

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.

**THE EPIDEMIOLOGY OF MASTITIS  
IN AUSTRALIAN DAIRY CATTLE**

A dissertation submitted in partial fulfilment of the requirements  
for the degree of  
Masters of Veterinary Studies (Epidemiology)  
at Massey University

*Richard William Shephard*

2000

## Abstract

This study represents an aggregation of knowledge on mastitis within the Australian dairy industry. Aspects of the epidemiology and economics of mastitis have been collated and areas of missing knowledge identified. A clinical treatment trial was conducted on subclinical mastitis to identify the role of therapy upon subclinical infection. The effect of individual variables on mastitis risk was studied and aggregated in order to facilitate the development of a computer simulation model of mastitis within Australian dairy herds.

A literature review of mastitis within the Australian dairy industry was conducted. The economic impact of mastitis was examined and the pathway of economic loss to the dairy industry is discussed. The epidemiology of mastitis was studied with special emphasis on quantification of the effect of individual risk factors on the occurrence of disease. Performance parameters for the current diagnostic tests applied within the dairy industry are presented and their suitability for use in a commercial environment discussed. The impact of self-cure and the efficacy of therapeutic intervention in the disease are examined. The role of culling is presented. The chapter concludes with an estimation of the total economic losses experienced on a commercial dairy farm in Victoria in 1998 for three different mastitis levels. The economic benefit to be gained from a reduction in mastitis is also presented.

A clinical treatment trial of subclinically infected cows (high somatic cell count) was conducted in order to determine if therapeutic intervention was an effective management tool. Cows with somatic cell counts in excess of 500,000 cells per ml and more than 14 days calved were selected and randomly assigned to treatment and control groups. A pooled quarter milk sample was taken prior to treatment and repeated at around six weeks after treatment. Treated cows received a course of intramammary and parenteral antibiotics and control cows were untreated. Cows were followed for the rest of the lactation of treatment and into the subsequent lactation and somatic cell counts were recorded. The major pathogens identified were *S aureus* and *S uberis*. Treatment did not have a significant or commercially useful effect upon bacteriological cure rates, survival of cows to the next lactation or somatic cell count for the remainder of the lactation. Treatment of high somatic cell count cows during lactation is not recommended and is discussed.

A requirement exists for the development of a stochastic simulation model of mastitis within Australian dairy herds. The structure of such a model was developed and is presented. Underlying production and somatic cell count responses in Australian cattle were derived. Infection status variables were included and stochasticity was introduced through the use of control variates. State transition probabilities were collected from the literature. Deficiencies in knowledge were identified and methods for modelling these deficient areas discussed. The aggregated information is presented. It is expected that a working stochastic simulation model of mastitis within Australian dairy herds will be developed from information collected in this dissertation.

## Acknowledgments

I would like to thank a few key people who have helped me achieve this goal. I was only able to undertake this course of study because Terri, my wife, was willing and able to handle the increased responsibility of caring for our small children whilst I was absent. Terri also has a genuine interest in my work. This has made it easier for me to balance study, full time work and family. This is a shared honour.

This study has been the most stimulating and enjoyable educational experience that I have undertaken. The knowledge gained and the techniques learned have helped me to investigate problems that previously were impossible to me. I now have the confidence and skills to learn many more techniques of the discipline under my own guidance. Most importantly, I now think in a logical manner. I thank three people in particular for these abilities: Dr Dirk Pfeiffer, Professor Roger Morris and Dr Ron Jackson.

Dr Dirk Pfeiffer gave me the necessary skills through his quality teaching. He presented information in a way that was always interesting but also at the limits of my understanding and knowledge. This approach enabled me to make great advances during the few weeks of contact time that we had each year. Professor Roger Morris gave inspirational demonstrations of his use of epidemiology in answering relevant animal health questions the world over. The motivation (and enjoyment) that I obtained from these discussions was enormous. Dr Ron Jackson helped me to understand and apply my new skills in my own area of expertise through many hours of casual discussion. He was able to guide me around the relevant problems of the dairy industry in such a way that I was able to visualise how many of them could be investigated and answered. His greatest skill was making me believe that I had reached the necessary conclusion on my own. Ron's input gave me the confidence to take my training and use it with real problems in my home environment. Ron and June Jackson also welcomed me into their family whenever I was attending Massey. Their company, guidance and friendship have been a highlight of this adventure.

## Table of contents

ABSTRACT.....	I
ACKNOWLEDGMENTS.....	III
TABLE OF CONTENTS.....	IV
LIST OF TABLES.....	VII
LIST OF FIGURES.....	IX
LIST OF ABBREVIATIONS.....	X
INTRODUCTION.....	1
<b>CHAPTER 1.....</b>	<b>2</b>
<b>REVIEW OF SUBCLINICAL MASTITIS.....</b>	<b>2</b>
INTRODUCTION.....	3
ECONOMICS OF SUBCLINICAL MASTITIS IN AUSTRALIA.....	3
LOSS OF PRODUCTION.....	4
REDUCTION IN MILK QUALITY.....	6
RISK OF CLINICAL EPISODES.....	7
RISK OF INCREASED CULLING.....	8
RISK OF INCREASED SPREAD.....	9
COST OF TREATMENT.....	10
COST OF PREVENTION.....	11
EPIDEMIOLOGY OF SUBCLINICAL MASTITIS.....	12
PATHOGENS ASSOCIATED WITH SUBCLINICAL MASTITIS IN AUSTRALIA.....	12
ESTABLISHMENT OF INFECTION.....	13
<i>Invasion</i> .....	13
<i>Infection</i> .....	14
<i>Inflammation</i> .....	14
RISK FACTORS FOR ESTABLISHMENT OF INFECTION.....	16
<i>Exposure</i> .....	16
<i>Teat end condition</i> .....	17
<i>Milking machines</i> .....	18
<i>Milking technique and milking management</i> .....	18
<i>Miscellaneous factors</i> .....	19
DIAGNOSIS OF SUBCLINICAL MASTITIS.....	20
CULTURE.....	21
SOMATIC CELL COUNT.....	21
<i>Affect of infection on somatic cell count</i> .....	21
<i>Use of SCC at the quarter level</i> .....	22
<i>Use of SCC at the cow level</i> .....	22
<i>Use of SCC at the herd level</i> .....	24
<i>Causes of variation in somatic cell count</i> .....	24

<b>ELIMINATION OF INFECTION.....</b>	<b>26</b>
SPONTANEOUS ELIMINATION OF INFECTION.....	27
ROLE OF THERAPY IN ELIMINATION OF INFECTION.....	27
<i>Treatment at drying off</i> .....	27
<i>Treatment during lactation</i> .....	28
CULLING.....	29
<b>ESTIMATION OF ECONOMIC COST OF MASTITIS FOR AN AVERAGE VICTORIAN DAIRY FARM.....</b>	<b>29</b>
MODEL ASSUMPTIONS.....	30
MODEL PHYSICAL OUTPUT.....	32
MODEL ECONOMIC OUTPUT.....	33
<b>CHAPTER 2.....</b>	<b>35</b>
<b>A CLINICAL TRIAL TO EVALUATE THE EFFECTIVENESS OF TREATING HIGH SOMATIC CELL COUNT COWS DURING LACTATION.....</b>	<b>35</b>
INTRODUCTION.....	36
MATERIALS AND METHODS.....	36
STATISTICAL ANALYSIS.....	38
RESULTS.....	38
<i>Farm level data</i> .....	38
<i>Cow level data</i> .....	39
<i>Multivariate analysis</i> .....	49
DISCUSSION.....	52
<i>Bacteriological cure</i> .....	52
<i>Somatic cell count</i> .....	54
<i>Survival</i> .....	54
<b>CHAPTER 3.....</b>	<b>56</b>
<b>DEVELOPMENT OF BASELINE DATA NECESSARY FOR THE PRODUCTION OF A STOCHASTIC COMPUTER SIMULATION MODEL OF MASTITIS IN AUSTRALIAN DAIRY HERDS.....</b>	<b>56</b>
INTRODUCTION.....	57
MATERIALS AND METHODS.....	58
<i>Structure of the model</i> .....	58
<i>Source of data</i> .....	59
RESULTS.....	59

<i>Flow chart of model logic</i> .....	59
<i>Derivation of transition probabilities</i> .....	60
<i>Modelling the effect of infection upon somatic cell count</i> .....	74
<i>Modelling the effect of infection upon production</i> .....	77
<i>Development of decision algorithms</i> .....	83
<b>DISCUSSION</b> .....	<b>84</b>
<b>ACKNOWLEDGMENTS</b> .....	<b>86</b>
<b>GENERAL DISCUSSION</b> .....	<b>87</b>
<b>REFERENCES</b> .....	<b>91</b>



## List of tables

TABLE 1: SPECIES OF MICRO-ORGANISMS COMMONLY ASSOCIATED WITH MASTITIS IN DAIRY CATTLE (FROM BRAMLEY ET AL., 1992).	13
TABLE 2: PROBABILITY OF INFECTION WITH A MAJOR PATHOGEN WITHIN EACH ICCC RANGE (FROM MCDERMOTT ET AL., 1982).	23
TABLE 3: SENSITIVITY AND SPECIFICITY FOR DETERMINING INFECTION WITH MAJOR PATHOGENS FOR VARIOUS ICCC THRESHOLDS (FROM MCDERMOTT ET AL., 1982).	23
TABLE 4: TYPICAL BULK MILK CELL COUNT SUPPLY PATTERN FOR SEASONAL VICTORIAN DAIRY HERDS WITH DIFFERENT SEASON PEAK BMCC.	30
TABLE 5: TYPICAL MILK QUALITY PAYMENT SCHEME FOR BULK MILK SUPPLIED TO A MAJOR MILK PROCESSOR IN VICTORIA IN 1998	30
TABLE 6: ESTIMATED FARM PHYSICAL PERFORMANCE FOR A 200 COW HERD FOR THREE SEASONAL PEAK BMCC LEVELS	32
TABLE 7: ESTIMATED ECONOMIC LOSSES DUE TO MASTITIS IN A 200 COW HERD FOR THREE SEASONAL PEAK BMCC LEVELS	33
TABLE 8: TRIAL FARM POPULATION	38
TABLE 9: FATE OF TRIAL FARMS OVER THE DURATION OF THE STUDY	39
TABLE 10: DISTRIBUTION OF PATHOGENS AT FIRST AND SECOND CULTURE AND AVERAGE ICCC PRIOR TO THE FIRST CULTURE PERIOD	39
TABLE 11: CULTURE STATUS AT FIRST AND SECOND SAMPLING PERIODS FOR TREATMENT AND CONTROL GROUPS	41
TABLE 12: NUMBER AND PREVALENCE OF INDIVIDUAL PATHOGEN TYPES (AS ISOLATED AT INITIAL CULTURE) FOR NEWLY INFECTED AND CHRONICALLY INFECTED TRIALISTS.	42
TABLE 13: CULTURE STATUS AT FIRST AND SECOND SAMPLING PERIODS FOR TREATMENT AND CONTROL GROUPS FOR COWS CLASSIFIED WITH NEW INFECTIONS DURING THE LACTATION OF TREATMENT (1995/96)	42
TABLE 14: CULTURE STATUS AT FIRST AND SECOND SAMPLING PERIODS FOR TREATMENT AND CONTROL GROUPS FOR COWS CLASSIFIED WITH CHRONIC INFECTIONS DURING THE LACTATION OF TREATMENT (1995/96)	43
TABLE 15: AVERAGE ICCC AND PERCENTAGE OF TOTAL ICCC'S LESS THAN 250,000 CELLS/ML FOR EACH PATHOGEN AND TREATMENT GROUP OVER THE REMAINDER OF THE LACTATION OF TREATMENT	44
TABLE 16: AVERAGE ICCC AND PERCENTAGE OF ICCC'S LESS THAN 250,000 CELLS/ML FOR EACH PATHOGEN AND TREATMENT GROUP FOR THE LACTATION FOLLOWING TREATMENT	45
TABLE 17 : AVERAGE ICCC AND PERCENTAGE OF ICCC'S LESS THAN 250,000 CELLS/ML FOR NEWLY INFECTED AND CHRONICALLY INFECTED COWS WITHIN EACH TREATMENT GROUP FOR THE LACTATION OF TREATMENT	46
TABLE 18 : AVERAGE ICCC AND PERCENTAGE OF ICCC'S LESS THAN 250,000 CELLS/ML FOR NEWLY INFECTED AND CHRONICALLY INFECTED COWS WITHIN EACH TREATMENT GROUP FOR THE LACTATION FOLLOWING TREATMENT.	47
TABLE 19: SURVIVAL OF TREATMENT, CONTROL AND ELIGIBLE NON-TRIALIST COWS FROM INITIAL TREATMENT TIME TO BEGIN THE LACTATION FOLLOWING TREATMENT	48
TABLE 20: SURVIVAL, ODDS AND ODDS RATIO OF SURVIVAL OF TREATMENT AND CONTROL COWS FOR EACH PATHOGEN (AS ISOLATED AT THE FIRST CULTURE)	48
TABLE 21 : SURVIVAL TO THE LACTATION FOLLOWING TREATMENT FOR NEWLY INFECTED AND CHRONICALLY INFECTED COWS AND FOR INFECTION STATUS-TREATMENT SUBGROUPS	49
TABLE 22: COVARIANCE PARAMETER ESTIMATES	50
TABLE 23: TESTS OF FIXED EFFECTS.	50
TABLE 24: LEAST SQUARE MEANS FOR FIXED EFFECTS FOR DIFFERENT TREATMENT, HERD TEST NUMBER AND LACTATION YEAR COMBINATIONS	50
TABLE 25: EFFECT OF TREATMENT GROUP AND LACTATION YEAR SLICES	51
TABLE 26: ESTIMATED SINGLE SAMPLE CULTURE DIAGNOSTIC TEST PARAMETERS AS ESTIMATED FROM GRIFFIN ET AL., 1977.	53
TABLE 27: TRANSITION PROBABILITIES FOR INFECTION FROM THE START OF THE DRY PERIOD TO PARTURITION WITHOUT DRY COW ANTIBIOTIC THERAPY	65

TABLE 28: TRANSITION PROBABILITIES FOR INFECTION FROM THE START OF THE DRY PERIOD TO PARTURITION FOLLOWING DRY COW ANTIBIOTIC THERAPY .....	65
TABLE 29: RELATIVE RISK OF INFECTION FROM THE START OF THE DRY PERIOD TO PARTURITION FOR COWS TREATED WITH DRY COW ANTIBIOTIC THERAPY COMPARED TO UNTREATED COWS .....	65
TABLE 30: QUANTIFICATION OF RISK FACTOR PROBABILITIES AS OBTAINED FROM INTERNATIONAL LITERATURE REVIEW .....	68
TABLE 31: LIKELY METHODS OF INCORPORATION OF RISK FACTOR PROBABILITIES AS OBTAINED FROM INTERNATIONAL LITERATURE REVIEW INTO MODEL ARCHITECTURE .....	72
TABLE 32: MIXED REGRESSION COEFFICIENT ESTIMATES FOR SCC PREDICTIVE EQUATION.....	75
TABLE 33: REGRESSION COEFFICIENT ESTIMATES OF PREDICTIVE EQUATION FOR DAILY MILK VOLUME (LITRES) ONLY INCLUDING DAYS IN LACTATION AS A PREDICTOR VARIABLE.....	78
TABLE 34: MIXED REGRESSION COEFFICIENT ESTIMATES OF PREDICTIVE EQUATION FOR DAILY MILK VOLUME (LITRES).....	78
TABLE 35: REGRESSION COEFFICIENT ESTIMATES OF PREDICTIVE EQUATION FOR DAILY MILK FAT PERCENTAGE ONLY INCLUDING DAYS IN LACTATION AS A PREDICTOR VARIABLE .....	80
TABLE 36: MIXED REGRESSION COEFFICIENT ESTIMATES OF PREDICTIVE EQUATION FOR DAILY MILK FAT PERCENTAGE.....	81
TABLE 37: REGRESSION COEFFICIENT ESTIMATES OF PREDICTIVE EQUATION FOR DAILY MILK PROTEIN PERCENTAGE ONLY INCLUDING DAYS IN LACTATION AS A PREDICTOR VARIABLE .....	82
TABLE 38: MIXED REGRESSION COEFFICIENT ESTIMATES FOR DAILY PROTEIN % PREDICTIVE EQUATION.....	83
TABLE 39: SURVIVAL PROBABILITIES AND HERD AGE STRATA STRUCTURE FOR ALL 1998 HERD TESTING FARMS OF THE MAFFRA HERD IMPROVEMENT CO-OPERATIVE.....	84

## List of figures

FIGURE 1: BOX PLOTS OF SOMATIC CELL COUNT DISTRIBUTION FOR HERD TESTS OCCURRING BEFORE TREATMENT FOR EACH PATHOGEN GROUP (AT INITIAL CULTURE) .....	40
FIGURE 2: BOX PLOTS OF SOMATIC CELL COUNT DISTRIBUTION FOR HERD TESTS OCCURRING AFTER TREATMENT BUT WITHIN THE LACTATION OF TREATMENT FOR EACH PATHOGEN GROUP (AT INITIAL CULTURE) AND TREATMENT COMBINATION.....	44
FIGURE 3: BOX PLOTS OF SOMATIC CELL COUNT DISTRIBUTION FOR HERD TESTS OCCURRING IN THE LACTATION FOLLOWING TREATMENT FOR EACH PATHOGEN GROUP (AT INITIAL CULTURE) AND TREATMENT COMBINATION.....	45
FIGURE 4 : BOX PLOTS OF SOMATIC CELL COUNT DISTRIBUTION FOR HERD TESTS OCCURRING IN THE LACTATION OF TREATMENT FOR EACH INFECTION STATUS AND TREATMENT COMBINATION .....	46
FIGURE 5 : BOX PLOTS OF SOMATIC CELL COUNT DISTRIBUTION FOR HERD TESTS OCCURRING IN THE LACTATION FOLLOWING TREATMENT FOR EACH INFECTION STATUS AND TREATMENT COMBINATION	47
FIGURE 6: SCHEMATIC REPRESENTATION OF THE BASIC MASTITIS INFECTION MODEL LOGIC.....	60
FIGURE 7: SITES OF RISK FACTOR IMPACT UPON MODEL TRANSITION PROBABILITIES .....	61
FIGURE 8: REGRESSION CURVE OF THE PROBABILITY OF AN INCIDENT CLINICAL CASE OF <i>S AUREUS</i> MASTITIS VERSUS MONTH OF LACTATION WITH ASSOCIATED 95% CONFIDENCE INTERVALS.....	63
FIGURE 9: REGRESSION CURVE OF THE PROBABILITY OF AN INCIDENT CLINICAL CASE OF <i>S UBERIS</i> MASTITIS VERSUS MONTH OF LACTATION WITH ASSOCIATED 95% CONFIDENCE INTERVALS.....	64
FIGURE 10: LOG 10 AVERAGE SCC AND REGRESSION LINE VERSUS DAYS CALVED (SOL) .....	75
FIGURE 11: AVERAGE DAILY LITRES MILK AND REGRESSION LINE VERSUS DAYS CALVED .....	77
FIGURE 12: AVERAGE DAILY FAT PERCENTAGE AND REGRESSION VERSUS DAYS CALVED .....	80
FIGURE 13: AVERAGE OBSERVED DAILY PROTEIN PERCENTAGE AND PREDICTED REGRESSION LINE VERSUS DAYS CALVED .....	82

## List of abbreviations

ABV .....	AUSTRALIAN BREEDING VALUE
AMMTA .....	AUSTRALIAN MILKING MACHINE TRADE ASSOCIATION
BMCC .....	BULK MILK CELL COUNT
CMT .....	CALIFORNIA MASTITIS TEST
COAG. NEG. STAPH .....	COAGULASE NEGATIVE STAPHYLOCOCCUS SPP.
DCT .....	DRY COW THERAPY
DOF .....	DEGREES OF FREEDOM
DRDC .....	DAIRY RESEARCH & DEVELOPMENT CORPORATION
E. COLI .....	ESCHERICHIA COLI
EBMSCC .....	ESTIMATED BULK MILK SOMATIC CELL COUNT
EC .....	ELECTRICAL CONDUCTIVITY
GMSCC .....	GEOMETRIC MEAN SOMATIC CELL COUNT
ICCC .....	INDIVIDUAL COW CELL COUNT
IQCC.....	INDIVIDUAL QUARTER CELL COUNT
LT .....	LACTATION THERAPY
MHI .....	MAFFRA HERD IMPROVEMENT CO-OPERATIVE LTD.
MID .....	MACALISTER IRRIGATION DISTRICT
NAGASE .....	N-ACETYL- $\alpha$ -D-GLUCOSAMINIDASE
NIR .....	NEW INFECTION RATE
PI .....	PRODUCTION INDEX
QIR .....	QUARTER INFECTION RATE
S. AURUES .....	STAPHYLOCOCCUS AURUES
S. UBERIS .....	STREPTOCOCCUS UBERIS
SAMM .....	SEASONAL APPROACH TO MANAGING MASTITIS
SCC .....	SOMATIC CELL COUNT
SCS .....	SOMATIC CELL SCORE
SOL .....	STAGE OF LACTATION (DAYS)
VMRG .....	VICTORIAN MASTITIS RESEARCH GROUP