrum and immune milk. Fonterra intends to continue with research and development in milk products with nutritional or medical benefits e.g. adding calcium into some products (Pilkington 2001, *pers. comm.*). Fonterra also has the size to launch a niche product relatively quickly, should the opportunity arise or in response to the launching of a similar product by a competitor.

Equity issues may arise because of the co-operative nature of the New Zealand dairy industry. All farmers contribute to industry good research and development (R&D) costs. However, R&D may result in the development of a niche product produced from the milk of a few select suppliers who are paid a premium for this milk. The return to all suppliers from this niche product will be associated with the company's share of the profit from adding value to this product, and this should be reflected in the value of dairy company shares and the value added component of the payout.

Previously, all New Zealand dairy products were marketed through the New Zealand Dairy Board (Fonterra 2001b). However, the recent deregulation of the dairy industry opens the market for smaller speciality dairy companies to develop and supply of high value, niche market products. Tatua dairy company has successfully supplied niche products for some years now, consistently having the highest dairy company payout to its farmers. A2 Corporation has recently been formed to supply milk with only A2 α -casein, with possible health benefits to those susceptible to diabetes (Elliot *et al.* 1999). This milk would also need to be differentiated at the farm level by cow genotype.

In the past New Zealand had many small factories processing the milk from local farms (MAF 1999). This has been replaced by the development of mega-sites with the capability to rapidly process very large volumes of milk. Efficiencies gained in processing bulk milk have outweighed the extra cost associated with its transport. The transport, storage and processing implications of milk differentiation is counter to this trend. Batches for storage and processing will be smaller, and special facilities and equipment for processing may be required compared to non-segregation of milk. An extra silo may be required on-site for the storage of differentiated milk, depending on the rate of processing.

These factors will increase milk processing costs. Alternatively, differentiated milk could be collected every second or third day, requiring more on-farm storage but reducing transport and processing costs. A smaller speciality processing facility could be added to the mega-site, which would require capital input initially but may improve efficiencies. This may be of greatest advantage during peak milk supply when the factory is close to being fully utilised for bulk milk processing, and small runs of specialist milks are likely to be an inconvenience or impractical. Another alternative is to process niche products at a smaller processing plant, developed or adapted specifically for this purpose. Farmers within a region or locality could be approached to produce a particular type of differentiated milk. This would be efficient where there are regional effects associated with milk composition or if milk from only a few farms is required to meet market requirements. Future investment in the development of

smaller batch processing facilities, either at the mega-sites or separately, rather than continued investment in bulk processing facilities would be a step back in time in terms of dairy industry infrastructure. However, the development of smaller processing facilities may make the processing of niche products more efficient, and therefore more economic.

Cross contamination of milk types, in both transport and storage, may be of importance with some milk types. Minor cross contamination may not be critical with milks of different genotypes segregated because of their processing properties. Other milk types may need to be kept separate e.g. organic milk or white milk if it is close to the cut-off to avoid dilution, and this will increase costs. Either separate tanker runs for each milk type, or separate pumps for the truck and trailer units on the tanker increasing capital requirement and reducing load size, will be required. A farm with two cow types may also need to flush out the milk line between milking the two herds, increasing time and costs slightly. This would also increase milking times and inconvenience.

Transport issues were extensively discussed in Chapter 4. The extra cost of transporting differentiated milk over 20 years, with volumes of each type fluctuating over time as more milk changed from standard to differentiated was up to 23% more than non-differentiated milk. A difference of 0.7 to 1.3 cents per litre more was assumed, or about an extra 8 to 10 cents per kilogram milksolids making the cost of milk transport between 40 and 50 cents per kilogram milksolids, a 20% to 25% increase in transport costs over non-differentiated milk. Once all milk was one type or the other the extra cost of transporting differentiated milk decreased (Chapter 4). The extra transport cost represented a relatively large proportion (over half the cost) of the extra premium required in the qualitative scenarios (Table 6.6), but not for the some of the quantitative scenarios where a larger premium was required to break even (Table 6.1). The transport model was run assuming milk quantities similar to that for qualitative scenario 1. The extra transport cost associated with the quantitative scenarios may be greater than the one cent per litre more assumed in the model because of the relatively small amounts of segregated milk produced initially. The second qualitative scenario is likely to have a lower transport cost because all milk is the same type (differentiated) in year 1. A processor collecting differentiated milk would collect milk from suppliers with proportionally different amounts of segregated milk over time depending on the policies adopted and base volumes.

Although the milk payout includes the volume charge, the farmer never sees this because payment is deducted by the processor. However, farmers changing policy should be made aware of the impact the extra transport cost associated with differentiated milk has on their

milk income. This has been discussed previously (Sections 6.2 and 7.6). The dairy company will need to ensure that the milk premium is sufficient to compensate for extra transport and other costs associated with the change.

Fonterra's offshore expansion opens up opportunities for the development and processing of niche market products overseas. This may be a more practical alternative for Fonterra than producing some niche products from differentiated milk in New Zealand for export, as the milk in overseas countries may be more suited to the production of these products. For example, milk from cows in Europe is whiter than that of cows in New Zealand. Organic milk is also more readily available in Europe than in New Zealand. However, while these products could be sold under a New Zealand brand, they could not be traded as being a New Zealand product. Although the production and export of differentiated milk products from New Zealand may be more expensive for Fonterra than developing them overseas, long term returns for these may be greater.

7.10 BREEDING TECHNOLOGIES

Genetic gain is influenced by the generation interval, the selection intensity, the accuracy of prediction and genetic standard deviation of the traits (Van Vleck *et al.* 1987). Issues in relation to breeding strategies were discussed in Chapter 3. These are in reference to a qualitative trait, but most are also applicable to quantitative traits.

The effect on genetic gain of selecting on one trait rather than including a number of traits in the selection index has been discussed earlier in this chapter. Some of the issues discussed in Chapter 3 will be briefly mentioned here. Restricting selection to a limited group of animals (e.g. BB genotype animals or low milk colour animals) reduces selection intensity and therefore genetic gain in the other traits i.e. fewer bulls available for selection (Chapter 3). The availability of sufficient bulls may also arise if a sub-set of industry bulls is used.

A number of breeding or reproductive strategies can be used to increase progress in a desired trait. Yearling mating increases genetic gain by decreasing the generation interval. This was shown in Chapter 3 to be an effective method of increasing gene frequency, and will also increase the rate of genetic gain in a quantitative trait. A higher replacement rate will also reduce the generation interval and increase genetic gain. Testing cows to identify the genotype as well as using BB bulls increased the BB cows in the herd more quickly than not testing (Chapter 3). Sourcing differentiated milk within a breed or region could also be an

effective approach, although it will be important to ensure the milk from the breed with the desired trait does not have disadvantages in processing (Chapter 3).

Marker assisted selection is not yet widely used by dairy farmers, but has the potential to be used more in the future (Visscher *et al.* 1998) for differentiated milks. Milk proteins can act as marker genes or affect a milk trait directly (i.e. as a quantitative trait locus), as discussed in Chapter 3. Technology, not yet widely available, has made sexed semen a potential method of increasing the number of female replacements (and increasing selection on the female side) or the number of bull calves born to bull mothers. Multiple ovulation and embryo transfer (MOET) could be used to speed up genetic progress, particularly in a trait where the number of cows meeting the criterion was low, by breeding a number of progeny from these cows. These technologies, although more expensive than current breeding practices, could all increase the volumes of desired milk at a faster rate.

New technologies are on the horizon that in the long-term may have practical applications in the development of differentiated milks. Cloning of farm animals has been achieved on an experimental basis, however, this is very expensive and has a very low success rate (Cunningham 1998; Wells *et al.* 1998). An economic and successful means of cloning would enable a herd of cows producing differentiated milk to be produced in one generation. A drawback of cloning is potential loss of genetic variation in a population and possibly a reduction in genetic gain in production traits compared to non-differentiated herds. Unless a bull was produced that carried the required gene, herd replacements would also need to be cloned. These factors would be of less concern if cows were cloned in only a few select herds to produce differentiated milk for small volumes of very valuable products.

Genetic modification may have a future role in the production of differentiated milk, either for genes which modify milkfat or protein synthesis in the cow, or for the production of high-value proteins not normally produced in the mammary gland (e.g. pharmaceuticals) (Cunningham 1998). Genetic modification is likely to be an expensive technology and the most likely application is for the production of highly valuable pharmaceuticals. High levels of desirable components could be produced by the introduction of multiple copies of a gene, or undesirable genes can be “turned off”. Transgenes affecting milk composition could be introduced into select herds. The time estimated for commercial herds to start production of differentiated milk is 8.75 years after the introduction of the transgenic founder bull (Gibson 1998). Genetic modification trials are currently underway in New Zealand (L’Huillier 1999), however public opinion on genetic modification issues is divided (with strong anti-genetic

modification opinions) making the nature of future application of transgenic animals in New Zealand uncertain.

The New Zealand dairy industry is dominated by Friesian (57%), Jersey (15%) and Friesian-Jersey cross cows (20%) (LIC 2000). For many generations the majority of cows were bred for increased milkfat and more recently, for increased protein and reduced milk volume, with most bulls and cows selected on a national breeding index. The majority of cows have been bred to a few intensively selected sires by artificial insemination, leading to genetic gains of about 1% of the mean per annum in these traits. The predominance of only two breeds and the mating of the New Zealand dairy cow population to a small number of bulls means there is likely to have been loss in genetic variation for some milk components over this time. In contrast, many breeds, some locality specific, exist in places like Europe, although the number of breeds is declining. Milk produced in a specific herd or area is often used to produce only one product. These breeds have “evolved” or been selected because of their adaptation to the local environment, or for the quality and quantity of their milk for the production of a local product e.g. high protein levels in the Reggiana and Modenese breeds on the Po Plains in Italy where parmesan cheese was traditionally produced (Avon 1990). As a result, there may be greater variation in milk composition of European cows compared to New Zealand cows.

It may be worthwhile to import genetics (semen or embryos) from some of these breeds if they are identified as having a milk composition ideally suited to the production of niche products. While the BSE scare in Europe rules out the importation of live animals, the importation of genetic material may still be possible. It would be important to compare the milk composition of these breeds under New Zealand conditions, to determine how much of the difference was breed related rather than environmental (e.g. management or feed) before releasing the genetics to the industry. This, and the necessity for quarantine for some imports, would delay the availability of these breeds to alter milk composition. However, the New Zealand sheep industry has shown the importation of exotic breeds (East Friesian, Texel and Finnish Landrace) can be used to fast track gains in lean growth and reproduction through crossbreeding (Allison 1995; Clarke 1995; Jopson *et al.* 2000).

7.11 MODEL APPLICATION AND EVALUATION

This simulation model was developed to predict the on-farm impact of milk differentiation, as well as the minimum financial premium required for the policy to break even with the status quo. Research into milk differentiation policies by experimentation is long-term and involves

irreversible changes to the herds' genetic composition. Simulation modelling therefore provides a cost-effective and practical way to evaluate the effects of milk differentiation. The research objective was to develop a model that could compare a milk differentiation policy with the status quo for any particular set of farm inputs. The model is not an optimisation model. However, the reality is that farms are not optimised for either production or profit, as a farmer's abilities and goals also affect management practices (Kay and Edwards 1994).

The model is deterministic, driven by genetic gain over time in the breeding models. It is assumed that the full change in the genetic potential of the cows is realised. The farmer's management ability and pasture production of the farm are assumed to be common to the status quo and scenario. Therefore, the herd's milk production and feed requirements are determined by the potential of the cows to produce for each of the scenarios. These two factors were similar for the qualitative scenarios modelled. However, for the quantitative scenarios the production potential of the cows (milk, milkfat and protein yields) selected on colour declined compared to the status quo. Hence, their feed requirement was also lower so more cows could be fed from the pasture produced, allowing a higher stocking rate.

Cows in New Zealand do not reach their full genetic potential (Holmes *et al.* 1984; Davis, S.R. 1997). Therefore, had the scenario cows been run at the same stocking rate as the status quo cows, they would have achieved higher production per cow than that modelled because of their higher feed intakes. However, had they been run at the same stocking rate and feed availability per cow as the status quo, their lower genetic potential suggests their production would still be lower and they would eat less than the status quo cows. Pasture utilisation would be also lower and they would convert more feed to body fat. Therefore, to avoid confounding the management and cow effects, stocking rate was adjusted for the scenarios to match management (e.g. the same pasture quality, utilisation, lactation length) with cow genetic potential.

Milk composition for the scenario options was manipulated through breeding. Other factors can also affect milk colour. Manipulation of milk composition by feeding was not modelled, although this is possible with milk colour, as shown by the lighter milk colour of European cows fed on a higher proportion of low β -carotene feeds (e.g. concentrates) compared to New Zealand cows fed a pasture-based diet (McDowell and McDowell 1953; Thompson *et al.* 1964). The lack of specific quantitative information on the effect of feed supplementation (e.g. concentrates) on the milk colour of cows under New Zealand conditions makes the modelling of this difficult. Feed supplementation also affects the production traits, with possible carryover effects after supplementation ceases or in the subsequent lactation.

Feed effects could be included in the model, if required. This feed component of the model could be fine-tuned, as more information becomes available on feed impacts on colour and production traits. The outputs from cow physiological models such as the Cornell Net Carbohydrate Model (Fox *et al.* 1992; Cottrill 1998) could possibly be included for this purpose, however, these models may need to be developed further to include other traits. The lactation curve for milk colour in the model was derived from information obtained from a spring calving herd; this curve may differ from that of an autumn calving herd because of the effects of stage of lactation and level of β -carotene in the feed.

Two feeding sub-models were developed. The cow requirements model predicts milk composition, colour and feed requirements over the lactation. The feed model then calculates the stocking rate associated with a farm (of specific size, pasture production and utilisation characteristics), and estimates the quantity and cost of supplements made or purchased. Although inputs (e.g. pasture production, utilisation and lactation length) may vary between years depending on season, an "average" year was assumed. A small incremental increase in pasture production was included each year to reflect the gains an "average" farm may achieve. Determining stocking rate is a longer-term decision based on expected production, and therefore an "average" year is an appropriate basis to calculate this.

It may or may not be appropriate to include feed supplements (e.g. crops, concentrates, purchased silage) in the status quo as well as the scenario. Where this is part of the current farming system then it should be included in both. Adding feed supplements to the scenario primarily to change milk composition will also increase production. A similar change of feeding in the status quo system would also increase production and possibly returns. It could be argued that the change should also be included in the status quo if it is relatively straightforward and economic, because a farmer who is prepared to change the management for one system may also be prepared to make the same change in the other for an increased return. An example here may be growing a crop or purchasing silage. However, some feed changes incorporated into a system to alter milk composition, such as the feeding of particular concentrates or protected lipids, may be financially beneficial for the scenario, but not for the status quo.

Different feeds are likely to be an effective means of manipulating milk colour, particularly the feeding of low β -carotene feeds such as concentrates (McDowell and McDowell 1953; Thompson *et al.* 1964; Keen 1986). However, this may or may not be economic, and provided

the impact of concentrate feeding on colour and other traits was known, the model could be used to estimate the cost-effectiveness of this practice. If feeding as well as breeding was used to manipulate colour, the breeding colour threshold could be set higher with more cows in the white milk herd. Alternatively, the cut-off criterion could remain the same and concentrates could be fed to the “white” milk herd in those months when the criterion was not met to increase whiteness. This is likely to be in early lactation and/or the spring months. Yellow milk colour is associated with feeding leafy spring pasture which is high in β -carotene, but there is also a lactation effect, possibly associated with the mobilisation of body reserves (Walstra and Jenness 1984; Keen and Wilson 1993). However, the increasing pasture supply in spring means that feeding concentrates at this time may also lead to an increase in supplements made (e.g. silage) and/or a reduction in pasture utilisation, regardless of any associated increase in stocking rate.

Stochasticity, for example, in pasture growth rates could be included by rerunning through another adaptation of the feed model after calculating stocking rate, to determine the effect of variation in pasture growth rate on the need for supplements (extra may be carried over to the following year or some may need to be purchased). Alternatively, seasonal variation could be allowed for by altering lactation length, and therefore production. However, this would require rerunning the data through an adapted cow requirement model as well. These approaches would make the model considerably more complex, and may be more appropriate in comparing the effects of different management systems where long-term time effects are not also being modelled. The advantage of a stochastic approach is that it does show variation and hence production risk. However, in terms of comparing the NPV required to break even, an average year is adequate and avoids the complications associated with the transport model where the status quo may be optimal in any given year but the scenario may not be, for example. Over the 20 year time frame used, and assuming average years, these effects balance out.

The model assumed an average farm. The costs that differed between the status quo and the scenario, with the exception of an extra vat, were cow-related, therefore altering either the farm or herd size would make little difference to the premium required for NPV to equal zero. However, if the per cow costs between the status quo and the scenario were not the same the required premium would differ, particularly where the number of cows varied considerably.

The model could be used, possibly with some adaptation, to model scenarios other than the effect of breeding and feeding on milk composition and production. These could include: the manipulation of milk flavour through feeding (Keen and Wilson 1993); altering calving

pattern to ensure a more consistent milk quantity and composition throughout the year; and the stimulation of cows to produce milk with immune properties by the administration of injections e.g. IgA milk (Dingwall 1991; Fenwick and Marshall 1991; Regester *et al.* 1997). In the future, milk composition may be altered by interference in the pathways that produce milk components e.g. the modification of rumen microflora to alter flavour (Joblin 1993; Joblin and Hudson 1997). These scenarios could all be modelled using the current model with little or no adaptation. The farm production system used can add value to the outputs (e.g. organics) and the model could be adapted to simulate this. The partial budget approach in the economic model would need to be extended to include farm inputs such as fertiliser, and other sub-models altered to allow for differences in milk production, and pasture quality and production.

The sub-models included in the model could be used separately. For example, the milk model component could be used as a stand-alone model to compare milk returns with a shoulder pricing policy compared to the same price all year (Paul 1985; Gray *et al.* 1994), or to compare returns with different values placed on the various milk components. In this study the qualitative breeding model was used as a stand alone model to determine the quickest way to change the gene frequency in a population (Chapter 3).

This simulation model could prove useful in predicting potential future scenarios for the dairy industry. Dairy companies and farmers contemplating changing to a differentiated milk policy will require production and economic information before a differentiated milk policy will be implemented by either party. A dairy company will need to work closely with farmers throughout the establishment of a differentiated milk policy e.g. feasibility studies, identification of constraints, development of strategies, implementation, and follow-up and problem solving to encourage farmers to continue producing differentiated milk. Experimentation or demonstration farms will be impractical because of the long time frame associated with milk differentiation, particularly with breeding. Simulation modelling could be used to predict the changes over time. This model could act as a tool for both farmers and companies to assist with the evaluation process.

7.12 SUMMARY

Model outcomes have been discussed in this chapter in terms of their implications and other factors that need to be considered in relation to milk segregation policies on farm. The following chapter presents an overview of the study, recommendations and areas for further research.

CHAPTER EIGHT

SUMMARY AND RECOMMENDATIONS

The New Zealand dairy industry is moving away from the production of commodity-based production and processing to one where product specification drives the industry. Opportunities exist for the production of tightly defined niche products based on specialised milk production systems. Milk composition already varies, both between cows and between herds, suggesting that milk could be differentiated based on milk composition. Milk composition can be further manipulated through breeding, feeding and management. Segregation of herds could enable milk to be matched by composition and quality to products for high-value niche market opportunities.

8.1 MODEL DEVELOPMENT, RESULTS AND GENERAL DISCUSSION

The purpose of this study was to explore issues related to the segregation of milk on-farm according to its composition. Factors affecting milk composition and ways these could be manipulated were identified. Although the study was undertaken largely from a farmer perspective, factors that impact on the implementation of milk segregation policies both on- and off-farm were considered. A model was developed to determine the break-even premium required for a farmer to be no worse off financially if a segregated milk policy was adopted. Model components included qualitative and quantitative breeding, cow requirement and feeding, and milk income and farm economics.

Four milkfat colour scenarios (a quantitative breeding trait), and two scenarios selecting for B homozygous β -lactoglobulin cows (a qualitative breeding trait) were modelled. “White” milkfat can be used to manufacture dairy products that are naturally light coloured, and for which a premium may be paid¹. BB β -lactoglobulin milk, which has more casein and less whey than AA or AB β -lactoglobulin milks, produces higher cheese yields than AA or AB milks and has processing advantages for other products². General concepts discussed in relation to these traits could apply to other milk quantitative or qualitative traits.

¹ See Keen (1986) for discussion of milk colour.

² See Hill *et al.*(1997) for discussion of β -lactoglobulin genotypes.

The six policies, and the premiums required for these differentiated milk alternatives to break even with the status quo over 20 years are summarised in Table 8.1. Breakeven values were also calculated for 10 and 20+ year (infinity) periods (Tables 6.1 and 6.6). The premium was paid only on the differentiated milk. It was assumed no premium was paid on protein in the quantitative scenarios (i.e. status quo price was paid) because value is added through the milkfat component of the niche products made from this milk. However, a premium is assumed for protein in the qualitative scenario.

Table 8.1: The premium required per kilogram of protein and milkfat for each scenario, for the NPV to equal zero over 20 years. The total component value is shown in the first row and the increase over the status quo is shown in the second row.

Scenario	Protein value	Milkfat value
Status Quo	\$6.24	\$2.89
Quantitative scenarios		
No. 1: Selection on colour only, initial colour 8.0	\$6.24 -	\$4.00 \$1.11
No. 2: Selection on colour and milkfat yield, initial colour 8.0	\$6.24 -	\$3.97 \$1.08
No. 3: Selection on colour only as for No. 1, but with initial colour 6.0	\$6.24 -	\$3.35 \$0.46
No. 4: As for No. 1 for first 10 years, then reverting to SQ for genetic gain and prices received.	\$6.24 -	\$8.51 \$5.62
Qualitative scenarios		
No. 1: Changing to a BB herd over time by testing and selection of cows.	\$6.45 \$0.212	\$2.99 \$0.098
No. 2: Changing to a BB herd in year 1 by testing, and cow and heifer purchase.	\$6.50 \$0.256	\$3.01 \$0.119

The proportion of the total milk attracting a premium increased over time for all scenarios except qualitative scenario 2, with only small volumes of milk attracting a premium in the early years for some of the scenarios. This contributed to the high premium required for some of the scenarios, particularly quantitative scenarios 1, 2 and 4. Only 2.4% of the milk met differentiated milk specifications in year 1 in these scenarios. This increased to 20.0% for

scenarios 1 and 4, and 14.8% for scenario 2 by year 10. In contrast 37.9% of scenario 3 milk was differentiated in year 1, increasing to 93.7% by year 10. Almost half (46.9%) of the qualitative scenario 1 milk met requirements in year 1, and this had increased to 84.3% by year 10. The policy of buying and selling cows in qualitative scenario 2 meant all milk met the requirements in year 1.

The reduction in per cow production of the milkfat and protein components also contributed to the high premium required under the quantitative scenarios. Shifting some or all selection emphasis to reducing colour slowed genetic progress in the production traits relative to the status quo. This lower production per cow resulted in a higher stocking rate and lower production per hectare with the difference increasing over time e.g. 5.5% more cows, and 5.1% less milksolids including 1.1% less milkfat per hectare for quantitative scenario 1 compared to the status quo after 20 years. The increased premium had to compensate for any reduction in income due to lower production and the increased costs because of the higher stocking rate compared to the status quo.

The scenarios were modelled over three time frames (10 years, 20 years and infinity). In general, the premium required decreased as the time period increased (Tables 6.1 and 6.6) because of the larger volumes of differentiated milk produced in the later years. The exceptions were quantitative scenarios 3 and 4. The premium required for scenario 3 was low anyway, and only a slight increase (up to 6 cents more) was required for scenario 3 over 20 and 20+ years because the increase in income from a greater proportion of white milk did not fully compensate for the lower production and higher costs incurred with this policy compared to the status quo. A very high premium was required for scenario 4 over longer time periods (\$2.08, \$5.62 and \$9.66 per kg milkfat, for 10 years, 20 years and infinity, respectively). The premium paid on the low volume of differentiated milk produced in the first 10 years had to compensate for the lower production and higher costs associated with a differentiated policy compared to the status quo. Even though selection changed to the status quo objective after 10 years, it would still take many years for the production and stocking rate under scenario 4 to come close to that of status quo. This highlights the downside risk associated with the future loss of, or reduction in, the premium for differential milk because of other technology advances (e.g. processing means to produce white milkfat could be developed), reduction in demand because of changes in consumer preferences, or oversupply of differentiated milk.

The riskier a policy is perceived to be the lower the likely technology uptake, and a higher premium (greater relative advantage) will be needed to offset this. The model calculates a

breakeven premium to cover incremental costs. The premium would need to be constructed so as to compensate for some, or all, of the risk associated with a segregated milk policy in order to facilitate farmer adoption. The breakeven premium for quantitative scenario 1 over infinity is \$0.92 per kg milkfat. A risk neutral farmer who assumes that the premium for segregated milk will stay at this level or increase into the future (i.e. no risk) will accept this premium. As discussed, this same scenario, assuming a premium is discontinued after 10 years would require a premium of \$9.66 per kg milkfat to break even. The premium any individual farmer will be prepared to accept will depend on their perception of the risk associated with the policy and their attitude toward risk. A company is very unlikely to be able, or be prepared, to pay a premium of \$9.66 per kg milkfat (i.e. assume all the risk). However, a company can encourage adoption by decreasing the risk associated with a policy. This could be by premium redistribution with a higher premium being paid to farmers in the early years, offering farmers a bonus payment up front to change, or guaranteeing the value, and/or length of time, of the premium payment. This would need to benefit all farmers whom the processor wanted to encourage to adopt a milk segregation policy.

While a milk differentiation initiative may come from industry (processors and marketers), farmer adoption of a differentiated milk policy will be critical in determining its success. The differentiated milk supply will need to be sufficient to produce differentiated products to meet the market requirements. While milk will generally be available for the production of higher value products made with standard milk, because the processing of lower-value commodity milk products can be reduced if milk supply decreases, niche products produced with differentiated milk will require a reliable and predictable supply of differentiated milk. Therefore, a dairy company proposing to develop or process a product requiring a differentiated milk supply will need to put considerable effort into developing strategies to encourage the production of differentiated milk and determining the level of farmer adoption of differentiated milk policies required to meet the demand for milk. They will need to identify who to target, the likely level and rate of uptake, the continuance once the policy is adopted, the strategies likely to be adopted and the change in milk supply over time as more differentiated milk becomes available.

Farmer uptake of differentiated milk policies may be limited by the attributes of the technology. Differentiated milk policies are not readily trialled or observed, may be complex, are not necessarily reversible, and can be risky. Changes to a differentiated milk policy may take considerable time, possibly years, to incorporate into the system, particularly where breeding is involved or there are extensive changes to management e.g. organics requiring certification. Therefore, the relative advantage will need to be considerable to encourage

adoption. It is likely that the financial returns associated with a differentiated milk policy will need to be considerably greater than the breakeven value with the status quo. Farmers will need access to information and decision support to enable them to make decisions and judgements about whether or not the technology is appropriate for them. The involvement of farmers as well as industry people and researchers in research and extension is likely to lead to the development of more effective strategies for a differentiated milk policy. This will also result in a greater understanding of the policy and strategies developed, and the implications of this complex system by all parties. The development of effective strategies and enhanced understanding by all parties increases the likelihood of the technology being adopted (Guerin and Guerin 1994; Frank 1997).

Farmers who produce milk with characteristics approaching that required, who are receptive to new technologies, or all farmers, could be approached. If only a few select herds are required it may be less difficult to obtain sufficient milk, as this is likely to be for a very high value product and therefore a high premium could be offered. Herds with milk closest to that required could be approached, or it may be economic to identify cows with desired milk traits and amalgamate these onto a few farms. However, if larger amounts of milk were required or the premium offered was lower, acquiring enough milk will be more difficult, particularly initially when lower volumes of differentiated milk are produced. The premium offered would also need to be sufficient to encourage those targeted with herds that have milk composition furthest from that required to adopt the policy. At this premium it will be economically advantageous for those with milk closest to the required composition to change.

The price a company will receive for a differentiated milk product, its processing and marketing costs, and expected return all need to be taken into account before calculating how much they can afford to pay for milk. The differentiated milk supply available could also have an impact e.g. amount and timing of supply, a critical mass may be needed to meet market requirements. The number of herds adopting the policy and the rate of uptake will affect differentiated milk supply. This differentiated milk supply will increase over time as more of the cows in the herds meet specifications. This may lead to oversupply of differentiated milk in the future if further markets are not established, resulting in reduced premium or a quota. Farmers changing should be aware of these future possibilities.

The reason for milk differentiation could affect both the payment system and strategy adopted. If the milk component is extracted from the milk, or the level of a component affects processing qualities (e.g. B β -lactoglobulin milk), milk may not need to be segregated at the farm level and payment could be based on the level of the component in the milk. The level of

the component could still be manipulated over time by breeding or feeding, and may be transported separately. However, for qualities such as “white” milk, on-farm segregation is required. These issues all make the determination of payment and the implementation of a differentiated milk policy complex.

Results suggest that the qualitative scenarios may be viable. However, the quantitative scenarios are unlikely to be viable at the premium required for white milkfat, except for a very few “white” herds where the premium required is lower. As mentioned, the premium required will probably be higher than the breakeven because of the risk associated with the adoption of this policy.

8.2 MODEL APPLICATION AND EVALUATION

This study was methodologically complex. The model developed consisted of a number of deterministic sub-models, and the amalgamation of information from a range of disciplines. Information was sourced largely from the scientific literature and industry sources. Outputs from the biological sub-models were drawn together in an integrating economic sub-model.

Milk composition was manipulated by breeding in the scenarios modelled, although buying and selling of cows was also considered in qualitative scenario 2. Breed was accounted for by specifying initial milk composition and yield, liveweight, and expected gains. “White” milk cows were assumed to be Friesian and β -lactoglobulin cows were assumed to be Jersey. Stage of lactation effects were imposed on milk composition. “White” milk was not produced all year around by the differentiated milk herd and therefore did not receive a premium over the whole year. Milk composition could also be manipulated by feeding. However, this was not modelled although the model could have incorporated this. Differential payments for peak and shoulder milk for each herd are able to be included although this also was not modelled. Changes in payment over time were allowed for in evaluating premium redistribution scenarios.

The model has the potential to investigate a wide range of scenarios and can evaluate both the production and economic consequences of segregating cows on-farm based on milk composition. This makes it a useful tool, particularly as the time required to change to a milk segregation system makes physical trialling impractical. The development of the model as a series of sub-models also allows individual sub-models to be used as stand-alone models, or included as sub-models in other models. The inclusion of stochastic variables would have

allowed the range and probability of different outcomes to be evaluated, and been useful for risk assessment. However, the size of the model, its development as a series of sub-models and the inclusion of the 20 year time dimension would have made achieving this complex. Sub-models could be more readily manipulated this way. Sensitivity analysis was possible on a select number of variables.

Milk colour can be effectively manipulated by feeding, although this was not modelled because of the lack of information, particularly on milk colour e.g. feeding effect on milk colour, relationship with other traits, stage of lactation interactions. The approach adopted for defining the feeding effect was relatively simplistic, and outputs from cow physiological models that are currently being developed could be included in the future to improve the precision of quantifying changes in milk composition. "Other" milk traits would need to be incorporated into these physiological models.

8.3 RESEARCH RECOMMENDATIONS

Milk is made up of over 2000 components. Research continues on milk composition, the identification of "useful" components, the processing properties of milks with different composition, and the development of new products and markets which may require or take advantage of variability in milk composition. The output from these studies will be required for milk segregation studies to identify components on which to base milk segregation and the level of segregation required.

Information on the factors affecting milk composition is available for milk, milkfat and protein yield, and to a limited extent on the casein and whey components of the protein. However, information on other milk components is more limited and work needs to be done on identifying and measuring these, particularly for traits that may be useful. The level and variability of a component within a population, heritabilities, relationships with other traits, breed effects, effects of different feeds and feeding levels, and stage of lactation all need to be considered. Interactions between these can also occur, and these effects can also vary within breed, family, or genotype groups. Work on the New Zealand cow population and incorporating our pasture-based feeding systems is likely to be most useful.

Work continues into the development of genetic and reproductive technologies to alter milk composition (L'Huilier 1999). The results of this work need to be made available to allow evaluation of manipulating milk composition by these means. Specialised systems may need

to be developed to manage these herds their physical and financial feasibility will need to be assessed.

This study provided useful information about the on-farm production and economic consequences of milk segregation on farm. However, a complete study of the milk segregation system would need to be wider, and include the human activity system aspects of milk segregation. An understanding of these would be required to assist in developing effective milk segregation systems, determining how best to implement these, and understanding technology adoption issues in relation to milk segregation. That would include the risk associated with milk segregation, which will have significant effects on the premium required and technology adoption.

Technology adoption information could then be used to further expand the study into an industry evaluation of the milk segregation issue. Industry information on product composition and mixes, manufacturing costs, supply and demand of the various products and associated product returns is limited or commercially sensitive. Therefore the industry components of the milk segregation value system may need to be modelled at the industry level or by researchers working co-operatively with the dairy industry.

REFERENCES

- A2 Corporation 2001: A2 milk - the future of milk. Advertising brochure. In: *New Zealand Dairy Exporter* 77(1).
- ADFF, 1999: Taking responsibility for the future. Advancing dairy Australia. Final report of the working group, June 1999. Australian Dairy Farmers' Federation. [Online] Available: [http://www.adff.com.au/adff/index.nsf/\[issues\]/](http://www.adff.com.au/adff/index.nsf/[issues]/). [Retrieved 21 February 2002].
- AEU, 1997: Animal evaluation review. Review of the inputs to the breeding objectives model. Report of an expert advisory group, 1 December 1997. Animal Evaluation Unit.
- AFRC, 1993: Energy and protein requirements of ruminants. CAB International, Wallingford, England.
- AFRC, 1998: Response in the yield of milk constituents to the intake of nutrients by dairy cows. AFRC Technical Committee on Responses to Nutrients, Report No. 11. CAB International, Wallingford, U.K.
- Aggrey, S.E.; Sabour, M.P.; Lin, C.Y.; Zadworny, D. Kuhnlein, U. 1998: Analysis of the β -lactoglobulin locus using the grand-daughter design in the Canadian Holstein population. *Canadian Journal of Animal Science* 78:245-248.
- Allison, A.J. 1995: Importing a sheep which offers more – the East Friesian. *Proceedings of the New Zealand Society of Animal Production* 55:321-323.
- Anderson, J.R.; Dillon, J.L.; Hardaker, J.B. 1977: Agricultural decision analysis. Iowa State University Press, Ames, Iowa, USA.
- Anon., 1997: Pioneer project working through issues of payment, breeding, testing, logistics. *New Zealand Dairy Exporter* 73(4):98.
- Anon., 1998a: Cashing in on casein. *New Zealand Dairy Exporter* 73(10):118.
- Anon., 1998b: 5 tanker fills to make 1kg of high value. *New Zealand Dairy Exporter* 73(10):90.
- Anon., 1998c: Beneficial acid is a casualty of animal diets and the war on fats. *Hoard's Dairyman* (June):458
- Anon., 2001: NZ among lowest production cost. *New Zealand Dairy Exporter* 77(5):95.
- ARC, 1980: The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Farnham Royal, England.
- Arnon, I 1989: Agricultural research and technology transfer. Elsevier Applied Science, New York, USA.
- Ashes, J.R.; Gulati, S.K.; Scott, T.W. 1997: Potential to alter the content and composition of milk fat through nutrition. *Journal of Dairy Science* 80:2204-2212.

- Atkinson, K. 1999: To BST or not to BST – cow hormone raises concerns. [Online] Available: <http://www.rsnz.govt.nz>. [Retrieved 26 March 1999].
- Audirac, I.; Bealieu, L.J. 1986: Microcomputers in agriculture: a proposed model to study their diffusion/adoption. *Rural Sociology* **51**:60-77.
- Auldish, M.J.; Coats, S.T.; Sutherland, B.J.; Clarke, P.T.; McDowell, G.H.; Rogers, G.L. 1996: Effect of somatic cell count and stage of lactation on the quality of full cream milk powder. *Australian Journal of Dairy Technology* **51**:94-98.
- Auldish, M.J.; Prosser, C.G. 1998: Differential effects of short-term once-daily milking on milk yield, milk composition and concentrations of selected blood metabolites in cows with low or high pasture intake. *Proceedings of the New Zealand Society of Animal Production* **58**:41-43.
- Auldish, M.J.; Walsh, B.J.; Thomson, N.A. 1997: Seasonal and lactational influences on milk composition in New Zealand. *Proceedings of the New Zealand Society of Animal Production* **57**:205-206.
- Auldish, M.J.; Walsh, B.J.; Thomson, N.A. 1998: Seasonal and lactational influences on bovine milk composition in New Zealand. *Journal of Dairy Research* **65**:401-411.
- Avon, L. 1990: Conservation and management of genetic resources in Western Europe: cattle breeds. Pp 45-58. In: Genetic conservation of domestic livestock. L. Alderson (ed). CAB International, Wallingford, England.
- Baer, R.J. 1991: Alteration of the fatty acid content of milk fat. *Journal of Food Protection* **54** (5):383-386.
- Baker, R.L.; Shannon, P.; Garrick, D.J.; Blair, H.T.; Wickham, B.W. 1990: The future impact of new opportunities in reproductive physiology and molecular biology on genetic improvement programmes. *Proceedings of the New Zealand Society of Animal Production* **50**:197-210.
- Banks, W. 1991: Milk fat production. Pp 1-8. In: Milk fat production, technology and utilization. K.K. Rajah and K.J Burgess (eds). The Society of Dairy Technology, Huntingdon, England.
- Banks, W.; Muir, D.D. 1984: Milk utilization and manipulation of composition in the future. Pp 17-25. In: Milk compositional quality and its importance in future markets. Occasional Publication No. 9. British Society of Animal Production. M.E. Castle and R.G.Gunn (eds). British Society of Animal Production, Edinburgh.
- Barioni, L. 1997: A dynamic simulation model for planning and controlling grazing systems. M.Appl.Sc.Thesis, Massey University, Palmerston North.
- Barry, P.J.; Ellinger, P.N.; Hopkin, J.A.; Baker, C.B. 1995: Financial management in agriculture. Fifth Edition. Interstate Publishers Inc, Illinois, U.S.A.
- Bates, S.A.E. 1998: Issues arising from the milk pricing mechanisms of the New Zealand dairy sector. *Farm Management* **10**(2):55-62.

- Bauman, D.E. 1992: Bovine somatotrophin: a review of an emerging animal technology. *Journal of Dairy Science* **75**:3432-3451.
- Bawden, R. 2000: Of knowing "systems" and change. Pp 1-16. In: Achieving change through improved knowledge systems. Proceedings of a conference held in Palmerston North, New Zealand, August 2000. J.D. Stantiall and C.M. McDiarmid (eds). Centre for Agricultural and Veterinary Continuing Education, Massey University, Palmerston North.
- Bayliss, H. 1998: New Zealand dairy industry rationalisation: Kiwi's views. *Proceedings of the Massey University Dairyfarming Annual* **50**:239-242.
- Beaulieu, A.D.; Palmquist, D.L. 1995: Differential effects of high fat diets on fatty acid composition in milk of Jersey and Holstein cows. *Journal of Dairy Science* **78**:1336-1344.
- Berner, L.A. 1993: Defining the role of milk fat in balanced diets. *Advances in Food and Nutrition Research* **37**:131-257.
- Bobe, G.; Beitz, D.C.; Freeman, A.E.; Lindberg, G.L. 1999: Associations among individual proteins and fatty acids in bovine milk as determined by correlations and factor analyses. *Journal of Dairy Research* **66**:523-536.
- Boehlje, M.; Hofing, S.L.; Schroeder, R.C. 1999: Value chains in the agricultural industries. Staff Paper 99-10. Department of Agricultural Economics, Purdue University. [Online] Available: <http://www.centrec.com/resources.htm>. [Retrieved 7 March 2002].
- Boehlje, M.; Schrader, L.F. 1998: The industrialization of agriculture: questions of coordination. Pp 3-26. In: The industrialization of agriculture: vertical coordination in the U.S. food system. J.S. Royer and R.T. Rogers (eds). Ashgate Publishing Ltd, Aldershot, England.
- Boland, M.J. 1997: Genetic polymorphism: What are the benefits for the real world dairy industry? Pp 474-480. In: Milk protein polymorphism. Proceedings of the IDF seminar held in Palmerston North, New Zealand, February, 1997. International Dairy Federation, Brussels, Belgium.
- Boland, M.; Hill, J.; O'Connor, P. 2000: Changing the milk supply to increase cheese yield. Pp 305-316. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Bonneau, M.; Laarveld, B. 1999: Biotechnology in animal nutrition, physiology and health. *Livestock Production Science* **59**:223-241.
- Bourdon, R.M. 1997: Understanding animal breeding. Prentice-Hall, New Jersey, USA.
- Bovenhuis, H.; van Arendonk, J.A.M.; Korver, S. 1992: Associations between milk protein polymorphisms and milk production traits. *Journal of Dairy Science* **75**:2549-2559.

- Bovenhuis, H.; Weller J.I. 1994: Mapping and analysis of dairy cattle quantitative trait loci by maximum likelihood using milk protein genes as genetic markers. *Genetics* **137**(1):267-280.
- Bremel, R.D.; Yom, H-C; Bleck, G.T. 1989: Alteration of milk composition using molecular genetics. *Journal of Dairy Science* **72**:2826-2833.
- Brew, K.; Grobler, J.A. 1992: α -lactalbumin. Pp 191-230. In: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Brookes, I.M. 2000: Senior Lecturer, Massey University, Palmerston North.
- Brookes, I.M.; Morris, S.T.; Parker, W.J. 1993: Computer spreadsheets for predicting feed requirements and feed budgeting. *Proceedings of the New Zealand Grassland Association* **55**:209-210.
- Bryant, A.M. 1979: Effects of nutrition on milk composition. *Proceedings of the 31st Ruakura Farmers' Conference* pp 121-130.
- Buckles, B.P.; Petry, F.E. 1992: An overview of genetic algorithms and their applications. Pp 1-4. In: Genetic algorithms. B.P. Buckles; F.E. Petry (eds). IEEE Computer Society Press, Los Alamitos, California.
- Campbell, H.; Fitzgerald, R. 2000: New Zealand's food exports in the 21st century: whither the green option? *Proceedings of the New Zealand Society of Animal Production* **60**:72-77.
- Campbell, J.R.; Marshall, R.T. 1975: The science of providing milk for man. McGraw-Hill Book Publications in the Agricultural Sciences, McGraw-Hill Book Company, New York, U.S.A.
- Chamala, S. 1987: Adoption processes and extension strategies for conservation farming. Pp 400-419. In: Tillage: New directions in Australian agriculture. P.S Cornish and J.E. Pratley (eds). Inkata Press, Melbourne, Australia.
- Checkland, P. 1999: Systems thinking, systems practice – includes a 30-year retrospective. John Wiley and Sons Ltd, Chichester, England.
- Christie, R. 2000: Food markets of the future. *Proceedings of the New Zealand Society of Animal Production* **60**:78-82.
- Clark, A.J. 1998: Animal breeding: Technology for the 21st century. A.J. Clark (ed). Harwood Academic Publishers. Amsterdam, Netherlands.
- Clark, D.A.; Penno, J.W.; Neil, P.G. 1997: Nutritional merits and problems of pastures. Pp 397-418. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Clarke, J.N. 1995: New sheep – a catalyst for change. *Proceedings of the New Zealand Society of Animal Production* **55**:318-320.

- Collier, R.J. 1997: Strategies for POSILAC use in dairy herds. Pp 295-306. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Collinson, M. 2000: A history of farming systems research. M. Collinson (ed). CABI Publishing, Wallingford, U.K. and FAO, Rome, Italy.
- Cooke, J.R. 1998: Using mathematics as a problem-solving tool. Pp 63-92. In: Agricultural systems modeling and simulation. R.M. Peart and R.B. Curry (eds). Marcel Dekker Inc., New York, USA.
- Cottrill, B.R. 1998: A review of current nutritional models: what we need to measure. Pp 21-31. In: In vitro techniques for measuring nutrient supply to ruminants. Occasional Publication No. 22. British Society of Animal Science. E.R. Deaville, E. Owen, A.T. Adesogan, C. Rymer, J.A. Huntington and T.L.J. Lawrence (eds). British Society of Animal Science, Edinburgh.
- Crabtree, R.M. 1984: Milk compositional ranges and trends. Pp 35-42. In: Milk compositional quality and its importance in future markets. Occasional Publication No. 9. British Society of Animal Production. M.E. Castle and R.G.Gunn (eds). British Society of Animal Production, Edinburgh.
- Cunningham, E.P. 1998: The potential of new reproductive and genetic technologies. Pp 67-76. In: Impact of reproductive technology on animal breeding and genetic conservation. Acta Agriculturae Scandinavica, Section A, Animal Science, Supplementum 29. S. Einarsson and J. Rendel (eds). Scandinavian University Press, Oslo, Norway.
- Cunningham, E.P. 1999: The application of biotechnologies to enhance animal production in different farming systems. *Livestock Production Science* 58:1-24.
- DairyInsight, 2001: About DairyInsight New Zealand. [Online] Available: http://www.dairyinsight.co.nz/about_us.html. [Retrieved 15 February 2002].
- Dalgleish, D.G. 1997: The effects of milk protein on the functionality of milk products. Pp 105-118. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Davis, K. 1997: Single-product Kaikoura pins hopes on casein breeding. *New Zealand Dairy Exporter* 73(4):97.
- Davis, L. 1991: Handbook of genetic algorithms. Reinhold, New York.
- Davis, S.R. 1997: Limits to productivity in dairy cows. Pp 533-544. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Davis, S.R.; Farr, V.C.; Stelwagen, K. 1999: Regulation of yield loss and milk composition during once-daily milking: a review. *Livestock Production Science* 59:77-94.
- Dematawewa, C.M.B.; Berger, P.J. 1998: Break-even cost of cloning in genetic improvement of dairy cattle. *Journal of Dairy Science* 81:1136-1147.

- den Daas, J.H.G. 1997: Genetic gain through reproductive technologies. Pp 357-362. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Dent, J.B. 1990: Optimising the mixture of enterprises in a farming system. Pp 113-130. In: Systems theory applied to agriculture and the food chain. J.G.W. Jones and P.R. Street (eds). Elsevier Science Publishers Ltd, Essex, England.
- Dent, J.B.; Blackie, M.J. 1979: Systems simulation in agriculture. Applied Science Publishers Ltd, Essex, England.
- DePeters, E.J.; Medrano, J.F.; Reed, B.A. 1995: Fatty acid composition of milk fat from three breeds of dairy cattle. *Canadian Journal of Animal Science* 75:267-269.
- de Wit, J.N. 1998: Nutritional and functional characteristics of whey proteins in food products. *Journal of Dairy Science* 81:597-608.
- Dingwall, B. 1991: A new functional food: Stollait milk for quality of life. Pp 150-159. In: Crossroads '91 foods of the 90's. Proceedings of the New Zealand Institute of Food Science and Technology Conference, Nelson. 15th-18th May 1991. G.P.Savage (ed). Institute of Food Science and Technology, Christchurch, New Zealand.
- Dodd, F.H. 1984: Herd management effects on compositional quality. Pp 77-83. In: Milk compositional quality and its importance in future markets. Occasional Publication No. 9. British Society of Animal Production. M.E. Castle and R.G.Gunn (eds). British Society of Animal Production, Edinburgh.
- Dorward, A. 2001: The effects of transaction costs, power and risk on contractual arrangements: a conceptual framework for quantitative analysis. *Journal of Agricultural Economics* 52(2):59-73.
- Doyle, C.J. 1990: Application of systems theory to farm planning and control: modelling resource allocation. Pp 89-112. In: Systems theory applied to agriculture and the food chain. J.G.W. Jones and P.R. Street (eds). Elsevier Science Publishers Ltd, Essex, England.
- Ebersohn, J.P. 1976: A commentary on systems studies in agriculture. *Agricultural Systems* 1: 173-184.
- Einarsson, S.; Rendel, J. 1998: Impact of reproductive technology on animal breeding and genetic conservation. Acta Agriculturae Scandinavica, Section A, Animal Science, Supplementum 29. S. Einarsson and J. Rendel (eds). Scandinavian University Press, Oslo, Norway.
- Elliot, R.B.; Harris, D.P.; Hill, J.; Bibby, N.J.; Wasmuth, H.E. 1999: Type I (insulin-dependent) diabetes mellitus and cow milk: casein variant consumption. *Diabetologia* 42:292-296.
- Elliot, R.B.; Wasmuth, H.; Hill, J.; Songini, M.; Bottazzo, G.F. 1996: Diabetes and cows' milk. *Lancet (British Edition)* 348: 9042, 1657.

- Eman, M.; Gommans, J. 2001: Milk & money or milk & steel. *Proceedings of the Massey University Dairyfarming Annual* **53**:151-161.
- Falconer, D.S. 1960: Introduction to quantitative genetics. Oliver and Boyd, Edinburgh, Great Britain.
- Fearon, A.M.; Mayne, C.S. 2000: Modifying milk fat composition an example of current technology in practice. Pp 241-248. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Fennessey, P.F. 1990: Animal production in the future – a New Zealand response. *Proceedings of the New Zealand Society of Animal Production* **50**:361-371.
- Fenwick, R.M. 1995: Dairy products for our future. *Proceedings of the Massey University Dairyfarming Annual* **47**:91-95.
- Fenwick, R.M.; Marshall, K.R. 1991: What sort of milk do we need for the 1990's? *Proceedings of the 43rd Ruakura Farmers' Conference* pp 1-7.
- FitzGerald, R.J. 1997: Exploitation of casein variants. Pp 153-171. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- FitzGerald, R.J.; Hill, J.P. 1997: The relationship between milk protein polymorphism and the manufacturing and functionality of dairy products. Pp 355-371. In: Milk protein polymorphism. Proceedings of the IDF seminar held in Palmerston North, New Zealand, February, 1997. International Dairy Federation, Brussels, Belgium.
- Flack, B. 1998: A genetic algorithms review. Research report 98-19. School of Mathematical and Computing Sciences, Victoria University, Wellington.
- Fleisher, B. 1990: Agricultural risk management. Lynne Reinner Publishers, Colorado, U.S.A.
- Flynn, A.; Cashman, K. 1997: Nutritional aspects of minerals in bovine and human milks. Pp 257-302. In: Advanced dairy chemistry - Volume 3: Lactose, water, salts and vitamins. Second Edition. P.F. Fox (ed). Chapman and Hall, London.
- Fonterra, 2001a: Fonterra: facts and figures.[Online] Available: <http://www.fonterra.com/facts/index.html>. [Retrieved 15 February 2002].
- Fonterra, 2001b: About Fonterra. [Online] Available: <http://www.fonterra.com/who/index.html>. [Retrieved 15 February 2002].
- Fonterra, 2001c: Fonterra's application period, share price and standard, and peak note price and standard. [Online] Available: <http://www.fonterra.com/shareholders/index.html>. [Retrieved 15 February 2002].
- Fonterra, 2001d: Select committee submission. Outline of capital structure. [Online] Available: http://www.fonterra.com/how/archive/select_committee/background/outline.html. [Retrieved 19 February 2002].

- Fonterra, 2001e: Working with a fair value share [Online] Available: http://www.fonterra.com/shareholders/fair_value_share/index.html. [Retrieved 22 February 2002].
- Fox, D.G.; Sniffen, C.J.; O'Connor, J.D.; Russell, J.B.; Van Soest, P.J. 1992: A net carbohydrate and protein system for evaluating cattle diets: III. Cattle requirements and diet adequacy. *Journal of Animal Science* **70**:3578-3596.
- Fox, P.F. 1992: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Fox, P.F. 1995: Advanced dairy chemistry - Volume 2: Lipids. Second Edition. P.F. Fox (ed). Chapman and Hall, London.
- Fox, P.F.; Flynn, A. 1992: Biological properties of milk proteins. Pp 255-284. In: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Fox, P.F.; Guinee, T.P. 2000: Processing characteristics of milk constituents. Pp 29-69. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Frank, B.R. 1997: Adoption of innovations in the North Queensland beef industry. III: Implications for extension management. *Agricultural Systems* **55**(3):347-358.
- Franks, R. 1993: The New Zealand dairy industry needs low cell milk count. *Proceedings of the 45th Ruakura Farmers' Conference* pp 62-64.
- Franks, R. 2001: Milk Quality Manager, New Zealand Dairy Group, Hamilton.
- Freeman, A.E.; Lindberg, G.L. 1993: Challenges to dairy cattle management: genetic considerations. *Journal of Dairy Science* **76**:3143-3159.
- Freyer, G.; Liu, Z.; Erhardt, G.; Panicke, L. 1999: Casein polymorphism and the relation between milk production traits. *Journal of Animal Breeding and Genetics* **116**:87-97.
- Garcia, S.C.; Holmes, C.W. 1999: Effects of time of calving on the productivity of pasture-based dairy systems: a review. *Journal of Agricultural Research* **42**:347-362.
- Garcia-Muniz, J.G.; Holmes, C.W.; Garrick, D.J.; Lopez-Villalobos, N.; Wickham, B.W.; Wilson, G.F.; Brookes, I.M.; Purchas, R.W. 1998: Growth curves and productivity of Holstein-Friesian cows bred for heavy or light mature liveweight. *Proceedings of the New Zealand Society of Animal Production* **58**:68-72.
- Garner, I.; Coleman, A. 1998: Therapeutic proteins from livestock. Pp 215-228. In: Animal breeding: Technology for the 21st century. A.J. Clark (ed). Harwood Academic Publishers. Amsterdam, Netherlands.
- Garrick, D.J.; Lopez-Villalobos, N. 1998: Tomorrow's cows – some kiwi cows of the future. *Proceedings of the 50th Ruakura Farmers' Conference* pp 39-43.

- Garrick, D.J.; Lopez-Villalobos, N. 2000: Potential for economic benefits to the producer from altering the composition of milk. Pp 93-108. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Georges, M. 1997: Perspectives for marker assisted selection in dairy cattle breeding. Pp 265-269. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- German, J.B.; Morand, L; Dillard, C.J.; Xu, R. 1997: Milk fat composition: Targets for alteration of function and nutrition. Pp 35-72. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Gibson, J.P. 1989: Altering milk composition through genetic selection. *Journal of Dairy Science* 72:2815-2825.
- Gibson, J.P. 1991: The potential for genetic change in milk fat composition. *Journal of Dairy Science* 74:3258-3266.
- Gibson, J.P. 1998: Breeding genetically manipulated traits. Pp 201-214. In: Animal breeding: Technology for the 21st century. A.J. Clark (ed). Harwood Academic Publishers. Amsterdam, Netherlands.
- Gibson, J.P. 2000: Options for genetic improvement of milk composition. Pp 109-118. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Gibson, J.P.; Jansen, G.B.; Rozzi, P. 1991: The use of κ -casein genotypes in dairy cattle breeding. *Proceedings of the 4th World Congress on Genetics applied to Livestock Production, Edinburgh, 23-29 July 1990*, XIV:163-166.
- Goff, H.D.; Hill, A.R. 1993: Chemistry and physics. Pp 1-82. In: Dairy science and technology handbook, Volume 1: Principles and properties. Y.H. Hui (ed). VCH Publishers Inc., New York.
- Gray, D.I.; Parker, W.J. 1990: The planning, implementation and control of pastoral based systems. Agricultural and Horticultural Systems Management, Massey University, Palmerston North.
- Gray, D.I.; Yuretich, P.A.; Lynch; G.A. 1994: Farm management implications of a seasonal price differential for factory supply milk production. *Proceedings of the New Zealand Society of Animal Production* 54:383-387.
- Grefenstette, J.J. 1992: Optimization of control parameters for genetic algorithms. Pp 5-11. In: Genetic algorithms. B.P. Buckles; F.E. Petry (eds). IEEE Computer Society Press, Los Alamitos, California.
- Grummer, R.R. 1991: Effects of feed on the composition of milkfat. *Journal of Dairy Science* 74:3244-3257.

- Guerin, L.J.; Guerin, T.F. 1994: Constraints to the adoption of innovations in agricultural research and environmental management: a review. *Australian Journal of Experimental Agriculture* 34:549-571.
- Guilbault, L.A.; Pothier, F.; Twagiramungu, H.; Sirard, M.-A. 1998: New technologies to improve the reproductive efficiency of dairy cattle. *Canadian Journal of Animal Science* 78(Suppl.):113-129.
- Gurr, M.I. 1991: Dietary fats. Pp 17-29. In: Milk fat production, technology and utilization. K.K. Rajah and K.J Burgess (eds). The Society of Dairy Technology, Huntingdon, England.
- Hambling, S.G; McAlpine, A.S.; Sawyer, L. 1992: β -lactoglobulin. Pp 141-190. In: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Hambraeus, L. 1992: Nutritional aspects of milk proteins. Pp 457-490. In: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Hamilton, G. 1998: Co-learning tools: powerful instruments of change in Southern Queensland, Australia. Pp 172-190. In: Facilitating sustainable agriculture. N.G. Roling and M.A.E. Wagemakers (eds). Cambridge University Press, Cambridge, U.K.
- Hardaker, J.B.; Huime, R.B.M; Anderson, J.R. 1997: Coping with risk in agriculture. CAB International, Wallingford, U.K.
- Harmon, R. 1995: Mastitis and milk quality. Pp 25-39. In: Milk Quality. F. Harding (ed). Chapman and Hall, Glasgow, Great Britain.
- Harris, B.L. 1997: Selection to increase the β -lactoglobulin B variant in New Zealand dairy cattle. Pp 467-473. In: Milk protein polymorphism. Proceedings of the IDF seminar held in Palmerston North, New Zealand, February, 1997. International Dairy Federation, Brussels, Belgium.
- Harris, P.M.; Lee, J. 1998: Natural enhancement of nutritionally significant amino acids in milk. *Bulletin of the International Dairy Federation* 336:51-55.
- Harsh, S.B.; Connor, L.J.; Schwab, G.D. 1981: Managing the farm business. Prentice-Hall, New Jersey, U.S.A.
- Hawke, J.C.; Taylor, M.W. 1995: Influence of nutritional factors on the yield, composition and physical properties of milk fat. Pp 37-88. In: Advanced dairy chemistry - Volume 2: Lipids. Second Edition. P.F. Fox (ed). Chapman and Hall, London.
- Henderson, H.V.; Pringle, R.M. 1982: How do the lactation curves of New Zealand cows shape up? Pp 275-276. In: Proceedings of the conference on dairy production from pasture, held in Hamilton, February, 1982. K.L MacMillan and V.K. Taufa (eds). New Zealand Society of Animal Production.
- Henning, R.H.; Mulholland, M.V.; Cushnahan, A.; Peoples, A.C.; Bruce, D.W. 2000: Demonstration of technologies and best management practice to improve milk

- protein content in a commercial dairying situation. Pp 159-164. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Hesse, R 1997: Managerial spreadsheet modeling and analysis. Unwin, Chicago and Boston, USA.
- Hettinga, D.H. 1989: Why alter milk composition? *Journal of Dairy Science* **72**:2790-2800.
- Hill, J.P.; Thresher, W.C.; Boland, M.J.; Creamer, L.K.; Anema, S.G.; Manderson, G.; Otter, D.E.; Paterson, G.R.; Lowe, R.; Burr, R.G.; Motion, R.L.; Winkelman, A.; Wickham, B. 1997: The polymorphism of the milk protein β -lactoglobulin: A review. Pp 173-202. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Hiraoka, Y.; Segawa, T.; Kuwajima, K.; Sugai, S.; Murai, N. 1980: α -lactalbumin: a calcium metalloprotein. *Biochem. Biophys. Research Communication* **95**:1098-1104.
- Hobman, P. 1992: The influence of the market on industry R&D. *Proceedings of the 44th Ruakura Farmers' Conference* pp 57-60.
- Holland, J.H. 1975: Adaptation in natural and artificial systems. University of Michigan Press, Ann Arbor, Michigan.
- Holmes, C.W. 1989: Effects of feeding on the composition of milk and on the yields of its components. Pp 43-53. In: Milk payment and quality. Animal Industries Workshop, Lincoln College, 1989. G.K. Barrell (ed). Lincoln College, Canterbury, New Zealand.
- Holmes, C.W. 1998: Dairy production in New Zealand 1948 to 1998: focus on systems for the future. *Proceedings of the Massey University Dairyfarming Annual* **50**:11-30.
- Holmes, C.W.; Davey, A.W.F.; Grainger, C. 1981: The efficiency with which feed is utilised by the dairy cow. *Proceedings of the New Zealand Society of Animal Production* **41**:16-27.
- Holmes, C.W.; Mackenzie, D.D.S.; Brookes, I.M.; Garrick, D.J.; Wilson, G.F. 1996: Dairy production study guide (17.351). Department of Animal Science, Massey University, Palmerston North.
- Holmes, C.W.; Wilson, G.F.; Mackenzie, D.D.S.; Flux, D.S.; Brookes, I.M.; Davey, A.W.F. 1984: Milk production from pasture. Butterworths Agricultural Books, Wellington, New Zealand.
- Holsinger, V.H. 1997: Physical and chemical properties of lactose. Pp 1-38. In: Advanced dairy chemistry - Volume 3: Lactose, water, salts and vitamins. Second Edition. P.F. Fox (ed). Chapman and Hall, London.
- Hughes, T. 2002: Peak notes. Options to boost farm business's productivity. *New Zealand Dairy Exporter* **77**(7): 12-13.

- IDF, 1997: Milk protein polymorphism. Proceedings of the IDF seminar held in Palmerston North, New Zealand, February, 1997. International Dairy Federation, Brussels, Belgium.
- Jakob, E. 1994: Genetic polymorphism of milk proteins. *Bulletin of the International Dairy Federation* **298**:17-27.
- Jakob, E. 1995: Effect of genetic polymorphisms on milk protein composition. *Bulletin of the International Dairy Federation* **305**:7-8.
- Jakob, E.; Puhan Z. 1995: Implications of genetic polymorphism of milk proteins on production and processing of milk. Proceedings of the IDF seminar held in Zurich, Switzerland, March, 1995. E. Jakob and Z. Puhan (eds). *Bulletin of the International Dairy Federation* **304**:2-25.
- Jedlicka, A.D. 1979: Risk-taking in rural development. *Desarrollo Rural en las Americas* **11**:50-51.
- Jenness, R. 1974: The composition of milk. Pp 3-108. In: Lactation. A comprehensive treatise. Volume III. Nutrition and biochemistry of milk/maintenance. B.L. Larsen and V.R. Smith (eds). Academic Press, New York and London.
- Jensen, R.G; Ferris, A.M.; Lammi-Keefe, C.J.; Henderson, R.A. 1990: Lipids of bovine and human milks : A comparison. *Journal of Dairy Science* **73**:223.
- Jensen, R.G.; Ferris, A.M.; Lammi-Keefe C.J. 1991: The composition of milk fat. *Journal of Dairy Science* **74**:3228-3243.
- Jensen, S.K.; Johannsen, A.K.B.; Hermansen, J.E. 1999: Quantitative secretion and maximal secretion capacity of retinol, β -carotene and α -tocopherol into cow's milk. *Journal of Dairy Research* **66**:511-522.
- Jimenez-Flores, R.; Richardson, T. 1988: Genetic engineering of the caseins to modify the behaviour of milk during processing: a review. *Journal of Dairy Science* **71**:2640-2654.
- Joblin, K.N. 1993: Rumen microorganisms: their potential as modifiers of milk flavour. Pp 95-100. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Joblin, K.N.; Hudson, J.A. 1997: Management of milk flavour through the manipulation of rumen microorganisms. Pp 455-463. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Johnson, D.L.; Petch, S.F.; Winkelman, A.M.; Bryant, M. 2000: Genetics of milk characteristics in New Zealand dairy cattle. *Proceedings of the New Zealand Society of Animal Production* **60**:318-319.
- Johnson, R.J.; Thomson N.A. 1996: Effect of pasture species on milk yield and milk composition. *Proceedings of the New Zealand Grassland Association* **57**:151-156.

- Johnston, M. 2001: Dairy Liaison Officer, Kiwi Cooperative Dairy Company, Palmerston North.
- Jolly, R.W. 1983: Risk management in agricultural production. *American Journal of Agricultural Economics* **65**(5):1107-1113.
- Jones, J.W.; Luyten, J.C. 1998: Simulation of biological processes. Pp 19-62. In: Agricultural systems modeling and simulation. R.M. Peart and R.B. Curry (eds). Marcel Dekker Inc., New York, USA.
- Jopson, N.B.; Dodds, K.G.; Knowler, K.J.; Wheeler, R.; McEwan, J.C. 2000: Lamb and ewe performance of East Friesian x Coopworths relative to pure-bred Coopworths. *Proceedings of the New Zealand Society of Animal Production* **60**:47-50.
- Karatzas, C.N.; Turner, J.D. 1997: Toward altering milk composition by genetic manipulation: current status and challenges. *Journal of Dairy Science* **80**:2225-2232.
- Kay, R.D.; Edwards, W.M. 1994: Farm management. Third Edition. McGraw-Hill, U.S.A.
- Keen, A.R. 1986: Future developments for profitable dairy farming: The colour and flavour of dairy products. *Proceedings of the Massey University Dairyfarming Annual* **38**:36-39.
- Keen, A.R. 1993: Some observed differences between milkfats from Jersey and Friesian cows – some effects of diets on lactones and baked flavour. Pp 72-77. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Keen, A.R.; Wilson, R.D. 1993: Effect of breed on colour and flavour. Pp 50-54. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Kefford, B.; Christian, M.P.; Sutherland, B.J.; Mayes, J.J.; Grainger, C 1995: Seasonal influences on cheddar cheese manufacture: influence of diet quality and stage of lactation. *Journal of Dairy Research* **62**(3):529-537.
- Kelly, C. 1997: International dairy market beyond 2000. *Proceedings of the Massey University Dairyfarming Annual* **49**:22-24.
- Kennelly, J.J. 1996: Producing milk with 2.5% fat – the biology and health implications for dairy cows. *Journal of Animal Feed Science Technology* **60**:161-180.
- Kennelly, J.J.; Glimm, D.R. 1998: The biological potential to alter the composition of milk. *Canadian Journal of Animal Science* **78**(Suppl.):23-56.
- Knight, C.H.; Sorensen, A.; Muir, D.D. 2000: Non-nutritional (novel) techniques for manipulation of milk compositional. Pp 223-239. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.

- Knight, T.W.; Waghorn, G.C. 1993: Absorption and deposition of β -carotene in beef and dairy cattle. Pp 55-61. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Kolver, E.S.; Bryant, A.M. 1992: Changing milk composition by feeding. *Proceedings of the 44th Ruakura Farmers' Conference* pp 61-71.
- Korhonen, H. 1998: Colostrum immunoglobulins and the complement system – potential ingredients of functional foods. *Bulletin of the International Dairy Federation* **336**:36-40.
- Kuipers, A.; Shook, G.E. 1980: Net returns from selection under various component testing plans and milk pricing schemes. *Journal of Dairy Science* **63**:1006-1018.
- Kuwata, T.; Yajima, T.; Kaneko, T. 1997: Recent and future improvements of protein fraction in cow's milk-based infant formula. Pp 215-230. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Langdon, I. 2001: The next decade of change: an Australian view. *Proceedings of the Massey University Dairyfarming Annual* **53**:227-231.
- Larcombe, M. 1990: UDDER: a desktop dairy farm for extension and research. Dairy Cattle Society of the New Zealand Veterinary Association. *Proceedings of the Society's 7th Seminar*:151-152.
- Larking, P.A. 1989: Dairy company payouts calculated using the A + B - C system. Pp 13-18. In: Milk payment and quality. Animal Industries Workshop, Lincoln College, 1989. G.K. Barrell (ed). Lincoln College, Canterbury, New Zealand.
- Larsen, W. 1997: Speech to Ruakura farmers' conference. *Proceedings of the 49th Ruakura Farmers' Conference* pp 1-9.
- Larson, B.L 1992: Immunoglobulins of the mammary secretions. Pp 231-254. In: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- L'Huillier, P. 1999: Genetic modification of livestock for the production of therapeutics and designer foods. *Proceedings of the New Zealand Grassland Association* **61**:109-115.
- LIC, 1996: Dairy Statistics 1995-1996. Livestock Improvement Corporation Ltd, Hamilton, New Zealand.
- LIC, 1997: Dairy Statistics 1996-1997. Livestock Improvement Corporation Ltd, Hamilton, New Zealand.
- LIC, 1998: Dairy Statistics 1997-1998. Livestock Improvement Corporation Ltd, Hamilton, New Zealand.
- LIC, 1999: Dairy Statistics 1998-1999. Livestock Improvement Corporation Ltd, Hamilton, New Zealand.

- LIC, 2000: Dairy Statistics 1999-2000. Livestock Improvement Corporation Ltd, Hamilton, New Zealand.
- Lincoln University, 1996: Farm technical manual. P.Fleming (ed). Department of Farm and Horticultural Management, Lincoln University, Canterbury.
- Lincoln University, 1996-2000: Financial budget manuals 1996-2000. E.S. Burt (ed). Farm Management Group, Lincoln University, Canterbury.
- Lincoln University, 2000: Financial budget manual 2000. E.S. Burt (ed). Farm Management Group, Lincoln University, Canterbury.
- Ling, K.C.; Liebrand, C.B. 1998: Dairy cooperatives' role in vertical integration. Pp 333-346. In: The industrialization of agriculture: vertical coordination in the U.S. food system. J.S. Royer and R.T. Rogers (eds). Ashgate Publishing Ltd, Aldershot, England.
- Lockhart, J.C.; Cartwright, R.W. 1997: Alternative pathways for the dairy industry's future: challenges to, and opportunities for success in international markets. *Proceedings of the Massey University Dairyfarming Annual* 49:13-21.
- Lonnerdal, B.; Glazier, C. 1985: Calcium binding by α -lactalbumin in human milk. *Journal of Nutrition* 115:1209-1216.
- Lopez-Villalobos, N. 2000-2002: Scientist, Massey University, Palmerston North.
- Lopez-Villalobos, N.; Garrick, D.J.; Holmes, C.W.; Blair, H.T.; Spelman, R.J. 2000: Profitabilities of some mating systems for dairy herds in New Zealand. *Journal of Dairy Science* 83:144-153.
- Lopez-Villalobos, N.; Lemus-Ramirez, V.; Holmes, C.W.; Garrick, D.J. 2001: Lactation curves for milk traits, live weight and body condition score for heavy and light Holstein-Friesian cows. *Proceedings of the New Zealand Society of Animal Production* 61:217-220.
- Lunden, M.; Nilsson, M.; Janson, L. 1997: Marked effect of β -lactoglobulin polymorphism on the ratio of casein to total protein in milk. *Journal of Dairy Science* 80:2996-3005.
- Lynch, G.A. 1998: The relative advantages and disadvantages of co-operative and non co-operative business organisations. *Proceedings of the Massey University Dairyfarming Annual* 50:231-236.
- MacDonald, K.A.; Penno, J.W.; Kolver, E.S.; Carter, W.A.; Lancaster, J.A. 1998: Balancing pasture and maize silage diets for dairy cows using urea, soybean meal or fishmeal. *Proceedings of the New Zealand Society of Animal Production* 58:102-105.
- MacGibbon, A.K.H. 1996: Herd-to-herd variations in the properties of milkfat. *Proceedings of the New Zealand Society of Animal Production* 56:224-227.
- MacGibbon, A.K.H. 2001: Scientist, New Zealand Dairy Research Institute, Palmerston North.

- MacGibbon, A.K.H.; McLennan 1987: Hardness of New Zealand patted butter: seasonal and regional variation. *New Zealand Journal of dairy science and Technology* **22**:143-156.
- Macheboeuf, D.; Coulon, J.B.; D'Hour, P. 1993: Effect of breed, protein genetic variants, feeding and lactation number on cow milk coagulation properties. *Productions Animales (Paris)* **6**(5):333-344.
- Mackle, T.R.; Bryant, A.M. 1995: What's in milk? *Proceedings of the 47th Ruakura Farmers' Conference* pp 63-70.
- Mackle, T.R.; Bryant, A.M. 1996: Feeding, milk composition and product quality - an overview. *Proceedings of the New Zealand Grassland Association* **57**:167-172.
- Mackle, T.R.; Bryant, A.M.; Petch, S.F.; Hill J.P.; Auldist, M.J. 1999a: Nutritional influences on the composition of milk from cows of different protein phenotypes in New Zealand. *Journal of Dairy Science* **82**:172-180.
- Mackle, T.R.; Bryant, A.M.; Petch, S.F.; Hooper, R.J.; Auldist, M.J. 1999b: Variation in the composition of milk protein from pasture-fed dairy cows in late lactation and the effect of grain and silage supplementation. *New Zealand Journal of Agricultural Research* **42**:147-154.
- Mackle, T.R.; Petch, S.F.; Bryant, A.M.; Auldist, M.J.; Henderson, M.J.; MacGibbon, A.K.H. 1997: Variation in the characteristics of milkfat from pasture-fed dairy cows during late spring and the effects of grain supplementation. *New Zealand Journal of Agricultural Research* **40**:349-359.
- Macmillan, K.L. 1990: Dairy herd management in 2000. *Proceedings of the 42th Ruakura Farmers' Conference* pp 77-82.
- Macmillan, K.L.; Vishwanath, R.; Xu, Z.Z. 1997: Controlled breeding technologies. Pp 3363-372. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- MacRae, J.C.; Bequette, B.J.; Crompton, L.A. 2000: Synthesis of milk protein and opportunities for nutritional manipulation. Pp 179-200. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- MAF, 1999: Pastoral agriculture: the competitive edge. The New Zealand dairy industry. [Online] Available: <http://www.maf.govt/mafnet/publications/overview/nzoverview007.htm>. [Retrieved 15 February 2002].
- MAF, 2000: Dairy monitoring report. July 2000. Ministry of Agriculture and Forestry.
- MAF, 2001: Situation and outlook for New Zealand agriculture and forestry. July 2001. Ministry of Agriculture and Forestry.
- Maher, J.; Perkins, A. 2000: Participatory appraisal and technology adoption. Pp 87-92. In: Achieving change through improved knowledge systems. Proceedings of a

- conference held in Palmerston North, New Zealand, August 2000. J.D. Stantiall and C.M. McDiarmid (eds). Centre for Agricultural and Veterinary Continuing Education, Massey University, Palmerston North.
- Malossini, F.; Bovolenta, S.; Piras, C.; Rosa, M.D.; Ventura, W. 1996: Effect of breed and diet on milk composition and rennet coagulation properties of milk. *Annales de Zootechnie* **45**(1):29-40.
- Manhire, J. 1999: Producing to market specifications – the challenge for the future. *Proceedings of the New Zealand Grassland Association* **61**:91-93.
- Marra, M.; Pannell, D.J.; Abadi Ghadim, A. 2001: The economics of risk, uncertainty, and learning in the adoption of new agricultural technologies: where are we on the learning curve. Sustainability and Economics in Agriculture Working Paper 01/10. [Online] Available: <http://www.general.uwa.edu.au/u/dpannell/dpap0110.htm>. [Retrieved 15 October 2001].
- Marshall, K.R. 1989a: The origin and history of the A+B-C payment system. Pp 9-11. In: Milk payment and quality. Animal Industries Workshop, Lincoln College, 1989. G.K. Barrell (ed). Lincoln College, Canterbury, New Zealand.
- Marshall, K.R. 1989b: How does the New Zealand Dairy Board determine the value for milkfat and protein? Pp 19-22. In: Milk payment and quality. Animal Industries Workshop, Lincoln College, 1989. G.K. Barrell (ed). Lincoln College, Canterbury, New Zealand.
- Marshall, K.R. 1995: What is the potential size of the dairy industry? Markets. *Proceedings of the Massey University Dairyfarming Annual* **47**:73-81.
- Marshall, K.R. 2000: Biosciences: an explanation of why the New Zealand Dairy Industry is investing in research. *Proceedings of the Massey University Dairyfarming Annual* **52**:169-173.
- Marshall, K.R.; Fenwick, R.M. 1998: Future trends in dairy technology. Pp 41-50. In: Symposium on new developments in dairy science and technology. Proceedings of the 25th International Dairy Congress held in Aarhus, Belgium, September, 1998. International Dairy Federation, Brussels, Belgium.
- Martin, S.K. 1994: Risk perceptions and management responses to risk in pastoral farming in New Zealand. *Proceedings of the New Zealand Society of Animal Production* **54**:363-368.
- Martin, S.K. 1996: Risk management strategies in New Zealand agriculture and horticulture. *Review of Marketing and Agricultural Economics* **64**(1): 31-44.
- Marziali, A.S.; Ng-Kwai-Hang, K.F. 1986: Relationships between milk protein polymorphisms and cheese yielding capacity. *Journal of Dairy Science* **69**:1193-1201.
- Massey, C.; Hurley, E. 2001: New Zealand dairy farmers as organisational learners. *The Learning Organization* **8**(3):169-175.

- Massey University, 1997: Calving date systems comparison. First annual report 1996/97. F. Cayzer (ed). Farm Services Section, Massey University, Palmerston North.
- Massey University, 1998: Calving date systems comparison. Second annual report 1997/98. Agricultural Services, Massey University, Palmerston North.
- Mayer, D.G; Belward, J.A.; Burrage, K.; Stuart, M.A. 1995: Optimisation of a dairy farm model - Comparison of simulated annealing, simulated quenching and genetic algorithms. Pp 33-39. In: MODSIM 95. Proceedings of the International Congress on Modelling and Simulation. Volume 1: Agriculture, Catchment Hydrology and Industry. P. Binning; H. Bridgman; B. Williams (eds).
- Mayer, D.G; Belward, J.A.; Widell, H.; Burrage, K. 1999: Survival of the fittest - genetic algorithms versus evolution strategies in the optimization of systems models. *Agricultural Systems* **60**:113-122.
- McClintock, A.E. 1998: Possible impact of new technologies on dairy cattle breeding. *Proceedings of the New Zealand Society of Animal Production* **58**:1-5.
- McCombs, P. 1986: Review of costs associated with the seasonal pattern of milk production. *Proceedings of the Massey University Dairyfarming Annual* **38**:67-82.
- McDowell, A.K.R; McDowell, F.H. 1953: The vitamin A potency of New Zealand butter. *Journal of Dairy Research* **20**:76-100.
- McEldowney, L. 1997: DRC pivotal to future research. *New Zealand Dairy Exporter* **72**(7):86.
- McFadden, T.B. 1997: Prospects for improving lactational persistency. Pp 319-340. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- McFadden, T.B.; Besser, T.E.; Barrington, G.M. 1997: Regulation of immunoglobulin transfer into mammary secretions of ruminants. Pp 133-152. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- McLaren, R.D.; Auldist, M.J.; Prosser, C.G. 1998: Diurnal variation in the protein composition of bovine milk. *Proceedings of the New Zealand Society of Animal Production* **58**:49-51.
- McLean, D.M.; Graham, E.R.B.; Ponzoni, R.W.; McKenzie, H.A. 1984: Effects of milk protein genetic variants on milk yield and composition. *Journal of Dairy Research* **51**:531-546.
- Mellalieu P.J.; Hall K.R. 1981: An interactive planning model for the New Zealand dairy industry. Research Report 3/81. Economics Research Division, Ministry of Agriculture and Fisheries.
- Merz, P.; Freisleben, B. 1999: Fitness landscapes and memetic algorithm design. Pp 245-260. In: New ideas in optimization. D. Corne; M. Dorigo; F. Glover (eds). McGraw-Hill Publishing Company, Berkshire, England.

- Meuwissen, T.H.E.; Van Arendonk, J.A.M. 1992: Potential improvements in rate of genetic gain from marker-assisted selection in dairy cattle breeding schemes. *Journal of Dairy Science* **75**:1651-1659.
- Moss, G.W. 2001: Supplier representative, New Zealand Dairy Group of Companies, Hamilton.
- Moss, G.W. 2002: Member of the Shareholders Council, Fonterra Co-operative Group Ltd.
- Mulder, H.; Walstra, P. 1974: The milk fat globule: Emulsion science as applied to milk products and comparable foods. CAB, Bucks., England. Centre for Agricultural Publishing and Documentation, Wageningen, The Netherlands.
- Mulvihill, D.M. 1992: Production, functional properties and utilization of milk protein products. Pp 369-404. In: *Advanced dairy chemistry - Volume 1: Proteins*. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Murphy, J.J. 2000: Synthesis of milk fat and opportunities for nutritional manipulation. Pp 201-222. In: *Milk composition*. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Murphy, J.J.; O'Mara, F.O. 1993: Nutritional manipulation of milk protein concentration and its impact on the dairy industry. *Livestock Production Science* **35**:117-134.
- Mustapha, A.; Hertzler, S.R.; Savaiano, D.A. 1997: Lactose: Nutritional significance. Pp 127-154. In: *Advanced dairy chemistry - Volume 3: Lactose, water, salts and vitamins*. Second Edition. P.F. Fox (ed). Chapman and Hall, London.
- Neil, P.G.; Thomson, N.A. 1997: Effect on milk production and liveweight of feeding balanced or unbalanced supplements to cows grazing restricted summer pasture. *Proceedings of the New Zealand Society of Animal Production* **57**:151-153.
- Newman, S-A.; Knight, T.W.; O'Neill, A.F.; Death, A.F.; Ridland, M. 1994: Effect of breed on plasma carotene concentration in New Zealand dairy heifers. *Proceedings of the New Zealand Society of Animal Production* **54**:119-120.
- Ng-Kwai-Hang, K.F. 1998: Genetic polymorphism of milk proteins: Relationships with production traits, milk composition and technological properties. *Canadian Journal of Animal Science* **78**(Suppl.):131-147.
- Ng-Kwai-Hang, K.G.; Grosclaude, F. 1992: Genetic polymorphism of milk proteins. Pp 405-456. In: *Advanced dairy chemistry - Volume 1: Proteins*. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Nickerson, S.C. 1995: Milk production: factors affecting milk composition. Pp 3-24. In: *Milk Quality*. F. Harding (ed). Chapman and Hall, Glasgow, Great Britain.
- Nitschke, T.; O'Keefe, M. 1997: Managing the linkage with primary producers: experiences in the Australian grain industry. *Supply Chain Management* **2**(1):4-6.

- Noakes, M.P.; Nestel, P.J.; Clifton, P.M. 1996: Modifying the fatty acid profile of dairy products through feedlot technology lowers the plasma cholesterol of humans consuming the products. *American Journal of Clinical Nutrition* **63**:42.
- O'Brien, B. 2000: Composition and processability of bovine milk from herds with different calving patterns. Pp 77-86. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- O'Brien, J.O. 1997: Reaction chemistry of lactose: non-enzymatic degradation pathways and their significance in dairy products. Pp 155-232. In: Advanced dairy chemistry - Volume 3: Lactose, water, salts and vitamins. Second Edition. P.F. Fox (ed). Chapman and Hall, London.
- O'Connor, D.L.; Masor, M.L.; Paule, C.; Benson, J. 1997: Amino acid composition of cow's milk and human requirements. Pp 203-214. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Ojala, M.; Famula, T.R.; Medrano, J.F. 1997: Effects of milk protein genotypes on the variation for milk production traits of Holstein and Jersey cows in California. *Journal of Dairy Science* **80**:1776-1785.
- O'Keefe, M. 1994: Vertical co-ordination in agribusiness: a literature review. RIRDC Occasional Paper Series No 94/1. Rural Industries Research and Development Corporation, Barton, Australia.
- O'Keefe, M. 1998a: Value chain analysis: new insights for firm strategies in agribusiness. Proceedings from the 1998 Australian Agribusiness Congress. Session 1 – The agri-food and fibre chain. [Online] Available: <http://www.agrifood.info/congress/congress97-98/session1/paper3.htm>. [Retrieved 7 March 2002].
- O'Keefe, M. 1998b: Establishing supply chain partnerships: lessons from Australian agribusiness. *Supply Chain Management* **3**(1):5-9.
- Oste, R.; Jagerstad, M.; Andersson, I. 1997: Vitamins in milk and milk products. Pp 347-402. In: Advanced dairy chemistry - Volume 3: Lactose, water, salts and vitamins. Second Edition. P.F. Fox (ed). Chapman and Hall, London.
- Ostensen, S.; Foldager, J.; Hermansen, J.E. 1997: Effects of stage of lactation, milk protein genotype and body condition at calving on protein composition and renneting properties of bovine milk. *Journal of Dairy Research* **64**:207-219.
- Pacheco-Rios, D.; McNabb, W.C.; Hill, J.P.; Barry, T.N.; Mackenzie, D.D.S. 1997: The effects of methionine supply upon milk composition and production of dairy cows in mid-lactation. *Proceedings of the New Zealand Society of Animal Production* **57**:147-150.
- Palisade Corporation, 1998: Guide to Evolver: the genetic algorithm solver for Microsoft Excel. Palisade Corporation, New York, USA.

- Palmquist, D.L.; Beaulieu, 1992: Differences between Jersey and Holstein cows in milk fat composition [Abstract only]. *Journal of Dairy Science* **75**(Suppl. 1):292.
- Palmquist, D.L.; Beaulieu, A.D.; Barbano, D.M. 1993: Feed and animal factors influencing milk fat composition. *Journal of Dairy Science* **76**:1753-1771.
- Pan, Y.S.; McLean, D.M.; Graham, E.R.G.; Ellis, N.J.S. 1978: Effect of heat stress on the protein composition and manufacturing properties of milk from two diverse breeds of dairy cattle. *Proceedings of the 20th International Dairy Congress*:28-29.
- Papalois, M.; Leach, F.W.; Dungey, S.; Yep, Y.L.; Versteeg, C. 1996: Australian milkfat survey - physical properties. *Australian Journal of Dairy Technology* **51**:114-117.
- Paquin, P. 1998: The key to added value: Fractionation and the use of milk components. *Canadian Journal of Animal Science* **78**(Suppl.):149-157.
- Parminter, T.G.; Parminter, I.A. 1994: Making use of technology diffusion. *Proceedings of the New Zealand Society of Animal Production* **54**:389-391.
- Parodi, P.W. 1994: Conjugated linoleic acid: An anticarcinogenic fatty acid present in milk fat. *Australian Journal of Dairy Technology* **49**:93-97.
- Parodi, P.W. 1999: Conjugated linoleic acid and other anticarcinogenic agents of bovine milk fat. *Journal of Dairy Science* **82**:1339-1349.
- Paul, K.J. 1982: Spreading milk intake advantages and disadvantages for factories and farmers. *Proceedings of the 34th Ruakura Farmers' Conference* pp 91-95.
- Paul, K.J. 1985: A new direction for the payment of milk. *Proceedings of the 37th Ruakura Farmers' Conference* pp 77-85.
- Pedersen, J. 1991: Selection to increase frequency of kappa-casein variant B in dairy cattle. *Journal of Animal Breeding and Genetics* **108**:434-445.
- Pell, J.M.; Flint, D.J. 1997: Immunomodulation of lactation. Pp 307-318. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Petch, S.F.; Bryant, A.M.; Napper, A.R. 1997: Effects of pasture intake and grain supplementation on milk nitrogen fractions. *Proceedings of the New Zealand Society of Animal Production* **57**:154-156.
- Pilkington, D. 2001: Managing Director, New Zealand Milk, Fonterra, Wellington.
- Puhan, Z. 1997: Introduction to the subject. Pp 12-21. In: Milk protein polymorphism. Proceedings of the IDF seminar held in Palmerston North, New Zealand, February, 1997. International Dairy Federation, Brussels, Belgium.
- Rajah, K.K; Burgess, K.J. 1991: Milk fat production, technology and utilization. K.K. Rajah and K.J Burgess (eds). The Society of Dairy Technology, Huntingdon, England.
- Ramshaw, T. 2001: District Manager, Livestock Improvement Corporation, Palmerston North.

- Reid, J.I. 1996: Farming systems research: a background paper to the farmer first research project at Massey University. Farming Systems Research Discussion Paper 96-1, Department of Agricultural and Horticultural Systems Management, Massey University, Palmerston North.
- Reid, J.I.; Coulson, J.L.; Cameron E.A. 1996: A framework for understanding the adoption and use of technologies by dairy farmers. Farming Systems Research Discussion Paper 96-2, Department of Agricultural and Horticultural Systems Management, Massey University, Palmerston North.
- Regester, G.O.; Smithers, G.W.; Mitchell, I.R.; McIntosh, G.H.; Dionysius, D.A. 1997: Bioactive factors in milk: natural and induced. Pp 119-132. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Rendel, J.M.; Harris, B.L. 1997: Economic considerations of protein variants in the design of breeding schemes. Pp 461-466. In: Milk protein polymorphism. Proceedings of the IDF seminar held in Palmerston North, New Zealand, February, 1997. International Dairy Federation, Brussels, Belgium.
- Robin, O.; Turgeon, S.; Paquin, P. 1993: Functional properties of milk proteins. Pp 277-354. In: Dairy science and technology handbook, Volume 1: Principles and properties. Y.H. Hui (ed). VCH Publishers Inc., New York.
- Rogers, E.M. 1983: Diffusion of innovations. Third Edition. The Free Press, MacMillan Publishing Ltd, New York, U.S.A.
- Rogers, G.L.; Stewart, J.A. 1982: The effects of some nutritional and non-nutritional factors on milk protein concentration and yield. *Australian Journal of Dairy Technology* 37:26-32.
- Rogers, N. 2001: Dexcel Consulting Officer (Regional Manager), Dexcel, Waikato.
- Rollema, H.S. 1992: Casein association and micelle formation. Pp 111-140. In: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Rosenberg, N. 1976: On technological innovations. *Economic Journal* 86:523-535.
- Rountree, J.H. 1977: Systems thinking – some fundamental aspects. *Agricultural Systems* 2:247-254.
- Rowney, M.; Christian, M. 1996: Effect of cow diet and stage of lactation on the composition of milkfat for cheese manufacture. *Australian Journal of Dairy Technology* 51:118-122.
- Ryan, L. 1996: Current research into future milk quality. *Proceedings of the Massey University Dairyfarming Annual* 48:191-194.
- Sabour, M.P.; Lin, C.Y.; Lee, A.J.; McAllister, A.J. 1996: Association between milk protein genetic variants and genetic values of Canadian Holstein bulls for milk yield traits. *Journal of Dairy Science* 79:1050-1056.

- Sapru, A.; Barbano, D.M.; Yun, J.J.; Klei, L.R.; Oltenacu, A.; Bandler, D.K. 1997: Cheddar cheese: Influence of milking frequency and stage of lactation on composition and yield. *Journal of Dairy Science* **80**:437-446.
- Scott, J.D.J.; Rattray, P.V.; Smeaton, D.C. 1976: Environmental factors associated with summer-autumn growth rates of cattle and sheep. *Proceedings of the New Zealand Society of Animal Production* **36**:103-119.
- Scrimgeour 1999: Future directions for the dairy industry. *Proceedings of the Massey University Dairyfarming Annual* **51**:9-16.
- Shanahan, T. 2000: Applying current technology to improve protein at farm level. Pp 249-274. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Shaw, B. 2001: The next decade of change: the world dairying scene. *Proceedings of the Massey University Dairyfarming Annual* **53**:227-231.
- Shook, G.E.; Schutz, M.M. 1994: Selection on somatic cell score to improve resistance to mastitis in the United States. *Journal of Dairy Science* **77**:648-658.
- Smidt, D.; Niemann, H. 1999: Biotechnology in genetics and reproduction. *Livestock Production Science* **59**:207-221.
- Smith, C. 1998: Introduction: current animal breeding. Pp 1-10. In: Animal breeding: Technology for the 21st century. A.J. Clark (ed). Harwood Academic Publishers. Amsterdam, Netherlands.
- Sonka, S.T.; Patrick, G.F. 1984: Risk management and decision making in agricultural firms. Pp 95-115. In: Risk management in agriculture. P.J. Barry (ed). Iowa State University Press, Iowa, U.S.A.
- Sorensen, J.T. 1998: Modeling and simulation in applied livestock production science. Pp 475-494. In: Agricultural systems modeling and simulation. R.M. Peart and R.B. Curry (eds). Marcel Dekker Inc., New York, USA.
- South, M.C.; Wetherill, G.B.; Tham, M.T. 1993: Hitch-hiker's guide to genetic algorithms. *Journal of Applied Statistics* **20**(1):153-175.
- Southward, C.R. 1986: Utilisation of milk components: casein. Pp 317-368. In: Modern dairy technology - Volume 1: Advances in milk processing. R.K. Robinson (ed). Elsevier Applied Science Publishers Ltd, London.
- Spedding, C.R.W. 1976: Editorial. *Agricultural Systems* **1**:1-3.
- Spedding, C.R.W. 1988a: An introduction to agricultural systems. Second Edition. Elsevier Applied Science Publishers Ltd, Essex, England.
- Spedding, C.R.W. 1988b: General aspects of modelling and its application in livestock production. Pp 3-9. In: Modelling of livestock production systems. S. Korver and J.A.M. Arendonk (eds). Kluwer Academic Publishers, Dordrecht, Netherlands.

- Spedding, C.R.W. 1994: Farming systems research/extension in the European context. Pp 46-52. In: Rural farming and systems analysis: European perspectives. J.B. Dent and M.J. McGregor (eds). CAB International, Wallingford, UK.
- Spelman, R.J.; Garrick, D.J. 1997a: Utilisation of marker assisted selection in a commercial dairy cow population. *Livestock Production Science* **47**:139-147.
- Spelman, R.J.; Garrick, D.J. 1997b: Effect of live weight and differing economic values on responses to selection for milk fat, protein, volume and live weight. *Journal of Dairy Science* **80**:2557-2562.
- Spelman, R.J.; Garrick, D.J.; van Arendonk, J.A.M. 1999: Utilisation of genetic variation by marker assisted selection in commercial dairy cow populations. *Livestock Production Science* **59**:51-69.
- Spooner, P. 2000: General Manager Transport Operations, New Zealand Dairy Group, Hamilton.
- Spring, D. 1997: Control of the dairy industry: By farmers or who? *Proceedings of the Massey University Dairyfarming Annual* **49**:1-9.
- Stantiall, J.D.; Parker W.J. 1997: Adoption of technology and information on New Zealand dairy farms. Report on a dairy industry exchange forum, June 1997. J.D. Stantiall and W.J. Parker (eds). Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North.
- Steffert, I.J. 1993: Compositional changes in cow's milk associated with health problems. Pp 119-125. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Stevenson, P. 2000: Food for calves (and babies) cash winner. *New Zealand Herald*, September 26th:D5.
- Stewart, J.D. 1989: The new pricing system: its influence on husbandry practices on the farm. Pp 1-8. In: Milk payment and quality. Animal Industries Workshop, Lincoln College, 1989. G.K. Barrell (ed). Lincoln College, Canterbury, New Zealand.
- Street, P.R. 1990: A systems view of commercial supply and marketing links. Pp 159-203. In: Systems theory applied to agriculture and the food chain. J.G.W. Jones and P.R. Street (eds). Elsevier Science Publishers Ltd, Essex, England.
- Stroud, A.; Kirkby, R. 2000: The application of FSR to technology development. Pp 95-129. In: A history of farming systems research. M. Collinson (ed). CABI Publishing, Wallingford, U.K. and FAO, Rome, Italy.
- Stull, J.W.; Brown, W.H. 1964: Fatty acid composition of milk. II. Some differences in common dairy breeds. *Journal of Dairy Science* **47**:1412.
- Sutton, J.D. 1984: Feeding and milk fat production. Pp 43-52. In: Milk compositional quality and its importance in future markets. Occasional Publication No. 9. British Society of

- Animal Production. M.E. Castle and R.G.Gunn (eds). British Society of Animal Production, Edinburgh.
- Sutton, J.D. 1989: Altering milk composition by feeding. *Journal of Dairy Science* **72**:2801-2814.
- Sutton, J.D.; Morant, S.V. 1989: A review of the potential of nutrition to modify milk fat and protein. *Livestock Production Science* **23**:219-237.
- Swaigood, H.E. 1992: Chemistry of the caseins. Pp 63-110. In: Advanced dairy chemistry - Volume 1: Proteins. P.F. Fox (ed). Elsevier Science Publishers Ltd, London and New York.
- Sykes, A.R. 1989: Use of supplementary feeds. Pp 73-79. In: Milk payment and quality. Animal Industries Workshop, Lincoln College, 1989. G.K. Barrell (ed). Lincoln College, Canterbury, New Zealand.
- Teather, R.M.; Forster, R.J. 1998: Manipulating the rumen microflora with bacteriocins to improve ruminant production. *Canadian Journal of Animal Science* **78**(Suppl.):57-69.
- Tervit, H.R. 1997: *In vitro* production of cattle embryos. Pp 341-356. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Thomas, C. 1984: Milk compositional quality and the role of forages. Pp 69-76. In: Milk compositional quality and its importance in future markets. Occasional Publication No. 9. British Society of Animal Production. M.E. Castle and R.G.Gunn (eds). British Society of Animal Production, Edinburgh.
- Thomas, P.C. 1984: Feeding and milk protein production. Pp 53-68. In: Milk compositional quality and its importance in future markets. Occasional Publication No. 9. British Society of Animal Production. M.E. Castle and R.G.Gunn (eds). British Society of Animal Production, Edinburgh.
- Thomas, L.; Rowney, M. 1996: Australian milkfat survey - fatty acid composition. *Australian Journal of Dairy Technology* **51**:112-114.
- Thompson, M.P.; Farrell, H.M. 1974: Genetic variants of milk proteins. Pp 109-134. In: Lactation : A comprehensive treatise, Volume III. B.L Larson and V.R Smith (eds). Academic Press, New York and London.
- Thompson, S.Y.; Henry, K.M.; Kon, S.K. 1964: Factors affecting the concentration of vitamins in milk. 1. Effect of breed, season and geographical location on fat-soluble vitamins. *Journal of Dairy Research* **31**:1-25.
- Thomson, N.A. 1993: Dairy farm production/manufacturing of dairy products - let's come closer together. Pp 17-23. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Thomson, N.A. 1999: Effect of summer forages on milk characteristics. *Proceedings of the 51st Ruakura Farmers' Conference* pp 99-100.

- Thomson, N.A.; Clark, D.A.; Waugh, C.D.; Van der Poel, W.C.; MacGibbon, A.K.H. 2000: Effect on milk characteristics to supplementing cows on a restricted pasture allowance with different amounts of either turnips or sorghum. *Proceedings of the New Zealand Society of Animal Production* **60**:320-323.
- Thomson, N.A.; Van der Poel, W. 2000: Seasonal variation of the fatty acid composition of milkfat from Friesian cows grazing pasture. *Proceedings of the New Zealand Society of Animal Production* **60**:314-317.
- Townsend, S.J.; Siebert, B.D.; Pitchford, W.S. 1997: Variation in milk fat content and fatty acid composition of Jersey and Friesian cattle. *Proceedings of the Association for the Advancement of Animal Breeding and Genetics* **12**:283-286.
- Townshend, R. 1994: Processing future milk volumes. *Proceedings of the 46th Ruakura Farmers' Conference* pp 1-5.
- Tyrrell, H.F.; Reid, J.T. 1965: Prediction of the energy value of cow's milk. *Journal of Dairy Research* **48**(2):1215-1223.
- Uribe, J.V.; Parker, W.J.; Dake, C.K.G.; McDonald, A. 1996: A whole farm approach to feed planning and ration balancing using UDDER and CAMDAIRY. *Proceedings of the New Zealand Society of Animal Production* **56**:285-288.
- Van Vleck, L.D.; Pollak, E.J.; Oltenacu, E.A.B. 1987: Genetics for the animal sciences. W.H. Freeman and Company, New York.
- Verdier-Metz, I.; Coulon, J.B.; Pradel, P.; Viallon, C.; Berdague, J.L. 1998: Effect of forage conservation (silage or hay) and cow breed on the coagulation properties of milks and on the characteristics of ripened cheeses. *Journal of Dairy Research* **65**(1):9-21.
- Vetharaniam, I.; Davis, S.R.; Soboleva, T.K.; Shorten, P.R.; Wake, G.C. 2001: Modelling the impact of milking frequency on lactation. *Proceedings of the New Zealand Society of Animal Production* **61**:239-240.
- Villotte, J-L.; Soulier, S.; Persuy, M-A.; Lepourry, L.; Legrain, S.; Printz, C.; Stinnakre, M-G.; L'Huillier, P.; Mercier, J-C. 1997: Application of transgenesis to modifying milk protein composition. Pp231-242. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Visscher, P.M.; Van der Beek, S.; Haley, C.S. 1998: Marker assisted selection. Pp 119-136. In: Animal breeding: Technology for the 21st century. A.J. Clark (ed). Harwood Academic Publishers. Amsterdam, Netherlands.
- Waghorn, G.C.; Knight, T.W. 1993: β -carotene intake, digestion, absorption and metabolism in the dairy cow. Pp 42-49. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Wall, R.J. 1999: Biotechnology for the production of modified and innovative animal products: transgenic livestock bioreactors. *Livestock Production Science* **59**:243-255.

- Wall, R.J.; Kerr, D.E.; Bondioli, K.R. 1997: Transgenic dairy cattle: Genetic engineering on a large scale. *Journal of Dairy Science* **80**:2213-2224.
- Wallace, J.R. 1997: Rumen microbiology and efficiency of digestion. Pp 465-488. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Walstra, P.; Jenness, R. 1984: Dairy chemistry and physics. John Wiley and Sons, New York.
- Wardle, P. 2001: About the dairy community. [Online] Available: <http://www.fencepost.com/dairy/overview/home.jhtml>. [Retrieved 15 February 2002].
- Welch, R.A.S.; Burns, D.J.W.; Davis, S.R.; Popay, A.I.; Prosser, C.G. 1997: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Wells, D.N.; Misica, P.M.; Tervit, H.R. 1998: Future opportunities in livestock production and biomedicine from advances in animal cloning. *Proceedings of the New Zealand Society of Animal Production* **58**:32-35.
- West, R. 1991: Passive immunotherapy using food preparations containing active and specific bovine milk antibodies. *Proceedings of the Nutrition Society of New Zealand* **16**:133-135.
- White, N. 2000: Consumer requirements for milk and milk products – current and future trends. Pp 1-17. In: Milk composition. Occasional Publication No. 25. British Society of Animal Science. R.E. Agnew, K.W. Agnew and A.M. Fearon (eds). British Society of Animal Science, Edinburgh.
- Wickham, B.W. 1989: Breeding for future profit. Pp 37-41. In: Milk payment and quality. Animal Industries Workshop, Lincoln College, 1989. G.K. Barrell (ed). Lincoln College, Canterbury, New Zealand.
- Wilkins, R.J. 1991: α -lactalbumin - the milk manipulator's dream. *Proceedings of the New Zealand Society of Animal Production* **53**:211-217.
- Wilmot, I. 1998: Progress in combining embryo techniques and gene technology. Pp 37-43. In: Impact of reproductive technology on animal breeding and genetic conservation. Acta Agriculturae Scandinavica, Section A, Animal Science, Supplementum 29. S. Einarsson and J. Rendel (eds). Scandinavian University Press, Oslo, Norway.
- Wilmot, I.; McWhir, J.; Campbell, K. 1997: Nuclear transfer from cultured cells: a new opportunity in animal breeding? Pp 389-396. In: Milk composition, production and biotechnology. R.A.S. Welch; D.J.W. Burns; S.R. Davis; A.I. Popay; C.G. Prosser (eds). CAB International, Wallingford, England.
- Wilson, G.F. 1993: Dairy cow nutrition and milk flavour. Pp 91-94. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Wilson, K.; Morren, E.B. 1990: Systems approaches for improvement in agriculture and resource management. Macmillan Publishing Company, New York, USA.

- Wilson, P.N.; Dahlgran, R.D.; Conklin, N.C. 1993: "Perceptions as reality" on large-scale dairy farms. *Review of Agricultural Economics* **15**(1):89-101.
- Wilson, R.D. 1993: The effect of feed on the flavour components of milk. Pp 68-71. In: New Zealand Dairy Research Institute Milkfat Flavour Forum. Summary of proceedings 3-4 March 1992, Palmerston North, New Zealand. New Zealand Dairy Research Institute, Palmerston North.
- Winkelman A.M. 1997: Associations of β -lactoglobulin A, B and C variants with production traits in New Zealand dairy cattle. Pp 83-86. In: Milk protein polymorphism. Proceedings of the IDF seminar held in Palmerston North, New Zealand, February, 1997. International Dairy Federation, Brussels, Belgium.
- Winkelman, A.M.; Johnson, D.L.; MacGibbon, A.K.H. 1999: Estimation of heritabilities and correlations associated with milk color traits. *Journal of Dairy Science* **82**:215-224.
- Winkelman, A.M.; Wickham, B.W. 1996: Associations between milk protein variants and production traits in New Zealand dairy cattle. *Proceedings of the New Zealand Society of Animal Production* **56**:24-27.
- Wood, P.D.P 1967: Algebraic model of the lactation curve in cattle. *Nature* **214**:164-165.
- Wood, P.D.P 1976: Algebraic models of the lactation curves for milk, fat, and protein production, with estimates of seasonal variation. *Animal Production* **22**:35-40.
- Wood, P.D.P 1979: A simple model of lactation curves for milk yield, food requirement and body weight. *Animal Production* **28**:55-63.
- Wood, P.D.P 1980: Breed variations in the shape of the lactation curve of cattle and their implications for efficiency. *Animal Production* **31**:133-141.
- Woodward, S.; Macdonald, K. 2001: A decade of DRC – DRC's contribution to the New Zealand dairy farming. *Proceedings of the Massey University Dairyfarming Annual* **53**:79-96.
- Zadow, J.G. 1986: Utilisation of milk components: whey. Pp 273-316. In: Modern dairy technology - Volume 1: Advances in milk processing. R.K. Robinson (ed). Elsevier Applied Science Publishers Ltd, London.

APPENDIX ONE

MODEL INPUTS AND OUTPUTS

QUANTITATIVE BREEDING MODEL

Inputs

Base year

Base year production for all traits (oldest cows unadjusted for age)

Age adjustment factors for selected, correlated and production traits and liveweight

Proportion of the herd in each age group

Lactation number

Phenotypic correlations of other traits with the correlated trait

Phenotypic standard deviations of all traits

Genetic gain per year over two periods for all traits (years 1-10, then later years)

Selected trait cut-off value

Outputs

Selected trait cut-off value for each year

Proportion of the cows in each herd by year

Average per cow production and liveweight in each of the herds, and total by year

QUALITATIVE BREEDING MODEL

Inputs

Age adjustment factors for the production traits
Base year milk, milkfat and protein yields (oldest cows unadjusted for age)
Proportion of the herd in each age group
Genetic gain per year in milk, milkfat and protein yield
Differences between genotypes in milk, milkfat and protein yields
Genotypes of bulls used, and proportion of each genotype
Initial frequency of the B allele in the population
Yearling heifers AI or not (Y/N)
Percentage of AI heifers born per cow
Percentage of heifers retained for replacement per cow
Extra replacement calves purchased or not (Y/N)
Base year liveweight
Genetic gain per year in liveweight
Liveweight age adjustment (2- and 3-year old cows)
Culling factor (for heifers and cows, by culling reason)

Outputs

Change in genetic frequencies over the years by age group and overall (i.e. proportion in each herd)
Production per cow by genotype and year
Production per cow by herd (i.e. BB cows and other cows) and year
Average liveweight by age and per year

COW REQUIREMENTS MODEL

Inputs

Breed

Actual lactation length for both herds

Lactation length specified to calculate lactation curve

Calving, peak milk and drying off day

Condition score at these 3 times, and at next calving

Production per cow (by herd and year) for milk, milkfat, protein, LWT and “other” (from Breeding Model)

Lactation curve parameters (optional)

Proportion of day 1 value of the “other” trait recorded in each period

Effect of feed on milk, milkfat, protein and other by period and herd

Energy value of diet by period and herd (from Feed Model)

Culling over the year by period and herd

Initial calving month and period by herd

Median and final calving date by herd

Calving spread variance by herd

Outputs

Milk, milkfat, protein and milksolids production per cow by herd, period and year

Other trait concentration by herd, period and year

Feed requirement per cow by herd, period and year

FEED MODEL

Inputs

Effective area

Hay made or purchased (Y/N)

Crop able to be consumed per ha

Percentage increase in PGR per year

Percentage increase in utilisation per year

Pasture growth rate by period (year 1)

Pasture utilisation by period (year 1)

Maximum and minimum allowable pasture covers over the year

Proportion of the crop area out of pasture over the year

Nitrogen (kg DM grown) by period

Proportion of cows (alive) on farm in that period i.e. not grazed off (see Feed)

Proportion of the cows in each herd over the years (from Breeding Model)

Cow requirements (kg DM/cow/day) by herd, period and year (from Cow Requirements Model)

Proportion of the diet provided by up to 5 different feeds by herd and period

Energy value of the various feeds over the year

Cost of the feeds per unit (hay, maize silage, concentrates, crop, nitrogen, grass silage)

Outputs

Stocking rate by year

Number of cows by year

Opening covers by year

Grass silage eaten by year

Grass silage made by year

Hay made and eaten by year

Concentrates, crop and maize silage eaten by year

Pasture grown by year

Energy value of diet by period and herd

Periods grazed off-farm per cow per year by herd

Maximum proportion of cows grazed off by herd

Total feed costs by year (hay, maize silage, concentrates, crop, nitrogen, grass silage)

STOCK RECONCILIATION MODEL

Inputs

Initial number of cows in year 1 (from Feed Model)
Closing numbers of cows by year (from Feed Model)
Proportion of the herd in each age group (cows and heifers from Breeding Models)
Proportion of the cows in each herd by year (from Breeding Model)
Calving percentage by year
Losses and Culls percentages by class and year
Number of specific sales and purchases by class and year e.g. on cow type
Sale and purchase prices for each class of stock by year
Periods grazed off-farm per cow per year by herd (from Feed Model)
Maximum proportion of cows grazed off by herd (from Feed Model)
Proportion of young stock and bulls grazed off by class
Weeks young stock are grazed off
Grazing costs per class of stock per week
Freight costs per class of stock
Calf feed costs per calf
Capital value of stock by class, herd and year

Outputs

Sales and purchase numbers
Sales income by year
Sales minus purchase costs by year
Purchase costs by year
Grazing costs by year
Freight costs by year
Calf feed costs by year
Capital value of stock by year

MILK INCOME MODEL

Inputs

Effective area

Milk, milkfat, protein and milksolids production per cow by herd, period and year (from Cow Requirements model)

Other trait concentration by herd, period and year (from Cow Requirements Model)

Proportion of the cows in each herd by year (from Breeding Model)

Number of cows by year (from Feed Model)

Discount rate

Cut-off value for quantitative trait to meet criteria by year

Indicator as to whether peak or off-peak price applies by month

Prices for milk, milkfat, protein and other by criteria (above or below) by peak or off-peak by herd, for a series of up to 3 years.

Premium value per kg of milkfat (Quantitative Breeding Scenario) OR

Multiplier value per component (milk, milkfat, protein and other) (Qualitative Breeding Scenario)

Outputs

Cut-off value by year

Income earned from milk produced above and below the cut-off value by year, and total by year

Amounts of the milk components (including other) produced above and below, the cut-off value by herd and year, and total by year

Periods above and below the cut-off value by herd and year

Discounted milk income by year

ECONOMIC MODEL

This calculates the NPV for the “with” minus “without” scenario, so the inputs come from two series of the previous spreadsheets; the with scenario being selection on another trait and the without being the status quo.

Inputs

Proportion of the cows in each herd by year (from Breeding Model)

Number of cows by year (from Feed Model)

Milk income by herd and total, year and scenario (from Milk Income Model)

Sales income minus purchase costs by year and scenario (from Stock Rec. Model)

Grazing costs by year and scenario (from Stock Rec. Model)

Freight costs by year and scenario (from Stock Rec. Model)

Calf feed costs by year and scenario (from Stock Rec. Model)

Total feed costs by year and scenario (from Feed Model)

Capital value of stock by year and scenario (from Stock Rec. Model)

Discount rate

Wages cost by year and scenario

Contracting costs by year and scenario

Animal health per cow by year and scenario

Breeding expenses per cow by year and scenario

Herd expenses per cow by year and scenario

Dairy expenses per cow by year and scenario

Power cost per cow by year and scenario

Vat, plant and other capital costs by year for with scenario

Outputs

With minus without income and expense values, and income minus expenses values, by year

Present value of “with” minus “without” income minus expense values by year

Net present value of “with” minus “without” income minus expense values over 10 year, 20 year and infinity time periods

Net present value of “with” minus “without” income and expense values by year over 10 year, 20 year and infinity time periods

APPENDIX TWO

QUALITATIVE BREEDING MODEL TABLES

Table A2.1: Selection for BB β -lactoglobulin cows at a .684 gene frequency for the B allele with no heifer AI.

YEAR 20 (B frequency =.684, No Yearling AI)	BB Bulls Test cows		BB Bulls No Test		Status Quo	
Cows (2- to 10-year old) by genotype						
AA cows	0.0000		0.0000		0.0999	
AB cows	0.0001		0.0698		0.4323	
BB cows	0.9999		0.9302		0.4679	
Gene frequency (B)	1.000		0.965		0.684	
Calves selected by genotype						
AB calves	0.000		0.038		0.432	
BB calves	1.000		0.962		0.468	
Production (total per cow, portion of per cow total)	Total	Part	Total	Part	Total	Part
Milk Yield (litres)						
AA cows	-	-	-	-	3481	348
AB cows	3354	1	3520	246	3463	1497
BB cows	3435	3435	3431	3192	3435	1607
Total		3435		3437		3452
Milkfat (kilograms)						
AA cows	-	-	-	-	188.9	18.9
AB cows	184.1	0.0	193.9	13.5	190.8	82.5
BB cows	191.4	191.3	191.1	177.8	191.4	89.5
Total		191.4		191.3		190.9
Protein (kilograms)						
AA cows	-	-	-	-	160.1	16.0
AB cows	150.3	0.0	161.4	11.3	159.3	68.8
BB cows	158.0	158.0	157.8	146.8	158.0	73.9
Total		158.0		158.1		158.7

Table A2.2: Selection for BB β -lactoglobulin cows at a .684 gene frequency for the B allele with heifer AI.

YEAR 20 (B frequency =.684, Yearling AI)	BB Bulls		BB Bulls		Status Quo	
	Test cows		No Test			
Cows (2- to 10-year old) by genotype						
AA cows	0.0000		0.0000		0.0999	
AB cows	0.0000		0.0545		0.4323	
BB cows	1.0000		0.9455		0.4679	
Gene frequency (B)	1.000		0.973		0.684	
Calves selected by genotype						
AB calves	0.000		0.027		0.432	
BB calves	1.000		0.973		0.468	
Production (total per cow, portion of per cow total)	Total	Part	Total	Part	Total	Part
Milk Yield (litres)						
AA cows	-	-	-	-	3481	348
AB cows	-	-	3526	192	3463	1497
BB cows	3435	3435	3432	3245	3435	1607
Total		3435		3437		3452
Milkfat (kilograms)						
AA cows	-	-	-	-	188.9	18.9
AB cows	-	-	194.2	10.6	190.8	82.5
BB cows	191.4	191.4	191.2	180.8	191.4	89.5
Total		191.4		191.3		190.9
Protein (kilograms)						
AA cows	-	-	-	-	160.1	16.0
AB cows	-	-	161.6	8.8	159.3	68.8
BB cows	158.0	158.0	157.8	149.2	158.0	73.9
Total		158.0		158.1		158.7

Table A2.3: Parameters used and first year production in selection for BB β -lactoglobulin cows at a 0.5 gene frequency for the B allele.

YEAR 1						
Gene frequency (B)	0.500					
Cows (2- to 10-year old) by genotype						
AA cows	0.25					
AB cows	0.50					
BB cows	0.25					
Production (Total per cow, Portion of per cow total)	Milk Yield		Milkfat		Protein	
	Total	Part	Total	Part	Total	Part
AA cows	2950	737	158.4	39.6	121.4	30.3
AB cows	2935	1467	160.0	80.1	120.8	60.4
BB cows	2912	728	160.5	40.1	119.8	30.0
Herd 1 (Test option)	2940	2205	159.5	119.6	121.0	90.7
Herd 2 (Test option)	2912	728	160.5	40.1	119.8	30.0
Total		2933		159.7		120.7
Gain over time (Base level, Response to selection)	Milk Yield		Milkfat		Protein	
	Base	Gain	Base	Gain	Base	Gain
AA cows	3082	30.17	164.6	1.79	121.7	2.21
AB cows	3066	30.02	166.3	1.80	121.1	2.20
BB cows	3042	29.78	166.8	1.81	120.1	2.18

Table A2.4: Selection for BB β -lactoglobulin cows at a .5 gene frequency for the B allele with no heifer AI.

YEAR 20 (B frequency =.5, No Yearling AI)	BB Bulls Test cows		BB Bulls No Test		Status Quo	
Cows (2- to 10-year old) by genotype						
AA cows	0.000		0.000		0.250	
AB cows	0.009		0.110		0.500	
BB cows	0.991		0.890		0.250	
Gene frequency (B)	0.996		0.945		0.500	
Calves selected by genotype						
AB calves	0.000		0.060		0.500	
BB calves	1.000		0.940		0.250	
Production (total per cow, portion of per cow total)	Total	Part	Total	Part	Total	Part
Milk Yield (litres)						
AA cows	-	-	-	-	3472	868
AB cows	3557	32	3512	388	3455	1727
BB cows	3426	3396	3420	3042	3427	857
Total		3427		3430		3452
Milkfat (kilograms)						
AA cows	-	-	-	-	189.3	47.3
AB cows	196.3	1.7	194.3	21.5	191.2	95.6
BB cows	191.7	190.0	191.4	170.2	191.8	47.9
Total		191.8		191.7		190.9
Protein (kilograms)						
AA cows	-	-	-	-	159.7	39.9
AB cows	160.4	1.4	161.0	17.8	158.9	79.4
BB cows	157.6	156.2	157.3	139.9	157.6	39.4
Total		157.6		157.7		158.7

Table A2.5: Selection for BB β -lactoglobulin cows at a .5 gene frequency for the B allele with heifer AI.

YEAR 20 (B frequency =.500, Yearling AI)	BB Bulls Test cows		BB Bulls No Test		Status Quo	
Cows (2- to 10-year old) by genotype						
AA cows	0.000		0.000		0.250	
AB cows	0.000		0.086		0.500	
BB cows	1.000		0.914		0.250	
Gene frequency (B)	1.000		0.957		0.500	
Calves selected by genotype						
AB calves	0.000		0.043		0.500	
BB calves	1.000		0.957		0.250	
Production (total per cow, portion of per cow total)	Total	Part	Total	Part	Total	Part
Milk Yield (litres)						
AA cows	-	-	-	-	3472	868
AB cows	-	-	3518	303	3455	1727
BB cows	3427	3427	3421	3126	3427	857
Total		3427		3429		3452
Milkfat (kilograms)						
AA cows	-	-	-	-	189.3	47.3
AB cows	-	-	194.6	16.8	191.2	95.6
BB cows	191.8	191.8	191.5	175.0	191.8	47.9
Total		191.8		191.7		190.9
Protein (kilograms)						
AA cows	-	-	-	-	159.7	39.9
AB cows	-	-	161.2	13.9	158.9	79.4
BB cows	157.6	157.6	157.4	143.8	157.6	39.4
Total		157.6		157.7		158.7

Table A2.6: Year in which proportion of BB cows is over the stated amount with and without yearling mating to AI at .5 gene frequency.

Proportion	0.50	0.60	0.70	0.80	0.85	0.90	0.95	1.00
No Yearling AI mating								
Cows tested	7	9	11	13	14	15	-	-
Cows untested	8	10	13	16	18	-	-	-
Yearling AI mating								
Cows tested	5	6	7	8	9	10	11	15
Cows untested	7	9	12	15	17	19	-	-

Note: Year 20, B Frequency = 0.5

At a gene frequency of 0.5 for the B allele with no yearling mating to AI, all calves selected in the tested herd will be genotype BB in year 14, and the whole herd will be BB genotype by year 24. Where yearlings are AB mated, all calves selected in the tested herd will be genotype BB in year 6, and the whole herd will be BB genotype by year 16.

APPENDIX THREE

TRANSPORT MODEL TABLES

Table A3.1: Transport information for the North Island, at peak lactation and able to collect two milk types in the same run.

Year	Total cost				Cost (\$/kilolitre)				Number of trips				Number of stops			
	SQ	25%	50%	100%	SQ	25%	50%	100%	SQ	25%	50%	100%	SQ	25%	50%	100%
1	753.14	762.11	774.87	757.62	8.11	8.21	8.35	8.16	4	4	4	4	30	33	35	60
2	754.52	764.87	775.22	767.63	8.01	8.12	8.23	8.15	4	4	4	4	30	37	43	60
3	757.28	777.29	779.01	769.01	7.92	8.13	8.15	8.04	4	4	4	4	30	38	45	60
4	757.28	786.26	770.73	821.45	7.81	8.11	7.95	8.47	4	4	4	4	30	38	45	60
5	761.76	787.64	769.35	819.72	7.74	8.01	7.82	8.33	4	4	4	4	30	38	45	60
6	762.11	781.43	789.71	769.70	7.64	7.83	7.91	7.71	4	4	4	4	30	38	45	60
7	762.11	784.53	781.43	769.01	7.53	7.75	7.72	7.60	4	4	4	4	30	38	45	60
8	762.45	790.05	769.35	816.62	7.43	7.70	7.50	7.96	4	4	4	4	30	38	45	60
9	762.45	809.72	775.91	802.47	7.33	7.79	7.46	7.72	4	4	4	4	30	38	45	60
10	768.66	809.37	790.05	841.80	7.30	7.68	7.50	7.99	4	4	4	4	30	38	45	60
11	767.97	796.61	818.34	823.86	7.19	7.46	7.67	7.72	4	4	4	4	30	38	45	60
12	768.32	797.99	816.27	959.45	7.11	7.38	7.55	8.87	4	4	4	5	30	38	45	60
13	769.35	803.16	832.49	952.89	7.02	7.33	7.60	8.70	4	4	4	5	30	38	45	60
14	769.35	826.28	960.83	868.37	6.94	7.45	8.66	7.83	4	4	5	4	30	38	45	60
15	769.35	938.06	963.24	976.01	6.85	8.35	8.58	8.69	4	5	5	5	30	37	43	54
16	774.18	935.64	842.49	938.60	6.81	8.23	7.41	8.25	4	5	4	5	30	33	39	48
17	916.32	935.64	950.82	930.47	7.96	8.13	8.26	8.08	5	5	5	5	30	33	34	36
18	920.12	934.95	942.54	918.74	7.90	8.03	8.09	7.89	5	5	5	5	30	31	32	30
19	920.12	934.61	941.85	920.12	7.81	7.93	7.99	7.81	5	5	5	5	30	30	30	30
20	919.77	932.19	936.68	919.43	7.71	7.82	7.85	7.71	5	5	5	5	30	30	30	30

Table A3.2: Transport information for the North Island, in late lactation and able to collect two milk types in the same run.

Year	Total cost			Cost (\$/kilolitre)			Number of trips			Number of stops		
	SQ	25%	50%	SQ	25%	50%	SQ	25%	50%	SQ	25%	50%
1	553.73	580.64	590.99	9.61	10.08	10.26	3	3	3	30	33	35
2	553.38	580.98	585.47	9.47	9.94	10.01	3	3	3	30	37	43
3	553.38	594.44	585.47	9.33	10.02	9.87	3	3	3	30	38	45
4	556.14	590.99	584.78	9.24	9.82	9.71	3	3	3	30	38	45
5	568.91	590.99	584.43	9.32	9.68	9.57	3	3	3	30	38	45
6	571.32	590.99	584.43	9.23	9.54	9.44	3	3	3	30	38	45
7	571.67	590.99	579.95	9.11	9.41	9.24	3	3	3	30	38	45
8	571.67	590.99	578.22	8.98	9.29	9.08	3	3	3	30	38	45
9	573.74	588.92	576.50	8.89	9.13	8.94	3	3	3	30	38	45
10	574.43	588.92	576.50	8.79	9.01	8.82	3	3	3	30	38	45
11	576.15	588.92	576.50	8.70	8.89	8.70	3	3	3	30	38	45
12	575.81	588.92	576.50	8.58	8.78	8.59	3	3	3	30	38	45
13	575.81	588.92	578.57	8.47	8.66	8.51	3	3	3	30	38	45
14	576.15	588.92	613.07	8.37	8.56	8.91	3	3	3	30	38	45
15	576.15	588.92	622.38	8.27	8.45	8.93	3	3	3	30	37	43
16	578.22	588.57	605.48	8.19	8.34	8.58	3	3	3	30	33	39
17	578.57	591.68	602.37	8.10	8.28	8.43	3	3	3	30	33	34
18	578.22	597.54	612.03	8.00	8.27	8.47	3	3	3	30	31	32
19	578.22	602.37	599.96	7.90	8.23	8.20	3	3	3	30	30	30
20	584.78	599.96	599.96	7.90	8.11	8.11	3	3	3	30	30	30

Table A3.3: Transport information for the South Island, at peak lactation and able to collect two milk types in the same run.

Year	Total cost			Cost (\$/kilolitre)			Number of trips			Number of stops		
	SQ	25%	50%	SQ	25%	50%	SQ	25%	50%	SQ	25%	50%
1	4495.48	4531.77	4531.17	12.94	13.05	13.05	13	13	13	30	33	35
2	4495.48	4575.99	4671.30	12.75	12.98	13.25	13	13	13	30	37	43
3	4804.19	4744.45	4946.15	13.43	13.26	13.83	14	13	14	30	38	45
4	4804.17	4876.83	4933.07	13.24	13.44	13.59	14	14	14	30	38	45
5	4814.03	4901.05	4976.19	13.08	13.31	13.52	14	14	14	30	38	45
6	4824.90	4916.03	4993.80	12.92	13.17	13.38	14	14	14	30	38	45
7	5122.11	4892.62	5008.78	13.53	12.92	13.23	15	14	14	30	38	45
8	5138.29	5223.42	5271.70	13.39	13.61	13.74	15	15	15	30	38	45
9	5143.37	5221.95	5029.64	13.22	13.42	12.93	15	15	14	30	38	45
10	5157.36	5237.79	5335.52	13.08	13.29	13.54	15	15	15	30	38	45
11	5178.77	5289.80	5374.96	12.97	13.24	13.46	15	15	15	30	38	45
12	5204.19	5363.74	5373.88	12.86	13.26	13.28	15	15	15	30	38	45
13	5480.90	5341.56	5634.97	13.37	13.03	13.75	16	15	16	30	38	45
14	5489.51	5553.95	5711.45	13.23	13.38	13.76	16	16	16	30	38	45
15	5487.66	5590.36	6005.21	13.06	13.30	14.29	16	16	17	30	38	44
16	5514.61	5590.56	5911.07	12.96	13.14	13.89	16	16	17	30	37	41
17	5534.82	5578.49	5637.33	12.85	12.95	13.09	16	16	16	30	33	37
18	5830.05	5855.85	5867.40	13.38	13.44	13.46	17	17	17	30	30	31
19	5839.65	5909.30	6144.18	13.24	13.40	13.93	17	17	18	30	30	30
20	6129.10	6160.73	6160.98	13.73	13.80	13.81	18	18	18	30	30	30

Table A3.4: Transport information for the North Island, at peak lactation, able to collect two milk types in the same run and collected every second day.

Transport information for the South Island, at peak lactation and able to collect only one milk type per run.

Year	North Island (collect every 2 nd day at peak)								South Island (one milk type per load at peak)							
	Total cost		\$/kilolitre		No. of trips		No. of stops		Total cost		\$/kilolitre		No. of trips		No. of stops	
	25%	50%	25%	50%	25%	50%	25%	50%	25%	50%	25%	50%	25%	50%	25%	50%
1	1467.98	1482.12	7.91	7.98	8	8	33	35	4849.67	4604.77	13.96	13.26	14	13	33	35
2	1314.11	1493.16	6.97	7.92	7	8	37	43	4595.63	4660.76	13.04	13.22	13	13	37	43
3	1325.84	1502.82	6.93	7.86	7	8	38	45	4909.37	4987.15	13.72	13.94	14	14	38	45
4	1326.18	1496.27	6.84	7.71	7	8	38	45	4907.26	4990.52	13.52	13.75	14	14	38	45
5	1482.47	1384.49	7.53	7.04	8	7	38	45	4926.78	5020.54	13.38	13.64	14	14	38	45
6	1486.61	1494.20	7.45	7.49	8	8	38	45	4926.39	5011.03	13.20	13.42	14	14	38	45
7	1487.99	1515.24	7.35	7.49	8	8	38	45	5226.97	5307.61	13.81	14.02	15	15	38	45
8	1494.20	1508.69	7.28	7.35	8	8	38	45	5222.67	5315.15	13.61	13.85	15	15	38	45
9	1493.51	1505.24	7.18	7.24	8	8	38	45	5226.32	5093.12	13.44	13.09	15	14	38	45
10	1504.20	1528.01	7.14	7.25	8	8	38	45	5229.33	5335.06	13.27	13.53	15	15	38	45
11	1501.10	1657.04	7.03	7.76	8	9	38	45	5552.63	5619.41	13.90	14.07	16	16	38	45
12	1499.37	1679.81	6.93	7.77	8	9	38	45	5582.24	5614.45	13.80	13.88	16	16	38	45
13	1513.86	1680.15	6.91	7.67	8	9	38	45	5594.01	5436.43	13.65	13.27	16	15	38	45
14	1662.90	1687.40	7.50	7.61	9	9	38	45	5603.15	5681.93	13.50	13.69	16	16	38	45
15	1667.73	1669.46	7.42	7.43	9	9	37	43	5892.28	6015.05	14.02	14.31	17	17	38	44
16	1669.46	1731.21	7.34	7.61	9	9	33	39	5872.76	5969.80	13.80	14.03	17	17	37	41
17	1665.66	1667.04	7.24	7.24	9	9	33	34	5857.26	5942.56	13.60	13.80	17	17	33	37
18	1670.49	1799.52	7.17	7.72	9	10	31	32	5890.36	5893.98	13.51	13.52	17	17	30	31
19	1678.77	1796.76	7.12	7.62	9	10	30	30	5901.91	6162.23	13.38	13.97	17	18	30	30
20	1684.98	1801.59	7.06	7.55	9	10	30	30	6160.27	6445.83	13.80	14.44	18	19	30	30

Table A3.5: Average cost of milk collection (\$/kilolitre), and the increased cost compared to the status quo cost in that year (%).

Year	North Island						North Island				South Island			
	25% Peak		50% Peak		100% Peak		25% Late		50% Late		25% Peak		50% Peak	
	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
1	8.21	1.19%	8.35	2.89%	8.16	0.59%	10.08	4.86%	10.26	6.73%	13.05	0.81%	13.05	0.79%
2	8.12	1.37%	8.23	2.74%	8.15	1.74%	9.94	4.99%	10.01	5.80%	12.98	1.79%	13.25	3.91%
3	8.13	2.64%	8.15	2.87%	8.04	1.55%	10.02	7.42%	9.87	5.80%	13.26	-1.24%	13.83	2.95%
4	8.11	3.83%	7.95	1.78%	8.47	8.47%	9.82	6.27%	9.71	5.15%	13.44	1.51%	13.59	2.68%
5	8.01	3.40%	7.82	1.00%	8.33	7.61%	9.68	3.88%	9.57	2.73%	13.31	1.81%	13.52	3.37%
6	7.83	2.54%	7.91	3.62%	7.71	1.00%	9.54	3.44%	9.44	2.29%	13.17	1.89%	13.38	3.50%
7	7.75	2.94%	7.72	2.53%	7.60	0.91%	9.41	3.38%	9.24	1.45%	12.92	-4.48%	13.23	-2.21%
8	7.70	3.62%	7.50	0.90%	7.96	7.10%	9.29	3.38%	9.08	1.15%	13.61	1.66%	13.74	2.60%
9	7.79	6.20%	7.46	1.76%	7.72	5.25%	9.13	2.65%	8.94	0.48%	13.42	1.53%	12.93	-2.21%
10	7.68	5.30%	7.50	2.78%	7.99	9.52%	9.01	2.52%	8.82	0.36%	13.29	1.56%	13.54	3.45%
11	7.46	3.73%	7.67	6.56%	7.72	7.28%	8.89	2.22%	8.70	0.06%	13.24	2.14%	13.46	3.79%
12	7.38	3.86%	7.55	6.24%	8.87	24.88%	8.78	2.28%	8.59	0.12%	13.26	3.07%	13.28	3.26%
13	7.33	4.39%	7.60	8.21%	8.70	23.86%	8.66	2.28%	8.51	0.48%	13.03	-2.54%	13.75	2.81%
14	7.45	7.40%	8.66	24.89%	7.83	12.87%	8.56	2.22%	8.91	6.41%	13.38	1.17%	13.76	4.04%
15	8.35	21.93%	8.58	25.20%	8.69	26.86%	8.45	2.22%	8.93	8.02%	13.30	1.87%	14.29	9.43%
16	8.23	20.86%	7.41	8.82%	8.25	21.24%	8.34	1.79%	8.58	4.71%	13.14	1.38%	13.89	7.19%
17	8.13	2.11%	8.26	3.77%	8.08	1.54%	8.28	2.27%	8.43	4.11%	12.95	0.79%	13.09	1.85%
18	8.03	1.61%	8.09	2.44%	7.89	-0.15%	8.27	3.34%	8.47	5.85%	13.44	0.44%	13.46	0.64%
19	7.93	1.57%	7.99	2.36%	7.81	0.00%	8.23	4.18%	8.20	3.76%	13.40	1.19%	13.93	5.21%
20	7.82	1.35%	7.85	1.84%	7.71	-0.04%	8.11	2.60%	8.11	2.60%	13.80	0.52%	13.81	0.52%

Table A3.6: Cost of collection of Type 2 milk (\$/kilolitre) assuming Type 1 milk collection cost is equal to the status quo cost, and the increased cost compared to the status quo cost in that year (%).

Year	North Island						North Island				South Island			
	25% Peak		50% Peak		100% Peak		25% Late		50% Late		25% Peak		50% Peak	
	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
1	9.73	19.88%	11.59	42.84%	8.25	1.63%	18.81	95.62%	17.97	86.90%	16.38	26.55%	14.82	14.48%
2	8.94	11.63%	9.14	14.08%	8.39	4.77%	13.33	40.88%	12.08	27.61%	15.74	23.39%	15.97	25.22%
3	9.52	20.23%	8.96	13.11%	8.21	3.62%	14.54	55.93%	11.64	24.82%	11.91	-11.34%	15.36	14.39%
4	9.84	26.10%	8.37	7.20%	9.18	17.59%	13.12	42.02%	11.05	19.57%	14.86	12.27%	14.77	11.60%
5	9.38	21.12%	8.03	3.65%	8.86	14.44%	11.53	23.73%	10.19	9.41%	14.79	13.07%	14.78	13.00%
6	8.75	14.53%	8.57	12.21%	7.77	1.72%	11.02	19.43%	9.90	7.29%	14.53	12.42%	14.51	12.31%
7	8.71	15.59%	8.13	7.88%	7.64	1.44%	10.71	17.66%	9.49	4.25%	9.89	-26.93%	12.57	-7.13%
8	8.76	17.85%	7.63	2.61%	8.21	10.43%	10.46	16.44%	9.26	3.12%	14.62	9.16%	14.42	7.70%
9	9.44	28.65%	7.68	4.75%	7.86	7.19%	9.97	12.07%	9.00	1.22%	14.26	7.82%	12.42	-6.08%
10	8.98	23.09%	7.81	7.05%	8.19	12.24%	9.74	10.86%	8.86	0.86%	14.06	7.46%	14.25	8.88%
11	8.31	15.44%	8.33	15.73%	7.83	8.86%	9.49	9.06%	8.71	0.14%	14.22	9.65%	14.16	9.17%
12	8.19	15.31%	8.12	14.29%	9.17	29.00%	9.35	8.91%	8.60	0.26%	14.55	13.09%	13.83	7.49%
13	8.20	16.79%	8.29	18.09%	8.90	26.73%	9.20	8.60%	8.56	1.00%	11.98	-10.39%	14.20	6.19%
14	8.84	27.43%	10.62	53.08%	7.90	13.95%	9.05	8.12%	9.46	12.98%	13.84	4.61%	14.36	8.57%
15	12.28	79.19%	10.42	52.15%	8.78	28.22%	8.92	7.91%	9.57	15.79%	13.99	7.12%	15.58	19.34%
16	11.78	72.95%	8.02	17.81%	8.30	21.83%	8.70	6.19%	8.94	9.04%	13.62	5.10%	14.82	14.33%
17	8.55	7.34%	8.55	7.45%	8.09	1.56%	8.73	7.81%	8.73	7.76%	13.22	2.84%	13.32	3.61%
18	8.34	5.58%	8.28	4.80%	7.89	-0.15%	8.91	11.44%	8.88	10.98%	13.59	1.56%	13.54	1.22%
19	8.23	5.44%	8.17	4.64%	7.81	0.00%	9.03	14.28%	8.46	7.05%	13.80	4.21%	14.56	9.94%
20	8.07	4.66%	7.99	3.61%	7.71	-0.04%	8.60	8.87%	8.28	4.87%	13.98	1.82%	13.87	0.99%

Table A3.7: The extra collection cost to the farmer in dollars per annum and percentage above the status quo (herd not changing) for a North Island farm for 25% of farms changing. Costs used are those for peak lactation, late lactation and an average of the two. Three different ways of calculating costs have been used.

Year	Peak Lactation Cost					Late Lactation Cost					Average Cost				
	A ¹	A	B ²	C ³	C	A	A	B	C	C	A	A	B	C	C
	\$	%	\$	\$	%	\$	%	\$	\$	%	\$	%	\$	\$	%
1	294	6.30	330	303	6.98	1675	338	30.31	306	6.00	984	19.32	336	307	6.49
2	172	3.69	330	308	6.98	716	338	12.96	311	6.00	444	8.71	336	311	6.49
3	363	7.73	400	377	8.42	1181	408	21.39	381	7.24	772	15.12	406	381	7.83
4	535	11.41	457	437	9.62	1019	468	18.37	442	8.27	777	15.18	465	442	8.95
5	482	10.21	508	490	10.64	651	530	11.47	495	9.15	566	10.90	523	496	9.89
6	368	7.79	564	551	11.80	594	590	10.41	557	10.14	481	9.22	581	558	10.97
7	435	9.21	621	616	13.00	595	650	10.42	622	11.17	515	9.87	640	623	12.08
8	543	11.49	678	681	14.17	604	709	10.58	688	12.18	573	10.99	698	688	13.18
9	941	19.93	733	746	15.32	481	769	8.40	754	13.17	711	13.61	756	754	14.24
10	819	17.21	791	810	16.41	464	825	8.10	818	14.11	642	12.23	814	819	15.26
11	582	12.23	840	872	17.45	413	880	7.18	881	15.00	497	9.47	866	882	16.22
12	606	12.73	882	927	18.31	426	923	7.41	937	15.74	516	9.82	909	938	17.03
13	696	14.60	924	982	19.15	430	965	7.48	992	16.46	563	10.71	951	993	17.81
14	1183	24.82	961	1035	19.92	423	1005	7.35	1045	17.13	803	15.27	990	1047	18.52
15	3526	73.99	992	1082	20.57	425	1037	7.39	1093	17.68	1975	37.57	1022	1094	19.13
16	3345	69.77	1022	1121	21.05	342	1066	5.92	1133	18.10	1844	34.90	1051	1134	19.58
17	417	7.34	1265	1187	22.02	451	1115	7.81	1199	18.93	434	7.58	1191	1200	20.47
18	318	5.58	1270	1201	22.02	660	1114	11.44	1213	18.93	489	8.53	1193	1215	20.47
19	310	5.44	1270	1216	22.02	824	1114	14.28	1228	18.93	567	9.89	1193	1229	20.47
20	266	4.66	1270	1230	22.02	518	1127	8.87	1242	18.93	392	6.79	1199	1244	20.47

1 = A is calculated using unadjusted milk transport costs.

2 = B is calculated using unadjusted type 1 (equals SQ) transport costs, but with type 2 milk transport costs at a constant percentage above type 1 (22.3% at peak, 19.3% in late lactation and 20.8% average). NB. The percentage value for B is similar to that for C.

3 = C is calculated with adjusted type 1 (equals SQ) and type 2 milk costs at a constant for all years (Peak: type 1=\$7.56, type 2=\$9.23; Late: type 1=\$8.89, type 2=\$10.57; Average: type 1=\$8.22, type 2=\$9.91. Costs are in \$/kilolitre).

Table A3.8: The extra collection cost to the farmer in dollars per annum and percentage above the status quo (herd not changing) for a North Island farm, for 50% of farms changing. Costs used are those for peak lactation, late lactation and an average of the two. Three different ways of calculating costs have been used.

Year	Peak Lactation Cost					Late Lactation Cost					Average Cost				
	A ¹ \$	A %	B ² \$	C ³ \$	C %	A \$	A %	B \$	C \$	C %	A \$	A %	B \$	C \$	C %
1	633	13.58	210	193	4.45	1522	27.54	176	159	3.11	1078	21.15	196	179	3.78
2	209	4.46	211	196	4.45	483	8.75	176	161	3.11	346	6.79	196	181	3.78
3	235	5.01	255	240	5.36	524	9.49	212	198	3.76	380	7.44	237	222	4.56
4	148	3.15	291	279	6.13	475	8.55	243	229	4.29	311	6.08	271	258	5.21
5	83	1.77	324	312	6.78	258	4.55	275	257	4.75	171	3.29	305	289	5.76
6	309	6.54	360	351	7.52	223	3.90	307	289	5.26	266	5.10	339	325	6.39
7	220	4.65	396	392	8.28	143	2.51	338	323	5.80	181	3.48	373	363	7.04
8	79	1.68	432	434	9.03	115	2.01	368	357	6.32	97	1.86	407	401	7.68
9	156	3.31	467	475	9.76	49	0.85	400	391	6.84	102	1.96	441	439	8.30
10	250	5.26	505	516	10.46	37	0.64	429	425	7.32	144	2.74	474	477	8.89
11	593	12.47	536	556	11.12	6	0.11	457	457	7.79	300	5.70	505	514	9.45
12	566	11.89	563	591	11.67	12	0.22	479	486	8.17	289	5.50	530	546	9.92
13	750	15.73	589	626	12.20	50	0.87	501	515	8.55	400	7.61	554	579	10.37
14	2288	48.02	613	659	12.69	676	11.75	522	543	8.89	1482	28.19	577	610	10.79
15	2322	48.72	633	689	13.10	848	14.75	539	567	9.18	1585	30.14	596	637	11.14
16	817	17.03	652	714	13.41	499	8.65	554	588	9.40	658	12.45	613	661	11.41
17	423	7.45	807	756	14.03	448	7.76	579	622	9.82	436	7.61	694	699	11.93
18	274	4.80	810	765	14.03	634	10.98	579	630	9.82	454	7.91	695	708	11.93
19	264	4.64	810	775	14.03	407	7.05	579	637	9.82	336	5.85	695	716	11.93
20	206	3.61	810	784	14.03	284	4.87	586	645	9.82	245	4.25	699	725	11.93

1 = A is calculated using unadjusted milk transport costs.

2 = B is calculated using unadjusted type 1 (equals SQ) transport costs, but with type 2 milk transport costs at a constant percentage above type 1 (14.2% at peak, 10.0% in late lactation and 12.1% average). NB. The percentage value for B is similar to that for C.

3 = C is calculated with adjusted type 1 (equals SQ) and type 2 milk costs at a constant for all years (Peak: type 1=\$7.56, type 2=\$8.62; Late: type 1=\$8.89, type 2=\$9.76; Average: type 1=\$8.22, type 2=\$9.21. Costs are in \$/kilolitre).

Table A3.9: The extra collection cost to the farmer in dollars per annum and percentage above the status quo (herd not changing) for a South Island farm where 25% and 50% of farms are changing. Costs used are those for peak lactation. Three different ways of calculating costs have been used.

Year	25% of farms changing					50% of farms changing				
	A ¹	A	B ²	C ³	C	A	A	B	C	C
	\$	%	\$	\$	%	\$	%	\$	\$	%
1	2285	8.42	385	392	1.42	1246	4.59	698	710	2.57
2	2013	7.42	385	398	1.42	2170	7.99	698	721	2.57
3	-1258	-4.33	496	487	1.71	1597	5.50	900	882	3.11
4	1556	5.36	567	564	1.96	1471	5.07	1028	1023	3.55
5	1836	6.32	629	633	2.17	1827	6.28	1139	1147	3.93
6	1939	6.65	699	712	2.40	1923	6.60	1266	1290	4.35
7	-4919	-15.90	817	795	2.65	-1301	-4.21	1481	1441	4.80
8	1829	5.89	894	879	2.89	1537	4.95	1620	1593	5.23
9	1691	5.44	967	963	3.12	-1314	-4.23	1753	1745	5.65
10	1732	5.56	1039	1046	3.34	2062	6.62	1883	1895	6.06
11	2391	7.64	1109	1126	3.55	2272	7.26	2010	2041	6.44
12	3423	10.89	1169	1197	3.73	1959	6.23	2119	2170	6.76
13	-2991	-9.03	1288	1268	3.90	1781	5.38	2334	2299	7.07
14	1384	4.18	1342	1336	4.06	2571	7.75	2432	2422	7.35
15	2206	6.66	1385	1397	4.19	5988	18.07	2511	2532	7.59
16	1624	4.88	1425	1448	4.29	4565	13.70	2583	2624	7.77
17	949	2.84	1495	1533	4.48	1207	3.61	2710	2777	8.12
18	550	1.56	1575	1551	4.48	431	1.22	2855	2811	8.12
19	1486	4.21	1578	1570	4.48	3507	9.94	2860	2845	8.12
20	675	1.82	1656	1588	4.48	367	0.99	3001	2878	8.12

1 = A is calculated using unadjusted milk transport costs.

2 = B is calculated using unadjusted type 1 (equals SQ) transport costs, but with type 2 milk transport costs at a constant percentage above type 1 (4.47% for 25%, and 8.11% for 50%). NB. The percentage value for B is similar to that for C.

3 = C is calculated with adjusted type 1 (equals SQ) and type 2 milk costs at a constant for all years (25%: type 1=\$13.14, type 2=\$13.73; 50%: type 1=\$13.14, type 2=\$14.21. Costs are in \$/kilolitre).

Table A3.10: Time taken to collect the milk (hours).

Year	North Island – Peak				North Island - Late			South Island –Peak(2types)			South Island – Peak (1type)		
	SQ	25%	50%	100%	SQ	25%	50%	SQ	25%	50%	SQ	25%	50%
1	11.1	11.8	12.2	17.1	9.8	10.5	10.9	44.6	45.5	45.9	44.6	48.2	46.4
2	11.1	12.6	13.8	17.2	9.8	11.3	12.5	44.6	46.6	48.5	44.6	46.7	48.4
3	11.1	12.8	14.2	17.2	9.8	11.6	12.9	47.3	48.0	51.3	47.3	49.7	51.6
4	11.1	12.9	14.2	17.4	9.8	11.5	12.9	47.3	49.4	51.2	47.3	49.7	51.6
5	11.2	12.9	14.2	17.4	9.9	11.5	12.9	47.4	49.6	51.5	47.4	49.8	51.9
6	11.2	12.8	14.3	17.2	9.9	11.5	12.9	47.5	49.7	51.7	47.5	46.8	51.8
7	11.2	12.8	14.2	17.2	9.9	11.5	12.9	50.1	49.5	51.8	50.1	52.4	54.4
8	11.2	12.9	14.2	17.4	9.9	11.5	12.9	50.2	52.4	54.2	50.2	52.4	54.5
9	11.2	13.0	14.2	17.3	9.9	11.5	12.9	50.2	52.4	51.9	50.2	52.4	52.4
10	11.2	13.0	14.3	17.5	9.9	11.5	12.9	50.3	52.5	54.9	50.3	52.5	54.6
11	11.2	12.9	14.4	17.4	9.9	11.5	12.9	50.5	52.9	54.9	50.5	55.3	57.1
12	11.2	12.9	14.4	18.5	9.9	11.5	12.9	50.7	53.4	54.9	50.7	55.5	57.1
13	11.2	12.9	14.4	18.4	9.9	11.5	12.9	53.1	53.3	57.2	53.1	55.6	55.3
14	11.2	13.0	15.5	17.6	9.9	11.5	13.0	53.2	55.3	57.8	53.2	55.6	57.6
15	11.2	13.8	15.1	17.3	9.9	11.3	12.7	53.2	55.5	60.2	53.2	58.2	60.3
16	11.2	13.0	13.3	16.2	9.9	10.5	11.8	53.4	55.3	58.9	53.4	57.8	59.3
17	12.3	13.0	13.2	13.6	9.9	10.6	10.8	53.0	54.4	55.7	53.0	56.9	58.3
18	12.3	12.6	12.8	12.3	9.9	10.2	10.4	56.1	56.3	56.6	56.1	56.6	56.8
19	12.3	12.4	12.4	12.3	9.9	10.0	10.0	56.2	56.7	58.9	56.2	56.7	59.0
20	12.3	12.4	12.4	12.3	9.9	10.0	10.0	58.8	59.0	59.0	58.8	58.8	61.5

APPENDIX FOUR

DESCRIPTION OF THE COW REQUIREMENTS MODEL DEVELOPED BY DR IAN BROOKES

Annual cow requirements were calculated using a model developed by Dr Ian Brookes at Massey University (Brookes *et al.* 1993). The year was divided into 24 periods, with the feed requirement calculated for the mid-day in each of these periods. These were then multiplied by 15.21 days per period to give the annual feed requirement. The equations used to calculate the daily feed requirements are described below.

FEED AND ME REQUIREMENTS, AND CORRECTION FACTOR

Daily feed requirements (kg DM/cow) are calculated as ME_{mp}/MD where:

ME_{mp} = ME (metabolisable energy) requirement for maintenance and production (MJ/d);

MD = metabolisable energy in the feed (MJ ME/kg DM).

ME_{mp} is the ME requirement for maintenance, lactation, growth and growth of the conceptus, multiplied by a correction factor which adjusts the ME requirement to give the ME actually available to the animal. This adjustment is necessary as the ME component of the feed is reduced at higher feeding levels because of reduced retention time in the rumen (AFRC 1993). The MD value is specified by the user.

$$ME_{mp} = CL \times (E_m/k_m + E_l/k_l + E_g/k_g + E_c/k_c) \quad (\text{AFRC 1993})$$

$$= CL \times (ME_m + ME_l + ME_g + ME_c)$$

where:

$ME_m = E_m/k_m$ = ME requirement for maintenance (MJ/d);

$ME_l = E_l/k_l$ = ME requirement for milk production (MJ/d);

$ME_g = E_g/k_g$ = ME requirement for liveweight change (MJ/d);

$ME_c = E_c/k_c$ = ME requirement for growth of conceptus (MJ/d);

E_m = net energy for maintenance;

E_l = net energy secreted as milk;

E_g = net energy retained or lost in daily LW change;

E_c = net energy retained in conceptus;

k_m = efficiency of utilisation of ME for maintenance;

k_l = efficiency of utilisation of ME for milk production;

k_g = efficiency of utilisation of ME for liveweight change;

k_c = efficiency of utilisation of ME for growth of conceptus;

CL = plane of nutrition factor in calculating ME requirements of lactating ruminants.

$$CL = 1 + 0.018(L-1) \quad (\text{AFRC 1993})$$

where: L = multiples of maintenance ME.

$$L = (ME_m + ME_l + ME_g + ME_c)/ME_m.$$

MAINTENANCE REQUIREMENTS

The ME requirement for maintenance is:

$$ME_m = E_m/k_m$$

The E_m values for dry and lactating cows were adapted from Holmes *et al.* (1981), with dry cows being 10% lower than lactating cows. These are:

$$E_m = (W_C^{.75} \times .39) \quad (\text{Dry Cows})$$

$$E_m = (W_C^{.75} \times .43) \quad (\text{Milking Cows})$$

where:

W_C = cow liveweight, calculated as $W_T - W_F$ (kg);

W_T = total cow liveweight (kg);

W_F = weight of the conceptus (kg).

The k_m value is (ARC 1980, for forages):

$$\begin{aligned}
 k_m &= ((q_m \times 0.207) + 0.559) && \text{(August - February)} \\
 k_m &= ((q_m \times 0.207) + 0.559) \times (1.318 - (0.0013 \times d_y)) && \text{(March - mid April)} \\
 k_m &= ((q_m \times 0.207) + 0.559) \times (0.4877 + (0.0013 \times d_y)) && \text{(mid April - June)} \\
 k_m &= ((q_m \times 0.207) + 0.559) \times (0.9587 + (0.0013 \times d_y)) && \text{(July)}
 \end{aligned}$$

where:

$$q_m = MD/GE \text{ where GE (gross energy value of the diet) = 18.4 MJ ME/kg DM (AFRC 1993);}$$

$$d_y = \text{time of year factor, days from July 1}^{\text{st}}.$$

A correction factor is included in the k_m value calculation from March to July to reflect the more efficient utilisation of feed in spring than in autumn (Scott *et al.* 1976).

PREGNANCY REQUIREMENTS

The ME requirement for pregnancy is:

$$ME_c = E_c/k_c$$

and

$$E_c = 0.025 \times W_B \times (E_t \times 0.0201e^{-0.0000576t}) \quad \text{(AFRC 1993)}$$

$$k_c = 0.133 \quad \text{(AFRC 1993)}$$

where:

W_B = calf birth weight (kg);

t = days from conception;

E_t = the energy in the gravid foetus at time t .

$$\text{and } \log_{10}(E_t) = 151.665 - 151.64e^{-0.0000576t} \quad \text{(AFRC 1993)}$$

LACTATION REQUIREMENTS

Daily milk production over the lactation was calculated using the Wood equation (Wood 1967). This is described in a separate section below. Dr Brookes assumed milkfat, protein and milksolids percentages were constant over the lactation. Milksolids was assumed to be 8.0% for Friesians, 10.0% for Jerseys and 8.8% for Crossbreds. Milkfat was 4.5% for Friesians, 5.8% for Jerseys and 5.0% for Crossbreds. Protein percentage was milksolids percentage less milkfat percentage. Milk composition and yield were then used to calculate the ME requirements for lactation.

The ME requirement for lactation is:

$$ME_l = E_l/k_l$$

AFRC (1993) recommended the equation of Tyrrell and Reid (1965) to calculate the energy value of a kilogram of milk. Dr Brookes used this equation and the fat concentration in the milk to calculate the energy value of a kilogram of milkfat. This energy value is then multiplied by milkfat yield to give the energy value of the milk produced.

$$NE_M = ((0.0376 \times MF) + (0.0209 \times P) + 0.948)$$

therefore: $NE_{MF} = NE_M/(MFC/100)$

and: $E_l = MFY \times NE_{MF}$

where:

NE_M = net energy in a kg of milk (MJ ME);

MF = milkfat content of the milk (g/kg) = $MFC \times 10$;

P = protein content of the milk (g/kg) = $PC \times 10$;

NE_{MF} = net energy in a kg of milkfat (MJ ME);

MFC = milkfat concentration in the milk (%);

PC = protein concentration in the milk (%);

MFY = milkfat yield (kg). (See later section on Wood equation)

The k_l value is (AFRC 1993):

$$k_l = ((q_m \times 0.35) + 0.42)$$

(August - February)

$$k_1 = ((q_m \times 0.35) + 0.42) \times (1.318 - (0.0013 \times d_y)) \quad (\text{March} - \text{mid April})$$

$$k_1 = ((q_m \times 0.35) + 0.42) \times (0.4877 + (0.0013 \times d_y)) \quad (\text{mid April} - \text{June})$$

$$k_1 = ((q_m \times 0.35) + 0.42) \times (0.9587 + (0.0013 \times d_y)) \quad (\text{July})$$

As for k_m , a correction factor is included in the k_1 value calculation from March to July to reflect the more efficient utilisation of feed in spring than in autumn (Scott *et al.* 1976).

GROWTH REQUIREMENTS

Liveweight stored during lactation

The ME requirement for growth is:

$$ME_g = E_g/k_g$$

$$E_g = LWC \times NE_g \quad (\text{AFRC 1993})$$

$$NE_g = \text{Net energy of gain (19 MJ ME/kg)} \quad (\text{AFRC 1993})$$

LWC = liveweight change (kg)

The efficiency value of gain is related to that for lactation such that:

$$k_g = k_1 \times 0.95 \quad (\text{AFRC 1993})$$

Liveweight utilised during lactation

The ME mobilised from liveweight loss during lactation and used for maintenance, lactation or conceptus growth is:

$$E_g = LWC \times NE_g \times 0.83$$

$$NE_g = \text{Net energy of gain (19 MJ ME/kg)}$$

LWC = liveweight change (kg)

This is a feed saving of:

$$ME_g = E_g/k_l$$

Note: The efficiency value for lactation is used here.

Liveweight stored while cows are dry

The ME requirement for growth is:

$$ME_g = E_g/k_g$$

$$E_g = LWC \times NE_g \quad (\text{AFRC 1993})$$

NE_g = Net energy of gain (19 MJ ME/kg)

LWC = liveweight change (kg)

The k_g value is (ARC 1980, for forages):

$$k_g = ((q_m \times 1.248) - 0.313) \quad (\text{August - February})$$

$$k_g = ((q_m \times 1.24) - 0.313) \times (1.953 - (0.0039 \times d_y)) \quad (\text{March - mid April})$$

$$k_g = ((q_m \times 1.24) - 0.313) \times (-0.5368 + (0.0039 \times d_y)) \quad (\text{mid April - June})$$

$$k_g = ((q_m \times 1.24) - 0.313) \times (0.8761 + (0.0039 \times d_y)) \quad (\text{July})$$

As for k_l and k_m , a correction factor is included in the k_g value calculation from March to July to reflect the more efficient utilisation of feed in spring than in autumn (Scott *et al.* 1976).

Liveweight utilised while cows are dry

The ME mobilised from liveweight loss for maintenance, lactation or conceptus growth is:

$$E_g = LWC \times NE_g$$

NE_g = Net energy of gain (19 MJ ME/kg)

LWC = liveweight change (kg)

This is a feed saving of:

$$ME_g = E_g/k_m$$

Note: The efficiency value for maintenance is used here.

LIVEWEIGHTS

Lactation day is specified for peak yield, drying off and next calving (assumed to be 365), with the current calving day being day 0. Condition score (CS) on each of these days is specified, as is cow liveweight at condition score 5. Liveweight (kg)/CS is 40 kg, 25 kg and 32.5 kg for Friesian, Jersey and Crossbred cows, respectively. Breed is used defined.

Cow liveweight

Total cow liveweight (W_T) used in the maintenance requirements calculation for a given lactation day (d_i) is:

$$\begin{aligned} W_T &= W_{cv} + W_F + (LWC \times d_i) && \text{(if } d_i \text{ is less than } d_{py}) \\ W_T &= W_{py} + W_F + (LWC \times (d_i - d_{py})) && \text{(if } d_i \text{ is between } d_{py} \text{ and } d_{do}) \\ W_T &= W_{do} + W_F + (LWC \times (d_i - d_{do})) && \text{(if } d_i \text{ is greater than } d_{do}) \end{aligned}$$

where:

d_i = day of lactation; (see below)

d_{py} = peak yield day;

d_{do} = drying off day;

W_F = conceptus weight (kg);

LWC = daily LW gain/loss on d_i (kg);

W_{cv} = calving liveweight (kg);

W_{py} = liveweight at peak milk yield (kg);

W_{do} = liveweight at drying off (kg).

These last three variable are calculated as:

$$W_{cv} = W_{C5} + ((CS_{cv} - 5) \times LCS)$$

$$W_{py} = W_{C5} + ((CS_{py} - 5) \times LCS)$$

$$W_{do} = W_{C5} + ((CS_{do} - 5) \times LCS)$$

where:

W_{C5} = liveweight at condition score 5;

LCS = kg of liveweight / condition score;

CS_{cv} = condition score at calving;

CS_{py} = condition score at peak milk yield;

CS_{do} = condition score at drying off.

Lactation day (d_l) is calculated as:

$$d_l = (m \times CP) - (0.75 \times m)$$

where:

m = days per month ($30.42 = 365/12$);

CP = calving period (24 periods per year (1 to 12.5), where 1 = the first lactation period).

Conceptus liveweight

Conceptus liveweight (W_F), used in calculating total cow liveweight and maintenance requirements is:

$$W_F = (W_B/40) \times (10^{(2.932 - (\text{EXP}(-0.00406 \times d_p) \times 3.347))}) \quad (\text{ARC 1980})$$

where:

d_p = days pregnant (see below);

W_B = calf birth weight;

$$W_B = 35/450 \times W_{cv2}; \quad (35/450 = 0.078, \text{ Garcia-Muniz } et al. 1998)$$

$$W_{cv2} = W_{C5} + ((CS_{cv2} - 5) \times LCS);$$

W_{cv2} = liveweight at next calving;

CS_{cv2} = condition score at next calving.

If day of lactation is less than days to next calving, $d_p = 0$, else:

$$d_p = d_l - d_c$$

where $d_c = 83$ = days to get in-calf = days to next calving (365) – gestation length (282).

Daily liveweight change

Daily liveweight change is assumed to be constant between calving and peak milk yield, peak milk yield and drying off, and drying off to next calving. Calculations are based on liveweights and condition scores at these times of the year. Calculations are shown below.

$$LWC = (W_{py} - W_{cv}) / (d_{py} - d_{cv}) \quad (\text{if } d_l \text{ is less than } d_{py})$$

$$LWC = (W_{do} - W_{py}) / (d_{do} - d_{py}) \quad (\text{if } d_l \text{ is between } d_{py} \text{ and } d_{do})$$

$$LWC = (W_{cv2} - W_{do}) / (d_{cv2} - d_{do}) \quad (\text{if } d_l \text{ is greater than } d_{do})$$

where:

d_{cv} = calving day (assumed to be 0);

d_{cv2} = days to next calving (usually assumed to be 365).

WOOD EQUATION CALCULATIONS (LACTATION CURVE)

Wood (1967) predicted yields over lactation as:

$$Y_n = an^b \exp^{-cn}$$

and the shape of the curve as $F(n) = n^b \exp^{-cn}$ (Wood 1976)

where:

Y_n = the production measured at time n of lactation where Y can be any trait;

n = time of lactation (weeks) = $d_l/7$;

e = base of natural logarithms;

$$b = 0.1286 \times z = 0.1929 ;$$

$$c = b/(d_{py}/7);$$

$$z = 1.5. \quad (b/c = .1286/.03215 = 4, \text{ peak lactation} = 6 \text{ weeks (42 days) therefore } z = 1.5)$$

a, b and c are coefficients measuring the lactation curve. The week of peak lactation = b/c. a is a scaling factor associated with the average daily yield at the start of lactation.

The model predicts the shape of the lactation curve (yield at time n), against a yield at peak lactation day of 1 as follows.

$RY_{n=1}$ = the daily production measured at time n of lactation, relative to a yield of 1 at peak.

and: $RY_{n=1} = Y_{n=1}/Y_{py}$

$$= ((d_l/7)/(b/c))^b \times \exp(b \times (1 - ((d_l/7)/(b/c))))$$

$$= (n/(b/c))^b \times \exp(b \times (1 - (n/(b/c))))$$

where l = current lactation period.

Note: b/c = time of lactation (n) at peak milk yield.

The proportion of production per day, in each period, is calculated as:

$$PP_{n=1} = RY_{n=1}/(\sum RY \times 365/24)$$

$$TPP_{n=1} = \sum PP \quad \text{for } n=1 \text{ to } n=l$$

where:

$PP_{n=1}$ = proportion of production at time n, where n is the current lactation period (l);

$TPP_{n=1}$ = cumulative production up to and including time n, where $n=l$;

$\sum RY$ = sum of the RY values for the 24 periods in the year.

Annual milk solids production is specified by the user and is used in the calculation of annual milkfat production.

$$\text{AMFY} = \text{AMSY} \times \text{MFC}/\text{MSC}$$

where:

AMFY = annual milkfat yield;

AMSY = annual milksolids yield;

MSC = milk solids concentration (%).

Daily milkfat production is calculated if lactation day is less than drying off day, otherwise it equals 0.

$$\text{MFY}_{n=l} = (\text{AMFY}/(\text{TPP}_{n=\text{do}}/\Sigma\text{PP})) \times \text{PP}_l$$

where:

$\text{MFY}_{n=l}$ = milkfat yield at time n, where n is the current lactation period (l);

$\text{TPP}_{n=\text{do}}$ = cumulative production up to time n, where n= drying off time;

ΣPP = sum of the PP values for the 24 periods in the year.

APPENDIX FOUR

NOTE ON TRANSPORT RELATED COSTS

The average total cost for milk collection was between 0.7 to 1.3 cents per litre. However, in the economic model this was assumed to be the difference in milk collection costs between the differentiated milk and the non-differentiated milk rather than the total cost of collection. The difference in milk transport costs between the differentiated milk and the non-differentiated milk, assuming volume flows modelled by the qualitative scenario 1, ranged from 4% to 23% more than the status quo, and therefore the actual milk collection cost difference should have been assumed to be 0.1 to 0.2 cents per litre more.

However, the volume charge to farmers was 4.1 cents per litre. This includes more than the transport charge. Farm vat repairs and factory-related volume charges (e.g. milk storage, grading and testing, separation and pasteurisation, evaporation and water removal from milk) are included in this figure (Larking 1989). Milk differentiation is likely to see some of these costs increase because of the need for increased storage facilities, and smaller differentiated milk batches resulting in higher costs per litre. For example, while the variable cost of drying milk may remain the same, the overhead or fixed costs associated with running a drier are likely to remain the same but will be spread over less milk. The difference in the volume charge related to differentiated milk should therefore include more than the collection costs. If the extra charge was assumed to be 20% of the 4.1 cents per litre, the volume charge would have been an extra 0.83 cents per litre for differentiated milk.

NZDG calculated colostrum collection costs to be in the vicinity of an extra 6.0 cents per litre compared to standard milk. While this is an extreme example it does demonstrate the effect very low milk volumes have on collection costs. The lower volumes of differentiated milk in the quantitative scenarios suggest that the increase in milk collection costs would have been greater than that modelled for the qualitative breeding scenario. Thus, an extra 1 cent per litre for the differentiated milk in the quantitative scenario, including factory costs, may not have been an unreasonable assumption.

The sensitivity of the breakeven premium to different increases in transport costs for the differentiated milk for four of the scenarios (20+ years) is shown in Table A4.1. Sensitivity has also been done for 10, 20 and 20+ years for quantitative scenario 1 (Table A4.2). The

increase required in the breakeven premium is approximately 1 cent per kilogram milksolids for every 0.1 cent increase in the volume charge for differentiated milk.

Table A4.1: Premium required for two quantitative and two qualitative scenarios at different increases in volume charges for differentiated milk (over 20+ years).

Increase in volume charge (cents/litre)	Quantitative 1	Quantitative3	Qualitative 1	Qualitative 2
	cents /kg milkfat		% increase in fat and protein value	
0.0	0.75	0.32	0.9	1.4
0.2	0.78	0.35	1.3	1.8
0.4	0.82	0.38	1.8	2.3
0.8	0.88	0.44	2.7	3.2
1.0	0.92	0.47	3.2	3.7

Table A4.2: Premium required for quantitative scenario 1 over three time periods with different increases in volume charges for differentiated milk.

Increase in volume charge (cents/litre)	10 years	20 years	20+ years
	cents /kg milkfat		
0.0	1.90	0.94	0.75
0.2	1.93	0.97	0.78
0.4	1.97	1.01	0.82
0.8	2.04	1.08	0.88
1.0	2.08	1.11	0.92

Any overestimation in transport costs would not have a large impact on the quantitative breeding scenario where the breakeven premium is required is already relatively high. Differences in production still have a far greater effect on these scenarios. Any overestimation in transport costs clearly would have had a greater impact on the qualitative breeding scenarios. Production differences between the status quo and the differentiated herd in this scenario are less and transport costs have a greater effect. However, the premium required to break even is also considerably less.

While any overestimation of volume charges affects the results, the general trend remains the same. The ability of the model and the outcomes demonstrated by the model are still relevant. The discussion and conclusions reached in the thesis would not have been changed much by this overestimation.

APPENDIX FIVE

OVERALL MODEL OUTPUT TABLES

QUANTITATIVE APPENDICES

Table A5.1: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years under the status quo scenario.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	1.000	0.000	4028	177.8	139.8	476.9	7.83	0	0.0	0.0	0.0	0.00	293
2	1.000	0.000	4052	179.2	141.6	477.0	7.80	0	0.0	0.0	0.0	0.00	294
3	1.000	0.000	4076	180.7	143.4	477.1	7.77	0	0.0	0.0	0.0	0.00	296
4	1.000	0.000	4099	182.2	145.2	477.2	7.74	0	0.0	0.0	0.0	0.00	297
5	1.000	0.000	4123	183.7	147.0	477.3	7.71	0	0.0	0.0	0.0	0.00	299
6	1.000	0.000	4147	185.2	148.8	477.4	7.68	0	0.0	0.0	0.0	0.00	300
7	1.000	0.000	4171	186.7	150.6	477.5	7.64	0	0.0	0.0	0.0	0.00	302
8	1.000	0.000	4194	188.2	152.4	477.6	7.61	0	0.0	0.0	0.0	0.00	303
9	1.000	0.000	4218	189.7	154.2	477.7	7.58	0	0.0	0.0	0.0	0.00	305
10	1.000	0.000	4242	191.2	156.0	477.8	7.55	0	0.0	0.0	0.0	0.00	306
11	1.000	0.000	4265	192.7	157.8	477.9	7.52	0	0.0	0.0	0.0	0.00	307
12	1.000	0.000	4289	194.2	159.6	478.0	7.49	0	0.0	0.0	0.0	0.00	309
13	1.000	0.000	4313	195.7	161.4	478.1	7.46	0	0.0	0.0	0.0	0.00	310
14	1.000	0.000	4337	197.2	163.1	478.2	7.43	0	0.0	0.0	0.0	0.00	311
15	1.000	0.000	4360	198.7	164.9	478.2	7.39	0	0.0	0.0	0.0	0.00	313
16	1.000	0.000	4384	200.2	166.7	478.3	7.36	0	0.0	0.0	0.0	0.00	314
17	1.000	0.000	4408	201.7	168.5	478.4	7.33	0	0.0	0.0	0.0	0.00	315
18	1.000	0.000	4432	203.1	170.3	478.5	7.30	0	0.0	0.0	0.0	0.00	317
19	1.000	0.000	4455	204.6	172.1	478.6	7.27	0	0.0	0.0	0.0	0.00	318
20	1.000	0.000	4479	206.1	173.9	478.7	7.24	0	0.0	0.0	0.0	0.00	319

Table A5.2: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	0.023	0.977	4083	181.2	142.1	474.6	4.40	4027	177.7	139.8	477.0	7.91	293
2	0.025	0.975	4106	182.6	143.9	474.7	4.40	4050	179.2	141.6	477.1	7.89	294
3	0.026	0.974	4129	184.1	145.6	474.9	4.40	4074	180.6	143.4	477.2	7.86	296
4	0.031	0.969	4082	182.6	144.9	468.7	4.40	4094	182.1	144.9	477.5	7.80	298
5	0.040	0.960	4024	180.8	143.7	462.6	4.40	4110	183.3	146.2	477.9	7.71	299
6	0.055	0.945	3983	179.8	142.9	459.5	4.40	4121	184.5	147.2	478.3	7.60	302
7	0.078	0.922	3964	179.8	142.7	458.5	4.40	4129	185.6	148.0	478.9	7.48	304
8	0.110	0.890	3959	180.4	142.9	459.0	4.40	4135	186.7	148.7	479.5	7.35	306
9	0.152	0.848	3961	181.3	143.3	460.1	4.40	4139	187.7	149.3	480.3	7.23	308
10	0.207	0.793	3968	182.4	143.9	461.7	4.40	4142	188.7	149.8	481.3	7.11	311
11	0.275	0.725	3977	183.6	144.5	463.5	4.40	4146	189.6	150.2	482.4	7.01	313
12	0.357	0.643	3986	184.8	145.2	465.3	4.40	4150	190.7	150.7	483.8	6.94	316
13	0.450	0.550	3995	186.0	145.8	467.2	4.40	4155	191.8	151.2	485.3	6.89	318
14	0.554	0.446	4005	187.3	146.5	469.1	4.40	4163	192.9	151.8	487.1	6.89	321
15	0.665	0.335	4015	188.5	147.1	471.0	4.40	4172	194.1	152.4	489.1	6.95	323
16	0.777	0.223	4024	189.7	147.8	472.9	4.40	4184	195.3	153.1	491.5	7.08	326
17	0.883	0.117	4032	190.9	148.4	474.7	4.40	4197	196.5	153.9	494.5	7.36	329
18	0.974	0.026	4039	192.0	148.9	476.4	4.40	4211	197.3	154.5	498.8	8.12	331
19	1.000	0.000	4036	192.8	149.1	477.0	4.24	0	0.0	0.0	0.0	0.00	334
20	1.000	0.000	4028	193.4	149.2	477.0	3.98	0	0.0	0.0	0.0	0.00	336

Table A5.3: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	0.023	0.977	4083	181.2	142.1	474.6	4.40	4027	177.7	139.8	477.0	7.91	293
2	0.025	0.975	4106	182.6	143.9	474.7	4.40	4050	179.2	141.6	477.1	7.89	294
3	0.026	0.974	4129	184.1	145.6	474.9	4.40	4074	180.6	143.4	477.2	7.86	296
4	0.030	0.970	4101	183.5	145.5	470.2	4.40	4097	182.2	145.0	477.6	7.81	297
5	0.038	0.962	4067	182.9	145.0	465.8	4.40	4119	183.9	146.5	478.1	7.73	299
6	0.049	0.951	4048	183.0	144.9	463.6	4.40	4140	185.7	147.8	478.9	7.63	300
7	0.065	0.935	4047	184.0	145.2	463.2	4.40	4160	187.4	148.9	479.7	7.53	302
8	0.087	0.913	4057	185.5	145.9	463.9	4.40	4179	189.3	149.9	480.7	7.41	303
9	0.115	0.885	4074	187.3	146.7	465.3	4.40	4197	191.1	150.9	481.9	7.29	305
10	0.152	0.848	4094	189.3	147.7	467.0	4.40	4215	193.0	151.8	483.1	7.18	306
11	0.197	0.803	4116	191.4	148.6	468.9	4.40	4233	195.0	152.6	484.5	7.08	308
12	0.250	0.750	4139	193.4	149.6	470.9	4.40	4252	196.9	153.5	485.9	6.98	309
13	0.313	0.687	4161	195.5	150.6	472.9	4.40	4271	198.9	154.4	487.5	6.91	311
14	0.385	0.615	4184	197.6	151.6	474.9	4.40	4292	200.9	155.3	489.2	6.86	312
15	0.466	0.534	4207	199.7	152.6	476.9	4.40	4313	203.0	156.2	491.0	6.83	313
16	0.553	0.447	4230	201.8	153.6	478.9	4.40	4334	205.0	157.2	493.0	6.83	315
17	0.645	0.355	4253	203.9	154.6	480.9	4.40	4357	207.1	158.2	495.1	6.87	316
18	0.739	0.261	4276	206.0	155.6	483.0	4.40	4381	209.2	159.2	497.5	6.96	318
19	0.831	0.169	4298	208.1	156.6	485.0	4.40	4406	211.3	160.3	500.1	7.13	319
20	0.917	0.083	4320	210.1	157.5	486.9	4.40	4432	213.3	161.3	503.3	7.45	320

Table A5.4: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	0.374	0.626	4052	179.2	140.8	475.9	4.40	4014	176.9	139.2	477.5	6.75	293
2	0.386	0.614	4075	180.7	142.6	476.1	4.40	4037	178.3	141.0	477.6	6.74	294
3	0.398	0.602	4098	182.2	144.4	476.2	4.40	4061	179.8	142.8	477.7	6.74	296
4	0.430	0.570	4093	182.5	145.0	474.0	4.40	4094	181.8	144.8	479.6	6.74	298
5	0.484	0.516	4081	182.6	145.4	472.1	4.40	4130	183.9	146.7	482.0	6.75	299
6	0.556	0.444	4073	183.0	145.7	471.5	4.40	4164	185.9	148.5	484.5	6.78	302
7	0.644	0.356	4074	183.7	146.3	471.9	4.40	4194	187.8	150.1	487.0	6.85	304
8	0.742	0.258	4079	184.7	146.9	472.9	4.40	4221	189.5	151.5	489.7	6.97	306
9	0.843	0.157	4087	185.9	147.6	474.4	4.40	4246	191.1	152.7	492.8	7.19	308
10	0.938	0.062	4096	187.0	148.2	476.0	4.40	4267	192.4	153.7	496.6	7.65	311
11	1.000	0.000	4099	188.0	148.7	477.2	4.36	0	0.0	0.0	0.0	0.00	313
12	1.000	0.000	4091	188.6	148.7	477.2	4.10	0	0.0	0.0	0.0	0.00	316
13	1.000	0.000	4083	189.2	148.8	477.2	3.84	0	0.0	0.0	0.0	0.00	318
14	1.000	0.000	4075	189.8	148.8	477.1	3.58	0	0.0	0.0	0.0	0.00	321
15	1.000	0.000	4068	190.4	148.9	477.1	3.32	0	0.0	0.0	0.0	0.00	323
16	1.000	0.000	4060	191.0	149.0	477.1	3.06	0	0.0	0.0	0.0	0.00	326
17	1.000	0.000	4052	191.6	149.0	477.1	2.81	0	0.0	0.0	0.0	0.00	329
18	1.000	0.000	4044	192.2	149.1	477.0	2.55	0	0.0	0.0	0.0	0.00	331
19	1.000	0.000	4036	192.8	149.1	477.0	2.29	0	0.0	0.0	0.0	0.00	334
20	1.000	0.000	4028	193.4	149.2	477.0	2.03	0	0.0	0.0	0.0	0.00	336

Table A5.5: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	0.023	0.977	4083	181.2	142.1	474.6	4.50	4027	177.7	139.8	477.0	8.09	293
2	0.025	0.975	4106	182.6	143.9	474.7	4.50	4050	179.2	141.6	477.1	8.06	294
3	0.026	0.974	4129	184.1	145.6	474.9	4.50	4074	180.6	143.4	477.2	8.03	296
4	0.031	0.969	4082	182.6	144.9	468.7	4.50	4094	182.1	144.9	477.5	7.97	298
5	0.040	0.960	4024	180.8	143.7	462.6	4.50	4110	183.3	146.2	477.9	7.88	299
6	0.055	0.945	3983	179.8	142.9	459.5	4.50	4121	184.5	147.2	478.3	7.77	302
7	0.078	0.922	3964	179.8	142.7	458.5	4.50	4129	185.6	148.0	478.9	7.64	304
8	0.110	0.890	3959	180.4	142.9	459.0	4.50	4135	186.7	148.7	479.5	7.51	306
9	0.152	0.848	3961	181.3	143.3	460.1	4.50	4139	187.7	149.3	480.3	7.39	308
10	0.207	0.793	3968	182.4	143.9	461.7	4.50	4142	188.7	149.8	481.3	7.27	311
11	0.000	1.000	0	0.0	0.0	0.0	0.00	4099	188.0	148.7	477.2	6.45	313
12	0.000	1.000	0	0.0	0.0	0.0	0.00	4091	188.6	148.7	477.2	6.18	316
13	0.000	1.000	0	0.0	0.0	0.0	0.00	4083	189.2	148.8	477.2	5.92	318
14	0.000	1.000	0	0.0	0.0	0.0	0.00	4081	189.9	149.1	477.2	5.69	321
15	0.000	1.000	0	0.0	0.0	0.0	0.00	4084	190.8	149.8	477.2	5.51	323
16	0.000	1.000	0	0.0	0.0	0.0	0.00	4093	191.9	150.8	477.2	5.37	325
17	0.000	1.000	0	0.0	0.0	0.0	0.00	4106	193.1	152.0	477.3	5.26	326
18	0.000	1.000	0	0.0	0.0	0.0	0.00	4122	194.4	153.4	477.3	5.17	328
19	0.000	1.000	0	0.0	0.0	0.0	0.00	4142	195.8	154.9	477.4	5.11	330
20	0.000	1.000	0	0.0	0.0	0.0	0.00	4163	197.2	156.6	477.5	5.06	331

Table A5.6: The proportion of cows in each herd, and the production per farm over the 20 years under the status quo scenario.

YEAR	PROPORTION		MILK YIELD			MILKFAT			PROTEIN		
	Herd 1	Herd 2	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	1.000	0.000	1180243	0	1180243	52081	0	52081	40971	0	40971
2	1.000	0.000	1191248	0	1191248	52698	0	52698	41639	0	41639
3	1.000	0.000	1206375	0	1206375	53499	0	53499	42453	0	42453
4	1.000	0.000	1217499	0	1217499	54123	0	54123	43129	0	43129
5	1.000	0.000	1232792	0	1232792	54934	0	54934	43955	0	43955
6	1.000	0.000	1244034	0	1244034	55566	0	55566	44640	0	44640
7	1.000	0.000	1259494	0	1259494	56388	0	56388	45479	0	45479
8	1.000	0.000	1270854	0	1270854	57027	0	57027	46173	0	46173
9	1.000	0.000	1286480	0	1286480	57859	0	57859	47025	0	47025
10	1.000	0.000	1297959	0	1297959	58506	0	58506	47728	0	47728
11	1.000	0.000	1309485	0	1309485	59156	0	59156	48434	0	48434
12	1.000	0.000	1325348	0	1325348	60003	0	60003	49304	0	49304
13	1.000	0.000	1336994	0	1336994	60660	0	60660	50020	0	50020
14	1.000	0.000	1348686	0	1348686	61320	0	61320	50739	0	50739
15	1.000	0.000	1364787	0	1364787	62182	0	62182	51626	0	51626
16	1.000	0.000	1376598	0	1376598	62850	0	62850	52354	0	52354
17	1.000	0.000	1388457	0	1388457	63521	0	63521	53086	0	53086
18	1.000	0.000	1404794	0	1404794	64397	0	64397	53991	0	53991
19	1.000	0.000	1416772	0	1416772	65076	0	65076	54732	0	54732
20	1.000	0.000	1428796	0	1428796	65757	0	65757	55476	0	55476

Table A5.7: The proportion of cows in herd 1, and the production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROP N	MILK YIELD				MILKFAT				PROTEIN			
		Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1
1	0.023	28580	1151671	1180251	0.024	1268	50813	52082	0.024	995	39977	40972	0.024
2	0.025	28741	1162491	1191232	0.024	1279	51418	52697	0.024	1007	40631	41638	0.024
3	0.026	33031	1173357	1206388	0.027	1473	52027	53499	0.028	1165	41288	42453	0.027
4	0.031	36741	1183158	1219900	0.030	1644	52613	54257	0.030	1304	41876	43181	0.030
5	0.040	48287	1179442	1227729	0.039	2169	52621	54791	0.040	1724	41954	43678	0.039
6	0.055	67712	1174522	1242234	0.055	3056	52594	55650	0.055	2429	41957	44386	0.055
7	0.078	95138	1156182	1251319	0.076	4315	51978	56293	0.077	3424	41452	44877	0.076
8	0.110	134600	1124685	1259285	0.107	6133	50774	56907	0.108	4859	40450	45309	0.107
9	0.152	186183	1080281	1266464	0.147	8521	48981	57503	0.148	6737	38961	45698	0.147
10	0.207	253956	1023164	1277119	0.199	11674	46597	58271	0.200	9210	36992	46202	0.199
11	0.275	341988	941076	1283064	0.267	15789	43050	58839	0.268	12429	34102	46531	0.267
12	0.357	450396	842389	1292785	0.348	20883	38706	59589	0.350	16403	30590	46993	0.349
13	0.450	571327	727201	1298528	0.440	26602	33557	60158	0.442	20850	26461	47312	0.441
14	0.554	712873	595302	1308176	0.545	33332	27583	60915	0.547	26070	21705	47775	0.546
15	0.665	863135	450621	1313756	0.657	40527	20960	61487	0.659	31630	16462	48092	0.658
16	0.777	1018042	305413	1323455	0.769	48000	14256	62256	0.771	37383	11177	48560	0.770
17	0.883	1173449	159490	1332939	0.880	55556	7466	63022	0.882	43177	5846	49024	0.881
18	0.974	1300676	37899	1338575	0.972	61832	1776	63608	0.972	47956	1391	49347	0.972
19	1.000	1347979	0	1347979	1.000	64382	0	64382	1.000	49811	0	49811	1.000
20	1.000	1353393	0	1353393	1.000	64968	0	64968	1.000	50129	0	50129	1.000

Table A5.8: The proportion of cows in herd 1, and the production per farm over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPN	MILK YIELD				MILKFAT				PROTEIN			
		Herd 1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1
1	0.023	28580	1151671	1180251	0.024	1268	50813	52082	0.024	995	39977	40972	0.024
2	0.025	28741	1162491	1191232	0.024	1279	51418	52697	0.024	1007	40631	41638	0.024
3	0.026	33031	1173357	1206388	0.027	1473	52027	53499	0.028	1165	41288	42453	0.027
4	0.030	36912	1180025	1216937	0.030	1652	52487	54139	0.031	1310	41759	43068	0.030
5	0.038	44740	1186385	1231125	0.036	2012	52971	54982	0.037	1595	42180	43775	0.036
6	0.049	60719	1179970	1240689	0.049	2745	52914	55659	0.049	2173	42110	44284	0.049
7	0.065	80933	1173092	1254025	0.065	3680	52861	56541	0.065	2905	41991	44896	0.065
8	0.087	105481	1157506	1262988	0.084	4823	52430	57253	0.084	3793	41533	45326	0.084
9	0.115	142587	1133202	1275789	0.112	6557	51608	58165	0.113	5136	40739	45875	0.112
10	0.152	188343	1095935	1284278	0.147	8709	50190	58899	0.148	6793	39462	46255	0.147
11	0.197	251098	1045634	1296732	0.194	11673	48157	59830	0.195	9066	37702	46768	0.194
12	0.250	318680	986454	1305134	0.244	14893	45689	60582	0.246	11520	35610	47130	0.244
13	0.313	403641	914071	1317712	0.306	18962	42570	61531	0.308	14607	33035	47643	0.307
14	0.385	502076	823981	1326057	0.379	23707	38580	62288	0.381	18190	29813	48003	0.379
15	0.466	614196	720205	1334401	0.460	29149	33898	63047	0.462	22276	26088	48364	0.461
16	0.553	735976	611164	1347139	0.546	35105	28911	64016	0.548	26723	22162	48885	0.547
17	0.645	867554	488020	1355573	0.640	41587	23198	64784	0.642	31534	17715	49250	0.640
18	0.739	1004758	363628	1368386	0.734	48400	17365	65765	0.736	36561	13213	49774	0.735
19	0.831	1139019	237915	1376934	0.827	55134	11410	66544	0.829	41491	8654	50144	0.827
20	0.917	1270188	115223	1385411	0.917	61778	5546	67324	0.918	46318	4195	50513	0.917

Table A5.9: The proportion of cows in herd 1, and the production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.

YEAR	PROPN	MILK YIELD				MILKFAT				PROTEIN			
	Herd 1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1
1	0.374	445720	734541	1180261	0.378	19717	32365	52082	0.379	15490	25482	40972	0.378
2	0.386	460491	730743	1191234	0.387	20420	32277	52697	0.387	16112	25526	41638	0.387
3	0.398	483597	722790	1206387	0.401	21495	32004	53499	0.402	17034	25419	42453	0.401
4	0.430	523852	696045	1219897	0.429	23355	30902	54257	0.430	18564	24616	43181	0.430
5	0.484	591687	636020	1227707	0.482	26473	28317	54790	0.483	21078	22599	43677	0.483
6	0.556	684317	557939	1242256	0.551	30738	24913	55651	0.552	24485	19902	44386	0.552
7	0.644	798430	452900	1251330	0.638	36012	20281	56293	0.640	28670	16207	44877	0.639
8	0.742	925924	333427	1259351	0.735	41936	14973	56909	0.737	33346	11965	45311	0.736
9	0.843	1062613	203789	1266401	0.839	48327	9174	57501	0.840	38367	7329	45696	0.840
10	0.938	1195893	81081	1276975	0.937	54611	3655	58266	0.937	43277	2921	46197	0.937
11	1.000	1283032	0	1283032	1.000	58837	0	58837	1.000	46529	0	46529	1.000
12	1.000	1292830	0	1292830	1.000	59590	0	59590	1.000	46994	0	46994	1.000
13	1.000	1298497	0	1298497	1.000	60157	0	60157	1.000	47311	0	47311	1.000
14	1.000	1308208	0	1308208	1.000	60917	0	60917	1.000	47776	0	47776	1.000
15	1.000	1313804	0	1313804	1.000	61489	0	61489	1.000	48093	0	48093	1.000
16	1.000	1323428	0	1323428	1.000	62255	0	62255	1.000	48559	0	48559	1.000
17	1.000	1333004	0	1333004	1.000	63025	0	63025	1.000	49026	0	49026	1.000
18	1.000	1338490	0	1338490	1.000	63605	0	63605	1.000	49344	0	49344	1.000
19	1.000	1347979	0	1347979	1.000	64382	0	64382	1.000	49811	0	49811	1.000
20	1.000	1353393	0	1353393	1.000	64968	0	64968	1.000	50129	0	50129	1.000

Table A5.10: The proportion of cows in herd 1, and the production per farm over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPN	MILK YIELD				MILKFAT				PROTEIN			
		Herd 1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1
1	0.023	28580	1151671	1180252	0.024	1268	50813	52082	0.024	995	39977	40972	0.024
2	0.025	28741	1162491	1191232	0.024	1279	51418	52697	0.024	1007	40631	41638	0.024
3	0.026	33031	1173357	1206388	0.027	1473	52027	53499	0.028	1165	41288	42453	0.027
4	0.031	36741	1183158	1219900	0.030	1644	52613	54257	0.030	1304	41876	43181	0.030
5	0.040	48287	1179442	1227729	0.039	2169	52621	54791	0.040	1724	41954	43678	0.039
6	0.055	67712	1174522	1242234	0.055	3056	52594	55650	0.055	2429	41957	44386	0.055
7	0.078	95138	1156182	1251319	0.076	4315	51978	56293	0.077	3424	41452	44877	0.076
8	0.110	134600	1124685	1259285	0.107	6133	50774	56907	0.108	4859	40450	45309	0.107
9	0.152	186183	1080281	1266464	0.147	8521	48981	57503	0.148	6737	38961	45698	0.147
10	0.207	253956	1023164	1277119	0.199	11674	46597	58271	0.200	9210	36992	46202	0.199
11	0.000	0	1283032	1283032	0.000	0	58837	58837	0.000	0	46529	46529	0.000
12	0.000	0	1292830	1292830	0.000	0	59590	59590	0.000	0	46994	46994	0.000
13	0.000	0	1298497	1298497	0.000	0	60157	60157	0.000	0	47311	47311	0.000
14	0.000	0	1310040	1310040	0.000	0	60969	60969	0.000	0	47877	47877	0.000
15	0.000	0	1319279	1319279	0.000	0	61644	61644	0.000	0	48393	48393	0.000
16	0.000	0	1330193	1330193	0.000	0	62371	62371	0.000	0	49004	49004	0.000
17	0.000	0	1338513	1338513	0.000	0	62950	62950	0.000	0	49547	49547	0.000
18	0.000	0	1352175	1352175	0.000	0	63760	63760	0.000	0	50311	50311	0.000
19	0.000	0	1366832	1366832	0.000	0	64602	64602	0.000	0	51132	51132	0.000
20	0.000	0	1378096	1378096	0.000	0	65271	65271	0.000	0	51840	51840	0.000

Table A5.11: The proportion of cows in herd 1, and the production per hectare over the 20 years under the status quo scenario.

YEAR	PROP _N	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	1.000	12691	0	12691	560	0	560	441	0	441	1001	0	1001
2	1.000	12809	0	12809	567	0	567	448	0	448	1014	0	1014
3	1.000	12972	0	12972	575	0	575	456	0	456	1032	0	1032
4	1.000	13091	0	13091	582	0	582	464	0	464	1046	0	1046
5	1.000	13256	0	13256	591	0	591	473	0	473	1063	0	1063
6	1.000	13377	0	13377	597	0	597	480	0	480	1077	0	1077
7	1.000	13543	0	13543	606	0	606	489	0	489	1095	0	1095
8	1.000	13665	0	13665	613	0	613	496	0	496	1110	0	1110
9	1.000	13833	0	13833	622	0	622	506	0	506	1128	0	1128
10	1.000	13957	0	13957	629	0	629	513	0	513	1142	0	1142
11	1.000	14080	0	14080	636	0	636	521	0	521	1157	0	1157
12	1.000	14251	0	14251	645	0	645	530	0	530	1175	0	1175
13	1.000	14376	0	14376	652	0	652	538	0	538	1190	0	1190
14	1.000	14502	0	14502	659	0	659	546	0	546	1205	0	1205
15	1.000	14675	0	14675	669	0	669	555	0	555	1224	0	1224
16	1.000	14802	0	14802	676	0	676	563	0	563	1239	0	1239
17	1.000	14930	0	14930	683	0	683	571	0	571	1254	0	1254
18	1.000	15105	0	15105	692	0	692	581	0	581	1273	0	1273
19	1.000	15234	0	15234	700	0	700	589	0	589	1288	0	1288
20	1.000	15363	0	15363	707	0	707	597	0	597	1304	0	1304

Table A5.12: The proportion of cows in herd 1, and the production per hectare over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPN	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	0.023	307	12384	12691	14	546	560	11	430	441	24	976	1001
2	0.025	309	12500	12809	14	553	567	11	437	448	25	990	1014
3	0.026	355	12617	12972	16	559	575	13	444	456	28	1003	1032
4	0.031	395	12722	13117	18	566	583	14	450	464	32	1016	1048
5	0.040	519	12682	13201	23	566	589	19	451	470	42	1017	1059
6	0.055	728	12629	13357	33	566	598	26	451	477	59	1017	1076
7	0.078	1023	12432	13455	46	559	605	37	446	483	83	1005	1088
8	0.110	1447	12093	13541	66	546	612	52	435	487	118	981	1099
9	0.152	2002	11616	13618	92	527	618	72	419	491	164	946	1110
10	0.207	2731	11002	13732	126	501	627	99	398	497	225	899	1123
11	0.275	3677	10119	13796	170	463	633	134	367	500	303	830	1133
12	0.357	4843	9058	13901	225	416	641	176	329	505	401	745	1146
13	0.450	6143	7819	13963	286	361	647	224	285	509	510	645	1156
14	0.554	7665	6401	14066	358	297	655	280	233	514	639	530	1169
15	0.665	9281	4845	14126	436	225	661	340	177	517	776	402	1178
16	0.777	10947	3284	14231	516	153	669	402	120	522	918	273	1192
17	0.883	12618	1715	14333	597	80	678	464	63	527	1062	143	1205
18	0.974	13986	408	14393	665	19	684	516	15	531	1181	34	1215
19	1.000	14494	0	14494	692	0	692	536	0	536	1228	0	1228
20	1.000	14553	0	14553	699	0	699	539	0	539	1238	0	1238

Table A5.13: The proportion of cows in herd 1, and the production per hectare over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPKN	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	0.023	307	12384	12691	14	546	560	11	430	441	24	976	1001
2	0.025	309	12500	12809	14	553	567	11	437	448	25	990	1014
3	0.026	355	12617	12972	16	559	575	13	444	456	28	1003	1032
4	0.030	397	12688	13085	18	564	582	14	449	463	32	1013	1045
5	0.038	481	12757	13238	22	570	591	17	454	471	39	1023	1062
6	0.049	653	12688	13341	30	569	598	23	453	476	53	1022	1075
7	0.065	870	12614	13484	40	568	608	31	452	483	71	1020	1091
8	0.087	1134	12446	13581	52	564	616	41	447	487	93	1010	1103
9	0.115	1533	12185	13718	71	555	625	55	438	493	126	993	1119
10	0.152	2025	11784	13809	94	540	633	73	424	497	167	964	1131
11	0.197	2700	11243	13943	126	518	643	97	405	503	223	923	1146
12	0.250	3427	10607	14034	160	491	651	124	383	507	284	874	1158
13	0.313	4340	9829	14169	204	458	662	157	355	512	361	813	1174
14	0.385	5399	8860	14259	255	415	670	196	321	516	451	735	1186
15	0.466	6604	7744	14348	313	364	678	240	281	520	553	645	1198
16	0.553	7914	6572	14485	377	311	688	287	238	526	665	549	1214
17	0.645	9329	5248	14576	447	249	697	339	190	530	786	440	1226
18	0.739	10804	3910	14714	520	187	707	393	142	535	914	329	1242
19	0.831	12248	2558	14806	593	123	716	446	93	539	1039	216	1255
20	0.917	13658	1239	14897	664	60	724	498	45	543	1162	105	1267

Table A5.14: The proportion of cows in herd 1, and the production per hectare over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.

YEAR	PROPN	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	0.374	4793	7898	12691	212	348	560	167	274	441	379	622	1001
2	0.386	4952	7857	12809	220	347	567	173	274	448	393	622	1014
3	0.398	5200	7772	12972	231	344	575	183	273	456	414	617	1032
4	0.430	5633	7484	13117	251	332	583	200	265	464	451	597	1048
5	0.484	6362	6839	13201	285	304	589	227	243	470	511	547	1059
6	0.556	7358	5999	13358	331	268	598	263	214	477	594	482	1076
7	0.644	8585	4870	13455	387	218	605	308	174	483	696	392	1088
8	0.742	9956	3585	13541	451	161	612	359	129	487	809	290	1099
9	0.843	11426	2191	13617	520	99	618	413	79	491	932	177	1110
10	0.938	12859	872	13731	587	39	627	465	31	497	1053	71	1123
11	1.000	13796	0	13796	633	0	633	500	0	500	1133	0	1133
12	1.000	13901	0	13901	641	0	641	505	0	505	1146	0	1146
13	1.000	13962	0	13962	647	0	647	509	0	509	1156	0	1156
14	1.000	14067	0	14067	655	0	655	514	0	514	1169	0	1169
15	1.000	14127	0	14127	661	0	661	517	0	517	1178	0	1178
16	1.000	14230	0	14230	669	0	669	522	0	522	1192	0	1192
17	1.000	14333	0	14333	678	0	678	527	0	527	1205	0	1205
18	1.000	14392	0	14392	684	0	684	531	0	531	1215	0	1215
19	1.000	14494	0	14494	692	0	692	536	0	536	1228	0	1228
20	1.000	14553	0	14553	699	0	699	539	0	539	1238	0	1238

Table A5.15: The proportion of cows in herd 1, and the production per hectare over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROP _N	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	0.023	307	12384	12691	14	546	560	11	430	441	24	976	1001
2	0.025	309	12500	12809	14	553	567	11	437	448	25	990	1014
3	0.026	355	12617	12972	16	559	575	13	444	456	28	1003	1032
4	0.031	395	12722	13117	18	566	583	14	450	464	32	1016	1048
5	0.040	519	12682	13201	23	566	589	19	451	470	42	1017	1059
6	0.055	728	12629	13357	33	566	598	26	451	477	59	1017	1076
7	0.078	1023	12432	13455	46	559	605	37	446	483	83	1005	1088
8	0.110	1447	12093	13541	66	546	612	52	435	487	118	981	1099
9	0.152	2002	11616	13618	92	527	618	72	419	491	164	946	1110
10	0.207	2731	11002	13732	126	501	627	99	398	497	225	899	1123
11	0.000	0	13796	13796	0	633	633	0	500	500	0	1133	1133
12	0.000	0	13901	13901	0	641	641	0	505	505	0	1146	1146
13	0.000	0	13962	13962	0	647	647	0	509	509	0	1156	1156
14	0.000	0	14086	14086	0	656	656	0	515	515	0	1170	1170
15	0.000	0	14186	14186	0	663	663	0	520	520	0	1183	1183
16	0.000	0	14303	14303	0	671	671	0	527	527	0	1198	1198
17	0.000	0	14393	14393	0	677	677	0	533	533	0	1210	1210
18	0.000	0	14540	14540	0	686	686	0	541	541	0	1227	1227
19	0.000	0	14697	14697	0	695	695	0	550	550	0	1244	1244
20	0.000	0	14818	14818	0	702	702	0	557	557	0	1259	1259

Table A5.16: Milkfat production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1			HERD 2	TOTAL			
	Herd 1	Herd 2	White	Yellow	kg units	Yellow	White	Yellow	Total	Propn White
1	0.023	0.977	855	414	660	50813	855	51227	52082	0.016
2	0.025	0.975	861	417	665	51418	861	51836	52697	0.016
3	0.026	0.974	992	480	766	52027	992	52507	53499	0.019
4	0.031	0.969	1107	536	855	52613	1107	53149	54257	0.020
5	0.040	0.960	1462	708	1129	52621	1462	53329	54791	0.027
6	0.055	0.945	2059	997	1590	52594	2059	53591	55650	0.037
7	0.078	0.922	2907	1408	2245	51978	2907	53386	56293	0.052
8	0.110	0.890	4132	2001	3191	50774	4132	52775	56907	0.073
9	0.152	0.848	5741	2780	4434	48981	5741	51761	57503	0.100
10	0.207	0.793	7866	3808	6074	46597	7866	50405	58271	0.135
11	0.275	0.725	10638	5151	8215	43050	10638	48200	58839	0.181
12	0.357	0.643	14070	6813	10865	38706	14070	45518	59589	0.236
13	0.450	0.550	17924	8678	13841	33557	17924	42235	60158	0.298
14	0.554	0.446	22458	10874	17342	27583	22458	38457	60915	0.369
15	0.665	0.335	27306	13221	21086	20960	27306	34181	61487	0.444
16	0.777	0.223	32341	15659	24974	14256	32341	29915	62256	0.519
17	0.883	0.117	37432	18124	28905	7466	37432	25590	63022	0.594
18	0.974	0.026	41661	20171	32171	1776	41661	21947	63608	0.655
19	1.000	0.000	43378	21003	39344	0	43378	21003	64382	0.674
20	1.000	0.000	48333	16635	49676	0	48333	16635	64968	0.744

Table A5.17: Milkfat production per farm over the 20 years with selection on milkfat production and fat colour with an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1			HERD 2	TOTAL			
	Herd 1	Herd 2	White	Yellow	kg units	Yellow	White	Yellow	Total	Propn White
1	0.023	0.977	855	414	660	50813	855	51227	52082	0.016
2	0.025	0.975	861	417	665	51418	861	51836	52697	0.016
3	0.026	0.974	992	480	766	52027	992	52507	53499	0.019
4	0.030	0.970	1113	539	859	52487	1113	53026	54139	0.021
5	0.038	0.962	1355	656	1047	52971	1355	53627	54982	0.025
6	0.049	0.951	1849	895	1428	52914	1849	53810	55659	0.033
7	0.065	0.935	2479	1200	1915	52861	2479	54061	56541	0.044
8	0.087	0.913	3250	1574	2510	52430	3250	54003	57253	0.057
9	0.115	0.885	4418	2139	3411	51608	4418	53747	58165	0.076
10	0.152	0.848	5868	2841	4531	50190	5868	53031	58899	0.100
11	0.197	0.803	7865	3808	6073	48157	7865	51966	59830	0.131
12	0.250	0.750	10034	4858	7748	45689	10034	50547	60582	0.166
13	0.313	0.687	12776	6186	9865	42570	12776	48756	61531	0.208
14	0.385	0.615	15973	7734	12335	38580	15973	46314	62288	0.256
15	0.466	0.534	19640	9509	15166	33898	19640	43407	63047	0.312
16	0.553	0.447	23653	11452	18265	28911	23653	40363	64016	0.369
17	0.645	0.355	28020	13567	21637	23198	28020	36765	64784	0.433
18	0.739	0.261	32611	15790	25182	17365	32611	33154	65765	0.496
19	0.831	0.169	37148	17986	28686	11410	37148	29397	66544	0.558
20	0.917	0.083	41624	20154	32142	5546	41624	25700	67324	0.618

Table A5.18: Milkfat production per farm over the 20 years with all selection on fat colour and an initial milkfat colour of 6.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1			HERD 2	TOTAL			
	Herd 1	Herd 2	White	Yellow	kg units	Yellow	White	Yellow	Total	Propn White
1	0.374	0.626	13285	6432	10258	32365	13285	38797	52082	0.255
2	0.386	0.614	13758	6662	10624	32277	13758	38939	52697	0.261
3	0.398	0.602	14483	7012	11183	32004	14483	39017	53499	0.271
4	0.430	0.570	15736	7619	12151	30902	15736	38521	54257	0.290
5	0.484	0.516	17837	8636	13773	28317	17837	36953	54790	0.326
6	0.556	0.444	20711	10028	15992	24913	20711	34940	55651	0.372
7	0.644	0.356	24264	11748	18736	20281	24264	32030	56293	0.431
8	0.742	0.258	28255	13681	21818	14973	28255	28654	56909	0.497
9	0.843	0.157	32561	15766	25143	9174	32561	24939	57501	0.566
10	0.938	0.062	36795	17816	28413	3655	36795	21471	58266	0.632
11	1.000	0.000	39643	19194	32019	0	39643	19194	58837	0.674
12	1.000	0.000	40150	19440	41242	0	40150	19440	59590	0.674
13	1.000	0.000	44754	15403	51534	0	44754	15403	60157	0.744
14	1.000	0.000	49693	11224	62965	0	49693	11224	60917	0.816
15	1.000	0.000	54696	6793	75307	0	54696	6793	61489	0.890
16	1.000	0.000	58996	3259	90087	0	58996	3259	62255	0.948
17	1.000	0.000	63025	0	106784	0	63025	0	63025	1.000
18	1.000	0.000	63605	0	124261	0	63605	0	63605	1.000
19	1.000	0.000	64382	0	142471	0	64382	0	64382	1.000
20	1.000	0.000	64968	0	160614	0	64968	0	64968	1.000

Table A5.19: Milkfat production per farm over the 20 years with all selection on fat colour for 10 years, and an initial milkfat colour of 8.0 mg beta-carotene/kg milkfat.

YEAR	PROPORTION		HERD 1			HERD 2	TOTAL			
	Herd 1	Herd 2	White	Yellow	kg units	Yellow	White	Yellow	Total	Propn White
1	0.023	0.977	855	414	660	50813	855	51227	52082	0.016
2	0.025	0.975	861	417	665	51418	861	51836	52697	0.016
3	0.026	0.974	992	480	766	52027	992	52507	53499	0.019
4	0.031	0.969	1107	536	855	52613	1107	53149	54257	0.020
5	0.040	0.960	1462	708	1129	52621	1462	53329	54791	0.027
6	0.055	0.945	2059	997	1590	52594	2059	53591	55650	0.037
7	0.078	0.922	2907	1408	2245	51978	2907	53386	56293	0.052
8	0.110	0.890	4132	2001	3191	50774	4132	52775	56907	0.073
9	0.152	0.848	5741	2780	4434	48981	5741	51761	57503	0.100
10	0.207	0.793	7866	3808	6075	46597	7866	50405	58271	0.135
11	0.000	1.000	0	0	0	58837	0	58837	58837	0.000
12	0.000	1.000	0	0	0	59590	0	59590	59590	0.000
13	0.000	1.000	0	0	0	60157	0	60157	60157	0.000
14	0.000	1.000	0	0	0	60969	0	60969	60969	0.000
15	0.000	1.000	0	0	0	61644	0	61644	61644	0.000
16	0.000	1.000	0	0	0	62371	0	62371	62371	0.000
17	0.000	1.000	0	0	0	62950	0	62950	62950	0.000
18	0.000	1.000	0	0	0	63760	0	63760	63760	0.000
19	0.000	1.000	0	0	0	64602	0	64602	64602	0.000
20	0.000	1.000	0	0	0	65271	0	65271	65271	0.000

Table A5.20: The proportion of milksolids attracting a premium and the proportion of the income from this milk for the four quantitative scenarios and the first qualitative scenario. The proportion of income is based on the return at which the NPV = 0 over 20 years.

Year	% milk attracting a premium					% income from milk attracting the premium				
	Quant 1	Quant 2	Quant 3	Quant 4	Qual 1	Quant 1	Quant 2	Quant 3	Quant 4	Qual 1
1	1.64%	1.64%	25.49%	1.64%	46.78%	1.90%	1.89%	26.36%	3.17%	47.01%
2	1.63%	1.63%	26.09%	1.63%	46.64%	1.89%	1.88%	26.98%	3.15%	46.87%
3	1.85%	1.85%	27.05%	1.85%	51.93%	2.15%	2.14%	27.96%	3.57%	52.19%
4	2.04%	2.05%	28.98%	2.04%	57.07%	2.36%	2.37%	29.93%	3.91%	57.34%
5	2.66%	2.46%	32.53%	2.66%	61.44%	3.08%	2.83%	33.54%	5.08%	61.71%
6	3.69%	3.32%	37.19%	3.69%	66.51%	4.27%	3.81%	38.25%	6.98%	66.78%
7	5.15%	4.37%	43.07%	5.15%	71.15%	5.94%	5.02%	44.18%	9.61%	71.40%
8	7.24%	5.66%	49.61%	7.24%	75.75%	8.32%	6.49%	50.74%	13.25%	75.98%
9	9.96%	7.57%	56.59%	9.96%	80.32%	11.39%	8.66%	57.69%	17.80%	80.52%
10	13.47%	9.93%	63.12%	13.47%	84.23%	15.32%	11.32%	64.15%	23.35%	84.39%
11	18.04%	13.11%	67.36%	0.00%	88.09%	20.37%	14.87%	68.34%	0.00%	88.22%
12	23.57%	16.52%	67.36%	0.00%	91.09%	26.39%	18.65%	68.43%	0.00%	91.20%
13	29.74%	20.71%	74.38%	0.00%	93.85%	32.99%	23.25%	75.30%	0.00%	93.93%
14	36.82%	25.59%	81.55%	0.00%	96.02%	40.39%	28.51%	82.27%	0.00%	96.08%
15	44.36%	31.09%	88.93%	0.00%	97.58%	48.11%	34.36%	89.40%	0.00%	97.62%
16	51.90%	36.89%	94.75%	0.00%	98.51%	55.65%	40.42%	94.98%	0.00%	98.53%
17	59.36%	43.20%	100.00%	0.00%	99.12%	62.94%	46.89%	100.00%	0.00%	99.14%
18	65.48%	49.54%	100.00%	0.00%	99.71%	68.80%	53.27%	100.00%	0.00%	99.72%
19	67.36%	55.78%	100.00%	0.00%	100.00%	70.70%	59.43%	100.00%	0.00%	100.00%
20	74.38%	61.80%	100.00%	0.00%	100.00%	77.28%	65.26%	100.00%	0.00%	100.00%

Table A5.21: A comparison of milk colour and the amount of milk that meets the colour criteria over the lactation in year 20 for scenarios 1 and 3. Both these scenarios put all selection pressure on colour, however the initial colour between the herds is different (8.0 in scenario 1 and 6.0 in scenario2).

Month	Scenario 1, Year 20					Scenario 3, Year 20				
	Milk yield	Milkfat	Protein	Kg units	Colour	Milk yield	Milkfat	Protein	Kg units	Colour
JULY(1)	0	0	0	0	0.00	0	0	0	0	0.00
JULY(2)	0	0	0	0	0.00	0	0	0	0	0.00
AUG(1)	14461	798	620	0	6.31	14461	798	620	1027	3.21
AUG(2)	49002	2603	2018	0	6.10	49002	2603	2018	3635	3.10
SEP(1)	74846	3777	2921	0	5.72	74846	3777	2921	5994	2.91
SEP(2)	97649	4792	3702	0	5.39	97649	4792	3702	8422	2.74
OCT(1)	98969	4665	3596	0	4.87	98969	4665	3596	9440	2.48
OCT(2)	98375	4559	3512	364	4.42	98375	4559	3512	10262	2.25
NOV(1)	96165	4426	3408	1987	4.05	96165	4426	3408	10793	2.06
NOV(2)	93100	4281	3296	3192	3.75	93100	4281	3296	11085	1.91
DEC(1)	89561	4130	3180	4034	3.52	89561	4130	3180	11180	1.79
DEC(2)	85766	3977	3063	4569	3.35	85766	3977	3063	11115	1.71
JAN(1)	81851	3825	2947	4852	3.23	81851	3825	2947	10922	1.64
JAN(2)	77908	3674	2833	4935	3.16	77908	3674	2833	10632	1.61
FEB(1)	73996	3527	2720	4862	3.12	73996	3527	2720	10269	1.59
FEB(2)	70157	3383	2611	4678	3.12	70157	3383	2611	9857	1.59
MARCH(1)	62269	3041	2348	4141	3.14	62269	3041	2348	8827	1.60
MARCH(2)	58878	2914	2251	3855	3.18	58878	2914	2251	8401	1.62
APRIL(1)	55613	2791	2158	3553	3.23	55613	2791	2158	7976	1.64
APRIL(2)	44477	2255	1744	2784	3.27	44477	2255	1744	6400	1.66
MAY(1)	20929	1067	826	1295	3.29	20929	1067	826	3017	1.67
MAY(2)	9421	484	374	574	3.31	9421	484	374	1361	1.69
JUNE(1)	0	0	0	0	0.00	0	0	0	0	0.00
JUNE(2)	0	0	0	0	0.00	0	0	0	0	0.00

Table A5.22: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 1 and 2) over 20 years. Note: stock income differences are not shown but are included in the total value. NPV over 20 years equals 0.

YEAR	SQ	Scenario 1 (Premium = \$1.11)						Scenario 2 (Premium = \$1.08)					
		Cow No.	Income	Expenses	Value	PV	Cow No.	Propn H1	Income	Expenses	Value	PV	Cow No.	Propn H1
1	293	967	7051	-6084	-5686	293	0.023	935	7051	-6116	-5716	293	0.023
2	294	965	2058	-1093	-954	294	0.025	934	2058	-1124	-982	294	0.025
3	296	715	2178	-1463	-1194	296	0.026	1089	2072	-983	-803	296	0.026
4	297	2078	2484	-406	-310	298	0.031	909	2082	-1173	-895	297	0.030
5	299	-1145	2228	-3373	-2405	299	0.040	567	2103	-1536	-1095	299	0.038
6	300	1470	2680	-1210	-806	302	0.055	209	2121	-1912	-1274	300	0.049
7	302	-774	2568	-3342	-2081	304	0.078	-255	2148	-2403	-1496	302	0.065
8	303	-130	3013	-3143	-1829	306	0.110	-740	2170	-2910	-1694	303	0.087
9	305	-2341	3075	-5416	-2946	308	0.152	-993	2201	-3194	-1737	305	0.115
10	306	-245	3388	-3633	-1847	311	0.207	-1444	2227	-3671	-1866	306	0.152
11	307	271	3684	-3413	-1621	313	0.275	1153	2380	-1227	-583	308	0.197
12	309	1891	4150	-2259	-1003	316	0.357	-405	2288	-2693	-1196	309	0.250
13	310	3242	4342	-1099	-456	318	0.450	2431	2442	-11	-5	311	0.313
14	311	7879	4767	3112	1207	321	0.554	4722	2470	2252	873	312	0.385
15	313	8049	5108	2941	1066	323	0.665	4711	2378	2333	846	313	0.466
16	314	13458	5427	8031	2720	326	0.777	8966	2533	6434	2179	315	0.553
17	315	18782	5854	12928	4093	329	0.883	11673	2667	9006	2851	316	0.645
18	317	19846	6196	13650	4039	331	0.974	15957	2865	13092	3874	318	0.739
19	318	22620	6517	16103	4453	334	1.000	18583	2625	15958	4413	319	0.831
20	319	27033	6818	20215	5224	336	1.000	20504	2760	17744	4585	320	0.917

Table A5.23: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 3 and 4) over 20 years. Note: stock income differences are not shown but are included in the total value. NPV over 20 years equals 0.

YEAR	SQ	Scenario 3 (Premium = \$0.46)						Scenario 4 (Premium = \$5.62)					
		Cow No.	Income	Expenses	Value	PV	Propn HI	Cow No.	Propn HI	Income	Expenses	Value	PV	Cow No.	Propn HI
1	293	4436	7051	-2615	-2444	293	0.374	5671	7051	-1380	-1289	293	0.023
2	294	4589	2058	2531	2211	294	0.386	5708	2058	3650	3188	294	0.025
3	296	4439	2178	2261	1846	296	0.398	6178	2178	4000	3265	296	0.026
4	297	6101	2484	3617	2759	298	0.430	8175	2484	5691	4342	298	0.031
5	299	3191	2228	963	687	299	0.484	6902	2228	4674	3333	299	0.040
6	300	6122	2680	3442	2294	302	0.556	12807	2680	10127	6748	302	0.055
7	302	4133	2568	1565	975	304	0.644	15230	2568	12663	7886	304	0.078
8	303	4775	3013	1762	1025	306	0.742	22618	3013	19605	11410	306	0.110
9	305	2189	3075	-887	-482	308	0.843	29267	3075	26192	14246	308	0.152
10	306	3316	3388	-72	-37	311	0.938	43058	3388	39670	20166	311	0.207
11	307	1895	3684	-1789	-850	313	1.000	-11827	1493	-13319	-6328	313	0.000
12	309	1001	4150	-3149	-1398	316	1.000	-14099	1938	-16037	-7121	316	0.000
13	310	422	4342	-3920	-1627	318	1.000	-17167	2116	-19282	-8002	318	0.000
14	311	2638	4767	-2129	-826	321	1.000	-16994	2509	-19503	-7564	321	0.000
15	313	195	5108	-4913	-1781	323	1.000	-20934	2710	-23643	-8569	323	0.000
16	314	2918	5428	-2510	-850	326	1.000	-20036	2695	-22731	-7700	325	0.000
17	315	5756	5854	-98	-31	329	1.000	-20939	2984	-23923	-7573	326	0.000
18	317	4426	6196	-1770	-524	331	1.000	-22177	2998	-25175	-7448	328	0.000
19	318	6017	6517	-500	-138	334	1.000	-20865	3126	-23991	-6634	330	0.000
20	319	5275	6818	-1543	-399	336	1.000	-21090	3130	-24221	-6259	331	0.000

Table A5.24: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 1 and 2) over 20+ years. Note: stock income differences are not shown but are included in the total value. NPV over 20+ years equals 0.

YEAR	SQ	Scenario 1 (Premium = \$0.92)						Scenario 2 (Premium = \$0.87)					
		Cow No.	Income	Expenses	Valuc	PV	Cow No.	Propn H1	Income	Expenses	Value	PV	Cow No.	Propn H1
1	293	769	7051	-6282	-5871	293	0.023	716	7051	-6335	-5920	293	0.023
2	294	766	2058	-1292	-1129	294	0.025	713	2058	-1345	-1175	294	0.025
3	296	485	2178	-1693	-1382	296	0.026	834	2072	-1238	-1010	296	0.026
4	297	1821	2484	-663	-506	298	0.031	624	2082	-1458	-1113	297	0.030
5	299	-1484	2228	-3712	-2646	299	0.040	220	2103	-1883	-1343	299	0.038
6	300	992	2680	-1688	-1125	302	0.055	-265	2121	-2386	-1590	300	0.049
7	302	-1448	2568	-4016	-2501	304	0.078	-891	2148	-3038	-1892	302	0.065
8	303	-1088	3013	-4101	-2387	306	0.110	-1573	2170	-3743	-2179	303	0.087
9	305	-3672	3075	-6748	-3670	308	0.152	-2125	2201	-4327	-2353	305	0.115
10	306	-2069	3388	-5457	-2774	311	0.207	-2948	2227	-5175	-2631	306	0.152
11	307	-2196	3684	-5880	-2794	313	0.275	-863	2380	-3243	-1541	308	0.197
12	309	-1372	4150	-5523	-2452	316	0.357	-2977	2288	-5265	-2338	309	0.250
13	310	-914	4342	-5256	-2181	318	0.450	-844	2442	-3286	-1364	311	0.313
14	311	2670	4767	-2096	-813	321	0.554	628	2470	-1842	-714	312	0.385
15	313	1716	5108	-3392	-1229	323	0.665	-323	2378	-2701	-979	313	0.466
16	314	5958	5427	530	180	326	0.777	2903	2533	371	126	315	0.553
17	315	10100	5854	4247	1344	329	0.883	4490	2667	1824	577	316	0.645
18	317	10184	6196	3988	1180	331	0.974	7598	2865	4733	1400	318	0.739
19	318	12243	6517	5725	1583	334	1.000	9061	2625	6436	1780	319	0.831
20	319	15153	6818	8335	2154	336	1.000	9834	2760	7075	1828	320	0.917
20+		216474	97396	119078	28759		1.000	140491	39423	101068	24409		

Table A5.25: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 3 and 4) over 20+ years. Note: stock income differences are not shown but are included in the total value. NPV over 20+ years equals 0.

YEAR	SQ	Scenario 3 (Premium = \$0.47)						Scenario 4 (Premium = \$9.66)					
		Cow No.	Income	Expenses	Value	PV	Propn HI	Cow No.	Income	Expenses	Value	PV	Propn HI
1	293	4598	7051	-2453	-2292	293	0.374	9886	7051	2835	2649	293	0.023
2	294	4757	2058	2699	2357	294	0.386	9956	2058	7898	6898	294	0.025
3	296	4616	2178	2438	1990	296	0.398	11071	2178	8893	7259	296	0.026
4	297	6293	2484	3809	2906	298	0.430	13637	2484	11153	8508	298	0.031
5	299	3409	2228	1181	842	299	0.484	14111	2228	11882	8472	299	0.040
6	300	6375	2680	3695	2462	302	0.556	22962	2680	20282	13515	302	0.055
7	302	4429	2568	1861	1159	304	0.644	29567	2568	26999	16814	304	0.078
8	303	5120	3013	2107	1226	306	0.742	42995	3013	39982	23270	306	0.110
9	305	2586	3075	-489	-266	308	0.843	57580	3075	54505	29647	308	0.152
10	306	3766	3388	377	192	311	0.938	81848	3388	78459	39885	311	0.207
11	307	2383	3684	-1301	-618	313	1.000	-11827	1493	-13319	-6328	313	0.000
12	309	1521	4150	-2630	-1168	316	1.000	-14099	1938	-16037	-7121	316	0.000
13	310	1016	4342	-3325	-1380	318	1.000	-17167	2116	-19282	-8002	318	0.000
14	311	3315	4767	-1452	-563	321	1.000	-16994	2509	-19503	-7564	321	0.000
15	313	957	5108	-4151	-1504	323	1.000	-20934	2710	-23643	-8569	323	0.000
16	314	3765	5428	-1662	-563	326	1.000	-20036	2695	-22731	-7700	325	0.000
17	315	6691	5854	837	265	329	1.000	-20939	2984	-23923	-7573	326	0.000
18	317	5417	6196	-779	-230	331	1.000	-22177	2998	-25175	-7448	328	0.000
19	318	7068	6517	551	152	334	1.000	-20865	3126	-23991	-6634	330	0.000
20	319	6383	6818	-435	-112	336	1.000	-21090	3130	-24221	-6259	331	0.000
20+		91189	97396	-6207	-1499		1.000	-301291	44717	-346008	-83565		0.000

Table A5.26: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 1 and 2) over 10 years. Note: stock income differences are not shown but are included in the total value. NPV over 10 years equals 0.

YEAR	SQ	Scenario 1 (Premium = \$2.08)						Scenario 2 (Premium = \$2.10)					
		Cow No.	Income	Expenses	Value	PV	Propn H1	Cow No.	Propn H1	Income	Expenses	Value	PV	Cow No.	Propn H1
1	293	1979	7051	-5072	-4741	293	0.023	1999	7051	-5052	-4721	293	0.023
2	294	1985	2058	-73	-63	294	0.025	2006	2058	-52	-45	294	0.025
3	296	1890	2178	-288	-235	296	0.026	2324	2072	252	206	296	0.026
4	297	3389	2484	905	691	298	0.031	2295	2082	212	162	297	0.030
5	299	586	2228	-1642	-1171	299	0.040	2255	2103	151	108	299	0.038
6	300	3908	2680	1228	818	302	0.055	2511	2121	391	260	300	0.049
7	302	2668	2568	100	62	304	0.078	2832	2148	684	426	302	0.065
8	303	4763	3013	1750	1018	306	0.110	3306	2170	1136	661	303	0.087
9	305	4457	3075	1382	752	308	0.152	4507	2201	2306	1255	305	0.115
10	306	9068	3388	5680	2887	311	0.207	5861	2227	3635	1848	306	0.152
11	307	12866	3684	9183	4363	313	0.275	10945	2380	8565	4069	308	0.197
12	309	18550	4150	14400	6394	316	0.357	12088	2288	9800	4351	309	0.250
13	310	24464	4342	20122	8350	318	0.450	18337	2442	15895	6596	311	0.313
14	311	34470	4767	29703	11519	321	0.554	24610	2470	22140	8586	312	0.385
15	313	40380	5108	35272	12784	323	0.665	29164	2378	26786	9708	313	0.466
16	314	51750	5427	46323	15691	326	0.777	38415	2533	35882	12154	315	0.553
17	315	63101	5854	57248	18123	329	0.883	46559	2667	43892	13895	316	0.645
18	317	69173	6196	62977	18633	331	0.974	56559	2865	53694	15886	318	0.739
19	318	75601	6517	69084	19102	334	1.000	64834	2625	62209	17201	319	0.831
20	319	87683	6818	80865	20897	336	1.000	72328	2760	69568	17978	320	0.917

Table A5.27: Difference in income, expenses, nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the quantitative comparisons (Scenarios 3 and 4) over 10 years. Note: stock income differences are not shown but are included in the total value. NPV over 10 years equals 0.

YEAR	SQ	Scenario 3 (Premium = \$0.41)						Scenario 4 (Premium = \$2.08)					
		Cow No.	Income	Expenses	Value	PV	Propn H1	Cow No.	Propn H1	Income	Expenses	Value	PV	Cow No.	Propn H1
1	293	3625	7051	-3426	-3202	293	0.374	1979	7051	-5072	-4740	293	0.023
2	294	3749	2058	1691	1477	294	0.386	1985	2058	-73	-63	294	0.025
3	296	3555	2178	1377	1124	296	0.398	1890	2178	-288	-235	296	0.026
4	297	5141	2484	2657	2027	298	0.430	3390	2484	905	691	298	0.031
5	299	2102	2228	-126	-90	299	0.484	586	2228	-1642	-1171	299	0.040
6	300	4858	2680	2178	1452	302	0.556	3908	2680	1228	819	302	0.055
7	302	2652	2568	84	52	304	0.644	2668	2568	101	63	304	0.078
8	303	3050	3013	37	22	306	0.742	4763	3013	1750	1018	306	0.110
9	305	201	3075	-2874	-1563	308	0.843	4458	3075	1382	752	308	0.152
10	306	1071	3388	-2318	-1178	311	0.938	9069	3388	5681	2888	311	0.207
11	307	-545	3684	-4229	-2009	313	1.000	-11827	1493	-13319	-6328	313	0.000
12	309	-1595	4150	-5746	-2551	316	1.000	-14099	1938	-16037	-7121	316	0.000
13	310	-2552	4342	-6894	-2861	318	1.000	-17167	2116	-19282	-8002	318	0.000
14	311	-746	4767	-5513	-2138	321	1.000	-16994	2509	-19503	-7564	321	0.000
15	313	-3616	5108	-8724	-3162	323	1.000	-20934	2710	-23643	-8569	323	0.000
16	314	-1319	5428	-6746	-2285	326	1.000	-20036	2695	-22731	-7700	325	0.000
17	315	1079	5854	-4775	-1512	329	1.000	-20939	2984	-23923	-7573	326	0.000
18	317	-529	6196	-6725	-1990	331	1.000	-22177	2998	-25175	-7448	328	0.000
19	318	763	6517	-5754	-1591	334	1.000	-20865	3126	-23991	-6634	330	0.000
20	319	-268	6818	-7086	-1831	336	1.000	-21090	3130	-24221	-6259	331	0.000

QUALITATIVE APPENDICES

Table A5.28: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years under the status quo scenario.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	1.000	0.000	3189	175.1	132.3	392.6	0.00	0	0.0	0.0	0.0	0.00	329
2	1.000	0.000	3218	176.9	134.5	392.7	0.00	0	0.0	0.0	0.0	0.00	330
3	1.000	0.000	3248	178.7	136.7	392.8	0.00	0	0.0	0.0	0.0	0.00	331
4	1.000	0.000	3278	180.5	138.9	392.9	0.00	0	0.0	0.0	0.0	0.00	332
5	1.000	0.000	3307	182.3	141.1	393.0	0.00	0	0.0	0.0	0.0	0.00	333
6	1.000	0.000	3337	184.0	143.3	393.1	0.00	0	0.0	0.0	0.0	0.00	335
7	1.000	0.000	3367	185.8	145.5	393.2	0.00	0	0.0	0.0	0.0	0.00	336
8	1.000	0.000	3396	187.6	147.7	393.3	0.00	0	0.0	0.0	0.0	0.00	337
9	1.000	0.000	3426	189.4	149.9	393.4	0.00	0	0.0	0.0	0.0	0.00	338
10	1.000	0.000	3456	191.2	152.1	393.5	0.00	0	0.0	0.0	0.0	0.00	339
11	1.000	0.000	3485	193.0	154.3	393.6	0.00	0	0.0	0.0	0.0	0.00	340
12	1.000	0.000	3515	194.8	156.5	393.7	0.00	0	0.0	0.0	0.0	0.00	341
13	1.000	0.000	3545	196.6	158.7	393.8	0.00	0	0.0	0.0	0.0	0.00	342
14	1.000	0.000	3575	198.4	160.8	393.9	0.00	0	0.0	0.0	0.0	0.00	343
15	1.000	0.000	3604	200.2	163.0	394.0	0.00	0	0.0	0.0	0.0	0.00	344
16	1.000	0.000	3634	202.0	165.2	394.1	0.00	0	0.0	0.0	0.0	0.00	345
17	1.000	0.000	3664	203.8	167.4	394.2	0.00	0	0.0	0.0	0.0	0.00	346
18	1.000	0.000	3693	205.6	169.6	394.3	0.00	0	0.0	0.0	0.0	0.00	347
19	1.000	0.000	3723	207.4	171.8	394.4	0.00	0	0.0	0.0	0.0	0.00	347
20	1.000	0.000	3753	209.2	174.0	394.5	0.00	0	0.0	0.0	0.0	0.00	348

Table A5.29: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with cows tested and BB cows' milk segregated from the remaining milk.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	0.468	0.532	3173	175.5	131.7	392.6	0.00	3202	174.7	132.9	392.6	0.00	329
2	0.468	0.532	3203	177.3	133.9	392.7	0.00	3232	176.5	135.1	392.7	0.00	330
3	0.529	0.471	3174	175.9	133.8	386.0	0.00	3327	181.9	139.8	400.5	0.00	331
4	0.580	0.420	3200	177.5	136.0	385.9	0.00	3377	184.8	142.6	402.6	0.00	332
5	0.624	0.376	3245	180.2	138.8	388.2	0.00	3399	186.1	144.3	401.0	0.00	334
6	0.671	0.329	3286	182.6	141.5	389.0	0.00	3422	187.6	146.1	401.5	0.00	335
7	0.718	0.282	3322	184.8	143.9	389.5	0.00	3454	189.6	148.4	402.6	0.00	336
8	0.764	0.236	3356	186.8	146.2	390.1	0.00	3488	191.7	150.7	403.6	0.00	337
9	0.807	0.193	3389	188.8	148.5	390.7	0.00	3524	193.9	153.2	404.8	0.00	338
10	0.847	0.153	3420	190.7	150.7	391.1	0.00	3573	196.7	156.1	406.7	0.00	339
11	0.885	0.115	3450	192.5	152.9	391.5	0.00	3640	200.6	159.9	409.5	0.00	340
12	0.916	0.084	3482	194.4	155.1	391.8	0.00	3708	204.5	163.4	414.4	0.00	341
13	0.941	0.059	3515	196.5	157.5	392.3	0.00	3757	207.3	166.0	417.4	0.00	342
14	0.961	0.039	3550	198.5	159.8	392.9	0.00	3784	208.8	167.7	418.1	0.00	343
15	0.976	0.024	3583	200.5	162.1	393.4	0.00	3788	209.1	168.4	418.1	0.00	344
16	0.986	0.014	3615	202.4	164.4	393.7	0.00	3779	208.7	168.5	418.2	0.00	345
17	0.993	0.007	3645	204.3	166.6	394.0	0.00	3758	207.6	168.0	418.2	0.00	346
18	0.997	0.003	3676	206.1	168.8	394.2	0.00	3718	205.5	166.7	418.3	0.00	347
19	0.999	0.001	3705	207.9	171.0	394.4	0.00	3667	202.8	165.0	418.3	0.00	348
20	1.000	0.000	3735	209.7	173.2	394.5	0.00	3646	201.8	164.7	418.4	0.00	348

Table A5.30: The proportion of cows in each herd, the number of cows, and the production per cow over the 20 years with the whole herd BB genotype from year 1.

YEAR	PROPORTION		HERD 1					HERD 2					COW NO
	Herd 1	Herd 2	Yield	Fat	Protein	LWT	FC	Yield	Fat	Protein	LWT	FC	
1	1.000	0.000	3173	175.5	131.7	392.6	0.00	0	0.0	0.0	0.0	0.00	329
2	1.000	0.000	3203	177.3	133.9	392.7	0.00	0	0.0	0.0	0.0	0.00	330
3	1.000	0.000	3232	179.1	136.0	392.8	0.00	0	0.0	0.0	0.0	0.00	331
4	1.000	0.000	3262	180.9	138.2	392.9	0.00	0	0.0	0.0	0.0	0.00	333
5	1.000	0.000	3291	182.7	140.4	393.0	0.00	0	0.0	0.0	0.0	0.00	334
6	1.000	0.000	3321	184.5	142.6	393.1	0.00	0	0.0	0.0	0.0	0.00	335
7	1.000	0.000	3351	186.3	144.8	393.2	0.00	0	0.0	0.0	0.0	0.00	336
8	1.000	0.000	3380	188.1	147.0	393.3	0.00	0	0.0	0.0	0.0	0.00	337
9	1.000	0.000	3410	189.9	149.2	393.4	0.00	0	0.0	0.0	0.0	0.00	338
10	1.000	0.000	3439	191.7	151.3	393.5	0.00	0	0.0	0.0	0.0	0.00	339
11	1.000	0.000	3469	193.5	153.5	393.6	0.00	0	0.0	0.0	0.0	0.00	340
12	1.000	0.000	3498	195.3	155.7	393.7	0.00	0	0.0	0.0	0.0	0.00	341
13	1.000	0.000	3528	197.1	157.9	393.8	0.00	0	0.0	0.0	0.0	0.00	342
14	1.000	0.000	3557	198.9	160.1	393.9	0.00	0	0.0	0.0	0.0	0.00	343
15	1.000	0.000	3587	200.7	162.3	394.0	0.00	0	0.0	0.0	0.0	0.00	344
16	1.000	0.000	3617	202.5	164.4	394.1	0.00	0	0.0	0.0	0.0	0.00	345
17	1.000	0.000	3646	204.3	166.6	394.2	0.00	0	0.0	0.0	0.0	0.00	346
18	1.000	0.000	3676	206.1	168.8	394.3	0.00	0	0.0	0.0	0.0	0.00	347
19	1.000	0.000	3705	207.9	171.0	394.4	0.00	0	0.0	0.0	0.0	0.00	348
20	1.000	0.000	3735	209.7	173.2	394.5	0.00	0	0.0	0.0	0.0	0.00	348

Table A5.31: The proportion of cows in herd 1 and the production per farm over the 20 years under the status quo scenario.

YEAR	PROPN	MILK YIELD				MILKFAT				PROTEIN			
		Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1
1	1.000	1049042	0	1049042	1.000	57597	0	57597	1.000	43528	0	43528	1.000
2	1.000	1062029	0	1062029	1.000	58365	0	58365	1.000	44385	0	44385	1.000
3	1.000	1075075	0	1075075	1.000	59136	0	59136	1.000	45246	0	45246	1.000
4	1.000	1088181	0	1088181	1.000	59911	0	59911	1.000	46112	0	46112	1.000
5	1.000	1101346	0	1101346	1.000	60690	0	60690	1.000	46982	0	46982	1.000
6	1.000	1117907	0	1117907	1.000	61656	0	61656	1.000	47999	0	47999	1.000
7	1.000	1131221	0	1131221	1.000	62444	0	62444	1.000	48881	0	48881	1.000
8	1.000	1144593	0	1144593	1.000	63235	0	63235	1.000	49766	0	49766	1.000
9	1.000	1158026	0	1158026	1.000	64029	0	64029	1.000	50656	0	50656	1.000
10	1.000	1171517	0	1171517	1.000	64828	0	64828	1.000	51550	0	51550	1.000
11	1.000	1185068	0	1185068	1.000	65629	0	65629	1.000	52449	0	52449	1.000
12	1.000	1198679	0	1198679	1.000	66435	0	66435	1.000	53352	0	53352	1.000
13	1.000	1212349	0	1212349	1.000	67244	0	67244	1.000	54259	0	54259	1.000
14	1.000	1226078	0	1226078	1.000	68057	0	68057	1.000	55171	0	55171	1.000
15	1.000	1239866	0	1239866	1.000	68873	0	68873	1.000	56087	0	56087	1.000
16	1.000	1253714	0	1253714	1.000	69693	0	69693	1.000	57007	0	57007	1.000
17	1.000	1267622	0	1267622	1.000	70516	0	70516	1.000	57932	0	57932	1.000
18	1.000	1281588	0	1281588	1.000	71343	0	71343	1.000	58862	0	58862	1.000
19	1.000	1291891	0	1291891	1.000	71966	0	71966	1.000	59624	0	59624	1.000
20	1.000	1305947	0	1305947	1.000	72799	0	72799	1.000	60560	0	60560	1.000

Table A5.32: The proportion of cows in herd 1 and the production per farm over the 20 years with cows tested and BB cows' milk segregated from the remaining milk.

YEAR	PROPN	MILK YIELD				MILKFAT				PROTEIN			
		Herd 1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1
1	0.468	488686	560354	1049040	0.466	27030	30568	57597	0.469	20277	23251	43528	0.466
2	0.468	493236	568804	1062040	0.464	27307	31058	58365	0.468	20614	23772	44385	0.464
3	0.529	555472	519078	1074550	0.517	30788	28369	59157	0.520	23421	21802	45223	0.518
4	0.580	617569	469469	1087038	0.568	34265	25684	59949	0.572	26239	19824	46063	0.570
5	0.624	674887	428219	1103106	0.612	37479	23454	60933	0.615	28869	18187	47056	0.614
6	0.671	739359	376371	1115730	0.663	41094	20637	61731	0.666	31829	16076	47906	0.664
7	0.718	800487	328103	1128591	0.709	44528	18011	62539	0.712	34671	14095	48766	0.711
8	0.764	862393	279063	1141456	0.756	48010	15335	63345	0.758	37571	12058	49628	0.757
9	0.807	925241	229083	1154324	0.802	51548	12602	64151	0.804	40538	9955	50494	0.803
10	0.847	981664	185780	1167444	0.841	54733	10231	64964	0.843	43252	8118	51370	0.842
11	0.885	1038552	141964	1180516	0.880	57949	7825	65774	0.881	46012	6235	52247	0.881
12	0.916	1086308	107526	1193834	0.910	60661	5929	66590	0.911	48397	4738	53135	0.911
13	0.941	1131978	75137	1207115	0.938	63258	4145	67403	0.939	50704	3320	54025	0.939
14	0.961	1171350	49188	1220538	0.960	65506	2715	68220	0.960	52742	2180	54922	0.960
15	0.976	1203807	30303	1234109	0.975	67369	1673	69042	0.976	54480	1347	55827	0.976
16	0.986	1228982	18893	1247874	0.985	68826	1044	69870	0.985	55899	842	56741	0.985
17	0.993	1250398	11273	1261670	0.991	70074	623	70697	0.991	57155	504	57659	0.991
18	0.997	1271752	3718	1275470	0.997	71320	206	71526	0.997	58415	167	58581	0.997
19	0.999	1289426	0	1289426	1.000	72361	0	72361	1.000	59512	0	59512	1.000
20	1.000	1299690	0	1299690	1.000	72986	0	72986	1.000	60270	0	60270	1.000

Table A5.33: The proportion of cows in herd 1 and the production per farm over the 20 years with the whole herd BB genotype from year 1.

YEAR	PROPN	MILK YIELD				MILKFAT				PROTEIN			
		Herd 1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1	Herd 1	Herd 2	Total	Prop H1
1	1.000	1044011	0	1044011	1.000	57745	0	57745	1.000	43319	0	43319	1.000
2	1.000	1056935	0	1056935	1.000	58515	0	58515	1.000	44172	0	44172	1.000
3	1.000	1069919	0	1069919	1.000	59288	0	59288	1.000	45029	0	45029	1.000
4	1.000	1086224	0	1086224	1.000	60246	0	60246	1.000	46029	0	46029	1.000
5	1.000	1099355	0	1099355	1.000	61028	0	61028	1.000	46897	0	46897	1.000
6	1.000	1112546	0	1112546	1.000	61814	0	61814	1.000	47769	0	47769	1.000
7	1.000	1125795	0	1125795	1.000	62604	0	62604	1.000	48646	0	48646	1.000
8	1.000	1139104	0	1139104	1.000	63397	0	63397	1.000	49527	0	49527	1.000
9	1.000	1152472	0	1152472	1.000	64194	0	64194	1.000	50413	0	50413	1.000
10	1.000	1165899	0	1165899	1.000	64994	0	64994	1.000	51303	0	51303	1.000
11	1.000	1179385	0	1179385	1.000	65798	0	65798	1.000	52197	0	52197	1.000
12	1.000	1192930	0	1192930	1.000	66606	0	66606	1.000	53096	0	53096	1.000
13	1.000	1206534	0	1206534	1.000	67417	0	67417	1.000	53999	0	53999	1.000
14	1.000	1220198	0	1220198	1.000	68231	0	68231	1.000	54906	0	54906	1.000
15	1.000	1233920	0	1233920	1.000	69050	0	69050	1.000	55818	0	55818	1.000
16	1.000	1247702	0	1247702	1.000	69872	0	69872	1.000	56734	0	56734	1.000
17	1.000	1261542	0	1261542	1.000	70697	0	70697	1.000	57655	0	57655	1.000
18	1.000	1275442	0	1275442	1.000	71526	0	71526	1.000	58579	0	58579	1.000
19	1.000	1289401	0	1289401	1.000	72359	0	72359	1.000	59509	0	59509	1.000
20	1.000	1299684	0	1299684	1.000	72986	0	72986	1.000	60269	0	60269	1.000

Table A5.34: The proportion of cows in herd 1 and the production per hectare over the 20 years under the status quo scenario.

YEAR	PROP	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	1.000	11280	0	11280	619	0	619	468	0	468	1087	0	1087
2	1.000	11420	0	11420	628	0	628	477	0	477	1105	0	1105
3	1.000	11560	0	11560	636	0	636	487	0	487	1122	0	1122
4	1.000	11701	0	11701	644	0	644	496	0	496	1140	0	1140
5	1.000	11842	0	11842	653	0	653	505	0	505	1158	0	1158
6	1.000	12021	0	12021	663	0	663	516	0	516	1179	0	1179
7	1.000	12164	0	12164	671	0	671	526	0	526	1197	0	1197
8	1.000	12307	0	12307	680	0	680	535	0	535	1215	0	1215
9	1.000	12452	0	12452	688	0	688	545	0	545	1233	0	1233
10	1.000	12597	0	12597	697	0	697	554	0	554	1251	0	1251
11	1.000	12743	0	12743	706	0	706	564	0	564	1270	0	1270
12	1.000	12889	0	12889	714	0	714	574	0	574	1288	0	1288
13	1.000	13036	0	13036	723	0	723	583	0	583	1306	0	1306
14	1.000	13184	0	13184	732	0	732	593	0	593	1325	0	1325
15	1.000	13332	0	13332	741	0	741	603	0	603	1344	0	1344
16	1.000	13481	0	13481	749	0	749	613	0	613	1362	0	1362
17	1.000	13630	0	13630	758	0	758	623	0	623	1381	0	1381
18	1.000	13781	0	13781	767	0	767	633	0	633	1400	0	1400
19	1.000	13891	0	13891	774	0	774	641	0	641	1415	0	1415
20	1.000	14042	0	14042	783	0	783	651	0	651	1434	0	1434

Table A5.35: The proportion of cows in herd 1 and the production per hectare over the 20 years with cows tested and BB cows' milk segregated from the remaining milk.

YEAR	PROPN	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	0.468	5255	6025	11280	291	329	619	218	250	468	509	579	1087
2	0.468	5304	6116	11420	294	334	628	222	256	477	515	590	1105
3	0.529	5973	5581	11554	331	305	636	252	234	486	583	539	1122
4	0.580	6641	5048	11689	368	276	645	282	213	495	651	489	1140
5	0.624	7257	4605	11861	403	252	655	310	196	506	713	448	1161
6	0.671	7950	4047	11997	442	222	664	342	173	515	784	395	1179
7	0.718	8607	3528	12135	479	194	672	373	152	524	852	345	1197
8	0.764	9273	3001	12274	516	165	681	404	130	534	920	295	1215
9	0.807	9949	2463	12412	554	136	690	436	107	543	990	243	1233
10	0.847	10556	1998	12553	589	110	699	465	87	552	1054	197	1251
11	0.885	11167	1526	12694	623	84	707	495	67	562	1118	151	1269
12	0.916	11681	1156	12837	652	64	716	520	51	571	1173	115	1287
13	0.941	12172	808	12980	680	45	725	545	36	581	1225	80	1306
14	0.961	12595	529	13124	704	29	734	567	23	591	1271	53	1324
15	0.976	12944	326	13270	724	18	742	586	14	600	1310	32	1343
16	0.986	13215	203	13418	740	11	751	601	9	610	1341	20	1361
17	0.993	13445	121	13566	753	7	760	615	5	620	1368	12	1380
18	0.997	13675	40	13715	767	2	769	628	2	630	1395	4	1399
19	0.999	13865	0	13865	778	0	778	640	0	640	1418	0	1418
20	1.000	13975	0	13975	785	0	785	648	0	648	1433	0	1433

Table A5.36: The proportion of cows in herd 1 and the production per hectare over the 20 years with the whole herd BB genotype from year 1.

YEAR	PROP	MILK YIELD			MILKFAT			PROTEIN			MILKSOLIDS		
		Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total	Herd 1	Herd 2	Total
1	1.000	11226	0	11226	621	0	621	466	0	466	1087	0	1087
2	1.000	11365	0	11365	629	0	629	475	0	475	1104	0	1104
3	1.000	11505	0	11505	638	0	638	484	0	484	1122	0	1122
4	1.000	11680	0	11680	648	0	648	495	0	495	1143	0	1143
5	1.000	11821	0	11821	656	0	656	504	0	504	1160	0	1160
6	1.000	11963	0	11963	665	0	665	514	0	514	1178	0	1178
7	1.000	12105	0	12105	673	0	673	523	0	523	1196	0	1196
8	1.000	12248	0	12248	682	0	682	533	0	533	1214	0	1214
9	1.000	12392	0	12392	690	0	690	542	0	542	1232	0	1232
10	1.000	12537	0	12537	699	0	699	552	0	552	1251	0	1251
11	1.000	12682	0	12682	708	0	708	561	0	561	1269	0	1269
12	1.000	12827	0	12827	716	0	716	571	0	571	1287	0	1287
13	1.000	12973	0	12973	725	0	725	581	0	581	1306	0	1306
14	1.000	13120	0	13120	734	0	734	590	0	590	1324	0	1324
15	1.000	13268	0	13268	742	0	742	600	0	600	1343	0	1343
16	1.000	13416	0	13416	751	0	751	610	0	610	1361	0	1361
17	1.000	13565	0	13565	760	0	760	620	0	620	1380	0	1380
18	1.000	13714	0	13714	769	0	769	630	0	630	1399	0	1399
19	1.000	13865	0	13865	778	0	778	640	0	640	1418	0	1418
20	1.000	13975	0	13975	785	0	785	648	0	648	1433	0	1433

Table A5.37: Difference in income, expenses, and nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the qualitative comparisons (Scenarios 1 and 2) over the 20 years. Note: stock income value differences are not shown but are included in the total value. NPV over 20 years equals 0.

YEAR	SQ	Scenario 1 (Multiplier = 1.034)						Scenario 2 (Multiplier = 1.041)					
		Cow No.	Income	Expenses	Value	PV	Propn H1	Cow No.	Propn H1	Income	Expenses	Value	PV	Cow No.	Propn H1
1	329	2075	17673	-15598	-14577	329	0.468	6831	71924	-65093	-60834	329	1.000
2	330	2130	2605	-475	-415	330	0.468	6994	1657	5337	4662	330	1.000
3	331	2386	2614	-228	-186	331	0.529	6748	1662	5086	4152	331	1.000
4	332	2165	2634	-469	-358	332	0.580	8638	1898	6740	5142	333	1.000
5	333	5211	2852	2359	1682	334	0.624	9836	2066	7771	5540	334	1.000
6	335	3126	2405	722	481	335	0.671	7677	1682	5995	3995	335	1.000
7	336	3402	2332	1070	666	336	0.718	7845	1688	6158	3835	336	1.000
8	337	3665	2254	1410	821	337	0.764	8014	1693	6321	3679	337	1.000
9	338	3915	2175	1740	946	338	0.807	8183	1698	6485	3528	338	1.000
10	339	4187	2097	2091	1063	339	0.847	8353	1703	6651	3381	339	1.000
11	340	4429	2020	2409	1145	340	0.885	8525	1708	6817	3239	340	1.000
12	341	4676	1955	2721	1208	341	0.916	8697	1713	6983	3101	341	1.000
13	342	4880	1717	3163	1313	342	0.941	8869	1718	7151	2968	342	1.000
14	343	5075	1722	3353	1300	343	0.961	9043	1723	7320	2839	343	1.000
15	344	5260	1728	3532	1280	344	0.976	9218	1728	7489	2714	344	1.000
16	345	5438	1720	3718	1259	345	0.986	9393	1720	7674	2599	345	1.000
17	346	5582	1725	3858	1221	346	0.993	9569	1725	7845	2483	346	1.000
18	347	5083	1730	3353	992	347	0.997	9102	1730	7372	2181	347	1.000
19	347	7848	1854	5994	1657	348	0.999	11893	1854	10038	2776	348	1.000
20	348	5967	1734	4233	1094	348	1.000	10075	1734	8340	2155	348	1.000

Table A5.38: Difference in income, expenses, and nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the qualitative comparisons (Scenarios 1 and 2) over 20+ years. Note: stock income value differences are not shown but are included in the total value. NPV over 20+ years equals 0.

YEAR	SQ	Scenario 1 (Multiplier = 1.032)						Scenario 2 (Multiplier = 1.037)					
		Cow No.	Income	Expenses	Value	PV	Propn H1	Cow No.	Propn H1	Income	Expenses	Value	PV	Cow No.	Propn H1
1	329	1666	17673	-16007	-14960	329	0.468	5081	71924	-66843	-62470	329	1.000
2	330	1715	2605	-890	-778	330	0.468	5214	1657	3557	3107	330	1.000
3	331	1916	2614	-698	-570	331	0.529	4937	1662	3275	2674	331	1.000
4	332	1639	2634	-995	-759	332	0.580	6791	1898	4893	3733	333	1.000
5	333	4633	2852	1781	1270	334	0.624	7959	2066	5893	4202	334	1.000
6	335	2491	2405	87	58	335	0.671	5769	1682	4087	2723	335	1.000
7	336	2712	2332	379	236	336	0.718	5906	1688	4218	2627	336	1.000
8	337	2918	2254	664	386	337	0.764	6043	1693	4351	2532	337	1.000
9	338	3110	2175	935	509	338	0.807	6181	1698	4484	2439	338	1.000
10	339	3331	2097	1234	627	339	0.847	6320	1703	4617	2347	339	1.000
11	340	3519	2020	1499	712	340	0.885	6460	1708	4752	2258	340	1.000
12	341	3720	1955	1766	784	341	0.916	6600	1713	4887	2170	341	1.000
13	342	3881	1717	2164	898	342	0.941	6741	1718	5023	2084	342	1.000
14	343	4038	1722	2315	898	343	0.961	6882	1723	5159	2001	343	1.000
15	344	4190	1728	2462	892	344	0.976	7025	1728	5296	1920	344	1.000
16	345	4342	1720	2622	888	345	0.986	7168	1720	5448	1846	345	1.000
17	346	4463	1725	2739	867	346	0.993	7312	1725	5587	1769	346	1.000
18	347	3941	1730	2212	654	347	0.997	6811	1730	5082	1503	347	1.000
19	347	6687	1854	4832	1336	348	0.999	9569	1854	7715	2133	348	1.000
20	348	4792	1734	3058	790	348	1.000	7725	1734	5991	1548	348	1.000
20+		68460	24778	43682	10549		1.000	110358	24778	85579	20668		1.000

Table A5.39: Difference in income, expenses, and nett income ("with" minus "without" cost-benefit analysis unadjusted figures) and the present value at a discount rate of 7% for the qualitative comparisons (Scenarios 1 and 2) over 10 years. Note: stock income value differences are not shown but are included in the total value. NPV over 10 years equals 0.

YEAR	SQ	Scenario 1 (Multiplier = 1.039)						Scenario 2 (Multiplier = 1.048)					
		Cow No.	Income	Expenses	Value	PV	Cow No.	Propn HI	Income	Expenses	Value	PV	Cow No.	Propn HI
1	329	3099	17673	-14574	-13620	329	0.468	9894	71924	-62030	-57972	329	1.000
2	330	3169	2605	564	492	330	0.468	10109	1657	8452	7383	330	1.000
3	331	3563	2614	949	775	331	0.529	9916	1662	8254	6738	331	1.000
4	332	3480	2634	845	645	332	0.580	11869	1898	9971	7607	333	1.000
5	333	6654	2852	3802	2711	334	0.624	13122	2066	11056	7883	334	1.000
6	335	4714	2405	2310	1539	335	0.671	11017	1682	9334	6220	335	1.000
7	336	5128	2332	2796	1741	336	0.718	11239	1688	9551	5948	336	1.000
8	337	5532	2254	3278	1908	337	0.764	11462	1693	9769	5686	337	1.000
9	338	5926	2175	3751	2040	338	0.807	11686	1698	9988	5433	338	1.000
10	339	6329	2097	4233	2152	339	0.847	11911	1703	10209	5190	339	1.000
11	340	6704	2020	4684	2225	340	0.885	12138	1708	10430	4955	340	1.000
12	341	7064	1955	5109	2269	341	0.916	12366	1713	10653	4730	341	1.000
13	342	7377	1717	5661	2349	342	0.941	12594	1718	10876	4513	342	1.000
14	343	7669	1722	5947	2306	343	0.961	12824	1723	11101	4305	343	1.000
15	344	7935	1728	6207	2250	344	0.976	13055	1728	11327	4105	344	1.000
16	345	8178	1720	6458	2188	345	0.986	13287	1720	11568	3918	345	1.000
17	346	8380	1725	6655	2107	346	0.993	13521	1725	11796	3734	346	1.000
18	347	7938	1730	6208	1837	347	0.997	13110	1730	11380	3367	347	1.000
19	347	10753	1854	8898	2460	348	0.999	15958	1854	14104	3900	348	1.000
20	348	8904	1734	7169	1853	348	1.000	14186	1734	12452	3218	348	1.000

PREMIUM REDISTRIBUTION

Table A5.40: The effect of redistributing the premium paid for the desired milk type in quantitative scenario 1 over 3 time periods at a 7% discount rate. The premium value specified is that for year 1. Distribution over the years is given in the table, relative to the year 1 value.

YEAR	EVEN DISTRIBUTION						UNEVEN (5x1.0, 5x0.75, 10x0.5)						UNEVEN (5x1.0, 10x0.75, 5x0.5)			
	10 years		20 years		20+ years		10 years		20 years		20+ years		20 years		20+ years	
Year 1	\$2.08 Value	PV	\$1.11 Value	PV	\$0.92 Value	PV	\$2.560 Value	PV	\$2.033 Value	PV	\$1.775 Value	PV	\$1.770 Value	PV	\$1.672 Value	PV
1	-5072	-4741	-6084	-5686	-6282	-5871	-4572	-4273	-5122	-4787	-5390	-5037	-5396	-5043	-5498	-5138
2	-73	-63	-1093	-954	-1292	-1129	432	377	-122	-107	-393	-343	-399	-348	-501	-438
3	-288	-235	-1463	-1194	-1693	-1382	293	239	-345	-282	-657	-536	-664	-542	-782	-638
4	905	691	-406	-310	-663	-506	1554	1185	841	642	494	377	486	371	354	270
5	-1642	-1171	-3373	-2405	-3712	-2646	-786	-561	-1727	-1231	-2185	-1558	-2196	-1566	-2370	-1690
6	1228	818	-1210	-806	-1688	-1125	825	550	-168	-112	-653	-435	-664	-442	-848	-565
7	100	62	-3342	-2081	-4016	-2501	-468	-292	-1871	-1165	-2555	-1591	-2571	-1601	-2830	-1762
8	1750	1018	-3143	-1829	-4101	-2387	941	548	-1052	-612	-2025	-1179	-2047	-1191	-2416	-1406
9	1382	752	-5416	-2946	-6748	-3670	259	141	-2511	-1366	-3863	-2101	-3893	-2118	-4406	-2396
10	5680	2887	-3633	-1847	-5457	-2774	4141	2105	347	176	-1505	-765	-1547	-787	-2249	-1143
11	9183	4363	-3413	-1621	-5880	-2794	-1208	-574	-4629	-2199	-6299	-2993	-592	-281	-1541	-732
12	14400	6394	-2259	-1003	-5523	-2452	657	292	-3868	-1718	-6077	-2698	1472	653	216	96
13	20122	8350	-1099	-456	-5256	-2181	2616	1085	-3149	-1307	-5962	-2474	3654	1516	2055	853
14	29703	11519	3112	1207	-2096	-813	7767	3012	544	211	-2981	-1156	9068	3517	7064	2740
15	35272	12784	2941	1066	-3392	-1229	8601	3117	-181	-66	-4467	-1619	10182	3690	7746	2808
16	46323	15691	8031	2720	530	180	14734	4991	4333	1468	-743	-252	-858	-291	-2781	-942
17	57248	18123	12928	4093	4247	1344	20686	6549	8648	2738	2773	878	2640	836	414	131
18	62977	18633	13650	4039	3988	1180	22285	6593	8887	2629	2348	695	2200	651	-278	-82
19	69084	19102	16103	4453	5725	1583	25378	7017	10987	3038	3964	1096	3805	1052	1143	316
20	80865	20897	20215	5224	8335	2154	30833	7968	14359	3711	6318	1633	6137	1586	3090	799
20+					119078	28759					90264	21800			44144	10662

Table A5.41: The effect of redistributing the premium paid for the desired milk type in qualitative scenario 2 over 3 time periods at a 7% discount rate. The multiplier value and dollar value specified is that for year 1. Distribution over the years is given in the table, relative to the year 1 value.

YEAR	EVEN DISTRIBUTION						UNEVEN DISTRIBUTION (1x1.0, 19x0.9)						UNEVEN DISTRIBUTION (1x1.0, 19x0.85)					
	10 years		20 years		20+ years		10 years		20 years		20+ years		10 years		20 years		20+ years	
Year 1	1.048 (\$4.58)		1.041 (\$4.55)		1.037 (\$4.53)		1.149 (\$5.02)		1.147 (\$5.00)		1.145 (\$5.00)		1.206 (\$5.27)		1.208 (\$5.28)		1.208 (\$5.28)	
	Value	PV	Value	PV	Value	PV	Value	PV	Value	PV	Value	PV	Value	PV	Value	PV	Value	PV
1	-62030	-57972	-65093	-60834	-66843	-62470	-18024	-16845	-18834	-17601	-19563	-18283	7307	6829	8008	7485	7975	7453
2	8452	7383	5337	4662	3557	3107	2102	1836	1360	1188	692	605	-1554	-1357	-947	-828	-976	-853
3	8254	6738	5086	4152	3275	2674	1795	1465	1041	850	362	295	-1923	-1570	-1306	-1066	-1335	-1090
4	9971	7607	6740	5142	4893	3733	3384	2581	2614	1995	1922	1466	-408	-312	221	168	191	146
5	11056	7883	7771	5540	5893	4202	4359	3108	3577	2550	2872	2048	504	359	1143	815	1113	793
6	9334	6220	5995	3995	4087	2723	2527	1684	1732	1154	1016	677	-1392	-927	-741	-494	-772	-515
7	9551	5948	6158	3835	4218	2627	2633	1640	1825	1137	1098	684	-1349	-840	-688	-429	-720	-448
8	9769	5686	6321	3679	4351	2532	2740	1595	1919	1117	1180	687	-1306	-760	-635	-370	-667	-388
9	9988	5433	6485	3528	4484	2439	2847	1549	2013	1095	1262	687	-1263	-687	-581	-316	-614	-334
10	10209	5190	6651	3381	4617	2347	2955	1502	2108	1072	1346	684	-1220	-620	-527	-268	-560	-285
11	10430	4955	6817	3239	4752	2258	3064	1456	2204	1047	1429	679	-1176	-559	-473	-225	-506	-241
12	10653	4730	6983	3101	4887	2170	3173	1409	2300	1021	1513	672	-1133	-503	-418	-186	-452	-201
13	10876	4513	7151	2968	5023	2084	3283	1362	2396	994	1597	663	-1088	-452	-363	-151	-398	-165
14	11101	4305	7320	2839	5159	2001	3393	1316	2493	967	1682	652	-1044	-405	-308	-119	-343	-133
15	11327	4105	7489	2714	5296	1920	3504	1270	2590	939	1768	641	-999	-362	-252	-91	-288	-104
16	11568	3918	7674	2599	5448	1846	3629	1229	2702	915	1867	633	-940	-319	-182	-62	-218	-74
17	11796	3734	7845	2483	5587	1769	3741	1184	2801	887	1954	618	-895	-283	-126	-40	-163	-51
18	11380	3367	7372	2181	5082	1503	3209	949	2255	667	1396	413	-1495	-442	-714	-211	-751	-222
19	14104	3900	10038	2776	7715	2133	5816	1608	4848	1341	3976	1099	1045	289	1836	508	1799	497
20	12452	3218	8340	2155	5991	1548	4070	1052	3091	799	2210	571	-755	-195	45	12	7	2
20+					85579	20668					31565	7623					105	25

MILKSOLIDS AT STATUS QUO PRICES

Table A5.42: The difference in milk composition in year 20 between the scenarios, and the effect this has on the price received per kilogram milksolids (MS) using status quo prices. The difference in milk income is also shown, but it should be noted that this is affected by milk production as well as milk composition.

Scenario	P:MF ratio	Milksolid %	litres/kg MS	Milkfat (\$)	Difference from SQ	Protein (\$)	Difference from SQ	Milk (\$)	Difference from SQ	\$/kg MS	Difference from SQ	Difference (\$/farm)
Year 20												
Quan SQ	0.8437	8.485%	11.786	1.570		2.856		-0.4895		3.936		
Quan 1	0.7716	8.504%	11.759	1.634	0.064	2.718	-0.138	-0.4883	0.0011	3.864	-0.073	-32,521
Quan 2	0.7503	8.506%	11.757	1.654	0.084	2.675	-0.181	-0.4883	0.0012	3.841	-0.096	-24,638
Quan 3	0.7716	8.504%	11.759	1.634	0.064	2.718	-0.138	-0.4883	0.0011	3.864	-0.073	-32,521
Quan 4	0.7942	8.498%	11.767	1.613	0.043	2.763	-0.093	-0.4887	0.0008	3.887	-0.049	-21,993
Qual SQ	0.8319	10.212%	9.793	1.580		2.834		-0.4067		4.007		
Qual 1	0.8258	10.253%	9.753	1.585	0.005	2.823	-0.011	-0.4051	0.0016	4.003	-0.004	-1,009
Qual 2	0.8258	10.253%	9.753	1.585	0.005	2.823	-0.011	-0.4051	0.0016	4.003	-0.004	-1,015
Year 1												
Quan SQ	0.7867	7.884%	12.684	1.620		2.748		-0.527		3.841		
Qual SQ	0.7557	9.640%	10.374	1.649		2.686		-0.431		3.904		