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**Nutritional, Genetic and Meat Quality Aspects of
Once-Bred Heifer Beef Production Systems in
New Zealand**

**A thesis presented in partial fulfilment of the
requirements for the degree of
Doctor of Philosophy
in Animal Science
at Massey University**

Ali-Akbar Khadem

1994



"In the Name of Allah, Most Gracious, Most Merciful"

ERRATA

Page	Paragraph	Line	Correct	Incorrect
i	2	3	"was"	"were"
vii	1	1	"BEHAVIOUR"	"BEAHVIOUR"
7	2	6	"beef cows reared few calves and"	"beef cows and"
30	1	1	"practised"	"practiced"
33	2	7	"inseminated with"	"mated to"
36	3	1	"the daily faecal output (FO)"	"the daily (FO)"
50	Table 2.5	9	"349.5"	"449.5"
59	1	4	"4 h or 28 h"	"4 h or 24 h"
61	3	7	"sides"	"slides"
82	2	3	"does"	"dose"
83	1	16	"liveweight"	"liveweight"
85	1	4	"anoestrous"	"anoestrus"
86	1	7	"oestrous"	"oestrus"
101	Table 4.3	9	"number of animals 13, 7, 12, 8"	"12, 8, 11, 9"
101	Table 4.3	14	"number of animals 11, 7, 10, 8"	"10, 8, 10, 8"
101	Table 4.3	22	"number of animals 13, 7, 12, 8"	"12, 8, 11, 9"
102	Table 4.4	10	"number of animals 13, 7, 12, 8"	"12, 8, 11, 9"
102	Table 4.4	15	"number of animals 11, 7, 10, 8"	"10, 8, 10, 8"
102	Table 4.4	23	"number of animals 13, 7, 12, 8"	"12, 8, 11, 9"
103	2	1	"None of the heifers"	"None of heifers"
110	2	7	"oversease"	"overseas"
111	3	4	"were"	"was"
114	2	2	"weaning heifers at"	"weaning heifers of"
114	4	2	"herbage is"	"pastures are"
121	2	8	"oestrous"	"oestrus"
134	2	14	"difference"	"differences"
142	2	3	"oestrous"	"oestrus"
143	Table 6.1	9	"oestrous"	"oestrus"
144	2	1	"basis for"	"basisfor"
150	Table 6.2	5,6	".. the gross margin would increase (e.g. by \$5.74, to \$47.42/SU for 3-month-old early-weaned heifers, see below)."	".. the gross margin (e.g. for 3-month-old early-weaned heifers, see below) would increase by \$5.74 to \$47.42/SU"
151	1	2	"\$1-2/SU"	"\$2-4/SU"
163	3	2	"use"	"sue"
186	2	1	"Roberts, J.S. 1986"	" <i>Roberts, J.S. 1986</i> "
195	Table All.1	14	"1.28"	"0.28"
195	Table All.1	18	"(±0.34)"	"(0.81)"
195	Table All.1	19	"(±0.35)"	"(1.05)"

ABSTRACT

Khadem, A.A. 1994: Nutritional, Genetic and Meat Quality Aspects of Once-Bred Heifer Beef Production Systems in New Zealand.

Issues related to the nutrition, management, carcass and meat quality traits, and the profitability of "Once-Bred Heifer" (OBH) beef production systems under New Zealand pastoral conditions were investigated in this research programme. Once-bred heifer beef production systems involve surplus heifers from the dairy industry which are mated to beef sire breeds at about 15 months of age and rear their calves for 3-6 months before being slaughtered at 30-32 months of age. Both the heifer dams and their progeny are thus prime meat-producing animals.

The performance of once-bred v. unbred heifers and of early-weaned (EW) heifers (heifers weaned at day 84 of lactation "L84") v. normal-weaned (NW) heifers (heifers weaned at L147) were studied in the first two trials. In the third trial, Hereford x Friesian (H x F) v. Simmental x Friesian (S x F) heifers offered a restricted herbage allowance (RHA, an allowance to maintain weight) v. normal herbage allowance (NHA, an allowance to grow at 0.6-0.7 kg/d) during mid pregnancy (from pregnancy day 114, "P114", to P214) were studied in an attempt to investigate the effects of dam genotype and prior herbage allowance on the performance of heifer dams (growth rate, reproduction and carcass and meat quality traits) and their progeny (growth rate and weaning weights). A gross margin analysis was also performed to evaluate the profitability of alternative OBH beef production systems.

Once-bred v. unbred Hereford x Friesian heifers consumed similar amounts of herbage organic matter (OM) during the period equivalent to late pregnancy of the former group (4.72 v. 5.15 kg OM/hd/d), but lactating heifers consumed more herbage OM than the comparable unbred group (11.36 v. 9.19 kg OM/hd/d, $P < 0.05$) to support the growth of their calves, as well as themselves. Unbred heifers had greater carcass weights and higher dressing-out percentages than once-bred heifers. However, the differences in other carcass and meat quality traits between the heifer groups were small, indicating that once-bred heifers are capable of producing meat comparable in

quality to that of unbred and empty heifers. Higher gross margins (\$5-10/Stock Unit (SU)) were calculated for once-bred v. unbred heifers.

During the 10 days immediately prior to weaning, NW heifers had organic matter, dry matter and energy intakes which were slightly higher ($P < 0.10$) than those of EW heifers (weaned at L84). Weaning caused a slight weight loss in both early- and normal-weaned heifers for the first 30-45 days post-weaning, but liveweight (LW) was recovered after this period. During L84 - L147, EW heifers had a higher daily liveweight gain (LWG) than NW heifers (0.79 v. 0.51 kg/d, $P < 0.01$). Calves weaned at L84 had significantly lower daily LWG than NW calves during the period L84 - L147 (0.73 v. 1.30 kg/d, $P < 0.001$). This resulted in EW calves being 30 kg lighter ($P < 0.001$) than NW calves at the time of weaning for the latter group. Early-weaned heifers reached the target slaughter weight in March and, overall, had slightly better carcass and meat quality characteristics than those of the normal weaned group. Although similar gross margins were calculated for EW (\$41.68/SU) v. NW (\$42.00/SU) heifers, early weaning offers advantages to OBH beef production systems through increased flexibility of grazing management and selling times for animals.

From P114 until P214, NHA heifers had significantly ($P < 0.001$) higher growth rates (0.72 ± 0.03 kg/d) than the RHA group (0.16 ± 0.02 kg/d). This resulted in a higher LW in NHA heifers at P214 ($P < 0.001$) and P270 ($P < 0.01$) than the RHA heifers. Gestation length, calving score, LW loss at calving and calf birth weight were not affected by dam genotype (Hereford x Friesian v. Simmental x Friesian) or prior herbage allowance. Meat quality traits were not affected by dam genotype, but it was concluded that the use of Simmental x dairy heifers in a OBH beef production system increases carcass weights of heifer dams in comparison to those of heifers derived from traditional British beef x dairy animals. However, gross margins were similar for H x F and S x F heifer groups indicating that little incentive would exist for dairy farmers to use sires of the large European breeds (e.g. Simmental) rather than Hereford sires which are commonly used to mate first-calving heifers in the dairy industry.

The results are discussed in the context of the development of once-bred heifer beef production systems in New Zealand.

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LIST OF ABBREVIATIONS

AFFCO	Auckland Farmers' Freezing Company
L, P, K, G & T	Carcass grades with 1-3, 4-7, 8-12, 13-18 and 19-24 millimeters of subcutaneous fat thickness over the fourth quarter of the eye muscle at the twelfth rib, respectively, based on the New Zealand export beef classification system.
AI	Artificial Insemination
AS	Angus-Sired
CS	Charolais-Sired
Cr ₂ O ₃	Chromic Oxide
CIDR	Controlled Internal Drug Releasing Device
CRC	Controlled Release Capsule
CSH	Compressed Sward Height
cm	centimeter(s)
c.	circa (approximately)
d or D	day(s)
L50	day 50 of Lactation
P260	day 260 of Pregnancy
°C	degree(s) Celsius
DO%	dressing-out percentage(s)
DM	Dry Matter
DMI	Dry Matter Intake
DOMD	Digestible organic matter in dry matter herbage
EW	Early-Weaned
FO	Faecal Output
g	gram(s)
hd	head
ha	hectare(s)
H x F	Hereford x Friesian
H	Height
h	hour(s)
HFRO	Hill Farming Research Organisation
IY	Initial yield
I	Intake
kg	Kilogram(s)
LS	Limousin-Sired
Ltd	Limited
LW	Live Weight
LWG	Live Weight Gain
LD	<i>longissimus dorsi</i> muscle
MAF	Ministry of Agriculture & Fisheries
ME	Metabolisable Energy
MJ	Megajoules

μm	micrometer(s)
mW	micro Wave length
mg	milligram(s)
ml	milliliter(s)
mm	millimeter(s)
mM	millimolar
m	minute(s)
N.R.C.	National Research Council
nm	nanometer
NZ	New Zealand
NHA	Normal Herbage Allowance
NW	Normal-Weaned
OBH	Once-Bred Heifer(s)
OM	Organic Matter
OMI	Organic Matter Intake
OMD	Organic Matter Digestibility
PF	Peak Force
%	percentage
KCl	Potassium Chloride
R630	Reflectance at a wavelength of 630 nanometer
WL	wave length
RHA	Restricted Herbage Allowance
S x F	Simmental x Friesian
cm ²	square centimeter(s)
m ²	square meter(s)
SSH	Sward Surface Height
TDN	Total Digestible Nutrients
L*, a* & b*	the brightness, redness and yellowness, respectively, of meat colour measured by Minolta Chroma Meter II, Minolta Camera Co., Meter Division, Ramsey, NJ, U.S.A.
v.	versus
WB	Warner-Bratzler
WHC	Water Holding Capacity (expressed juice)
W	Width
Statistical terms	
r	correlation coefficient
PSE	Pooled Standard Error of the Mean
SE	Standard Error
SEM	Standard Error of the Mean

CHAPTER ONE

INTRODUCTION

BACKGROUND

Current Systems of Beef Production in New Zealand

Two main types of beef production currently exist in New Zealand, namely the traditional beef breeding cow herd and beef that is produced as a by-product of the dairy industry (Dalton et al. 1980; Baker 1982; Brook 1982; Rattray & Brook 1982; Baker et al. 1986, 1990; Johnson et al. 1986; Morris et al. 1987, 1988, 1990a, 1993a; Nicol 1990, Morris et al. 1991). The beef industry is located predominantly in the North Island where approximately 80% of beef cattle and 90% of dairy cattle are farmed (LIC 1991; NZMWBES 1992, 1993).

The traditional beef cow sector is characterised by a low efficiency of production (meat produced per unit of feed energy), primarily due to the fact that 70-75% of total feed consumed is required for maintenance of the breeding cow and her replacement (Ferrell & Jenkins 1984, 1985; Taylor et al. 1985, 1986; McMillan 1989; Houghton et al. 1990a, 1990b; Morris et al. 1991). The low efficiency is also contributed to by a reluctance on the part of farmers to mate females at about 15 months of age. Nicol & Nicoll (1987) noted that the total lifetime productivity of beef cows would be increased by 0.7 calves if first joining was at 14-15 months rather than the traditional 26-27 months of age. Nunez-Dominguez et al. (1991) also found that, under USA cow-calf rearing systems, cost per unit output value was 6-8% lowered when beef heifers were managed to calve first at 2 rather than 3 years of age and all cows were culled at the optimal 7 to 9 years of age. Little or inappropriate use of crossbreeding to exploit

hybrid vigour and so increase the performance of the cow and calf (Hight et al. 1973; Cundiff et al. 1974; Rahnefeld et al. 1988; McMillan 1989; Baker et al. 1990; Morris & Lowe 1990; Jenkins et al. 1991; Lowman et al. 1993) is another reason for the low efficiency of traditional beef breeding cow systems. Furthermore, a significant number of the beef cow herds are located on steeper or marginal hill country areas which are prone to adverse climatic effects such as the severe East Coast drought during the 1988-1989 season (Morris et al. 1991; NZMWBES 1992, 1993) and are generally most sensitive to any downturn in product prices. Therefore, although the total beef cattle population increased by 1.7% to 4.671 million head during the 1991-1992 season, the extra numbers were mostly from the dairy industry and the number of beef breeding cows increased by only 0.1% to 1.388 million head (NZMWBES 1992). The number of breeding cows increased by a further 2.2% during the 1992-1993 season (NZMWBES 1993), but is still below the 1988-1989 season's figures.

Beef produced from the dairy industry consists of cull cow beef (Rattray & Brook 1982; Taylor 1987), male calves reared for either bull (Brook 1982; McRae 1992) or steer (Everitt et al. 1975, 1980; Morris et al. 1988) beef and some heifers reared to low carcass weights (180-220 kg, Taylor 1987; Newman et al. 1992; NZMWBES 1992, 1993). The current New Zealand dairy cattle population is 3.468 million head with 2.723 million head being in the "mature and heifer" milking cow population (NZMWBES 1993). The total number of adult cattle (beef plus dairy origin) slaughtered annually during the 1992-1993 season was about 2.170 million head (NZMWBES 1993). About 0.3-0.4 million cull dairy cows (Brook 1982; Rattray & Brook 1982; Taylor 1987; Morris et al. 1991), 0.5-0.6 million finished dairy bulls (Parker et al. 1991; McRae 1992) and a small number of beef x dairy heifers generated from dairy farms are slaughtered annually (Brook 1982; Taylor 1987; NZMWBES 1992, 1993). Thus cattle generated from the dairy industry contribute 40-45% of the total number of adult cattle slaughtered annually in New Zealand (Brook 1982; Morris et al. 1991).

Another group of beef-producing animals is the male and female "bobby calves", mostly generated from dairy cows. These number 0.8-0.9 million head per year (Ratray & Brook 1982; LIC 1991; Parker 1991) and are slaughtered as 4- to 14-day-old calves with average carcass weights of 16.1-17.2 kg (Ratray & Brook 1982; Morris et al. 1991; NZMWBES 1993). In fact, New Zealand is the only country in the world that maintains a bobby calf industry (Morris et al. 1991). This industry, while contributing 25-30% of the annual cattle slaughtered by number (Ratray & Brook 1982), yields less than 3% of total beef and veal produced in New Zealand (Morris et al. 1991). This system continues despite the fact that the opportunity exists to rear many of these calves (both male and female, see below) to produce beef for the North American (United States of America and Canada) and North Asian (Taiwan, South Korea, Japan, China and Hong Kong) markets (Thomson 1989a; Joyce 1992; Forgie 1993; NZMPB 1993).

Opportunities to Increase Beef Production

It is obvious that if the 0.9 million male and female bobby calves were reared to heavy weights, the total national beef volume could be increased. The bull beef industry is almost exclusively linked to the dairy sector and with its high gross margins has become well established in New Zealand during the last 2 decades (Baker et al. 1975; McRae 1992; Wright et al. 1993). But, despite this opportunity, a substantial number of male calves (about 425,000 head of dairy origin, Parker 1991; NZMWBES 1992, 1993; NZMPB 1993) are still slaughtered annually as 4-day-old bobby calves. However, the availability of bull calves is declining because most of the Friesian male progeny are being reared and only Jersey or Jersey crosses are left (S.T. Morris 1993, personal communication). With respect to female calves, however, more than 420,000 bobby calves will continue to be slaughtered at 4 days of age unless systems can be developed which permit these calves to be used for beef production with higher gross margins than those of traditional breeding cows or heifer finishing systems (Keeling et

al. 1991).

If dairy farmers are to be encouraged to use beef-type bulls over their dairy cows (i.e. cows due to be culled, those of low genetic merit for dairy production or first calving heifers), then there must be options available to the farmers for the sale of progeny from these crosses. The males from these crosses have the opportunity to enter profitable bull beef production or steer beef finishing systems (Everitt et al. 1975, 1980; Morris et al. 1987, 1988, 1990a; Morris et al. 1991; Parker 1991). The female crosses can either be reared for the light weight local beef market or sold to hill country farmers as crossbred heifers or cows for mating to beef bulls. Much greater potential exists, however, for efficient use of these heifers in the beef industry. Crossbred heifers produced from the mating of beef type bulls (e.g. Hereford) to dairy breed cows (e.g. Friesian) could be reared to 15 months of age, mated to a terminal sire (e.g. Angus or Simmental), calved down at 2 years of age, weaned and then slaughtered at 30-32 months of age. This will be referred to hereafter as the "Once-Bred Heifer" (OBH) beef production system.

The OBH system is biologically more efficient at producing beef than the traditional beef cow system because the dairy industry bears much of the overhead maintenance costs of supplying replacements (Crowley 1973; Taylor et al. 1985; Morris et al. 1991). The OBH beef production system fully exploits heterosis or hybrid vigour in the heifer dam (by use of crossbred females) and calf (by use of a beef terminal sire breed) traits. The resulting crossbred calves, both male and female, should command a premium in weaner sales due to their anticipated high growth performance (Everitt 1967; Bass et al. 1975; Broadbent et al. 1976; Smith et al. 1976; Everitt et al. 1978a, 1978b; Barlow & O'Neill 1978, 1980; Dalton et al. 1980; Morgan & Saul 1981; Kempster et al. 1982; Morris et al. 1987, 1988, 1990a, 1993a; Newman et al. 1989; Baker et al. 1990). More rapid growth of the calves to weaning would also be expected due to superior milk production in their dairy-cross dams (Russel et al. 1979; Wright & Russel 1987; Kress et al. 1990, 1992; Morris & Lowe 1990; Jenkins et al.

1991; Jenkins & Ferrell 1992) compared with calves reared by traditional beef breeding cows. Once-bred heifers could potentially be taken to heavier weights compared to maiden heifers without becoming excessively fat (Joseph & Crowley 1971; Petit 1975; Boucque et al. 1980; Bailey et al. 1991; Keane et al. 1991). This is because the demands of pregnancy and lactation require mobilisation of fat tissue, which may promote leaner carcasses (Joseph 1975; Petit 1975; Boucque et al. 1980; Romita et al. 1981).

The current beef schedule stipulates that "heifer beef" should come from female cattle having no more than six permanent incisor teeth erupted (Kirton 1989). This occurs at around 3 years of age (Andrews 1975), so that once-bred heifers would still command the heifer beef premium despite having borne a calf. In New Zealand, female cattle are graded as either "heifers" or "cows". Carcasses graded as "heifers" consistently have received a premium over beef produced from cows (about 15% per kilogram, based on the AFFCO Feilding Ltd meat schedule prices for the period July 1991 - July 1993).

Despite these potential advantages, the OBH system has not been adopted widely in New Zealand and most dairy-cross heifers continue to be slaughtered as low-value bobby calves. The objective of this study was to provide information which would allow the widespread adoption of profitable once-bred heifer beef production systems in New Zealand.

DEVELOPMENT OF ONCE-BRED HEIFER BEEF PRODUCTION SYSTEMS

Definition and History of Once-Bred Heifer Systems

The once-bred heifer (OBH) beef production system involves breeding heifers at 10-15 months of age and then slaughtering them either soon after calving (Crowley 1973; Roux et al. 1987; Keane 1988; Keane et al. 1991), or following a suckling period of up to 7 months (Brookes & O'Byrne 1965; Boucque et al. 1980; Romita et al. 1981; Waggoner et al. 1990; Vincent et al. 1991).

European countries were the first to establish the OBH beef production system (Brookes & O'Byrne 1965; Crowley 1973). Historically, following a reduction of milk quotas in the European Economic Community (EEC) during the 1970's, the number of dairy cows and consequently the number of progeny (i.e. bulls, steers and surplus heifers) generated from these cows declined, which caused a considerable reduction in total meat production (Brookes & O'Byrne 1965; Crowley 1973; Lowman & Broadbent 1987; Keane 1988). As it was difficult to increase the number of traditional beef cattle rapidly, one way of producing more meat was to utilise all the surplus heifers, which were normally slaughtered at an early age, to rear at least one offspring before slaughter. This had the dual purpose of producing more calves and a higher slaughter weight from the heifer dams. Thus OBH beef production systems were established in most of the EEC countries (Crowley 1973; Allen 1975b; Harte 1975; Petit 1975; Romita 1975). In the beginning, some of these OBH systems were not viable due to practical problems and low economic returns (Crowley 1973; Lowman & Broadbent 1987), but the systems continued to be developed since they were biologically efficient (Crowley 1973; Allen 1975b; Petit 1975; Taylor et al. 1985). During the last two decades, however, the combined effects of the reduction in milk quotas and increasing concern over the poor quality of straightbred cattle from dairy herds for beef production led to renewed interest in producing more beef from

beef x dairy, beef x beef and large European breeds x (beef or dairy) once-bred heifers. Further research into this system was conducted in EEC countries (Boucque et al. 1980; Romita et al. 1981; Roux et al. 1987), the United States of America (Bond et al. 1986; Waggoner et al. 1990; Bailey et al. 1991) and Canada (Vincent et al. 1991). Overall, it has been suggested that once-calved heifers have the capability to produce carcasses and meat with similar quality traits to the meat from maiden heifers. These issues will be discussed further in the following sections.

The Potential Profitability of OBH Beef Production Systems

The profitability of OBH beef production systems in comparison to other beef enterprises (e.g. traditional breeding cows, surplus heifer and bull finishing systems) has been examined in several studies. The use of beef x dairy heifers in traditional cow-calf rearing systems, mating them as yearlings and selling them while still relatively young was found (McMillan 1989) to be more profitable than the use of traditional straightbred beef cows and finally sold at older ages. Taylor (1977) also noted that the more offspring a dam has, the less efficient the production unit becomes because cull-cow meat is produced less efficiently the later the dam herself is slaughtered. Crowley (1973) found that the OBH system, as an intensive beef enterprise, compared favourably with the other systems of beef production in the United Kingdom. The productivity of four systems: 1) a traditional cow-calf rearing system; 2) a OBH system plus a traditional cow-calf rearing system; 3) a traditional cow-calf rearing system in which all offspring for slaughter were male progeny; and 4) a single-sex bred-heifer system, was compared by Taylor et al. (1985). The overall efficiency of food utilisation by animals in groups 2 and 3 was up to 1.08 times higher than that of group 1, but neither could compete with group 4. Waggoner et al. (1990) also found that OBH beef production systems were up to 3.8 times more profitable than traditional cow-calf systems in the United States of America. In addition, a model developed to simulate New Zealand hill country farming conditions by Keeling et al.

(1991), showed a gross margin of \$ 48.45 per Stock Unit (SU) for a OBH beef production system compared with \$ 42.50/SU for a traditional cow-calf system, \$ 31.70/SU for a 20-month heifer finishing system and \$ 52.80/SU for a bull beef system. This demonstrated that surplus heifers from the dairy and beef industries had the potential to be used to produce beef profitably under New Zealand pastoral conditions.

OBJECTIVES OF DEVELOPING OBH BEEF PRODUCTION SYSTEMS FOR NEW ZEALAND

As noted earlier, more than 0.4 million surplus heifers which traditionally have been slaughtered as 4-day-old bobby calves (Kirton et al. 1971; Kirton & Paterson 1973; Morris et al. 1991) or as 18-month-old light weight maiden heifers (Keeling et al. 1991; Morris et al. 1991; Newman et al. 1992; NZMWBES 1993) could potentially be used in OBH systems. The net improvement in export earnings, after correcting for reduced sheep meat production (due to substitution of the OBH system for sheep), and allowing for 20% adoption rate of a OBH system, was estimated to be worth about \$70 million annually (Parker 1991). It is therefore very important to identify the factors that are limiting the use of dairy heifers for beef production, and to define management programmes to increase the numbers of heifer calves that are suitable for beef production.

ISSUES IN THE DEVELOPMENT OF OBH BEEF PRODUCTION SYSTEMS

Choice of Breed

The establishment of OBH beef production systems overseas has been based primarily on the use of surplus heifers from the dairy or beef industries. However, dairy, beef, beef x dairy and *Bos indicus* x *Bos taurus* crossbred heifers mated to beef or large European breeds have been used in several OBH beef production systems to exploit hybrid vigour and so improve the performance of heifer dams and their progeny (Brookes & O'Byrne 1965; Crowley 1973; Schwark 1975; Boucque et al. 1980; Romita et al. 1981; Lowman & Broadbent 1987; Roux et al. 1987; Keane 1988; Waggoner et al. 1990; Bailey et al. 1991; Keane et al. 1991). Schwark (1975) noted that use of beef x dairy heifers in OBH systems enabled heifers to grow faster, produce calves with greater weaning weights, dry-off more quickly after weaning and produce carcasses with better conformation than the straightbred dairy heifers.

Performance of Heifers

Once-bred heifers should be as heavy as possible at mating to achieve reasonable reproductive performance at parturition and high liveweights at slaughter. Morgan (1981) and Bailey et al. (1991) noted that attainment of puberty by all heifers at 14-15 months of age is essential to a system which relies on calving at 2 years of age and slaughter of heifer dams at about 32 months of age. There was, however, a large range both between and within breeds in the weight and age at puberty. Puberty was found to occur when the liveweight of heifers reached about 45-55% of their estimated breed mature weight, at an age range of 320-600 days (Roy et al. 1975). Thimonier & Signoret (1992) noted that *Bos indicus* heifers consistently reach puberty later than heifers of the *Bos taurus* breeds. Dow et al. (1982) noted that under the same management conditions, only 16% of Hereford heifers reached puberty by 12 months

of age compared to 82% of Red Poll heifers. The onset of puberty in different breeds of cattle has been studied by several research workers in New Zealand (Dalton et al. 1975; Pleasants et al. 1975; Morris 1980a, 1984; Smeaton & Winn 1981; Morris et al. 1993a). Pleasants et al. (1975) reported that, under similar management, Friesian (348 d, 218 kg), Angus (368 d, 205 kg) and Friesian x Jersey (368 d, 193 kg) heifers had different ages and weights at puberty. The authors also noted that the weight and age of heifers at puberty were affected by breed of sire and year of birth, in that particular study. Morris (1980a) suggested a critical minimum liveweight of 254 kg for individual beef breed heifers. A target liveweight of at least 270 kg at about 14-15 months of age was suggested for Friesian replacement heifers under New Zealand conditions by Holmes & Wilson (1984). In a beef breed evaluation trial in New Zealand, Morris et al. (1993a) noted that female progeny derived from large European beef breeds x British origin beef breeds v. British beef breeds reached puberty at greater ages, and had lower reproductive performance (especially in less favourable environments) and larger mature size. McMillan (1989) noted that the average mob liveweight at the start of joining for Hereford x Friesian heifers should be more than 260 kg and the heifers should be gaining weight at a rate of about 1 kg/hd/d over joining. Under these conditions, the author suggested, over 90% of heifers will attain first joining at a mean age of about 400 days with pregnancy rates of 75-85% (by use of bulls for 42 days) and 70-80% (by use of CIDRs plus bulls for 28 days). High liveweights at mating for once-bred heifers were, however, recommended (Lowman & Broadbent 1987; Keane 1988; Keane et al. 1991) since these heifers are beef producing animals and the extra weight gain will be converted to meat soon after calving or after suckling of calves for a few months. Keane et al. (1991) reported 353 kg liveweight at mating for 449-day-old once-bred Hereford x Friesian heifers. These heifers were mated to an Angus sire and had a conception rate of about 84%, under the Irish beef production system. In the study of Bailey et al. (1991), Hereford, Red Poll, Hereford x Red Poll, Red Poll x Hereford, Angus x Hereford, Angus x Charolais, Brahman x Hereford and Brahman x Angus heifers were mated at about 14 months of age with an

overall average liveweight of about 308 kg. Roux et al. (1987) noted that straightbred Friesian and Charolais x Friesian heifers reached puberty at about 311 days of age with liveweights of 266 and 283 kg, respectively.

Heifers in OBH systems have been mated naturally (use of entire bulls), artificially (use of the artificial insemination (AI) technique) or by a combination of both methods (Boucque et al. 1980; Romita et al. 1981; Lowman & Broadbent 1987; Roux et al. 1987; Waggoner et al. 1990; Keane et al. 1991). Artificial insemination allows access to bulls of genetic superiority that have been selected on traits such as ease of calving and high growth rates. Oestrus synchronisation is often used in conjunction with artificial insemination to aid the detection of cycling cows and condense the calving pattern to make the management of the herd easier. Conception rates of 76% (in Simmental x Friesian heifers mated by Red Angus and White Park bulls (Waggoner et al. 1990)), 84% (in Hereford x Friesian heifers mated to Angus bulls (Keane et al. 1991)), 28-35% (in Hereford x Friesian heifers subjected to an oestrus synchronisation programme and mated by AI for only one cycle (Lowman & Broadbent 1987)) or 84-89% (in Hereford x Friesian and Charolais x Friesian heifers subjected to AI plus Hereford bulls (Keane et al. 1991)) were reported for OBH heifers delivering their first calf at about 24 months of age.

Dystocia (calving difficulty) is one of the major causes of stillbirth and early postnatal mortalities, especially in first-calving heifers where the incidence of dystocia was found to be up to four times higher than in older cows (Pollak & Freeman 1976). The sex, birth weight and breed of calf, and pelvic area of the dam or her liveweight at calving, were suggested as the major factors causing dystocia in 2-year-old first calving heifers (Bellows et al. 1971a, 1971b, 1991; Laster 1974; Morris 1980b; Axelsen et al. 1981; Dufour et al. 1981; Meijering 1984; Meijering & Postma 1984; Baker et al 1990; Berger et al. 1992; Thimonier & Signoret 1992; Basarab et al. 1993; King et al. 1993). Male calves had twice the incidence of dystocia as female calves in

the study of Axelsen et al. (1981). Bellows et al. (1991) reported that selection for large pelvic area in heifers resulted in increased size of the entire skeleton and increased calf birth weights. It was also found that the ratio of the heifer's pelvic area to her body weight can be used to select heifers that have relatively greater pelvic area per kilogram of body weight and reduce the rate of difficult births by about 10% (Basarab et al. 1993). However, King et al. (1993) reported that neither the liveweight and age of heifers at breeding or calving, nor the calf birth weight, were reliable predictors of dystocia in beef heifers. They suggested that heifers should be bred at 75-80% of their expected calving weight to reduce the risk of dystocia.

The control of dystocia has been more complicated in OBH systems than in other systems. This is because the heifer dams must be grown rapidly to mating and calving since they are to be meat-producing animals soon after calving or after suckling their calves for a few months. Calf mortality rates of 5-28% have been reported for OBH systems (Boucque et al. 1980; Romita et al. 1981; Lowman & Broadbent 1987; Keane et al. 1991). Heifers carrying calves sired by bulls of the large European breeds (e.g. Charolais-sired calves in the study of Boucque et al. (1980)) suffered a high incidence of dystocia (about 35% of calvings were carried out by caesarean operations). However, when small size beef breeds or sires known as easy-calving animals were used to mate yearling dairy, beef x dairy or large European x dairy heifers (Roux et al. 1987; Keane et al. 1991), the incidence of calving difficulty and mortality rates were considerably reduced. For example, only 5% of calvings were scored as 4 or 5 (out of a 1-5 scoring scale) and calf mortality rate was about 5% in the study of Roux et al. (1987).

Several breeds and crosses have been evaluated in terms of heifer growth and carcass weights. Romita et al. (1981) noted that among once-bred Chianina-, Limousin-, Marchigiana-, Piedmontese- and Charolais-cross Friesian heifers, the Chianina x Friesian heifers had highest liveweights at weaning and slaughter. Boucque et al.

(1980) found that Belgian White and Red dual purpose heifers, rearing their calves for about 6 months in intensive or extensive systems, had slaughter weights of 586 v. 567 kg at about 31 months of age. In the study of Bailey et al. (1991), feedlot performance (growth rate of 1.14 kg/d and slaughter weight of 520 kg) was similar in once-bred *Bos taurus* straightbred, *Bos taurus* x *Bos taurus* crossbred and *Bos indicus* x *Bos taurus* heifers rearing their calves for 6 months under range conditions and slaughtered at about 32 months of age after being finished on a lucerne-based feedlot ration for about 3 months post-weaning. Keane et al. (1991) noted that once-bred Charolais x Friesian heifers, weaned 6 days post-partum and finished for about 4 months, had slightly higher liveweights than Hereford x Friesian heifers at slaughter (539 v. 522 kg for the former and latter groups of heifers, respectively).

Performance of Progeny

In OBH beef production systems both heifer dams and their progeny are beef-producing animals and the greater the weight of heifer dams and their calves at weaning the more profitable the system should be. Calves with greater birth weights were found to have a higher incidence of dystocia at calving and consequently lower survival rates to weaning (Bellows & Short 1978; Boucque et al. 1980; Morris 1980b; Bellows et al. 1982, 1991). Boucque et al. (1980) noted that male and female calves sired by Charolais bulls and borne by once-bred Belgian White and Red heifers had an average birth weight of 44.5 kg, and about 20% of them were dead within 24 hours post-partum due to dystocia problems. The authors suggested that the high mortality rate was partly due to the conformation of Charolais-sired progeny, but high birth weight could also be a causal factor. The surviving calves, in that study, were weaned with an average weight of 180 kg at about 6 months of age. Romita et al. (1981) noted that calves born to once-bred Chianina x Friesian v. (Limousin, Marchigiana, Piedmontese or Charolais) x Friesian heifers and sired by Piedmontese bulls had greater liveweights at birth and weaning (7 months of age). However, the highest level

of calf mortality (29%) at parturition, in that study, was in calves born to Piedmontese x Friesian heifers, these calves having birth weights of only 38.9 kg (v. 41.7 kg in calves born to Chianina x Friesian heifers). Keane et al. (1991) found that calves born to once-bred Charolais x Friesian or Hereford x Friesian heifers, and sired by Angus or Hereford bulls, had similar birth weights (average 37 kg) and similar levels of dystocia at parturition.

Birth weight, sex, age at weaning and breed of calf, and age and milking ability of dam have been factors affecting the weaning weight of the calf in cow-calf rearing systems (Preston & Willis 1974; Morgan & Saul 1981; Baker et al. 1990; Dinkel et al. 1990; Morris et al. 1993a). Preston & Willis (1974) noted that birth weight has a significant effect on weaning weight but the relationship is not close. Male calves were found to grow faster and have greater weaning weights than their female counterparts of similar age (Everitt et al. 1978a, 1978b; Morgan & Saul 1981; Baker et al. 1990; Morris et al. 1993a). Baker et al. (1990) noted that the average liveweight of progeny of large European (Blonde d'Aquitaine, Charolais, Chianina, Limousin, Maine Anjou, Simmental, South Devon) x Angus cows was greater than that of Hereford x Angus or straightbred Angus progeny, at 13-months of age, in several environments in New Zealand. Calves reared by Hereford x Friesian dams with higher daily milk production had heavier calves at weaning than those reared by Blue Grey cross dams with lower milk producing ability in the study of Russel et al. (1979). Two-year-old v. 5-year-old cows reared calves weighing 154 and 185 kg at weaning (about 5 months of age) in the study of Morris et al. (1993a).

In summary, numerous breeds and crosses have been used in OBH systems overseas. The choice of heifer and sire of calf breed is an important consideration because it may affect heifer growth and carcass value, reproductive performance, the incidence of dystocia, and calf survival, growth and sale value. The development of OBH systems in New Zealand is likely to rely primarily on the use of crossbred heifers produced by

Friesian and Jersey dairy cows, simply because these breeds account for about 92.7% of the total dairy cows farmed (LIC 1991). At least initially, these heifers will be sired mainly by Angus and Hereford bulls since these are the non-dairy sire breeds used predominantly by the New Zealand dairy industry and have been recommended as small size sires for breeding heifers as yearlings (McMillan 1989; Morris et al. 1993a). However, opportunity exists to use bulls of other breeds both to generate the heifers and to sire their calves if the alternative breeds can be shown to have an economic advantage.

Feeding Policy

Feeding strategies for once-bred heifers must be devised to allow early puberty and high conception rates to first mating, and maximise heifer and calf liveweight gains to slaughter or sale, but at the same time minimise the incidence of dystocia and ensure survival of the heifer and her calf. As with the choice of heifer and sire-of-calf breed, a key issue is the conflict between growth of the heifer/calf and the need to minimise dystocia problems.

Performance of Heifers

It is well known that a low plane of nutrition, from weaning to mating, in heifers results in a delayed first oestrus because the onset of oestrus (puberty) is more closely related to the liveweight achieved than to the age of heifers (Roy et al. 1975; Roux et al. 1987). An average liveweight at puberty of 242 kg was reported for 347, 305, 288, 301 or 239-day-old British Friesian heifers growing at 0.58, 0.68, 0.75, 0.82 or 1.06 kg/d, respectively, from 3 to 12 months of age, by Little et al. (1981). Compared to traditional dairy or beef replacements, a slightly heavier liveweight has been recommended for once-bred heifers at mating (Lowman & Broadbent 1987; Keane 1988), since these heifers are both lactating and meat-producing animals and the extra

liveweight achieved can be converted to valuable meat at slaughter soon after calving or after a calf rearing period. In overseas studies, heifers obtained from dairy farms have been grown at 0.5-1.0 kg/d to achieve target mating liveweights of 270-380 kg at 12-18 months of age (Brookes & O'Byrne 1965; Crowley 1973; Allen 1975a; Harte 1975; Boucque et al. 1980; Lowman & Broadbent 1987; Roux et al. 1987; Keane 1988; Bailey et al. 1991; Keane et al. 1991). After being finished on a concentrate-based ration on feedlots, following range or pasture grazing, heifer dams were slaughtered with liveweights of 450-595 kg at 24-32 months of age.

As noted earlier, heifers mated as yearlings normally suffer higher levels of dystocia at parturition than do older cows. Morris (1980b) reported that calving difficulty was expected to rise by approximately 1.8% per 1 kg increase in birth weight of the calf. It has been suggested that the incidence of dystocia could be reduced by restricting the feeding level of heifers during pregnancy in an attempt to reduce the fatness of heifers (especially in the birth canal) and the birth weight of calves (Tudor 1972; Bellows & Short 1978; Axelsen et al. 1981; Bellows et al. 1982, 1991; Meijering 1984). Restricted feeding policies (at maintenance or sub-maintenance levels) during the last 21-150 days of pregnancy have been studied in heifers used in OBH beef production systems or as traditional beef replacements (Corah et al. 1975; Hodge et al. 1976; Nicoll 1979; Morris 1980b; Anderson et al. 1981, 1985; Little et al. 1981; Bellows et al. 1982, 1991; Nicoll et al. 1984; Pleasants & Barton 1987, 1992b; Whittier et al. 1988; Keane et al. 1991). Bellows et al. (1978), Morris (1980b) and Axelsen et al. (1981) reported that pre-calving feeding levels could affect birth weight, but that this was not always associated with a reduction in dystocia. Bellows et al. (1991) suggested that low feeding levels during the last one-third of pregnancy will not result in predictable effects on dystocia but will be detrimental to all aspects of rebreeding of the dam (the latter issue, of course, being irrelevant to once-bred heifers). Keane et al. (1991) also found that pre-calving feeding level did not significantly affect calf birth weight or calving difficulty in OBH dams, and that heifers offered a medium (slightly

above maintenance) feeding level, during the last 72 days pre-calving, had slaughter weights about 17 kg lower than those offered a high level of nutrition. In the study of Bond & Weinland (1978), heifers were fed at levels equivalent to 40, 60, 80, 100, or 140% of total digestible nutrient (TDN) requirements for growing and reproducing heifers, from 7 months of age through to calving at about 28 months of age. The heaviest dams at calving were those in the 140% TDN group (which also had the highest level of calf mortalities), but those in the 60, 80 and 100% groups had greater calf numbers surviving to calving and weaning.

It has also been reported that a severe nutritional restriction (a sub-maintenance level) during the last few months of pregnancy in 3- to 8-year-old cows reduced calf birth weight by 20-22% (Hight 1966, 1968a), 9% (Scales et al. 1977), 22% (Tudor 1972) or 15% (Russel et al. 1979). However, severely restricted feeding is not recommended for once-bred heifers since these heifers are meat-producing animals and, if they were fed at a below maintenance level during pregnancy, it would be impossible for them to compensate for liveweight losses caused by both calving (13-14% of dam liveweight at calving, Roux et al. 1987) and restricted feeding policies. This is especially true if the heifer dams are to rear their calves, rather than being weaned at birth. However, since there is evidence showing that early- and mid-pregnancy feeding in sheep (Robinson et al. 1977) and cattle (Bond & Weinland 1978) may affect subsequent foetal growth, research is required to find an appropriate level of feeding from early pregnancy through to calving, and its effect on the calf birth weight and incidence of dystocia, in once-bred heifers under New Zealand conditions.

Performance of Progeny

The effect of submaximal nutrition of the dam during pregnancy on the birth weight of the calf is dependent on the severity of the restriction imposed (Hight 1966, 1968a; Tudor 1972; Bellows & Short 1978; Bond & Weinland 1978; Morris 1980b; Bellows et al. 1982, 1991; Pleasants & Barton 1985, 1992a). Tudor (1972) found that a sub-maintenance ration fed to cows during the last 90 days of pregnancy significantly reduced the mean calf birth weight by 6.8 kg to 24 kg, compared with weights of calves born to heifers fed an above-maintenance diet. Dam feeding level, however, did not influence calf mortality rates or the incidence of dystocia in that study. In agreement with these findings, Bellows & Short (1978) reported that calves born to heifers exposed to a low or high level of a drylot ration (i.e. at a level of 1% v. 2% of their body weight) during last 90 days of pregnancy had significantly different birth weights (26.6 v. 28.5 kg) but that a lower calf birth weight did not affect the incidence or severity of calving difficulty. Corah et al. (1975) reported that calves borne by heifers restricted in energy pre-partum (65% of N.R.C. recommended) had lighter calves at birth but the calves were born with the same degree of calving difficulty as calves of adequately (100% of N.R.C. recommended) fed dams. A greater proportion of calves from nutritionally deprived heifers died at or near birth, in that particular study, and the surviving calves in this group were lighter at weaning than their counterparts borne by the 100% fed dam group. Thus while restricted nutrition (particularly severe restriction) of the heifer dam can reduce calf birth weights, this is not always associated with a reduction in the incidence of dystocia. Furthermore, low birth weights may actually disadvantage calves in terms of their ability to grow to high weaning weights.

Weaning Time

Beef breeding cows have traditionally been weaned at greater than 5 months of calf age based on the assumption that the higher the calf weaning weight, the more profitable the cow-calf system (Barton 1970; Basarab et al. 1986). However, in practice, the choice of weaning date is usually based on managerial convenience. In New Zealand, early weaning has been defined as "weaning calves before six months of age" (Hughes & Acland 1970). Heifers used in OBH beef production systems are "suckling cows", and the weight of their progeny at weaning is a good indicator of their productivity. However, these heifers are also prime beef producers, and there may be some merit in early weaning (including weaning a few days after calving) and then growing both heifer dams and their calves on high quality feeds through to slaughter especially in the very seasonal pasture supply system typical of New Zealand. Since neonatal calves in cow-calf rearing systems in New Zealand are solely dependent on the milk of their dams, research is required to find an appropriate time of weaning which optimises cow and calf production under pastoral systems of OBH beef production.

Performance of Heifers

Neville (1970) suggested that, under range conditions, feed utilisation would be more efficient and the cost of maintaining cows and calves could be lowered if calves were weaned early and fed a high-energy ration for maximum growth while their dams were fed at a maintenance level. Neville & McCormick (1981) found that 2-year-old heifers and mature cows weaned at 67 days post-calving had higher growth rates than those weaned at day 230 of lactation when the comparison was made from day 67 to day 230 of lactation for the latter group. In addition, Basarab et al. (1986) reported that heifer dams (2- to 3-year-old) or mature cows weaned at month 5 of lactation and grazed on native pastures had higher growth rates than those weaned at month 6 of lactation

when the comparison was made from month 5 to month 6 of lactation for the latter group. Other research conducted in both dairy and beef cattle rearing systems (Percival 1951; Aitken et al. 1963; Hight 1968b; Bellows et al. 1974; Donnelly & Fennessy 1978; Lusby et al. 1981; Holroyd et al. 1988; McCall et al. 1988; Sullivan et al. 1992) has shown that early weaning increases cow liveweight gain and decreases the post-partum anoestrus interval (which is not directly relevant to OBH systems) compared to later weaning. In the study of Hight (1968b), 3-year and older Angus cows weaned at earlier stages (weeks 14, 18 and 22 of calf age) onto hill country pastures, and used for roughage and fern control, lost less weight than those suckling their calves. The author suggested that the milking cows effectively served as a buffer for the calf during times of adverse feed conditions, between early and late weaning.

There has been, however, no reported study comparing the performance of once-bred heifers and their progeny weaned at different stages of lactation. In overseas OBH systems, heifers are typically weaned either a few days post-partum and then fattened before slaughter (Roux et al. 1987; Keane 1988; Keane et al. 1991) or suckled for up to 7 months and then slaughtered immediately after weaning or after a short finishing period on high energy-based ration (Boucque et al. 1980; Romita et al. 1981; Bond et al. 1986; Waggoner et al. 1990; Bailey et al. 1991; Vincent et al. 1991).

Performance of Progeny

Neville & McCormick (1981) found that beef calves weaned early (at 67 days of age), and fed with a concentrate-based diet on pasture or in a drylot, had higher weights at 230 days of age than the calves still suckling their dams. Lusby et al. (1981) reported that a group of calves weaned at 6-8 weeks of age and reared on a drylot had similar liveweights to calves suckling their dams and weaned at 7 months of age. However, in the study of Basarab et al. (1986), calves weaned at 5 months of age, and fed a grain-based diet with hay, had significantly lower daily liveweight gains than calves suckling

their dams and weaned at 6 months of age (0.16 v. 0.75 kg/d for early- and late-weaned calves from month 5 to 6 of the suckling period for the latter group). These results indicate that if suckling calves are weaned early and fed with a good quality concentrate-based ration their growth rates will generally be at least comparable to those of later weaned calves. Of greater relevance to New Zealand, however, are studies based on all-pasture systems. In this context, weaning times of 14, 18 or 22 weeks of age onto spelled hill country pasture (at Whatawhata Research Centre in New Zealand) with hay available to appetite, was chosen for calves borne by 3- to 8-year old Angus cows in the study of Hight (1968b). Calves weaned later, in that study, grew about 0.46 kg/d faster to 26 weeks of age than those weaned at earlier ages. Results from another 2-year study at the same research centre (McCall & Scott 1988) demonstrated that, when groups of calves, borne by Angus or Angus x Friesian cows, were weaned at about 3.5 months of age and offered pastures with 1500-2300 kg DM/ha as the only feed source, they were on average 14 kg lighter at about 5 months of age than calves still suckling their dams. Australian studies have also shown that calves weaned at 5 months of age and grazed under tropical range conditions had 57.4 kg lower liveweights than their counterparts suckling grazing cows and weaned at 8 months of age (Holroyd et al. 1988). Thus, in pastoral systems, early weaning is likely to increase the slaughter weight of heifer dams but at the expense of liveweight gain in their calves.

Carcass and Meat Quality Characteristics

The pioneer studies of OBH beef production systems (Brookes & O'Byrne 1965; Joseph & Crowley 1971, Joseph 1975; Petit 1975) showed little or no significant difference between the carcass and meat quality characteristics of once-bred v. unbred heifers. However, during the last two decades, further investigations have been conducted to study the effects of breeding, genotype, nutrition and time of weaning on the carcass and meat quality traits of once-bred heifers.

Effects of Breeding

Carcass weight, dressing-out percentage (DO%), carcass composition (the proportion of meat, bone and fat in the carcass), carcass conformation, ultimate pH, colour, cooking loss and tenderness of meat of once-bred v. unbred heifers have been evaluated in several studies. Bond et al. (1986) found that once-bred heifers slaughtered a few weeks post-partum had carcasses with lower DO% than unbred heifers finished on the same ration and slaughtered at similar liveweights. Roux et al. (1987) also noted that once-calved heifers finished for 120 days, after suckling their calves for 2-3 days, had lower DO% than empty heifers finished for 70 days and slaughtered at a similar age to the former group. Likewise, empty heifers slaughtered at 22 months of age had higher DO% than 32-month-old once-calved heifers that received the same diet during the last 3-4 months prior to slaughter and produced carcasses with similar weights to the empty group (Bailey et al. 1991). In the study of Vincent et al. (1988), once-bred heifers, slaughtered following suckling periods of up to 7 months, had higher carcass weights but a lower DO% (adjusted to a constant fatness) than unbred heifers slaughtered 10 months younger. Waggoner et al. (1990) also found higher DO% in 29-month-old empty heifers than in heifers calved once and slaughtered at 30 months of age (63.0 v. 60.7%). However, the difference was probably partly due to the higher mean carcass weight of the empty heifers, in that particular study, as DO% is known to increase with carcass weight (Field et al. 1966; Field & Schoonover 1967).

No significant difference in DO% was reported between unbred and calved Belgian White and Red dual-purpose heifers that were slaughtered after reaching a similar level of fatness (Boucque et al. 1980). In addition, Lowman & Broadbent (1987) reported that once-bred heifers weaned a few days post-partum and then finished with a mixture of pasture and barley for 4 months had 2% higher DO% than empty heifers slaughtered

4 months younger. However, the higher DO% was most likely due to the higher slaughter weights of calved heifers in that study. Thus, these studies suggest that if calved and unbred heifers are slaughtered at a uniform level of fatness regardless of age, then their DO% will be similar or slightly lower for the calved group.

Boucq et al. (1980) reported that carcasses of once-calved heifers were 5 cm longer than those of unbred heifers. In addition, both Lowman & Broadbent (1987) and Sinclair et al. (1989) reported lower conformation scores for calved heifers relative to empty heifers, and suggested that this was due to a slackening of the pelvis which allowed the carcasses of calved heifers to hang in a more angular shape. On a proportional basis, when the carcass data were adjusted to a constant total dissectible fat content, the once-bred heifers tended to produce more bone and less meat than unbred heifers that were slaughtered 12 months younger (Vincent et al. 1991). However, these differences would be related partly to the greater carcass weights of the calved heifers. In the study of Bailey et al. (1991) a significantly higher unadjusted mean total dissectible bone percentage was reported for 32-month-old calved heifers relative to a 22-month-old unbred group at a similar carcass weight. In addition, calved heifers in the study of Waggoner et al. (1990) had higher bone maturity scores than empty heifers. However, Roux et al. (1987) found that calved heifers suckling their calves for 2-3 days had similar total bone weights to empty heifers slaughtered at a similar weight and age.

Sinclair et al. (1989) found a lower total fat yield in the carcasses of calved v. unbred heifers. Other studies (Waggoner et al. 1990; Bailey et al. 1991; Vincent et al. 1991), however, found significantly higher intramuscular fat percentages and fat thicknesses in calved heifers relative to the unbred group. Vincent et al. (1988, 1991) showed that once-bred heifers offered grain-based rations for 5 or 7 months while suckling their calves prior to slaughter tended to be fatter and have a lower carcass lean percentage than the conventionally managed heifers or the OBH group which received the same

ration for 3 months prior to slaughter. However, the differences were presumably partly due to the higher carcasses in calved v. empty heifers.

Rib-eye areas were not significantly different between bred and unbred heifers in the studies of Waggoner et al. (1990) and Bailey et al. (1991). A significantly higher percentage of saleable meat was reported for calved heifers relative to an empty group in the study of Sinclair et al. (1989). In contrast, Boucque et al. (1980) showed no differences in total meat yield between calved and unbred heifers. In the study of Joseph (1975), Aberdeen Angus-cross once-calved heifers had similar total boned-out cut weights to maiden heifers. However, heavier back-cuts and lighter hindquarter cuts were recorded for calved heifers in that particular study. Similar yield grades were reported for empty and calved 29- to 30-month old heifers in the study of Waggoner et al. (1990). In addition, calved and empty heifers slaughtered at about 24 months of age had similar total meat yield in a OBH beef production system reported by Roux et al. (1987).

Similar meat ultimate pH values were reported for empty and calved heifers in the studies of Dumont et al. (1987) and Bailey et al. (1991). However, conventionally reared heifers had lower meat ultimate pH values than once-bred heifers in the study of Vincent et al. (1991), and the authors suggested that this was due to the OBH being slaughtered within a few days of weaning. Whereas Dumont et al. (1987) noted that pregnancy and calving had no effect on the lean colour of heifers, Bailey et al. (1991) found that beef from once-calved heifers was slightly darker than that from unbred heifers. In addition, in the study of Waggoner et al. (1990), unbred heifers had the lightest visually assessed lean colour, but empty and calved heifers had similar meat colour. A darker meat colour was also reported for once-bred v. unbred heifers in the studies of Bond et al. (1986) and Vincent et al. (1991). Vincent et al. (1991) suggested that the darker meat from once-calved heifers was most likely due to an increase in the myoglobin concentration in muscle, as this increases until an animal is about 36

months old.

Dumont et al. (1987) and Vincent et al. (1991) found that meat from unbred heifers was juicier than that from bred heifers. However, sensory panel juiciness scores and cooking loss percentages were not different among treatment groups in the studies of Joseph & Crowley (1971), Bond et al. (1986) and Waggoner et al. (1990). Consumer-panel tests in the trial of Vincent et al. (1991) indicated that once-bred heifers (that had suckled their calves for 3 to 5 months) and conventionally reared heifers produced beef with similar meat tenderness scores.

Effects of Genotype

Hereford x Angus heifers had slightly higher DO% than Hereford x dairy Shorthorn heifers in the study of Brookes & O'Byrne (1965). Likewise, Roux et al. (1987) found that, at the same mean age, once-bred Charolais x Friesian heifers had higher liveweights, greater carcass yields, and higher carcass weight-adjusted DO% (54 v. 52%) than Friesian heifers. In the study of Bailey et al. (1991), DO% was similar in once-bred Hereford, Red Poll, Hereford x Red Poll, Red Poll x Hereford, Angus x Hereford, Brahman x Hereford and Brahman x Angus heifers, with Angus x Charolais heifers having a slightly higher DO% than the others. Romita et al. (1981) reported that, among once-bred (Chianina, Limousin, Marchigiana, Piedmontese and Charolais) x Friesian heifers, Limousin x Friesian heifers had the lowest slaughter weights with no dam genotype effects on DO% of heifers.

Genotype effects were reported for the abovementioned once-bred heifers' carcass composition. Romita et al. (1981) found that Piedmontese x Friesian heifers had the highest quantity of dissectible meat and the lowest percentage of fat, but that the Chianina x Friesian heifers produced more bone than the other crosses. Although breed types were equivalent in fat thickness in the study of Bailey et al. (1991),

Hereford and Brahman x Hereford heifers were above average in percentage of total bone and Angus x Hereford dams ranked highest in marbling scores. Roux et al. (1987) also found that, at similar carcass weights, once-bred Friesian heifers produced less meat and bone but more fat than Charolais x Friesian heifers.

Dumont et al. (1987) reported that the meat of Friesian heifers was darker in colour than that of Charolais x Friesian crosses with a better water-holding capacity in the latter group. However, meat of all genotypes had similar colour (brightness) in the study of Romita et al. (1981). Bailey et al. (1991) also found no effects of dam genotype on the meat ultimate pH or meat colour of bred heifers of different breed types.

Among the various once-bred heifer genotypes in the study of Romita et al. (1981), Piedmontese x Friesian heifers produced meat with the highest tenderness values. However, there was no dam genotype effect on the tenderness of meat of once-bred *Bos taurus* straightbred and crossbred animals, and *Bos indicus* x *Bos taurus* heifers in the study of Bailey et al. (1991). Likewise, meat samples from the *longissimus dorsi* of once-bred Charolais x Friesian or Friesian heifers had similar tenderness values in the study of Dumont et al. (1987).

Effects of Feeding Policy

The effects of feeding levels, at different stages of life, on the carcass and meat quality characteristics of once-bred heifers have been evaluated in only a few studies. Roux et al. (1987) examined once-bred heifers that gained 0.70 (moderate) or 0.90 (high) kg/d from month 5 through to mating at 10 months of age onwards, calved at 20-24 months of age, suckled their calves for 2-3 days, and were slaughtered after being fed a concentrate-based ration for about 3 months. Heifers in the "moderate gain" group produced carcasses with higher meat, and lower fat and bone, proportions than those in

the "high" group while the weights of carcasses were similar. The meat quality traits of these heifers, evaluated by Dumont et al. (1987), were not affected by pre-mating feeding levels. Keane et al. (1991) also found that feeding levels (maintenance or slightly above maintenance v. high levels) during the last 42-72 days of pregnancy did not affect carcass weight, DO% or proportions of meat, bone and fat in carcasses of bred heifers. In the same study (experiment 2), however, when a short (58 days) or long (93 days) period of finishing at pasture was involved, heifers in the short finishing period group produced lighter (267 kg) carcasses than those in long finishing period (281 kg) group. The DO% of heifer dams in the two groups was similar and heifers in the short finishing period group produced carcasses with higher proportions of meat, and lower proportions of fat and bone, than those in long finishing period group. These results indicate that feeding heifers at an *ad libitum* level for long periods post-weaning will increase the amount of fat in carcasses which may be a disadvantage.

Effects of Weaning Time

Brookes & O'Byrne (1965) reported that once-calved heifers weaned 24 hours post-partum or after 10 weeks lactation, and slaughtered at similar ages, produced carcasses with similar DO%. In addition, bred heifers, weaned at day 10 or day 210 of lactation and slaughtered at different ages (day 10 or day 240 post-partum), had similar DO% in the study of Romita et al. (1981). Vincent et al. (1988) also reported that DO% (adjusted to a constant fatness) was not affected by the time of weaning when once-calved heifers were slaughtered immediately after weaning at 3-, 5- or 7-months of lactation. However, bred heifers slaughtered immediately after weaning, at day 7 v. days 24 or 42 of lactation, had lower DO% in the study of Bond et al. (1986). The lower DO% in once-bred heifers slaughtered at 7 days post-partum in the Bond et al. (1986) study indicates that calved heifers slaughtered at later stages, post-weaning, become fatter and produce carcasses with a higher DO%.

Romita et al. (1981) found that heifers rearing their calves for 210 days and slaughtered at day 240 post-partum v. those slaughtered 10 days after calving tended to produce carcasses with a lower proportion of meat and bone but an increased proportion of fat (i.e. subcutaneous, intramuscular and total fat). Bond et al. (1986) also noted that once-bred heifers slaughtered 24 or 42 days v. 7 days post-partum had carcasses with thicker subcutaneous fat depots. In addition, heifers rearing their calves for 3, 5 or 7 months and slaughtered soon after weaning, in the study of Vincent et al. (1991), produced carcasses with different subcutaneous fat thickness (8.8, 12.8 and 12.0 cm for the three groups, respectively), similar bone weight and different lean content (heifers in the 5 and 7 months groups had greater amounts of lean meat). These results were achieved when the values were adjusted to a constant side fat content. However, Lowman & Broadbent (1987) reported similar carcass traits (saleable meat weight, fat and bone yields) for similar carcass weights of once-bred heifers slaughtered after rearing their calves for 6 or 12 weeks.

Carcass conformation was not affected by time of weaning in the studies of Romita et al. (1980), Bond et al. (1986) and Lowman & Broadbent (1987). Vincent et al. (1991) reported that in once-calved heifers slaughtered a few days after weaning at months 3, 5 or 7 of lactation, the proportions of carcasses graded as class 1 (youthful), on the Canadian carcass grading system, decreased when heifers suckled their calves for more than 3 months.

Heifers weaned 10 days post-calving and slaughtered immediately post-weaning had darker muscle tissue than those rearing their calves for 210 days and slaughtered at about day 240 post-calving (Romita et al. 1981). The authors suggested that the darker meat in the former group was due to the stress of calving and lower quantity of intramuscular fat. In the study of Vincent et al. (1991) heifers suckled for 7 months, and slaughtered a few days post-weaning, produced meat with higher pH than those

suckled for a 3 or 5 month period and slaughtered soon after weaning. Brighter meat was, however, found in heifers slaughtered at month 5 of lactation than in the other two groups.

Tenderness of the *longissimus dorsi* muscle was not affected by weaning time in the studies of Romita et al. (1981) and Bond et al. (1986). Likewise, Vincent et al. (1991) noted that the rib-eye steaks of once-bred heifers slaughtered following 3, 5 or 7 months of lactation had similar consumer acceptability. However, meat of the 7-month group, in that particular study, had a higher amount of connective tissue, when evaluated by a trained panel, than meat of the other two heifer groups.

In summary, these studies have shown that, despite calving and suckling their calves for up to seven months of age, once-bred heifers are able to produce carcasses with similar meat quality characteristics to that of traditional maiden heifers. Although differences have been found for some carcass traits (e.g. dressing-out percentage) of bred v. unbred heifers, many of the comparisons that have been made are confounded to some degree by differences between the groups in age and/or carcass weight. Once-bred heifers produced carcasses with lower conformation scores than maiden groups, but greater proportions of lean meat have been produced by bred heifers in some studies. Once-bred beef x dairy or large European breeds x dairy heifers tended to produce heavier carcasses with better conformation scores than those of straightbred dairy heifers. The high fat levels in carcasses produced by once-bred heifers finished on a very high energy ration suggest that finishing heifers for long periods post-weaning on rations of this type should be avoided. However, that is not a situation specific to once-bred heifers.

PUPROSE AND SCOPE OF THE INVESTIGATION

Once-bred heifer beef production systems are not currently practiced to any degree in New Zealand. Nevertheless, there exist considerable research data showing that mating heifers at 15 months of age can be successful (Dalton et al. 1975, 1980; Pleasants et al. 1975; Nicoll 1979; Jury & Everitt 1980; Anderson et al. 1981, 1985; Smeaton & Winn 1981; Morris 1984; Nicoll et al 1984; Pleasants & Barton 1987, 1992; McMillan 1989; McMillan & McCall 1992; Morris et al. 1993a) and, if farmers were assured of the profitability of OBH systems, these systems could be widely implemented under New Zealand pastoral conditions (Spelman 1990). Although OBH systems have been extensively studied in the Northern Hemisphere, the results of these studies bear only limited relevance to the New Zealand situation because most were not based on pastoral systems and the heifer breeds/crosses used were generally not those which might be used, at least initially, in this country (primarily Hereford-or Angus-crosses with the Friesian or Jersey). The objective of this study was therefore to examine issues related to the development of profitable OBH systems in New Zealand. Specifically, the present study evaluated:

1. The growth performance, feed intake, and carcass and meat quality characteristics of bred v. unbred heifers.
2. Effects of early weaning on growth, feed intake, calf production, and carcass and meat quality characteristics of once-bred heifers.
3. The attributes of various heifer crosses and sire-of-calf breeds in terms of heifer and calf performance.
4. The relative feed utilisation and economic efficiencies of alternative once-bred heifer systems.

The ultimate objective of the programme was to develop a series of recommendations that would facilitate the adoption of once-bred heifer systems in New Zealand.

CHAPTER TWO

HERBAGE INTAKE, INGESTIVE BEHAVIOUR AND GROWTH PERFORMANCE IN UNBRED AND ONCE-BRED HEREFORD X FRIESIAN HEIFERS

ABSTRACT

The once-bred heifer beef production system involves mating heifers at 15 months of age to calve as 2-year-olds. This study compared the lifetime performance of once-bred v. never-pregnant Hereford x Friesian heifers. Liveweight gains (mean \pm SE) of 0.60 ± 0.01 v. 0.35 ± 0.03 kg/d were recorded for never-pregnant v. calved heifers from purchase (October 1989) until slaughter (November 1990 and May 1991 for the calved and never-pregnant heifers, respectively). Heifers carrying Limousin-sired (LS) calves had gestation lengths slightly longer than those carrying Charolais-sired (CS) calves (290.4 v. 286.6, PSE = 1.2 days, $P < 0.10$), but there was no effect of calf sex on gestation length. The average birth weight of calves was 40 ± 1 kg there being no difference between female and male, or LS and CS calves. Dystocia caused mortality rates of 19% in calves and 9% in heifer dams. Female calves had 9 kg lower weaning weights at 142 days of age than male calves, while the CS calves had greater weaning weights than LS calves (218.3 v. 204.9, PSE = 3.6 kg, $P < 0.01$). Dam weaning weights (kg) were 443.5 v. 394.7 (PSE = 9.5 kg, $P < 0.01$) and 437.5 v. 400.7 (PSE = 9.5 kg, $P < 0.05$) in heifers suckling female v. male or LS v. CS calves, respectively. Pregnant and never-pregnant heifers had similar ingestive behaviour, herbage intake (estimated using intraruminal chromic oxide capsules) and liveweight gain (LWG) when offered a restricted herbage allowance of 7 kg DM/hd/day during the period equivalent to late pregnancy in the former group. Never-pregnant and lactating heifers consumed 9.19 v. 11.36, PSE = 0.63 kg OM/hd/d ($P < 0.05$) when the comparison was

made under *ad libitum* allowances during the early lactation period for the latter group. During the same period, a LWG of 1.70 v. 0.61, PSE = 0.28 kg/d ($P < 0.05$) was recorded for the never-pregnant v. lactating heifers. Results are discussed in the context of beef production from unbred and once-bred heifers.

INTRODUCTION

Once-bred heifer (OBH) beef production systems, which are new to New Zealand, involve mating heifers at 15 months of age to calve as 2-year olds (Keane 1988; Bailey et al. 1991). Heifer dams can be slaughtered at or soon after calving, or they can be suckled for up to six months prior to slaughter. In order to grade as heifer beef in both the export and local grading systems, calved heifers must be slaughtered before their eighth permanent incisor teeth have erupted, usually at 30-33 months of age (Kirton 1989).

In traditional beef cattle breeding systems, 70-75% of the food consumed by the cow goes towards her own maintenance and that of her calf and replacement (McMillan 1989; Morris et al. 1991). Research in Europe indicates that biological efficiency of the OBH system is relatively high because the heifer is herself a growing meat animal and feed energy required for maintenance is reduced as a proportion of total feed intake (Crowley 1973; Allen 1975; Harte 1975). Taylor et al. (1985) reported that the theoretical efficiency of food utilization for meat production is potentially much higher in OBH systems than in traditional systems of beef production.

Information on the feed requirements of beef x dairy heifers is needed for feed planning and managing OBH systems to achieve production targets. Although the performance of maiden and once-calved heifers has been compared in overseas studies (Boucque et al. 1980; Roux et al. 1987; Waggoner et al. 1990; Keane et al. 1991), these studies were conducted on heifers reared in a mixture of indoor (concentrate

feeding) and outdoor (concentrate/forage feeding) systems in Europe and North America. For New Zealand, no data on complete OBH beef production systems have been published. The objective of this study was therefore to compare unbred and once-bred heifers in terms of patterns of growth, herbage intake and ingestive behaviour at specific times of the production cycle, and total productivity (heifer plus calf liveweight (LW) changes and the heifers' carcass weight). Carcass and meat quality characteristics of these heifers are described in Chapter 3.

MATERIALS AND METHODS

Fifty 1988-born Hereford x Friesian heifers (14 months old with a mean (\pm SE) LW of 241 ± 4 kg) were purchased in October 1989. Heifers were grazed on pastures of predominantly perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) at the Massey University Sheep and Beef Cattle Research Unit. Liveweight was recorded monthly from purchase through to slaughter (November 1990 and May 1991 for the unbred and once-bred heifers, respectively). Forty heifers (287 ± 4 kg LW), selected at random from the original 50, were mated to either Limousin (24 heifers) or Charolais (16 heifers) semen at 15 months of age (i.e. in November 1989). Oestrus was synchronised using progesterone-impregnated controlled internal drug release devices (CIDRs; Cattle EAZI-breed CIDR, Type B, Carter Holt Harvey Plastic Products, Hamilton, New Zealand) inserted intravaginally together with an oestradiol benzoate capsule (Jellie 1991) for 12 days. Heifers were mated by artificial insemination (AI) 48 hours after CIDR withdrawal. From this mating 21 heifers became pregnant, 13 to Limousin sires (LS) and 8 to Charolais sires (CS), and carried their calves until parturition. The remainder, comprising ten "unbred" heifers and nineteen heifers which were bred but not pregnant ("empty" heifers) were also retained to compare their performance with that of once-bred (pregnant and calved) heifers.

Calving commenced at the end of August and continued until mid September 1990.

The LW of the heifers was recorded one week prior to calving. Calves were weighed at birth and identified to their dams during morning and evening field inspections every day. Calving difficulties were scored from 1-5 as: 1 = no assistance; 2 = minor assistance; 3 = assisted, but easy calving; 4 = moderate assistance; 5 = substantial assistance (veterinary assistance required). No caesarean operations were performed. The loss of LW by the dam at calving was assumed to be equal to: (the calf birth weight + 15 litres of amniotic and allantoic fluids + the weight of placenta, calculated as 14% of the calf birth weight, Roberts (1986)). Post-calving LW was calculated by subtracting the dam LW loss at calving from the pre-calving liveweight. Two heifers and four calves (2 from dead heifers and 2 from other heifers) died because of problems related to dystocia (calving difficulty) at parturition.

Seventeen heifers suckled their own calves until weaning (25 January 1991, at a calf age of 5 months). One heifer which lost her calf did not accept a foster and became dry, while the other reared a fostered Friesian calf. Data from these two heifers were excluded from the analysis. The liveweights of heifers and calves were recorded monthly during the 5-month suckling period.

The herbage intake, ingestive behaviour and LWG of heifers were investigated in two experiments. These attributes were recorded in pregnant heifers during the late pregnancy period (days 260-270 of pregnancy (P260-P270)), and compared with those obtained at the same time for never-pregnant heifers (i.e. the combined "unbred" and "empty" groups) in Experiment 1 (August 1990). In Experiment 2 (October 1990), the performance of calved heifers during early lactation (days 50-60 of lactation (L50-L60)) was compared with that of never-pregnant heifers.

Experiment 1

The main purpose of this study was to compare the relative herbage intake of pregnant (P260-P270) and non-pregnant heifers. Ten pregnant and ten never-pregnant (5 unbred and 5 empty) heifers, randomly selected from their respective groups, were used. A 3 ha lowland pasture area on the Sheep and Beef Cattle Research Unit was prepared to a sward surface height of 10-12 cm for the experiment.

The trial commenced on 8 August and finished on 25 August 1990. Intraruminal chromium controlled release capsules (CRC, Captec (NZ) Ltd, 4.06 cm core, 65% Cr₂O₃, multi-orifice end-plate) were used to measure the faecal output (FO) of the heifers. Individually numbered capsules were inserted orally using the Captec balling gun (between 0900h and 1000h on day one (D1), after weighing). Careful placement of the capsule at the back of the tongue was necessary to avoid tooth damage to the chromium CRC plastic barrel and injury to the throat of the heifer (Morris et al. 1990b). Heifers were held in the yards until 1100h, to ensure that the capsules were retained in the rumen, prior to their allocation to the experimental paddocks. These paddocks were managed so as to provide a pre-grazing herbage mass of 2000-2200 kg DM/ha (i.e. a sward surface height of 10-12 cm). Sward surface height (SSH) and compressed sward height (CSH) were measured (50 readings each) daily using the HFRO sward stick (Hodgson 1990) and the Ellinbank rising plate meter (Earle & McGowan 1979), respectively.

A 6 day period was required for capsules to reach a steady rate of Cr₂O₃ release in the rumen (Morris et al. 1990b). Faecal samples were collected during two 5-day periods, from D7-D11 and D12-D16, inclusive. No regurgitation of chromium CRC by the heifers was observed before the end of the experiment. In each period, faecal samples (15-20 g wet weight) from each heifer were collected on at least 3 of the 5 days by inspecting the experimental area in the morning or afternoon and collecting (from the sward surface) samples from heifers observed defaecating. Samples were collected

into plastic pottles and dried, at 60-65°C for 3-4 days, to a constant weight. A sub-sample of faeces from each day within periods was then taken and bulked on an equal dry weight basis (0.5-1.0 g/day) into one pottle for each heifer in each sampling period. Replicates of the pooled faecal samples were used to determine the chromium content of faeces by atomic absorption spectrophotometry (Costigan & Ellis 1987; Parker et al. 1990; Parker et al. 1991).

Hand-plucked samples of herbage, similar to that consumed by the heifers, were collected on D7, D11, D12 and D16 (100-150 g wet weight per day). Samples were immediately frozen at -12°C and subsequently freeze dried. Sub-samples (5-10 g) from the dried and ground (passed through a mesh of 1 mm) herbage samples were used to determine the herbage digestibility by the *in vitro* method of Roughan and Holland (1977). Six standards of known *in vivo* digestibility ranging from 72.1 to 80.9% were run with each batch. The dry matter digestibility (DMD), organic matter digestibility (OMD), digestible organic matter in the dry matter (DOMD), and ash content (Ash) of samples were determined.

The daily (FO), and consequently the herbage intake (I) of heifers, was calculated (on a DM basis) as described by Parker (1990) (see Appendix I for details of calculations).

Heifers were yarded on D0 and D16 to record liveweights off pasture (at 1600h on D0 and D16) and after a sixteen hour fast (at 0800h on D1 and D17).

Ingestive behaviour was monitored on D10 (0600h-1200h), D11 (1200h-1800h), D12 (1800h-2400h) and D13 (2400h-0600h). Activities recorded for each animal were grazing, ruminating and idling as defined by Hodgson (1982), and biting rate (i.e. the time taken for 20 bites). Grazing parameters were coded by letter once every ten minutes using the method of Inwood et al. (1992). Biting rate was used to compute bites per minute (bite/m), and an estimate of the DMI and OMI per bite for each heifer.

Herbage mass (kg DM/ha) was estimated from quadrat samples (Frame 1981). Two days prior to the commencement of the trial, 15 quadrats of pasture (0.18 m² each) randomly selected throughout the experimental paddocks were cut to ground level using an electric shearing handpiece. Herbage samples were washed and dried at 80°C to constant weight to determine the herbage mass. At the time each quadrat sample was cut, the SSH (10 readings inside each frame area of 0.18 m²) and CSH (2 readings inside each frame area) were also measured. Herbage mass was regressed on the mean CSH or SSH reading for each quadrat (Earle & McGowan 1979) to develop the equation: $y = ax + b$, where: y = herbage mass (kg DM/ha), x = sward height (SSH or CSH, cm), a = intercept and b = regression coefficient. For CSH this yielded the equation $y = 149x + 644$, $r = 0.89$, which was used to monitor the daily herbage allowance (i.e. 7 kg DM/hd/d) to the heifers.

Herbage intake of heifers was also estimated by the difference technique to complement the values derived through use of the chromic oxide capsules. Ten pre- and post-grazing quadrats (0.18 m² each), taken at random across the heifers' daily herbage allocation area, were cut on D7, D8, and D9, and on D12, D13, and D14 (i.e. the first 3 days of each 5-day faecal sampling period). All herbage samples were treated as described above to calculate the daily pre- and post-grazing herbage mass (kg DM/ha). The average herbage intake of heifers within each 3-day period, and subsequently for the whole experimental period, was estimated by subtracting the post-grazing herbage mass from the pre-grazing mass and dividing this value by the number of heifers grazing on the restricted area.

Herbage samples (100-150 g wet weight) were collected before and after grazing on each day and frozen at -12°C. The samples were bulked across the 3 days (separately for each of the pre- and post-grazing samples), washed, and sub-samples (25-30 g wet weight) taken for the determination of pre- and post-grazing pasture composition using the method described by MAF (1975).

Experiment 2

The herbage intake, ingestive behaviour and LWG of early lactating (L50-L60) and never-pregnant heifers were compared in Experiment 2. Ten lactating heifers (372 ± 6 kg LW) and ten never-pregnant heifers (5 unbred and 5 empty; 426 ± 9 kg LW), previously used in Experiment 1, were studied.

The experiment, which commenced on 23 October 1990, was conducted on a 3 ha lowland pasture area at the Sheep and Beef Cattle Research Unit. The faecal output of heifers was measured using chromium CRCs inserted on D1 (23 October). Faecal samples were collected for two 5-day periods, from D7-D11 and D12-D16, inclusive. The chromium content of faeces, and consequently the FO of heifers, was calculated as described for Experiment 1. Four heifers (two in each of the early lactating and never-pregnant groups) regurgitated their chromium CRC during the experiment. Data from these heifers were not analysed. Samples of hand-plucked herbage, similar to that consumed by the heifers, were collected on D7, D9, D11, D12, D14 and D16 (100-150 g wet weight per day) to estimate the percent OMD, DMD, DOMD and ash in the herbage. The OMI, DMI and energy intake of the heifers were computed as described for Experiment 1.

The heifers were exposed to a continuous stocking system designed to permit *ad libitum* intakes. This was assumed to be 13 kg DM/hd/d for heifers with an average LW of 400 kg (Geenty & Rattray 1987). On this basis, daily intake was expected to be 260 kg DM of herbage (13 kg DM/hd/d x 20 heifers) over the 17-day experimental period. Herbage growth rate was expected to be 50 kg DM/ha/d (Milligan et al. 1987) or 150 kg DM/d from the 3 ha trial area. The target herbage mass at the commencement of the trial of 4200 kg DM/ha (equivalent to a sward height of 18-21 cm) was expected to reduce to 3576 kg DM/ha at the end of the trial, i.e. an intake of 260 kg DM/d comprising 150 kg DM/d of new herbage growth and 110 kg DM/d of existing herbage.

Liveweights (off pasture and 16 hour fasted) were recorded at the beginning and end of the experiment.

Two 24 hour ingestive behaviour studies were carried out on D7, D8, D9 and D11 of the first, and D12, D13, D14 and D16 of the second, 5-day faecal sampling periods. Two observers were used within each 6 hour-period in contrast to the one observer used in the study of Inwood et al. (1992). Total grazing, ruminating and idling times for each animal during a 24 hour period, and the rate of biting (recorded for each animal on the same days of behaviour monitoring) were calculated as described in Experiment 1.

Pre- and post-grazing herbage mass (kg DM/ha) were assessed using the quadrat cut technique (15 quadrats, each of 0.18 m², randomly selected from the experimental area) on D0 and D17. Herbage mass was calculated as described for Experiment 1. Herbage samples (at least 100-150 g wet weight, adjacent to the area cut for quadrat samples) were collected on D0 and D17 to assess the pre- and post-grazing pasture composition. The calibration of herbage mass on sward height was calculated as described previously. Sward height (SSH and CSH, 50 readings each per paddock) was assessed at 4-day intervals to estimate the herbage mass on the experimental area. Fifteen cages (0.18 m² each) were placed adjacent to the area of pre-grazing pasture cuts to estimate the rate of pasture growth using the "difference technique" described by Frame (1981).

Statistical Analyses

Statistical analyses were performed by the General Linear Model procedure (SAS 1985). Data relating to the herbage intake and ingestive behaviour of heifers in both experiments, and the LW and LWG of heifers throughout their lifetime, were analysed using model 2.1, below:

[Model 2.1]

$$Y_{ij} = \mu + \alpha_i + e_{ij}$$

Where: Y_{ij} = an observation on the j^{th} heifer in the i^{th} treatment
 μ = the overall mean
 α_i = the fixed effect of the i^{th} treatment ($i = 1, 2$)
 e_{ij} = the random residual associated with an observation on the j^{th} heifer in the i^{th} treatment.

Data related to cow and calf performance, from calving till weaning, were analysed using model 2.2 below:

[Model 2.2]

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ijk}$$

Where: Y_{ijk} = an observation on the k^{th} calf (or its dam) of the i^{th} sex and the j^{th} sire breed
 μ = the overall mean
 α_i = the effect of the i^{th} calf sex ($i = 1, 2$)
 β_j = the effect of the j^{th} calf sire breed ($j = 1, 2$)
 $(\alpha\beta)_{ij}$ = the interaction between the effects of the i^{th} calf sex and the j^{th} calf sire breed
 e_{ijk} = the random residual associated with an observation on the k^{th} calf (or its dam) of the i^{th} sex and the j^{th} sire breed.

Interaction effects were excluded from the models when they were not significant ($P > 0.05$) and the models refitted.

RESULTS

Preliminary analyses showed that there were no significant differences between "unbred" and "empty" heifers in their LWG, herbage intake or ingestive behaviour. Therefore comparisons were made only between never-pregnant (i.e. the combined "unbred" and "empty" groups) and pregnant heifers from mating until calving, and between never-pregnant and calved heifers from calving until slaughter.

Heifer and Calf Performance

Growth patterns of the two groups of heifers are shown in Figure 2.1. Never-pregnant and pregnant heifers had liveweight gains of 0.33 ± 0.01 v. 0.51 ± 0.01 kg/d ($P < 0.001$) during the 289 day period equivalent to pregnancy in the latter group. This was due to the fact that never-pregnant heifers had a slight LW loss during July-October 1990 because of pasture being conserved for the pregnant/calved heifers (Figure 2.1). However, never-pregnant heifers had an average gain of 0.60 ± 0.01 kg/d from purchase (October 1989) until slaughter at 475 ± 7 kg LW (November 1990); the corresponding daily gain was 0.42 ± 0.05 kg ($P < 0.01$) for pregnant/calved heifers and they weighed 395 ± 8 kg when the never-pregnant group was slaughtered.

Calved heifers had a daily LWG of 0.39 ± 0.03 kg during the 142 day suckling period. Weaned heifers exhibited a LW loss of 0.94 ± 0.10 kg/d (presumably caused by the weaning stress) during the period January-February 1991, but an overall LWG of 0.18 ± 0.02 kg/d was recorded for these heifers from weaning (end of January 1991) until slaughter (May 1991, see Figure 2.1). These heifers had an overall LWG of 0.35 ± 0.03 kg/d from purchase until slaughter.

Pregnancy rate, for one cycle of mating only, was 52% (i.e. 21 out of 40 heifers mated by AI following the CIDR treatment became pregnant). Dystocia caused a mortality rate of 9% and 19% in heifers and calves, respectively. Dead calves were all

Limousin-sired. A LW loss of 61 ± 2 kg/hd was recorded in calved heifers during the calving period (end of August until mid September, see Figure 2.1). Calving score was not significantly different between heifers delivering female v. male or Limousin- v. Charolais-sired (LS v. CS) calves (Table 2.1).

The performance of cows and their calves is summarised in Table 2.1. Heifers carrying LS calves had a gestation period slightly longer than those carrying CS calves (290.4 v. 286.6, PSE = 1.2 days, $P < 0.10$), but there was no effect of calf sex on gestation length. Heifers carrying female or male calves had similar pre-calving liveweights, but heifers with LS calves had pre-calving liveweights greater than those of heifers with CS calves (440.7 v. 410.7, PSE = 10.5 kg, $P < 0.10$). Post-calving LW was not significantly different between heifers which delivered female or male calves, but was greater in heifers which delivered LS calves than in those which delivered CS calves (379.5 v. 347.5, PSE = 9.5 kg, $P < 0.05$). Liveweight loss at calving was not significantly different between heifers with female v. male or with LS v. CS calves. Dam weaning weights (kg) were 443.5 v. 394.7 (PSE = 9.5 kg, $P < 0.01$) and 437.5 v. 400.7 (PSE = 9.5 kg, $P < 0.05$) in heifers suckling female v. male or LS v. CS calves, respectively. Daily LWG during the suckling period was significantly ($P < 0.05$) different between heifers nursing female v. male calves but not for heifers suckling LS v. CS calves.

There were no significant differences in birth weight between female v. male or LS v. CS calves (Table 2.1). Female calves had 9 kg lower weaning weights than male calves, while CS calves had greater weaning weights than LS calves (218.3 v. 204.9, PSE = 3.6 kg, $P < 0.01$). This reflected the fact that, during the suckling period, LS calves had lower daily LWG than CS calves (1.17 v. 1.24, PSE = 0.03 kg/d, $P < 0.10$). Female and male calves grew at a similar rate up to weaning. There were no interactions between the effects of calf sex and sire breed on cow and calf performance.

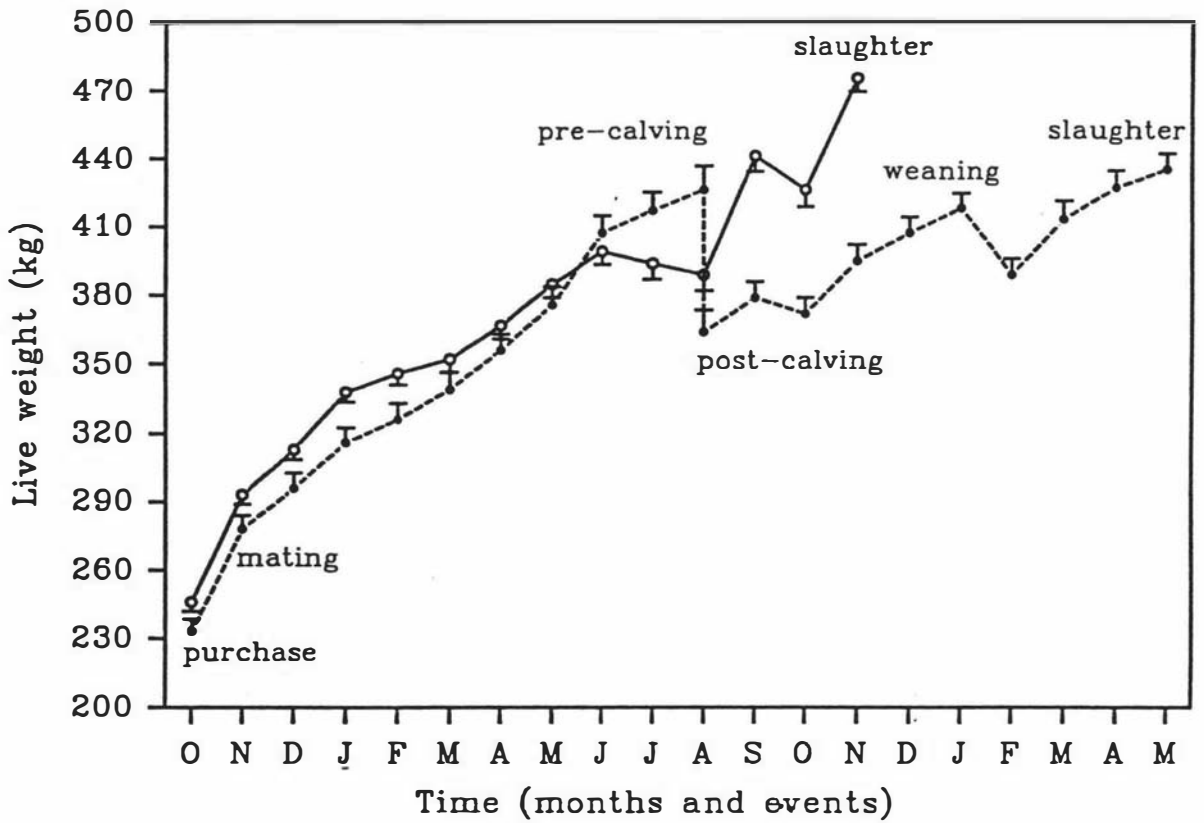


Figure 2.1 Liveweight of once-bred (*filled circles*) v. unbred (*empty circles*) Hereford x Friesian heifers from purchase through to slaughter. Vertical bars represent the standard errors of the mean.

Table 2.1 Effects of sex and sire breed of calf on heifer dam and calf performance.

	Sex		Sire breed		Pooled SE
	Female	Male	Limousin	Charolais	
Heifer performance					
Number of animals	8	9	9	8	
Gestation length ¹ (d)	289.5	288.5	290.4	286.6	1.2
Pre-calving weight ¹ (kg)	434.5	416.0	440.7	410.7	10.5
Post-calving weight ¹ (kg)	374.0	352.5	379.5 ^b	347.5 ^a	9.5
Liveweight loss ^{1, 2} (kg)	60.5	62.7	59.5	63.5	2.0
Calving score ¹	2.9	3.5	2.3	3.7	0.7
Weaning weight (kg)	443.5 ^b	394.7 ^a	437.5 ^b	400.7 ^a	9.5
Daily LWG ³ (kg)	0.49 ^b	0.30 ^a	0.41	0.37	0.03
Calf performance					
Birth weight ¹ (kg)	39.5	41.4	39.6	42.5	2.6
Weaning weight ⁴ (kg)	207.2	216.1	204.9 ^a	218.3 ^b	3.6
Daily LWG ³ (kg)	1.18	1.23	1.17	1.24	0.03

¹ Including data from heifers with live or dead calves (heifer performance) or from live and dead calves (calf performance).

² Heifers' liveweight loss at calving.

³ The daily live weight gain of heifers or calves during 142-day suckling period.

⁴ Figures are adjusted to a common calf weaning age (Nicoll & Rae 1978a, 1978b).

^{a, b} Means within main effects and rows with different superscripts are significantly different at $P < 0.05$.

Experiment 1

Pasture characteristics during Experiment 1 are shown in Table 2.2. Heifers grazed pastures with an average pre- and post-grazing herbage mass of 2719 ± 173 and 1495 ± 209 kg DM/ha, equivalent to sward heights of 11.5 ± 1.4 and 4.6 ± 0.9 cm as measured by the sward stick, or 11.4 ± 1.0 and 5.8 ± 0.8 cm as measured by the rising plate meter. Pastures contained $81 \pm 4\%$ perennial ryegrass and $8 \pm 2\%$ white clover before grazing; the corresponding values were $53 \pm 3\%$ and $2 \pm 1\%$ for pastures after grazing, respectively. The pastures had $44 \pm 4\%$ dead material post-grazing compared with $8 \pm 2\%$ prior to grazing.

The *in vitro* organic matter digestibility and ash content of hand-plucked herbage samples were $81 \pm 1\%$ and $11 \pm 2\%$ (on a DM basis), respectively.

There were no significant differences between pregnant (P260-P270) and never-pregnant heifers in their herbage consumption (OMI, DMI or MJ ME intake) or daily LWG (Table 2.3). Pregnant and never-pregnant heifers had a daily OMI of 1.41% and 1.17% of their body weight, respectively. Similar values (1.56% v. 1.30%) were recorded for their DMI.

Results from Table 2.3 indicate that pregnant v. never-pregnant heifers had herbage intakes of 5.71 and 5.23 (PSE = 0.36) kg DM/hd/d, respectively, during the late pregnancy period. An intake of 6.84 ± 0.65 kg DM/hd/d for the 20 heifers, irrespective of their pregnancy group (since they were grazing together), was estimated using the daily pre- and post-grazing pasture cut technique.

There were no significant differences between pregnant v. never-pregnant heifers in the time spent grazing, ruminating and idling, or in biting rate and bite weight (OMI or DMI per bite, Table 2.3).

Table 2.2 Herbage mass, sward height, botanical composition, *In vitro* digestibility, and ash content of herbage offered to the Hereford x Friesian heifers In August (Expt 1, mean \pm SE).

	Pre-grazing	Post-grazing
Herbage mass (kg DM/ha)	2719 \pm 173	1495 \pm 209
Sward height (cm)		
Sward surface height ¹	11.5 \pm 1.4	4.6 \pm 0.9
Compressed sward height ²	11.4 \pm 1.0	5.8 \pm 0.8
Botanical composition³		
Perennial ryegrass	0.81 \pm 0.04	0.53 \pm 0.03
White clover	0.08 \pm 0.02	0.02 \pm 0.01
Weeds	0.03 \pm 0.00	0.01 \pm 0.00
Dead material	0.08 \pm 0.02	0.44 \pm 0.04
<i>In vitro</i> digestibility³		
Organic matter digestibility		0.81 \pm 0.01
Dry matter digestibility		0.79 \pm 0.02
Digestible organic matter in dry matter		0.73 \pm 0.02
Ash content³		0.11 \pm 0.02

¹ Measured by HFRO sward stick.

² Measured by rising plate meter.

³ Proportions based on dry weight.

Table 2.3 Growth performance, herbage intake and ingestive behaviour of pregnant (pregnancy days 260-270) v. never-pregnant heifers offered a restricted (7 kg DM/hd/d) herbage allowance in August (Expt 1, mean \pm SE).

	Never-Pregnant	Pregnant	Pooled SE
Growth Performance			
Number of animals	10	10	
Initial weight ¹ (kg)	365.5 ^a	403.5 ^b	5.7
Final weight ¹ (kg)	366.6 ^a	402.3 ^b	5.7
Daily LWG (kg)	+0.04	-0.03	0.12
Herbage Intake			
Number of animals	10	10	
OMI ² (kg/hd/d)	5.15	4.72	0.33
DMI ³ (kg/hd/d)	5.71	5.23	0.36
MJ ME ⁴ /hd/d	67.91	62.22	4.25
OMI (kg/100 kg LW/d)	1.41	1.17	0.08
DMI (kg/100 kg LW/d)	1.56	1.30	0.09
MJ ME/100 kg LW/d	18.60	15.45	1.12
Ingestive behaviour			
Number of animals	10	10	
Grazing time (m/d)	503	522	19
Ruminating time (m/d)	291	294	27
Idling time (m/d)	662	624	28
Bite rate (bites/m)	68	64	2
Bite weight (mg OMI/bite)	153	144	11
Bite weight (mg DMI/bite)	174	162	13

¹ Sixteen-hour fasted liveweights.

² Organic matter intake.

³ Dry matter intake.

⁴ Megajoules metabolisable energy. (MJ ME) = (DMI*0.163*DOMD), where: DMI = dry matter herbage intake, 0.163 = correction factor (ARC 1980), and DOMD = the digestible (*in vitro*) organic matter in the dry matter of hand-plucked herbage samples.

^{a, b} Means within rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Experiment 2

In Experiment 2, heifers grazed a pre- and post-grazing herbage mass of 4299 ± 148 and 4180 ± 160 kg DM/ha, respectively (Table 2.4). The corresponding SSH and CSH values were 18.2 ± 1.6 and 15.1 ± 1.3 cm, and 21.2 ± 1.8 and 16.1 ± 1.3 cm, respectively. Pre- and post-grazing pastures comprised $74 \pm 3\%$ and $69 \pm 2\%$ perennial ryegrass, and $10 \pm 2\%$ and $7 \pm 1\%$ white clover, respectively. The dead material comprised $23 \pm 2\%$ of post-grazing pastures compared with $13 \pm 2\%$ in the pre-grazing sward.

The *in vitro* OMD, DMD, DOMD and the ash content of hand-plucked herbage samples determined for the October-grown herbage (Table 2.4) were similar to those estimated for the herbage grown in August (Table 2.2). Herbage growth rate was estimated to be 88 kg DM/ha/d over the trial period based on herbage accumulation under the cages.

Lactating (L50-L60) heifers had a higher herbage intake (11.36 v. 9.19 , PSE = 0.63 kg OMI/hd/d, $P < 0.05$) and lower rate of growth (0.61 v. 1.70 , PSE = 0.28 kg/d, $P < 0.05$) than never-pregnant heifers (Table 2.5). Metabolisable energy intake by the lactating heifers was significantly higher than that of never-pregnant heifers (147 v. 119 , PSE = 8 MJ ME/hd/d, $P < 0.05$, Table 2.5). Never-pregnant and lactating heifers had an OMI equivalent to 2.15% and 3.20% ($P < 0.05$) of their body weight, respectively. Similar ratios were recorded for their DMI (Table 2.5).

There were no significant differences between lactating (L50-L60) v. never-pregnant heifers in the time spent grazing, ruminating or idling. Biting rate and bite weight were not significantly different between the two groups (Table 2.5). However, both grazing time and bite weight tended to be higher in lactating heifers.

Table 2.4 Herbage mass, sward height, botanical composition, *in vitro* digestibility and ash content of herbage offered to the Hereford x Friesian heifers in October (Expt 2, mean \pm SE).

	Pre-grazing	Post-grazing
Herbage mass (kg DM/ha)	4299 \pm 148	4180 \pm 160
Sward height (cm)		
Sward surface height ¹	18.2 \pm 1.6	15.1 \pm 1.3
Compressed sward height ²	21.2 \pm 1.8	16.1 \pm 1.3
Botanical composition³		
Perennial ryegrass	0.74 \pm 0.03	0.69 \pm 0.02
White clover	0.10 \pm 0.02	0.07 \pm 0.01
Weeds	0.02 \pm 0.00	0.01 \pm 0.00
Dead material	0.13 \pm 0.02	0.23 \pm 0.02
<i>In vitro</i> digestibility³		
Organic matter digestibility		0.81 \pm 0.02
Dry matter digestibility		0.79 \pm 0.01
Digestible organic matter in dry matter		0.73 \pm 0.01
Ash content³		0.09 \pm 0.01

¹ Measured by HFRO sward stick.

² Measured by rising plate meter.

³ Proportions based on dry weight.

Table 2.5 Growth performance, herbage intake and ingestive behaviour of lactating (lactation days 50-60) v. never-pregnant heifers offered an *ad libitum* herbage allowance in October (Expt 2, mean \pm SE).

	Never-pregnant	Lactating	Pooled SE
Growth performance			
Number of animals	10	10	
Initial weight ¹ (kg)	412.5	449.5	10.5
Final weight ¹ (kg)	440.7 ^b	359.0 ^a	8.5
Daily LWG (kg)	1.70 ^b	0.61 ^a	0.28
Herbage Intake			
Number of animals	8	8	
OMI ² (kg/hd/d)	9.19 ^a	11.36 ^b	0.63
DMI ³ (kg/hd/d)	10.00 ^a	12.36 ^b	0.69
MJ ME ⁴ /hd/d	118.83 ^a	147.01 ^b	8.18
OMI (kg/100 kg LW/d)	2.15 ^a	3.20 ^b	0.08
DMI (kg/100 kg LW/d)	2.34 ^a	3.49 ^b	0.09
MJ ME/100 kg LW/d	27.89 ^a	41.52 ^b	1.65
Ingestive behaviour			
Number of animals	10	10	
Grazing time (m/d)	504	526	10
Ruminating time (m/d)	519	537	14
Idling time (m/d)	413	367	20
Bite rate (bites/m)	56	52	2
Bite weight (mg OMI/bite)	344	412	30
Bite weight (mg DMI/bite)	373	454	32

¹ Sixteen-hour fasted liveweights.

² Organic matter intake.

³ Dry matter intake.

⁴ Megajoules metabolisable energy (see footnote of Table 2.3).

^{a, b} Means within rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

DISCUSSION

Growth of never-pregnant versus calved heifers

Target weights of 450-500 kg at slaughter (March-May) were recommended for the OBH beef production system under New Zealand pasture conditions (Morris & Khadem 1991). Never-pregnant heifers, in this study, achieved a slaughter weight of 475 ± 7 kg in mid November 1990, 13 months after purchase. In comparison, calved heifers were slaughtered at 435 ± 6 kg LW in mid May 1991, six months after the former group had been slaughtered. The difference primarily reflects the energy costs of pregnancy and lactation in the calved heifers and the fact that calved heifers were fed restricted levels in late pregnancy in order to control calf birth weight and hence the incidence of dystocia. High feeding levels in lactation were required to partially compensate for this loss of LW during pregnancy. Although the calved heifers grew more slowly than the never-pregnant heifers, and were slaughtered at a greater age and lower carcass weight, they suckled calves which weighed more than 211 kg at weaning. These were sold as prime weaners.

Slaughter weights of 510 and 550 kg were achieved for Hereford x Friesian and Continental x Friesian heifers, respectively, in the United Kingdom where calves were removed from the dam at 3-4 days post-calving and heifer dams were reared on a mixture of herbage and concentrates (Keane 1988). Bond et al. (1986) reported that once-calved heifers had higher gains than non-pregnant heifers. However, the longest feeding period reported by those authors was only 42 days. In the study of Boucque et al. (1980), in which Belgian White and Red dual purpose heifers were mated to Charolais sires in a OBH beef production system, once-calved heifers suckling their calves had lower LWG than maiden heifers (0.28 v. 1.06 kg/d) during the finishing period (i.e. 131 and 200 days for the maiden and once-calved heifers, respectively).

The performance of nulliparous (unbred) and primiparous (once-bred) heifers was examined in a feedlot finishing policy in the United States of America (Bailey et al. 1991). Heifers were finished on the same ration for 4 months (unbred heifers, from 18-22 months of age) and 2.5 months (once-bred heifers, immediately after weaning, from 29.5-32 months of age). Live weight gain was 1.02 v. 1.26 kg/d for unbred v. once-bred heifers, respectively. These figures suggest that high (*ad libitum*) levels of intake are required for the calved heifers in OBH systems to show their potential liveweight gains, particularly after weaning.

Performance of pregnant/calved heifers

Target weights of 300-330 kg at mating (November-December) were recommended for 15-month-old dairy x beef heifers used in New Zealand OBH beef production systems (Morris & Khadem 1991). These liveweights were considered appropriate because heifer dams in a OBH system are not only producing calves but are also themselves prime beef-producing animals. Heifers used for the present study were purchased at 14 months of age so that there was no opportunity to manage their growth rates to achieve the above target weights at mating. Therefore, they were mated at an average weight of 287 kg at 15 months of age in November 1989. Roux et al. (1987) achieved liveweights at mating of 253 kg for 10-12 month old Friesian heifers and 288 kg for Charolais x Friesian heifers of the same age, under a feedlotting system in France.

The pregnancy rate (52%) achieved in this study using CIDRs for oestrus synchronisation was higher than the figures of 35% and 28% reported by Lowman & Broadbent (1987), who used prostaglandin to synchronise oestrus in once-bred heifers.

As noted earlier, a restricted level of intake was offered to the heifer dams so that they

maintained LW during the last two months of pregnancy. In spite of this, heavy (on average 40 kg) calves were born. Dystocia was experienced by 25% of the heifer dams, and 19% of the births resulted in calf mortality. Dead calves were all Limousin-sired and male calves.

Calving difficulty has been one of the major problems associated with use of young straightbred or crossbred heifers (Everitt et al. 1978a; Boucque et al. 1980; Morris 1980b; Romita et al. 1981; Baker et al. 1990; Bellows et al. 1991). Bellows et al. (1991) suggested that the dam pre-calving LW and pelvic area, and the sex and birth weight of calves, are the main factors influencing the incidence of dystocia in young heifers. Birth weights and calving difficulties of 35.7 v. 32.7 kg and 17.7 v. 5.5%, respectively, were recorded for CS v. LS calves born to Angus cows (2 years of age and older) in a beef breed evaluation study in New Zealand (Baker et al. 1990). The disadvantage of Charolais sires for mating Friesian cross heifers (2 years of age or older) was noted by Everitt et al. (1978a). A very low incidence of neonatal calf mortality was reported by Roux et al. (1987) when a group of young (10-12 month old) Friesian and Charolais x Friesian heifers were mated to Angus and Aubrac (a local beef breed) sires in France. Calves had birth weights of 31 to 34 kg. The authors suggested that the low calf birth weights, as well as the choice of sire breeds, were the main factors controlling the incidence of dystocia in that study. A calf mortality rate of 10-27% was reported by Romita et al. (1981) when young heifers were mated to Limousin sires. Their result is confirmed by this trial and suggests that Limousin sires cannot be regarded as easy calving sires for mating to young heifers in OBH beef production systems, at least under the high LWG system which is proposed.

Given that severe restriction of feed intake during pregnancy is counter-productive to the objective of maximising growth of the dam, research is required to identify easy calving sire breeds. Angus sires, which are widely used in traditional beef breeding systems and produce calves smaller than those sired by Charolais or Hereford bulls

(Baker et al. 1990), may be more appropriate for mating once-bred dairy x beef heifers in New Zealand.

The weaning weight (at 5 months of age) of calves achieved in this study is much greater than those reported (Carter 1975; Everitt et al. 1978a; Jury & Everitt 1980; Baker et al. 1990) for 2-way crossbred calves in different environments throughout New Zealand. Male calves, in the present study, had an average weaning weight 9 kg greater than that of female calves (216.1 v. 207.2 kg) and weights of heifers weaning male calves were significantly lower than weights of those weaning female calves (394.7 v. 443.5 kg). Similar differences in weight at weaning were observed between heifers suckling CS or LS calves (see Table 2.1). This suggests that heifers suckling male or CS calves used more energy to provide milk for their calves than heifers which suckled female or LS calves respectively. This presumably reflects the greater demand for milk by male and CS calves.

Herbage intake and ingestive behaviour of heifers

Herbage intake measurements using the chromium CRC technique were conducted in this study to examine possible differences in intake between the never-pregnant, pregnant and calved heifers. Ingestive behaviour studies were used to aid the interpretation of the herbage intake data.

The results of Experiment 1 indicated that pregnant and never-pregnant heifers had similar herbage intakes when the comparison was made during the late pregnancy period (P260-P270) of the former group (Table 2.3). There appears to be limited information in the literature comparing the herbage intake of never-pregnant and pregnant heifers at a stage similar to that of the heifers in Experiment 1. However, chromium controlled release capsules were used to estimate the herbage intake of heifers grazed on an *ad libitum* level of intake in the study of Inwood et al. (1992).

Similar herbage intake (7.9 v. 8.0 kg OMI/hd/d) and LWG (0.9 v. 1.1 kg/d) values were reported for the pregnant v. non-pregnant heifers when comparisons were made during the mid pregnancy (P180-P190) period of the former group. Likewise, Vanzant et al. (1991) found no difference between pregnant and non-pregnant heifers in forage OM intake twelve days prior to parturition. It should be noted, however, that these animals were supplemented with dehydrated alfalfa pellets while at grazing.

The pre- and post-grazing quadrat cut technique was used to estimate the herbage intake of pregnant Friesian, Angus and Angus x Friesian cows during the late pregnancy period under New Zealand hill country conditions (Nicoll 1979). Results reported in that particular study (6.3 kg DM/hd/d at a herbage allowance of 8 kg DM/hd/d for cows of an average LW of 444 kg) are similar to those (6.8 kg DM/hd/d at a herbage allowance of 7 kg DM/hd/d) achieved in the present study.

The feedlot performance of open v. pregnant heifers was compared during mid pregnancy (P120-P210) of the latter group by Walker et al. (1988). Heifers had similar feed intake, average daily gain and feed efficiency during the experimental period. This information, together with the performance of heifers during Experiment 1 of this study, suggests that the demand (intake) of pregnant and never-pregnant heifers is similar during the pregnancy period of the former group.

Biting rate, bite weight and the time spent grazing, ruminating and idling were not significantly different between the pregnant and never-pregnant heifers when a restricted herbage allowance of 7 kg DM/hd/d was offered to them during Experiment 1 (see Table 2.3). This is consistent with the lack of difference in herbage intake. However, the ability of heifers to increase their bite rate or bite weight, and hence their daily herbage intake, may have been constrained by the herbage allowance made available in this experiment.

Grazing time (612 v. 573 m/d), biting rate (57 v. 54 bites/m) and bite weight (0.21 v. 0.24 g OMI/bite) were similar in pregnant v. non-pregnant (20 months old) heifers when *ad libitum* levels of herbage allowance (sward heights of 7-11 cm) were offered (Inwood et al. 1992). However, in that study pregnant heifers were at mid-pregnancy (P180-P190) so that the additional feed demand required to support the pregnancy may have been lower than in the late pregnant heifers studied here.

Growing heifers in this trial consumed metabolisable energy (MJ ME/100 kg LW) at a rate similar to those suggested (Geenty & Rattray 1987) for grazing cattle under New Zealand pastoral conditions. Lactating heifers in Experiment 2 had a greater herbage intake than those of never-pregnant heifers (11.36 v. 9.19 kg OMI/hd/d), while LWG of never-pregnant heifers was significantly greater than that of lactating heifers (1.70 v. 0.61 kg/d). The higher herbage intake in lactating heifers was presumably due to the nutrient demand for milk production to support calves growing at a rate of more than 1.2 kg per day. Never-pregnant and lactating heifers had herbage intakes of 2.34 v. 3.49 kg DMI/100 kg LW/d during the early (L50-L60) lactation period of the latter group (see Table 2.5). Similar values (approximately 3.20 kg DMI/100 kg LW/d) were reported for grazing cattle, when the chromium CRC technique was used to estimate the herbage intake of lactating beef cows in Australia (Barlow et al. 1990). The 24% increase in herbage DMI recorded in lactating compared with never-pregnant heifers in this study is less than the 53% recorded under range conditions in North America (Havstad et al. 1986), but similar to the 17% increase reported by Vanzant et al. (1991). Hunter & Siebert (1986) also found that lactating Brahman x Hereford cows ate 25% more than non-lactating cows during the first month of lactation.

Herbage intakes of 12.9 and 14.7 kg OMI/hd/d were reported for Hereford x Friesian (490 kg LW) and Blue-Grey (510 kg) lactating cows, respectively, grazing on a herbage allowance of 50 g DM/kg of "cow plus calf" LW per day (Hodgson et al. 1980). In another study reported by Wright & Russel (1987), the same breeds of cows

were used to examine the effects of sward height on the performance of cows and calves during the mid- to late-lactation period. Herbage intakes of 12.6 v. 11.4 kg OMI/hd/d were reported for Hereford x Friesian v. Blue-Grey cows with liveweights of 500 v. 480 kg. Milk production was 8.93 and 6.88 kg/hd/d for the Hereford x Friesian and Blue-Grey cows, respectively. The corresponding LWG of Charolais-sired calves were 1.02 v. 0.95 kg/d for the two breeds of cows, respectively. Chromic oxide, administered twice daily, was used to estimate the faecal output and hence herbage intake of cows in both of the abovementioned studies. The high volume of milk production reported for the Hereford x Friesian heifers (Wright & Russel 1987) confirms the results of the present study (i.e. LWG more than 1 kg/d for calves) and suggests that Hereford x Friesian heifers have potential to grow heavy weaners in a OBH system.

Table 2.5 indicates that the lactating and never-pregnant heifers spent similar times grazing, ruminating and idling when an *ad libitum* level of herbage allowance was offered to them during Experiment 2. Heifers (never-pregnant v. lactating group) grazed at a rate of 56 v. 52 bites/m and consumed 344 v. 412 mg OMI/bite to meet their demand (i.e. an intake of 9.19 v. 11.36 kg OMI/hd/d, $P < 0.05$). The difference between the intake rate of the two groups of heifers was presumably due to the slight variation between the time each group spent grazing (526 v. 504 m/d, for the lactating v. never-pregnant heifers, respectively) and also due to a slightly greater bite weight in lactating heifers compared with that of the never-pregnant group.

CONCLUSIONS

There was little difference between never-pregnant and pregnant heifers in herbage intake or ingestive behaviour when both groups were offered a limited herbage allowance during a period equivalent to days 260 to 270 of pregnancy in the latter group. However, when offered an *ad libitum* allowance, heifers at days 50-60 of

lactation had greater intakes (a function of slightly longer grazing times and bite weights) than never-pregnant heifers. Calves sired by Limousin bulls had higher mortality rates and lower weaning weights, and hence a lower total calf weaning weight per dam calving, than Charolais-sired calves. This suggests that, on the basis of total calf productivity, the Charolais is to be preferred over the Limousin for mating to 15 month Hereford x Friesian heifers. However, other studies have shown that Limousin-sired calves have lower birth weights and a lower incidence of dystocia than Charolais-sired calves (Baker et al. 1990; Gregory et al. 1988). Therefore more extensive trials will be required to determine whether sire breed effects on the incidence of dystocia in once-bred heifers are real.

The information on performance (i.e. ingestive behaviour, herbage intake and LW changes of heifers and calves) of once-bred v. unbred heifers reported in this Chapter can be used to design appropriate management systems for OBH beef production in New Zealand. These will be discussed further in Chapter 6. The carcass and meat quality characteristic of heifers used in the experiments reported here are described in Chapter 3.

CHAPTER THREE

CARCASS AND MEAT QUALITY CHARACTERISTICS OF PASTURE-FED UNBRED AND ONCE-BRED HEREFORD X FRIESIAN HEIFERS

ABSTRACT

There has been limited research evaluating carcass and meat quality characteristics of heifers, especially once-bred heifer dams, in New Zealand. The carcass and meat quality traits of once-bred, bred but not pregnant ("empty") and "unbred" heifers, held for 4 h or 24 h prior to slaughter, were therefore studied in this experiment. Unbred and empty heifers had similar slaughter and carcass weights, but higher values than calved heifers (slaughtered 6 months later than the unbred and empty groups). Similar dressing-out percentages (DO%) were recorded for unbred v. empty and calved v. empty heifers, but DO% was lower ($P < 0.05$) in calved heifers than in the unbred group. Calved heifers had longer carcasses than unbred ($P < 0.05$) and empty ($P < 0.001$) heifers at the same carcass weight. Hind-quarter cut weights were generally highest for the calved group. Differences in measures of fatness (adjusted for carcass weight) between the three breeding-groups were not consistent. Meat from calved heifers was significantly brighter (i.e. higher reflectance values, $P < 0.05$) than meat from unbred heifers, with the empty group having intermediate values. Overall, similar Warner-Bratzler shear force parameters were recorded for meat of unbred, empty and calved heifers. Carcass characteristics of heifers slaughtered following either 4 or 28 hours holding were very similar except that the DO% was significantly ($P < 0.001$) higher for the 4 h group. Results are discussed in the context of carcass and meat quality traits of pasture-fed bred and unbred heifers.

INTRODUCTION

The once-bred heifer (OBH) beef production system involves breeding heifers at about 15 months of age and then slaughtering them either soon after calving at about 2 years of age (Crowley 1973; Roux et al. 1987; Keane et al. 1991), or following a suckling period of up to 7 months (Boucque et al. 1980; Romita et al. 1981; Waggoner et al. 1990; Vincent et al. 1991).

Once-bred heifers are likely to be older at slaughter than conventionally managed (unbred) heifers because it will take longer for them to reach a similar carcass weight after producing and suckling a calf (see Chapter 2). Therefore, it is important to determine whether bred heifers produce carcasses and meat with similar quality characteristics to unbred heifers. Bond et al. (1986) reported that calved heifers had lower dressing-out percentages (DO%), poorer conformation and lower yield grade scores than non-pregnant heifers, but visual quality traits of meat were similar between the two groups of heifers. Joseph & Crowley (1971) did not detect any differences in meat quality between unbred and once-bred heifers. Heifers in the abovementioned studies, however, were finished on concentrate-based feedlot rations (concentrate or a mixture of concentrate and herbage) and there are no published data on meat quality from OBH beef production within pastoral systems of beef production such as those used in New Zealand.

A research programme to investigate OBH beef production systems commenced at Massey University in 1989. The performance characteristics of unbred v. once-bred Hereford x Friesian heifers used in the 1989-1991 trial were described in Chapter 2. The objectives of this Chapter are to report: 1) the effects of pregnancy and lactation on the carcass and meat quality characteristics of heifers and, 2) the effects of pre-slaughter holding periods of 4 or 28 hours on carcass and meat quality characteristics. Some results of the holding-period treatment have been presented as part of a larger study (Purchas 1992).

MATERIALS AND METHODS

Animals

Ten unbred and 10 bred but not pregnant ("empty") heifers which had achieved target weights (450-500 kg liveweight) recommended for once-bred heifers under New Zealand pastoral conditions (Morris & Khadem 1991) were slaughtered on 12 and 13 November 1990. The carcass and meat quality characteristics of these heifers were compared with those of 15 calved heifers (two of 17 heifer dams rearing their own calves (see Chapter 2) died accidentally few days prior to slaughter) which were slaughtered on 14 and 15 May 1991 following a suckling period of about 5 months and an average post-weaning period of 110 days.

Slaughter Procedure

At each of the November and May slaughter times, heifers were weighed off pasture at 0800h and then randomly allocated to two holding-period groups before being transported about 20 km to a slaughter plant (AFFCO Feilding Ltd). The first group of heifers was slaughtered about 4 hours (4 h) after removal from pasture while the second group was held in lairage overnight (water was available) and slaughtered about 24 hours later than the 4 h group (i.e. approximately 28 hours (28 h) after removal from pasture).

Heifers were slaughtered using percussion stunning (Chrystall et al. 1989) and were dressed under normal commercial conditions. The number of erupted permanent incisor teeth was recorded. Kidney and pelvic fat from both sides of each carcass were combined and weighed. The carcass sides were weighed and evaluated for muscling and fat according to the New Zealand export beef carcass classification system (NZMPB 1991; Purchas et al. 1992). At the time of weighing the sides were identified by attaching plastic Allflex ear tags to the beef slides. This identified each hind-

quarter throughout the boning procedure. Carcass length, defined as the length from the distal end of the tarsal bones to the midpoint of the cranial edge of the first rib (Purchas 1990), was measured for each side.

A sample of *longissimus dorsi* (LD) muscle from the 10th to 13th rib region (c. 800-1000 g) was dissected from the right side of each carcass within 90 minutes *post mortem*. Each muscle sample was placed in a plastic bag, held at ambient temperature (16-19°C) for 24 h, and then transferred to a chiller (0-2°C) for 6 days and then frozen (at -15 to -20°C) for 5 to 16 weeks.

After the sides had been chilled overnight at 1-3°C, they were quartered and the cross-sectional area of the LD was traced from the left side of each carcass where it was cut between the 12th and 13th ribs. The traced area was subsequently determined using a digitising tablet and the VERSACAD computer programme. Subcutaneous fat thickness was measured on the quartered carcass at a point over the LD three-fourths the distance from its medial to its lateral edges.

The hind-quarters of carcasses were released to the boning room intermittently (approximately every third carcass was from this study). This provided time for collecting and weighing the six major hind-quarter cuts from both sides of each carcass. These cuts were tenderloin, striploin, rump, knuckle, topside and outside as defined by NZMPB (1991). Weights were collected on to a weighing/data-logging device in the boning room of the abattoir.

The femur bones from the right side of each carcass were collected. The weight, length and minimum circumference of each femur were measured after removing any remaining muscle and fat. Muscularity was calculated from the weights (g) of knuckle, topside and outside cuts and the length (cm) of the femur bone using the equation described by Purchas et al. (1991).

Meat Quality Measurements

The frozen samples of LD were thawed for about 1 hour at ambient temperature and 20-22 hours in a chiller at 3-5°C. A thin slice (2-10 mm, depending on the size of the sample) was cut from the cranial end to square it up and then sub-samples were taken to measure meat quality characteristics as follows, starting at the cranial end:

- (a) A 15 mm thick slice was prepared for colour and sarcomere length measurement. The middle portion (30 x 30 mm) was used for colour and then a central slither was taken from the medial portion and stored in a labeled test tube for sarcomere length measurement.
- (b) A steak of 25 mm was cut and placed in a plastic bag for assessing cooking loss and Warner-Bratzler (WB) shear force values.
- (c) A sample of at least 80 g was obtained from the middle part of a 40 mm thick slice and trimmed of subcutaneous fat, epimysium, and intermuscular fat. These samples were stored in plastic bags (snap-top) at -15°C for intramuscular fat analysis.
- (d) The medial part from the 40 mm thick slice was used to obtain samples for pH and water holding capacity assessments.

Ultimate pH

A 2.0-2.2 g sample of muscle excised from the central region of the muscle was placed in 10 ml of cold 5 mM sodium iodoacetate reagent and chopped with scissors (Bendall 1973). It was then prepared to a fine slurry using a homogenizer (Janke and Kunkel, Ultra Turrax Type TP 18/10). The pH was measured using a Jenway 3020 pH meter with an Automatic Temperature Compensation Probe that provided a continuous read-

out of sample temperature. The combination electrode was dipped into the homogenate, shaken gently and read when the pH value and temperature display stabilized. The electrode was cleaned thoroughly with distilled water between measurements.

Water Holding Capacity (WHC)

Water holding capacity of muscle was measured in terms of expressible water using a filter paper press method with a meat sample weighing 500 ± 20 mg. The sample was placed on a filter paper (Whatman No.1, 11.0 cm diameter qualitative, previously stored in a dessicator over saturated KCl) between plexiglass plates and then a 10 kg weight was applied to the sample for 5 minutes (Matyniak & Ziolecki 1983). The total wetted area of the filter paper was measured with the same computer programme used to assess the rib eye areas. The WHC was calculated as expressed water in terms of the total area of wetted filter paper per unit weight of the sample (cm^2/g).

Sarcomere Length

Sarcomere length was determined by a laser diffraction method, similar to that described by Cross et al. (1981). The apparatus consisted of a helium-neon laser generator (wavelength 632.8 nm, Spectra-Physics model 102, 2 mW laser head, model 212 power supply) which was mounted on a steel stand with a specimen-holding device and a screen. A small bundle of fibres was removed from the medial region of the selected muscle and then small groups of the fibres were teased out on a microscope slide with 2-3 drops of buffered sucrose solution (0.05 M Tris, pH 7.6, 0.25 M sucrose, Stromer & Goll (1967)) and covered with a coverslip. The slide was placed horizontally in the path of a vertically-oriented laser beam to give an array of diffraction bands on the screen which was 100 mm from the sample. These bands were perpendicular to the long axis of the fibres. Twelve measurements were taken of the distance between first order bands for each sample and the average values were used to

calculate the sarcomere length using a conversion table based on the formula given by Bouton et al. (1973).

Meat Colour (Reflectance Spectrophotometry)

Meat colour was measured as the percentage reflectance at a wavelength of 630 nm using a Bausch and Lomb Spectronic 20 fitted with a reflectance attachment (Ockerman & Cahill 1969; Strange et al. 1974). Samples for assessment were from approximately 15 mm-thick slices cut perpendicular to the fibres and trimmed of connective tissue and external fatty tissue. The measurement was conducted after the samples had been exposed to the atmosphere at 1-3°C for 90-120 minutes. The instrument was zeroed between each sample using the black standard supplied by the manufacturer.

Warner-Bratzler Shear Force Values

To assess shear force values, the 25 mm thick slices (cut previously across the LD samples) were weighed in plastic bags and cooked by suspending the bags in a water bath thermostatically controlled at $70 \pm 1^\circ\text{C}$ for 90 minutes (Purchas 1972). After cooking, liquids were poured off and the cooked meat was stored at 1-2°C overnight. Cooking losses were determined by weighing the cooked samples after drying with paper towels to remove excess surface moisture, and then six cores (13 x 13 mm cross section) were cut parallel to the orientation of the muscle fibres for each steak. Each core was sheared perpendicularly twice, using a modified version of the conventional WB shear device with a square-edged shear blade (Bouton et al. 1975, 1977) attached to a NEC multispeed microcomputer (Purchas & Aungsupakorn 1993).

Shearing was started and finished when a microswitch was switched on and off, respectively. For a single shear, about 872 recorded force values were transferred from the load cell to a data logger which displayed the peak force value. Pairs of adjacent values were averaged and

the resulting 436 values were sent from the data logger to the computer. The latter set of data was used to plot a shear force deformation curve on the screen (Purchas & Aungsupakorn 1993). The parameters measured from the shear deformation curves were:

- (a) Peak force (PF) = the maximum shear force value recorded.

- (b) Initial yield (IY) = the force at which the sample first began to yield (in order to identify the IY, the 436 values were first reduced to 145 by averaging groups of three sequential values, and then the first force value at which the increase to the next value was less than half of the increase from the previous value was taken to be the IY (Purchas & Aungsupakorn 1993)).

- (c) Work index = the mean of the 436 shear force values.

- (d) PF-IY = the peak force minus the initial yield force obtained by calculation.

Intramuscular Fat

The frozen samples of the LD (approximately 80 g each) were thawed (one at a time, in a microwave for 30 seconds). The thawed sample was then finely chopped and mixed before three subsamples, each of 15-20 g, were taken. These subsamples (placed on aluminium foil) were freeze dried (for approximately 4 days to a constant weight) and then fat extraction was carried out on two samples in a Soxhlet apparatus with petroleum ether (bp 40 - 60°C) for 8 hours (AOAC 1980). The third sample was extracted only when the difference in percent intramuscular fat between the first two replicates was greater than 0.5 percentage points.

Statistical Analyses

Data were analysed using General Linear Model (GLM) procedures (SAS 1985). Breeding-group (unbred, empty and calved heifers) and pre-slaughter holding-period (4 h and 28 h) were the main treatments. The adjusted least-square means for the variables measured were computed after fitting the carcass weight as a covariate. Differences between treatment means were tested by Student's *t*-test (Snedecor & Cochran 1967). Type III sums of squares (computed for each variable) were used to interpret the carcass weight (as a covariate), and the main treatments and interaction effects. The basic model used to analyse the data, when carcass weight was included as a covariate, was:

[Model 3.1]

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + b_{ij}(x_{ijk} - X) + e_{ijk}$$

- Where:
- Y_{ijk} = an observation on the k^{th} heifer of the i^{th} breeding-group and the j^{th} holding-period
 - μ = the overall mean
 - α_i = the effect of the i^{th} breeding-group ($i = 1..3$)
 - β_j = the effect of the j^{th} holding-period ($j = 1, 2$)
 - $(\alpha\beta)_{ij}$ = the interaction between the effect of the i^{th} breeding-group and the j^{th} holding-period
 - b_{ij} = the regression coefficient of the Y_{ijk} observation on the carcass weight of the k^{th} heifer in i^{th} breeding-group and j^{th} holding-period
 - x_{ijk} = the carcass weight of the k^{th} heifer of the i^{th} breeding-group and the j^{th} holding-period
 - X = the overall mean of carcass weight
 - e_{ijk} = the random residual associated with an observation on the k^{th} heifer of the i^{th} breeding-group and the j^{th} holding-period.

The interaction effect was excluded when not significant ($P > 0.05$) and the model refitted.

RESULTS

Breeding-Group Effects

Carcass Quality

The slaughter weights and carcass quality characteristics of heifer groups are shown in Table 3.1. Unbred and empty heifers had similar final weights and carcass weights, but calved heifers (slaughtered 6 months later than the unbred and empty groups) had significantly ($P < 0.001$) lower averages for these variables. Similar dressing-out percentages (DO%) were recorded for unbred v. empty and calved v. empty heifers, but DO% was lower ($P < 0.05$) in calved heifers than in the unbred group. Calved heifers had longer carcasses than unbred ($P < 0.05$) and empty ($P < 0.001$) heifers at the same carcass weight. All groups had similar rib-eye areas. Differences in measures of fatness adjusted for carcass weight between the three breeding-groups were not consistent, with the unbred heifers having more ($P < 0.01$) kidney and pelvic fat than empty heifers, and calved heifers having slightly less ($P < 0.10$) intramuscular fat than unbred and empty heifers. Fat depth was lowest in calved heifers but the difference was not significant.

As Table 3.2 indicates, there were no breeding-group effects on femur weight, femur weight to length ratio, or femur circumference but calved heifers had longer femur bones ($P < 0.01$) than unbred or empty heifers. Muscularity was similar for calved, empty and unbred heifers. Hind-quarter cut weights at a constant carcass weight were generally highest for the calved group, but not all differences were significant.

Table 3.1 The effects of breeding-group (unbred, empty and calved heifers) and pre-slaughter holding-period (4 h or 28 h) on carcass quality characteristics of Hereford x Friesian heifers.

	Breeding-group			Holding-period		Pooled SE
	Unbred	Empty	Calved	4 h	28 h	
Number of animals	10	10	15	18	17	
Final weight (kg)	468.00 ^b	482.90 ^b	435.25 ^a	460.25	464.50	10.75
Carcass weight (kg)	240.20 ^b	243.64 ^b	211.44 ^a	235.92	227.63	5.54
Dressing-out% ¹ (DO%)	51.13 ^a	50.16 ^{ab}	48.94 ^b	51.10 ^b	49.05 ^a	0.38
Carcass length ¹ (cm)	203.2 ^a	201.1 ^a	206.8 ^b	202.8	204.6	0.9
Rib-eye area ¹ (cm ²)	63.04	60.78	60.05	61.62	60.95	1.29
Kidney+pelvic fat ¹ (kg)	5.53 ^a	7.86 ^b	6.28 ^{ab}	6.08	7.04	0.58
Fat depth ¹ (mm)	6.17	6.36	5.07	6.50	5.23	0.65
Intramuscular fat ¹ (%)	4.07	5.61	3.62	4.67	4.19	0.63

¹ Means are adjusted to a constant carcass weight by covariance analysis.

a, b Means within groups or holding periods and within the same row with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Table 3.2 The effects of breeding-group (unbred, empty and calved heifers) and pre-slaughter holding-period (4 h or 28 h) on the femur bone characteristics, muscularity and hind-quarter cut weights of Hereford x Friesian heifers.

	Breeding-group			Holding-period		Pooled SE
	Unbred	Empty	Calved	4 h	28 h	
Number of animals	10	10	15	18	17	
Femur bone characteristics¹						
Femur weight (FW, g)	1704.30	1610.35	1767.32	1653.28	1734.42	40.30
Femur length (FL, mm)	380.10 ^a	381.09 ^a	394.32 ^b	383.35	387.41	3.24
Femur circumference (mm)	139.01	139.04	140.08	138.12	141.01	1.05
FW/FL	4.47	4.27	4.49	4.33	4.48	0.01
Muscularity²	0.55	0.54	0.53	0.54	0.53	0.01
Hind-quarter cut weights¹ (kg)						
Tenderloin	3.53 ^b	3.36 ^a	3.77 ^c	3.59	3.52	0.05
Striploin	7.01	6.58	6.87	6.93	6.71	0.17
Rump	8.63 ^{ab}	8.33 ^a	8.84 ^b	8.74	8.46	0.13
Knuckle	7.84 ^a	7.76 ^a	8.40 ^b	8.03	7.96	0.14
Topside	13.12 ^{ab}	12.66 ^a	13.58 ^b	13.05	13.20	0.18
Outside	12.16 ^{ab}	11.85 ^a	12.75 ^b	12.27	12.24	0.25
3-cuts ³	33.12 ^a	32.27 ^a	34.73 ^b	33.35	33.40	0.49
6-Cuts ⁴	52.29 ^{ab}	50.54 ^a	54.21 ^b	52.61	52.09	0.65

¹ Means are adjusted to a constant carcass weight by covariance analysis.

² Muscularity = (square root (weight of 3-cuts/femur length))/femur length), Purchas et al. (1991).

^{3&4} The sum of (knuckle, inside and outside), and the sum of all six cuts, respectively.

^{a, b, c} Means within groups or holding periods and within the same row with superscripts that do not contain a common letter are significantly different (P < 0.05).

Thirteen percent of the carcasses from calved heifers were classed as "L", based on the New Zealand export classification system, while no carcasses of unbred or empty heifers were placed in this class (Table 3.3). Conversely, a greater proportion of carcasses of the empty and unbred heifers were classified as G class. Calved heifers had no carcasses in the G class. However, the differences can be largely attributed to differences in carcass weight.

Table 3.3 Proportions (%) of carcasses of unbred, empty and calved heifers in four fatness classes, based on the New Zealand export beef carcass classification system.

	Fatness class			
	L (1-3mm) ¹	P (4-7mm)	K (8-12mm)	G (13-18mm)
Unbred	0	70	20	10
Empty	0	40	20	40
Calved	13	74	13	0

¹ Backfat thickness range in brackets.

Meat Quality

Meat from calved heifers was significantly brighter (i.e. higher reflectance values; $P < 0.05$) than meat from unbred heifers, with the empty group having intermediate values (Table 3.4). Expressed juice values were significantly higher in meat of unbred ($P < 0.05$) and empty ($P < 0.10$) heifers than in that from calved heifers. Significantly lower cooking losses were observed for meat from empty heifers compared with that of unbred ($P < 0.05$) or calved ($P < 0.01$) groups. The WB shear force measurements (Table 3.4) indicated that meat from unbred, empty and calved heifers had similar values for initial yield (IY) and peak forces (PF). However, the (PF-IY) value was significantly higher for calved heifers than for the unbred ($P < 0.05$) and empty ($P < 0.01$) groups. The interactions between breeding-group and holding-period, which were significant for meat ultimate pH, sarcomere length and WB work-index values (Table 3.5), are discussed in the next section.

Holding-Period Effects

Carcass characteristics of heifers slaughtered following either 4 or 28 hours holding were very similar except that the DO% was significantly higher ($P < 0.001$) for the 4 h group (Tables 3.1 and 3.2). Holding-period also had little effect on meat quality characteristic of heifers except that expressed juice values were lower ($P < 0.01$) for the 28 h group (Table 3.4).

Table 3.4 The effects of breeding-group (unbred, empty and calved heifers) and pre-slaughter holding-period (4 h or 28 h) on meat quality characteristics and on Warner-Bratzler (WB) shear force parameters for Hereford x Friesian heifers.

	Breeding-group			Holding-period		Pooled SE
	Unbred	Empty	Calved	4 h	28 h	
Number of animals	10	10	15	18	17	
Meat quality characteristics						
Fat colour ¹	3.95	3.95	4.03	3.90	4.02	0.22
Meat colour (R 630)	21.60 ^a	23.90 ^{ab}	25.45 ^b	24.42	22.88	1.28
Expressed juice (cm ² /g)	44.92 ^b	44.27 ^{ab}	42.78 ^a	45.16 ^b	42.82 ^a	0.67
Cooking loss (%)	26.28 ^b	25.03 ^a	26.41 ^b	25.82	25.98	0.39
WB shear force parameters (kg)						
WB initial yield (IY)	8.45	8.69	8.44	8.38	8.67	0.39
WB peak force (PF)	9.87	10.18	10.45	9.97	10.36	0.46
WB (PF-IY)	1.42 ^a	1.49 ^a	2.02 ^b	1.59	1.69	0.16

¹ Based on a set of 8 coloured paddles: 1 = nearly white to 8 = bright yellow (Purchas et al. 1992).

^{a, b} Means within groups or holding periods and within the same row with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

The significant interaction effects shown in Table 3.5 indicate that ultimate pH was lower for the empty than the unbred heifers within the 28 h group, but that there was no breeding-group effect within the 4 h group. The muscle from unbred heifers held for 4 h had shorter sarcomeres than muscle from their counterparts held for 28 h, but sarcomere length was not affected by holding-period for the other two groups. The WB work-index values in unbred and empty heifers held for 4 h were significantly lower ($P < 0.01$) than those of their counterparts held for 28 h, but holding-period did not affect this variable for the calved group.

Table 3.5 The effects of breeding-group (unbred, empty and calved heifers) and pre-slaughter holding-period (4 h or 28 h) on meat quality characteristics of Hereford x Friesian heifers for which the interaction between group and holding-period was significant ($P < 0.05$).

	Unbred		Empty		Calved		Pooled SE
	4 h	28 h	4 h	28 h	4 h	28 h	
Number of animals	5	5	5	5	7	8	
Meat ultimate pH	5.57 ^{ab}	5.64 ^c	5.58 ^{abc}	5.55 ^a	5.61 ^{bc}	5.58 ^{abc}	0.02
Sarcomere length μm	1.52 ^a	1.65 ^b	1.65 ^b	1.65 ^b	1.68 ^b	1.64 ^b	0.03
WB work-index	2.80 ^a	3.50 ^b	2.80 ^a	3.69 ^b	2.95 ^a	2.98 ^a	0.15

^{a, b, c} Means within the same row with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

DISCUSSION

Breeding-Group Effects

Carcass Weight and Dressing-Out Percentages

The mean slaughter weight of 435 kg recorded for calved heifers in this study was lighter than the 450-480 kg recommended for once-bred heifers under New Zealand pasture conditions by Morris & Khadem (1991), but the unbred and empty heifers had mean slaughter weights within this range despite the fact that they were 6 months younger. The lower final weight and the accompanying lower weight-adjusted DO% of the calved group could have been due to either a direct effect of pregnancy and lactation or to differences in the quality and level of herbage offered during the few months prior to slaughter.

Bailey et al. (1991) reported that empty heifers slaughtered at 22 months of age had heavier carcasses and higher DO% than 32-month-old calved heifers that received the same high-roughage alfalfa-based finishing diet, and that had suckled their calves for 6 months prior to being slaughtered 71 days post-weaning. However, the differences in DO% may have been partly due to the different carcass weights, as adjustments were not made. In the study of Waggoner et al. (1990), 29-month-old empty Simmental x Hereford heifers had higher DO% than similar calved heifers which were slaughtered at 30 months of age (63.0 v. 60.7%). However, the difference was probably partly due to the heavier mean carcass weight of the empty heifers (344 v. 311 kg), as DO% is known to increase with increased weight (Field et al. 1966; Field & Schoonover 1967). Heifer dams in that particular study were weaned at about 5 weeks prior to slaughter after suckling their calves for about 115 days.

Bond et al. (1986) reported that calved heifers slaughtered after receiving a feedlot

ration for 42 days had lower DO% than the open heifers (59.7 v. 63.3%) finished on the same ration and slaughtered at similar liveweights. Roux et al. (1987) also found lower carcass weight-adjusted DO% for once-bred Friesian and Charolais x Friesian heifers, fed a feedlot ration for 120 days prior to slaughter, than empty heifers finished on the same ration for 70 days before being slaughtered at an age similar to the former heifer group. However, in both those studies calves were removed from the dams within a few days of birth so the effect on DO% was due to pregnancy rather than pregnancy and lactation.

In the study of Vincent et al. (1988), once-bred heifers slaughtered at 765, 821, and 883 days of age following suckling periods of 3-, 5- or 7-month, respectively, had heavier carcass weights and lower unadjusted DO% than unbred heifers slaughtered at 457 days of age. Calved heifers were slaughtered within a few days of weaning and a feedlot ration was offered to them during the suckling period, as well as to their unbred counterparts. The authors noted that heifer dams had heavier udders since they were slaughtered soon after weaning. No published data were found on udder weights but it implies that the slaughter weights minus udder weights should be used in calculation of DO% of calved heifers in OBH beef production systems. Based on the DO% values obtained in the current study, the calved heifers would have had to be 15.7 kg heavier than the other two breeding-groups immediately pre-slaughter in order to produce carcasses of the same weight. Mean udder weights for similar cattle have been less than 5 kg (Khadem et al., unpublished data) indicating that differences in udder weights would have accounted for less than 35% of the DO% difference.

No significant difference in DO% between unbred and calved Belgian White and Red dual-purpose heifers in a OBH beef production system slaughtered after reaching a good body condition was reported by Boucque et al. (1980). In addition, Lowman & Broadbent (1987) reported that Simmental x Hereford once-bred heifers, which had suckled their calves for 4 weeks before being dried off and finished with a mixture of

herbage and barley (2 kg/hd/day) for 4 months, had 2% higher DO% than the empty heifers slaughtered at about 4 months younger. However, the higher DO% was most likely due to the 60 kg heavier slaughter weights recorded for calved heifers in that particular study. Thus, these studies suggest that if calved and unbred heifers are slaughtered at a uniform level of fatness regardless of age, then DO% will be similar or even higher for the calved group.

Weight, fatness, and diet all influence the DO% of animals (Berg & Butterfield 1975; Geay 1978; Kirton & Morris 1989) and could have been involved in the differences reported here. The empty and unbred heifers were heavier at slaughter after being grazed to appetite on high quality spring (September-November) pastures and growing at 1.36 kg/d during the 2.5 months prior to slaughter. In comparison, calved heifers were slaughtered at lower body weights in mid May following restricted grazing on a poorer quality summer pastures (Waghorn & Barry 1987) so that their growth rate was 0.36 kg/d for the 2.5 months pre-slaughter period. It is suggested that the differences in growth rate may have led to lower fatness and hence lower DO% (Berg & Butterfield 1975; Geay 1978) in calved heifers. In agreement with this suggestion, Sinclair et al. (1989) reported that once-bred Hereford x Friesian heifers slaughtered immediately after weaning at 6 weeks post-partum or after a suckling period of 12 weeks had about 5.5 and 3%, respectively, lower DO% than empty heifers slaughtered at a weight 20 kg heavier than the former groups. In addition, the good quality herbage fed to the empty and unbred groups would have passed out of the rumen faster than lower quality summer pasture (Waghorn & Barry 1987), and hence would have resulted in lighter gut contents and higher DO% in this group (Berg & Butterfield 1975; Geay 1978).

Conformation, Fatness and Meat Yield

The longer carcasses and femur bones of the calved heifers (Tables 3.1 and 3.2), after adjustment to a constant carcass weight, are in agreement with the results of Boucque et al. (1980) showing that carcasses of once-bred heifers were 5 cm longer than those of unbred heifers. However, in that study adjustments were not made to a constant weight so that the true difference may have been reduced due to the heavier carcasses of unbred heifers. In addition, both Lowman & Broadbent (1987) and Sinclair et al. (1989) reported low conformation scores for calved heifers relative to the empty groups, and suggested that this was due to a slackening of the pelvis which allowed the carcasses of calved heifers to hang in a more angular shape. On a proportional basis, when the carcass data were adjusted to a constant total dissectible fat content in the study of Vincent et al. (1991), the once-calved heifers tended to produce more bone and less lean meat than unbred heifers that were 12 months younger. In the study of Bailey et al. (1991), a significantly higher unadjusted mean total dissectible bone percentage was reported for 32-month-old calved heifers relative to a 22-month-old unbred group at a similar carcass weight. In addition, calved heifers in the study of Waggoner et al. (1990) had higher USDA bone maturity scores than empty heifers. Once-bred heifers in the present study, and in all of the studies reported above, were slaughtered some months later than their unbred counterparts following suckling periods of 2-7 months. It seems likely that the differences in carcass length and/or total bone percentages may have been due to the differences in age at slaughter. In agreement with this suggestion, once-calved heifers in the study of Roux et al. (1987) which had only 2-3 days suckling period, had similar total bone weights, adjusted for carcass weight, to the empty heifers slaughtered at same weight and age (13.11% v. 13.42%).

Measures of fatness in the current study were generally not significantly different between the heifer groups, but weight-adjusted values were lower for the calved

heifers. Other studies have also indicated that calved heifers tend to be less fat, e.g. Sinclair et al. (1989) in the case of total fat yield, and Waggoner et al. (1990) and Bailey et al. (1991) in the case of kidney and pelvic fat values, or that they need to be grown to heavier weights to achieve similar levels of fatness (Joseph 1975; Boucque et al. 1980; Bond et al. 1986; Roux et al. 1987). In some studies (Waggoner et al. 1990; Bailey et al. 1991; Vincent et al. 1991), significantly higher intramuscular fat percentages and fat thicknesses were reported for calved heifers relative to the unbred or empty groups, especially for heifers finished on high-grain rations. Vincent et al. (1988, 1991) found that calved heifers offered grain-based rations for 5 and 7 months pre-slaughter periods while suckling their calves tended to be fatter and have a lower carcass lean content than the conventionally managed heifers or the OBH group which were received the same ration for 3 months prior to slaughter. The authors noted that some restriction of feed would have been necessary 3 months following calving to prevent heifers becoming too fat. As noted earlier, unbred and empty heifers in this study were finished with good quality of spring herbage and produced fatter carcasses than the calved heifers which received poorer quality summer/autumn herbage during the post-weaning period and had no opportunity to receive extra energy to deposit as fat (Lalande & Fahmy 1975; Cianzio et al. 1982; Waggoner et al. 1990).

The absence of significant differences in weight-adjusted rib-eye area between the breeding-groups in this study is in agreement with the results of Bailey et al. (1991) and Waggoner et al. (1990). The combined weight of six hind-quarter cuts, after being adjusted to a constant carcass weight, was slightly greater in calved heifers than in the other two breeding-groups (Table 3.1), suggesting that calved heifers either had leaner carcasses than the other two breeding-groups or that they had higher muscle to bone ratio. In agreement with these results, a significantly higher percentage of saleable meat was reported for calved heifers relative to an empty group in the study of Sinclair et al. (1989). Some studies, however, have shown no differences in total meat yield between calved and unbred heifers. For example, Boucque et al. (1980) reported 60

and 62% total meat yield for empty and calved heifers, respectively. In the study of Joseph (1975), once-bred Aberdeen-Angus cross heifers, finished to a carcass weight of 217 kg after being weaned at 2 days post-partum, had similar total boned-out cuts, adjusted for carcass weight, to maiden heifers slaughtered at an average carcass weight of 172 kg and 6 months younger. However, heavier back-cuts and lighter hind-quarter cuts were recorded for calved heifers in that study. Similar USDA yield grades were reported for 16.5-, 29-, and 30-month-old open, empty and calved heifers, respectively, in the study of Waggoner et al. (1990). In addition, calved and empty heifers slaughtered at about 24 months of age had similar carcass weight-adjusted total meat yield in a OBH beef production system in which calves were removed within a few days of birth (Roux et al. 1987).

Meat Quality Characteristics

The lack of significant differences in meat ultimate pH values recorded for the unbred, empty and calved heifers in this study is in agreement with the results reported by Bailey et al. (1991) and Dumont et al. (1987). However, conventionally reared heifers had lower meat ultimate pH values than once-bred heifers in the study of Vincent et al. (1991), and the authors suggested that this was due to them being slaughtered within a few days of weaning.

A brighter meat colour was recorded for meat of calved heifers in this study, but Dumont et al. (1987) reported that pregnancy and calving had no effect on lean colour and Bailey et al. (1991) reported that beef from once-calved heifers was slightly darker than that from unbred heifers. In the study of Waggoner et al. (1990), the 16.5-month-old unbred heifers had the lightest visually assessed lean colour, but 29-month-old empty and 30-month-old calved heifers had similar scores for meat colour. The darker meat colour reported for once-calved heifers relative to unbred heifers in the studies of Bond et al. (1986) and Vincent et al. (1991) is not in agreement with the results of the

present study. Vincent et al. (1991) suggested that the darker meat from once-calved heifers was most likely due to an increase in the muscle pigment myoglobin, which increases until an animal reaches about 36 months of age.

Meat from calved heifers in the present study had lower expressed juice values than that from the unbred group which is consistent with the reports of Dumont et al. (1987) and Vincent et al. (1991). Bouton et al. (1982), however, reported that muscles from bred and unbred heifers slaughtered at 18 or 22 months of age, had similar cooking-loss percentages. Sensory panel juiciness and cooking loss percentages scores did not differ among treatment groups in the studies of Joseph & Crowley (1971), Bond et al. (1986) and Waggoner et al. (1990).

The finding that WB shear force values for meat from calved heifers were similar to those for meat from the other two breeding-groups (Tables 3.4 and 3.5) is in agreement with the results reported for tenderness of meat from once-bred and unbred heifers using either shear tests (Bond et al. 1986; Waggoner et al. 1988) or a trained laboratory panel (Joseph & Crowley 1971; Bond et al. 1986). In addition, similar WB shear values were recorded for the meat of unbred and calved heifers slaughtered at an age difference of about 10 months in the study of Bailey et al. (1991). Consumer-panel tests, in the trial of Vincent et al. (1991), recorded similar meat tenderness scores for the meat of once-bred and conventionally reared heifers.

Holding-Period Effects

The higher dressing-out percentages (51.10 v. 49.05%) recorded for heifers held for 4 h v. 28 h prior to slaughter, in the present study, is in agreement with the findings of Geay (1978) and emphasises that the pre-slaughter holding-period is one of the factors affecting DO%. Except for the expressed juice in muscle other carcass quality characteristics of heifers were not significantly affected by the pre-slaughter holding-

period. These and the results for bulls, steers and heifers reported by Purchas (1992), suggest that reducing the holding-period from 28 h to 4 h prior to slaughter may increase carcass weights and DO% slightly. In the report of Purchas (1992) the ultimate pH of beef from heifers was similar for 4 h and 28 h holding periods, but that for bulls, and to a lesser extent steers, was increased.

CONCLUSIONS

This study has indicated that it is possible to produce carcasses and meat with desirable quality attributes from once-bred heifers, although carcass weights and DO% were lower in that group. Thus breeding heifers once dose not have detrimental effects on their meat quality. The lower carcass weights recorded for the calved heifers were due to low growth rates during lactation and post-weaning (see Chapter 2) so that target liveweights were not achieved prior to winter. Approaches to avoid this problem include better nutrition (quantitative and qualitative) of heifer dams at an earlier stage before and after weaning. These aspects are discussed in Chapter 4.

CHAPTER FOUR

HERBAGE INTAKE, INGESTIVE BEHAVIOUR, GROWTH PERFORMANCE, AND CARCASS AND MEAT QUALITY CHARACTERISTICS OF EARLY- OR NORMAL-WEANED ONCE-BRED HEREFORD X FRIESIAN HEIFERS

ABSTRACT

Beef breeding cows are traditionally weaned at about 7-8 months of calf age in New Zealand but early weaning may have advantages in OBH beef production systems. This study compared the lifetime growth performance, and carcass and meat quality characteristics of once-bred Hereford x Friesian heifers mated to Angus or Charolais sires and weaned at an early (day 84 of lactation = L84) or normal (day 147 of lactation = L147) time. Heifers grew at 0.55 ± 0.02 kg/d from purchase (December 1989) until mating (November 1990) and at 0.34 ± 0.03 kg/d during the average 281 days of pregnancy. Heifers carrying Angus-sired (AS) calves had a gestation period slightly shorter than those carrying Charolais-sired (CS) calves (279.3 v. 284.3, PSE = 2.0 days, $P < 0.10$), but there was no effect of calf sex on gestation length. Mortality rate was 7% higher in CS calves than in AS calves (36% v. 29%). Birth weight of calves was not influenced by calf sex, but was significantly greater in CS v. AS calves (42.9 v. 36.8, PSE = 0.7 kg, $P < 0.001$). Weaning caused a slight weight loss in both early- (EW) and normal- (NW) weaned heifers for the first 30-45 days post-weaning, but liveweight (LW) was recovered after this period. During L84-L147, EW heifers had higher daily liveweight gain (LWG) than the NW heifers (0.79 v. 0.51, PSE = 0.07 kg/d, $P < 0.01$). Calves weaned at L84 had significantly lower daily LWG than NW calves during the period L84-L147 (0.73 v. 1.30, PSE = 0.05, $P < 0.001$). This resulted in 30 kg lighter ($P < 0.001$) weaning weight in EW v. NW calves at the time of

weaning for the latter group. Herbage intake (estimated using intraruminal chromium capsules), ingestive behaviour, biting rate and bite weight of heifer dams were not affected by the sex or sire breed of calves during L80-L90. However, during the period L140-L150, heifers weaned at L84 had organic matter (OM), dry matter and energy intakes slightly lower ($P < 0.10$) than those still suckling and weaned at L147. The EW v. NW heifers consumed OM herbage intakes of 3.01 v. 3.50, PSE = 0.16 kg DM/100 kg LW/d, ($P < 0.05$). Normal-weaned heifers spent more time grazing ($P < 0.01$) and ruminating ($P < 0.10$), and less time idling ($P < 0.01$) than the EW heifers. Overall, weaning time did not significantly affect the carcass and meat quality characteristics of EW or NW heifers. Results are discussed in the context of weaning time effects on the productivity and carcass and meat quality traits of once-bred heifers.

INTRODUCTION

In New Zealand, beef calves are commonly weaned from their dams at 7-8 months of age. However, there is evidence that a relatively low association exists between the dam's milk production beyond the first 4 months of lactation and the calf liveweight gain during that period (Gifford 1949). This is presumably because milk production in suckling beef cows declines after about 14 to 16 weeks of lactation (Hight 1968b) and the calves become more dependent on solid feed. Thus, Neville (1970) suggested that feed utilisation would be more efficient, and the cost of feeding cows and calves could be lowered, if calves were weaned early and fed a high-energy ration for maximum growth while their weaned dams were fed at a maintenance level. Based on these suggestions, research has been conducted in North America (Neville 1970; Bellows et al. 1974; Richardson et al. 1978; Lusby et al. 1981; Neville & McCormick 1981; Houghton 1990b), the United Kingdom (Aitken et al. 1963; Butler-Hogg et al. 1981), Canada (Basarab et al. 1986; Kubisch & Makarechian 1987; Makarechian et al. 1988), Australia (Holroyd et al. 1988; Sullivan et al. 1992) and New Zealand (Percival 1951;

Hight 1968b; Hughes & Acland 1970; Donnelly 1977; Donnelly & Fennessy 1978; McCall et al. 1988) to investigate how early weaning would affect the performance of cows and calves in beef cattle rearing systems. Early weaning generally increased LWG and decreased the post-partum anoestrus interval in cows. The LWG of early-weaned calves decreased relative to that of later weaned calves unless concentrate meals were offered. Carcass traits were similar in once-bred heifers (OBH) slaughtered after rearing their calves for 6 or 12 weeks (Lowman & Broadbent 1987). In the study of Vincent et al. (1991), the rib-eye steaks of once-bred heifers slaughtered following a 3-, 5- or 7-month suckling period had similar consumer acceptability, but meat of the 7-month group had a higher amount of connective tissue when evaluated by a trained panel than meat of the other two heifer groups.

Lowman & Broadbent (1987) suggested that a major improvement in carcass weight of calved heifers can be obtained only if they are weaned early or are allowed an appropriate finishing period after weaning. For New Zealand beef cattle systems, using meal supplementation is more costly than grazing alone (Donnelly 1977). Therefore, weaning should occur at a time when good quality pastures are available for the calf and also for the dam in a OBH system where a high cow growth rate is required post-weaning. The low quality of pastures during January-March in New Zealand (Radcliffe 1974; Smeaton et al. 1983b; Reid 1986; Nicol & Nicoll 1987; McCall et al. 1988) and the relatively low growth rate of once-bred heifers weaned in late January (see Chapters 2 and 3) suggests that weaning heifer dams in November, rather than in January, might allow calves to grow well and permit the heifers to reach the target slaughter weights recommended for New Zealand OBH beef production systems (Morris & Khadem 1991). The main purpose of this study was, therefore, to compare the herbage intake, ingestive behaviour, liveweight gain, cow and calf performance, and the carcass and meat quality characteristics of once-bred heifers weaned at either early (November, i.e. 2-3 months post-partum) or normal (January, i.e. 5 months post-partum) times.

MATERIALS AND METHODS

Forty-eight approximately 4-month-old Hereford x Friesian heifers with a mean (\pm SE) liveweight (LW) of 125 ± 4 kg were purchased in December 1989. Heifers were grazed on pastures of predominantly perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) at the Massey University Sheep and Beef Cattle Research Unit. Liveweights were recorded monthly from purchase through to slaughter in March 1992. Heifers (316 ± 4 kg LW) were mated to either Angus (24 heifers) or Charolais (24 heifers) sires at about 15 months of age over two oestrus cycles commencing in late November 1990. Oestrus was synchronised using CIDRs (see Chapter 2). Heifers were mated by artificial insemination (AI) 48 hours after CIDR withdrawal. From these matings 31 heifers became pregnant, 17 to Angus sires (AS) and 14 to Charolais sires (CS). The 17 remaining heifers were mated by a Friesian bull after the two rounds of AI, and 11 of them became pregnant. Heifers mated to the Friesian bull or unmated were excluded from the study on the basis that they were not comparable to the other groups.

Heifers were managed to gain weight until the seventh month of pregnancy (i.e. mid June 1991). From that time a maintenance level of intake comprising a mixture of herbage and hay (fed in the paddock or on a feed pad) was offered in an attempt to restrict fetal growth and avoid overfatness of the heifer dams, and hence reduce the incidence of dystocia at parturition.

Heifers carrying AS or CS calves calved during the period 18 August to 8 September 1991. The liveweight of heifers was recorded one week prior to the commencement of calving. Calves were weighed at birth and identified to their heifer dams during morning and evening field inspections each day. Calving ease score, dam LW loss at calving and post-calving dam LW were recorded/calculated as described in Chapter 2.

One heifer carrying a CS calf, and 10 calves (5 AS and 5 CS calves, one being from the dead heifer), died due to problems related to dystocia at calving. Heifers which lost their calves were sold as prime beef animals within a few months after calving.

Twenty-one heifers suckled their calves until 23 November 1991. At this time, 10 calves (balanced for liveweight, sex and sire breed) were weaned at 84 ± 2 (mean \pm SE) days of age. These are referred to as the "early-weaned" (EW) group. The EW dams, EW calves and the 11 heifers still suckling their calves (the "normal-weaned" or NW group) were allocated to three separate paddocks with similar pasture conditions until 24 January 1992 when the NW calves were weaned after 147 ± 2 days of suckling. The EW and NW calves were then sold as prime weaners, and the heifer dams (both EW and NW groups) were grazed together until slaughter in late March 1992. The sward heights on the experimental area were measured, and the herbage masses estimated, using the procedures described in Chapter 2, to ensure that adequate herbage was offered to the three groups of animals, from 23 November (i.e. day 84 of lactation (L84)) until 24 January (L147).

The herbage intake, ingestive behaviour and LWG of heifer dams were investigated in two experiments, the first involving heifers immediately prior to weaning of the EW group in November 1991 and the second examining the performance of EW and NW heifers immediately prior to weaning of the latter group (January 1992).

Experiment 1

Twenty heifers (405 ± 15 kg LW) were used for this experiment which was conducted on a 3 ha lowland pasture area. Intraruminal chromium controlled release capsules (CRC) were inserted into the rumen of heifers on D1 of the experiment (5 November 1991). The same procedures described in Chapter 2 were used to collect faecal and hand-plucked herbage samples to estimate the faecal output (FO) and digestibilities (i.e. organic matter digestibility (OMD), dry matter digestibility (DMD) and digestible organic matter in dry matter (DOMD)) and ash in the herbage and, consequently, to calculate the organic matter intake (OMI), dry matter intake (DMI) and energy intake of heifers. The intake trial was completed on 22 November. Two heifers regurgitated their capsules during the experiment, and intake data for these heifers were not analysed.

Heifer dams were exposed to a continuous stocking system designed to permit *ad libitum* levels of intake. This was assumed to be 13 kg DM/hd/d for heifers with an average LW of 400 kg (Geenty & Rattray 1987). On this basis, total daily intake was expected to be 260 kg DM of herbage (13 kg DM/hd/d x 20 heifers) over the 17-day experimental period. Herbage growth rate was expected to be 45 kg DM/ha/d (Milligan et al. 1987) or 135 kg DM/d from the 3 ha trial area. The target herbage mass at the commencement of the trial of 4000 kg DM/ha (equivalent to a sward height of 19-21 cm) was expected to reduce to 3292 kg DM/ha at the end of the trial, i.e. an intake of 260 kg DM/d comprising 135 kg DM/d of new herbage growth and 125 kg DM/d of existing herbage.

Liveweights (off-pasture and 16-hour-fasted) were recorded at the beginning and end of the experiment, and two 24-hour ingestive behaviour studies were conducted on D7, D8, D9 and D11 of the first, and D12, D13, D14 and D16 of the second, 5-day faecal sampling periods as described for Experiment 2, Chapter 2.

The pre- and post-grazing herbage mass, herbage composition, sward height and the rate of herbage growth were estimated (see Chapter 2).

Experiment 2

Experiment 2 was also conducted on 3 ha of pasture adjacent to the paddocks used for Experiment 1. The main purpose of this trial was to examine whether early weaning affected the performance of heifer dams. The 20 animals used in Experiment 1 (with liveweights of 449 ± 19 kg) were used with 10 having been weaned at L84 (i.e. end of Experiment 1), while the other 10 were still suckling their calves. Early-weaned and NW heifers were compared in terms of their herbage intake, ingestive behaviour and LWG during the period L140-L150 for the latter group (while the EW group were at days 50-60 post-weaning). Preparation of the pasture area and estimation of the mass, height and composition of herbage at the commencement and end of the experiment were as described for Experiment 1. The chromium CRCs were inserted into the rumen of heifers on 7 January 1992 (i.e. D1 of the trial). Faecal and hand-plucked herbage samples were collected to estimate daily FO of heifers and the digestibility of herbage offered, respectively, and hence the daily OM, DM and energy intakes. In addition to these measurements, the crude protein and fibre content of hand-plucked herbage samples were determined in both experiments using the Kejl Dahl method (AOAC 1980) and the method of Van Soest (1982), respectively.

As in Experiment 1, heifer dams were exposed to a continuous stocking system designed to permit an *ad libitum* level of intake. This was assumed to be 15 kg DM/hd/d of summer-grown pasture for heifers with an average LW of 450 kg (Geenty & Rattray 1987). On this basis, daily intake was expected to be 300 kg DM of herbage (15 kg DM/hd/d x 20 heifers) over the 17-day experimental period. Herbage growth rate was expected to be 15 kg DM/ha/d (Milligan et al. 1987) or 45 kg DM/d from the

3 ha trial area. The target herbage mass at the commencement of the trial of 4200 kg DM/ha (equivalent to a sward height of 19-22 cm) was expected to reduce to 2755 kg DM/ha at the end of the trial, i.e. an intake of 300 kg DM/d comprising 45 kg DM/d of new herbage growth and 255 kg DM/d of existing herbage.

Liveweights (off-pasture and 16-hour-fasted) were recorded at the beginning and end of the trial, and two 24-hour ingestive behaviour studies were conducted on D7, D8, D9 and D11 of the first, and D12, D13, D14 and D16 of the second, 5-day faecal sampling periods (see Chapter 2).

The trial was completed on 23 January 1992. Two heifers regurgitated their capsules during the experiment and intake data for these heifers were not analysed.

Carcass and Meat Quality Measurements

Carcass Quality Measurements

The weights of 19 heifers (two of the 21 heifer dams died accidentally) were recorded off-pasture at 0800h on 24 March 1992 before transportation about 20 km to a slaughter plant (Weddel Feilding Ltd). Heifers were slaughtered at about 0800h on 25 March. Udder weight, the number of erupted permanent incisor teeth and the weights of kidney and pelvic fat depots from both sides were recorded. Carcass length, defined as the length from the distal end of the tarsal bones to the midpoint of the cranial edge of the first rib (Purchas 1990), was measured for each side, before the sides were weighed and classified (NZMPB 1991). The subcutaneous fat colour was scored at the abattoir based on a set of 8 coloured paddles (Purchas et al. 1992). Fat colour was also measured on fat samples taken over the *longissimus dorsi* (LD) using a Minolta Chroma Meter II (Minolta Camera Co., Meter Division, Ramsey, NJ, U.S.A.).

A sample of the LD muscle from the 10th to 13th rib region (c. 750-1050 g) was dissected from the right side of each carcass within 90 minutes *post mortem*. Samples were placed in plastic bags, held at ambient temperature (15-18°C) for 24 h, transferred to a chiller (0-2°C) for 6 days and then frozen (at -15 to -20°C) for 5 to 16 weeks.

On the day after slaughter, the area of LD from each carcass was traced and the thickness of subcutaneous fat measured on the chilled (overnight at 1-3°C) and quartered carcasses as described in Chapter 3. On the same day, the weights of six major hind-quarter cuts from both sides of each carcass were recorded as they were prepared under normal commercial conditions (see Chapter 3).

In addition to the samples of LD taken from the right sides of unchilled carcasses, a similar sample of LD from the left side (c. 500-700 g from the 10th to 13th rib region) was also taken at the time of boning to determine whether chilling overnight affected the quality characteristics of meat. Samples were placed in plastic bags, transferred to a chiller (0-2°C) for 6 days and then frozen (at -15 to -20°C) for 5 to 16 weeks.

Meat Quality Measurements

The frozen samples of both chilled and unchilled LD were thawed (ambient temperature for 1 h and in a chiller at 3-5°C, for 20-22 h) and then the following cuts were made starting from the cranial end:

- (a) A thin slice (2-10 mm, depending on the size of the LD sample) was cut to square it up.
- (b) A 15 mm thick slice was prepared for colour and sarcomere length measurement. The middle portion (30 x 30 mm) was used to measure the meat colour using a

Minolta Chroma Meter II. A central slither was taken from the medial portion and stored in a labeled test tube to measure sarcomere length using the laser diffraction method (Cross et al. 1981).

- (c) A 25 mm steak was cut, placed in a plastic bag, weighed and cooked by suspending the bag in a water bath thermostatically controlled at $70 \pm 1^\circ\text{C}$ for 90 minutes (Purchas 1972). The cooking loss and Warner-Bratzler (WB) shear force values were determined on these samples as described in Chapter 3.

- (d) A sample of at least 80 g (from the right side LD samples only) was taken from the middle part of a 40 mm thick slice and trimmed of subcutaneous fat, intermuscular fat and the epimysium. These samples were then stored in snap-top plastic bags at -15°C for intramuscular fat analysis using the Soxhlet method (AOAC 1980).

- (e) The medial part from the 40 mm thick slice was used to obtain samples for pH and water holding capacity assessments as described in Chapter 3.

Statistical Analyses

Statistical analyses were performed using the General Linear Model procedure (SAS 1985). Data related to the performance of heifer dams (from mating to calving), cow and calf (from calving to early weaning at L84) and the herbage intake, ingestive behaviour and daily LWG of heifer dams in Experiment 1, were analysed using model 4.1 below:

[Model 4.1]

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ijk}$$

- Where:
- Y_{ijk} = an observation on the k^{th} calf (or its dam) of the i^{th} sex and the j^{th} sire breed
 - μ = the overall mean
 - α_i = the effect of the i^{th} calf sex ($i = 1, 2$)
 - β_j = the effect of the j^{th} calf sire breed ($j = 1, 2$)
 - $(\alpha\beta)_{ij}$ = the interaction between the effects of the i^{th} calf sex and the j^{th} calf sire breed
 - e_{ijk} = the random residual associated with an observation on the k^{th} calf (or its dam) of the i^{th} sex and the j^{th} sire breed.

Data related to the cow and calf performances from L84 through to normal weaning at L147 were analysed using model 4.2 below:

[Model 4.2]

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \Theta_k + (\alpha\beta)_{ij} + (\alpha\Theta)_{ik} + (\beta\Theta)_{jk} + e_{ijkl}$$

- Where:
- Y_{ijkl} = an observation on the l^{th} calf (or its dam) of the i^{th} sex, the j^{th} sire breed and the k^{th} weaning time
 - μ = the overall mean
 - α_i = the effect of the i^{th} calf sex ($i = 1, 2$)
 - β_j = the effect of the j^{th} calf sire breed ($j = 1, 2$)
 - Θ_k = the effect of the k^{th} weaning time ($k = 1, 2$)

- $(\alpha\beta)_{ij}$ = the interaction between the effects of the i^{th} calf sex and the j^{th} calf sire breed
 $(\alpha\Theta)_{ik}$ = the interaction between the effects of the i^{th} calf sex and the k^{th} weaning time
 $(\beta\Theta)_{jk}$ = the interaction between the effects of the j^{th} calf sire breed and the k^{th} weaning time
 e_{ijkl} = the random residual associated with an observation on the l^{th} calf (or its dam) of the i^{th} sex, the j^{th} calf sire breed and the k^{th} weaning time.

Data related to the carcass and meat quality characteristics were analysed using model 4.3 below:

[Model 4.3]

$$\begin{aligned}
 Y_{ijkl} &= \mu + \alpha_i + \beta_j + \Theta_k + (\alpha\beta)_{ij} + (\alpha\Theta)_{ik} + (\beta\Theta)_{jk} \\
 &\quad + b_{ijk} (x_{ijkl} - X) + e_{ijkl}
 \end{aligned}$$

This model is the same as model 4.2 except that carcass weight (X) is included as a covariate (see Chapter 3).

Weaning weights of calves (both at the early and normal weaning times) were adjusted to a constant weaning age. Dressing-out percentage (DO%) was calculated as: (DO% = carcass weight ÷ final liveweight x 100), where final liveweight was equal to the last liveweight minus udder weight.

Interaction effects were excluded from the models when they were not significant ($P > 0.05$) and the model refitted.

RESULTS

No significant interactions were observed between sex, sire breed of calf and weaning time. Results are, therefore, presented based on the effects of main treatment groups.

Heifer and Calf Performance

Heifers grew at 0.55 ± 0.02 kg/d from purchase (December 1989) until mating (November 1990) and at 0.34 ± 0.03 kg/d during the average 281 days of pregnancy. Weaning caused a slight weight loss in both EW and NW heifers for the first 30-45 days post-weaning, but liveweight was recovered after this period. From calving (late August 1991) until slaughter (late March 1992), the daily LWG was greater ($P < 0.10$) in heifers rearing female calves (0.44 ± 0.04 kg/d) v. male calves (0.31 ± 0.05 kg/d) and in early-weaned (0.45 ± 0.04 kg/d) v. normal-weaned (0.31 ± 0.05 kg/d) heifers but, during the same period, no effect of calf sire breed on the daily LWG of heifers was observed.

Pregnancy rate for all heifers over two cycles of mating was 65%, and heifers inseminated by Angus or Charolais semen had conception rates of 71% and 58%, respectively. Overall, mortality rates at calving of 3 and 32% were recorded for the heifer dams and their calves, respectively. Calving score was slightly but not significantly higher in heifers delivering CS v. AS calves (Table 4.1). Mortality rate was 7% higher in CS calves than in AS calves (29% v. 36%). Heifers carrying AS calves had a gestation period slightly shorter than those carrying CS calves (279.3 v. 284.3, PSE = 2.0 days, $P < 0.10$), but there was no effect of calf sex on gestation length. Liveweight loss of heifers at calving was not significantly affected by calf sex, but heifers with CS calves lost more weight than those with AS calves (64.0 v. 57.0, PSE = 0.8 kg, $P < 0.001$, Table 4.1).

Daily LWG during L1-L84 was higher in heifers rearing female calves than in those rearing male calves (0.50 v. 0.27, PSE = 0.07 kg/d, $P < 0.05$), but calf sire breed had no effect on daily LWG of the dam. No effects of sex, sire breed of calf or weaning time on the liveweight of heifer dams at L84 or L147 were observed. However, during L84-L147, EW heifers had higher daily LWG than the NW heifers (0.79 v. 0.51, PSE = 0.07 kg/d, $P < 0.01$). There was no effect of calf sire breed or time of weaning on dam daily LWG from calving until L147 but, during the same period, heifers rearing female calves had higher daily LWG than those rearing male calves (0.58 v. 0.42, PSE = 0.06 kg/d, $P < 0.05$).

Birth weight of calves was not influenced by calf sex (Table 4.1), but was significantly greater in CS calves than in AS calves (42.9 v. 36.8, PSE = 0.7 kg, $P < 0.001$). Similar differences in liveweight of AS and CS calves were found at L84 ($P < 0.05$) and L147 ($P < 0.10$). This reflected the fact that AS and CS calves had similar ($P < 0.19$) daily LWG from L1-L84 and from L84-L147 (Table 4.1). Daily LWG during L1-L84 was slightly higher in male calves than in female calves (1.26 v. 1.15, PSE = 0.04 kg/d, $P < 0.10$). This was consistent during L84-L147 and L1-L147 ($P < 0.05$). Similar liveweights were recorded for EW and NW calves at L84 (as expected) but, at L147, liveweight was 30 kg greater ($P < 0.001$) in NW calves. This was because calves weaned at L84 had significantly lower daily LWG than NW calves during the period L84-L147 (0.73 v. 1.30, PSE = 0.05, $P < 0.001$).

Experiment 1

Pasture characteristics during Experiment 1 are shown in Table 4.2. Heifers grazed pastures with an average pre- and post-grazing herbage mass of 4049 ± 268 and 3929 ± 180 kg DM/ha, respectively, equivalent to sward heights of 19.5 ± 1.2 and 15.4 ± 1.0 cm as measured by the sward stick, or 20.6 ± 1.2 and 15.6 ± 1.2 cm as measured by the rising plate meter. The pooled pre- and post-grazing pastures contained $70 \pm 1\%$ perennial ryegrass, $10 \pm 2\%$ white clover, $8 \pm 1\%$ weeds and $12 \pm 2\%$ dead material. The *in vitro* organic matter digestibility and ash content of hand-plucked herbage samples were $80 \pm 2\%$ and $10 \pm 1\%$ (on a DM basis), respectively. Herbage contained 30% crude protein, and 19, 18 and 16% cellulose, hemicellulose and lignin, 'respectively. Herbage growth rate was estimated to be 84 kg DM/ha/d over the trial period based on herbage accumulation under the cages.

Table 4.3 shows that during the Experiment 1 heifers rearing AS v. CS calves had significantly different daily LWG (0.50 v. 0.83 , PSE = 0.10 kg/d, $P < 0.05$), but there was no significant effect of calf sex on dam LWG. However, DM (13.53 v. 13.59 , PSE = 0.69 kg/hd/d) and OM (12.31 v. 12.37 , PSE = 0.63 kg/hd/d) herbage intakes were similar in heifers rearing AS v. CS calves. Overall, heifer dams consumed herbage OM and DM equivalent to 3.26 and 3.58% of their liveweights, respectively, during the mid lactation period in November. The ingestive behaviour, biting rate and bite weight of heifer dams were not affected by the sex or sire breed of calves at weeks 11-12 of lactation.

Table 4.1 Effects of sex and sire breed of calf, and weaning time on heifer dam and calf performance.

	Sex		Sire breed		Weaning time		Pooled SE
	Female	Male	Angus	Charolais	L84 ¹	L147 ²	
Heifer performance							
Number of animals	14	7	12	9	10	11	
Gestation length ³ (d)	281.0	282.6	279.3	284.3	-	-	2.0
Pre-calving LW ³ (kg)	451.8	457.1	454.0	454.9	-	-	10.9
Post-calving LW ³ (kg)	391.0	397.0	397.1	391.0	-	-	10.6
LW loss ^{3, 4} (kg)	60.8	60.1	57.0 ^a	64.0 ^b	-	-	0.8
Calving score ³	1.5	1.9	1.4	2.0	-	-	0.3
LWG (L1-L84, kg/d)	0.50 ^b	0.27 ^a	0.36	0.42	-	-	0.07
LW at L84 (kg)	433.8	420.3	430.3	423.7	415.4	438.6	16.6
LW at L147 (kg)	473.0	462.0	466.9	468.2	464.6	470.5	17.2
LWG (L84-L147, kg/d)	0.63	0.67	0.59	0.72	0.79 ^b	0.51 ^a	0.07
LWG (L1-L147, kg/d)	0.58 ^b	0.42 ^a	0.46	0.54	0.52	0.48	0.06
Calf performance							
Birth weight ³ (kg)	40.2	39.6	36.8 ^a	42.9 ^b	-	-	0.7
LWG (L1-L84, kg/d)	1.15	1.26	1.16	1.24	-	-	0.04
LW at L84 ⁵ (kg)	130.7	138.0	128.3 ^a	140.3 ^b	135.0	133.6	4.2
LW at L147 ⁵ (kg)	191.4	206.5	191.6	206.4	183.9 ^a	214.0 ^b	5.9
LWG (L84-L147, kg/d)	0.95 ^a	1.09 ^b	1.00	1.03	0.73 ^a	1.30 ^b	0.05
LWG (L1-L147, kg/d)	1.07 ^a	1.18 ^b	1.10	1.15	1.01 ^a	1.24 ^b	0.06

^{1&2} Days 84 and 147 of lactation or early weaning (EW) and normal weaning (NW) times, respectively.

³ Values are calculated for the performance of live and dead animals.

⁴ Heifers' liveweight (LW) loss at calving.

⁵ Figures are adjusted to a common calf weaning age (Nicoll & Rae 1978a, 1978b).

^{a, b} Means within treatment groups and within the same rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Table 4.2 Herbage mass, sward height, botanical composition, *in vitro* digestibility, ash, crude protein and fibre content of herbage offered to the Hereford x Friesian heifers during Experiments 1 and 2.

	Experiment 1	Experiment 2
Herbage mass (kg DM/ha)		
Pre-grazing	4049 ± 268	4291 ± 171
Post-grazing	3929 ± 180	3444 ± 159
Sward height (cm)		
<u>Sward surface height¹</u>		
Pre-grazing	19.5 ± 1.2	21.6 ± 0.4
Post-grazing	15.4 ± 1.0	10.3 ± 0.3
<u>Compressed sward height²</u>		
Pre-grazing	20.6 ± 1.2	18.6 ± 0.3
Post-grazing	15.6 ± 1.2	10.5 ± 0.3
Botanical composition^{3, 4}		
Perennial ryegrass	0.70 ± 0.01	0.46 ± 0.01
White clover	0.10 ± 0.02	0.18 ± 0.03
Weeds	0.08 ± 0.01	0.02 ± 0.00
Dead material	0.12 ± 0.02	0.34 ± 0.02
<i>In vitro</i> digestibility		
Organic matter digestibility	0.80 ± 0.02	0.74 ± 0.02
Dry matter digestibility	0.75 ± 0.01	0.69 ± 0.01
Digestible organic matter in dry matter	0.84 ± 0.02	0.78 ± 0.02
Ash content	0.10 ± 0.01	0.10 ± 0.00
Crude protein	0.30 ± 0.00	0.29 ± 0.00
Fibre		
Cellulose	0.19 ± 0.02	0.21 ± 0.02
Hemicellulose	0.18 ± 0.02	0.17 ± 0.02
Lignin	0.16 ± 0.00	0.26 ± 0.00

¹ Measured by HFRO sward stick.

² Measured by rising plate meter.

³ Proportions based on dry weight.

⁴ Pooled values for pre- and post-grazing pastures.

Experiment 2

In Experiment 2, heifers grazed a pre- and post-grazing pasture mass of 4291 ± 171 and 3444 ± 159 kg DM/ha, respectively (Table 4.2). The corresponding SSH and CSH values were 21.6 ± 0.4 and 10.3 ± 0.3 cm, and 18.6 ± 0.3 and 10.5 ± 1.3 cm, respectively. The pooled pre- and post-grazing pastures contained $46 \pm 1\%$ perennial ryegrass, $18 \pm 2\%$ white clover, $2 \pm 0\%$ weeds and $34 \pm 2\%$ dead material. The *in vitro* organic matter digestibility and the ash content of hand-plucked herbage samples were $74 \pm 2\%$ and $10 \pm 0\%$ (on a DM basis), respectively. Herbage contained 29% crude protein, and 21, 17 and 26% cellulose, hemicellulose and lignin, respectively. Herbage growth rate was estimated to be 80 kg DM/ha/d over the trial period based on herbage accumulation under the cages.

The sex and sire breed of calf had no significant effects on growth performance, herbage intake or ingestive behaviour of the dam during Experiment 2 (Table 4.4). Similar growth performance was recorded for EW and NW heifer dams (0.80 v. 0.78, PSE = 0.16 kg/d, $P > 0.10$). However, heifers weaned at early or normal times had slightly ($P < 0.10$) different OM (12.85 v. 14.68, PSE = 0.62 kg/hd/d), DM (13.97 v. 15.69, PSE = 0.63 kg/hd/d) and energy (166.24 v. 186.72, PSE = 7.49 MJ ME/hd/d) intakes. Overall, EW v. NW heifers consumed OM herbage intakes of 3.01 v. 3.50, PSE = 0.16 kg DM/100 kg LW/d, ($P < 0.05$). Normal-weaned heifers spent more time grazing (548 v. 485, PSE = 16 m/d, $P < 0.01$) and ruminating (552 v. 522, PSE = 12 m/d, $P < 0.10$), and less time idling (341 v. 433, PSE = 22 m/d, $P < 0.01$) than the EW heifers. Similar biting rates and bite weights were observed in the EW and NW heifers.

Table 4.3 Effects of sex and sire breed of calf on growth performance, herbage intake and ingestive behaviour of Hereford x Friesian heifers during Experiment 1.

	Sex		Sire breed		Pooled SE
	Female	Male	Angus	Charolais	
Growth performance					
Number of animals	12	8	11	9	
Initial weight ¹ (kg)	388.4	366.5	385.5	369.3	15.1
Final weight ¹ (kg)	399.0	379.9	394.6	384.3	15.3
Daily LWG (kg)	0.59	0.74	0.50 ^a	0.83 ^b	0.10
Herbage intake					
Number of animals	10	8	10	8	
OMI ² (kg/hd/d)	12.53	12.14	12.31	12.37	0.63
DMI ³ (kg/hd/d)	13.77	13.35	13.53	13.59	0.69
MJ ME ⁴ /hd/d	163.86	158.84	161.03	161.68	8.25
OMI (kg/100 kg LW/d)	3.27	3.26	3.21	3.33	0.14
DMI (kg/100 kg LW/d)	3.59	3.59	3.53	3.65	0.16
MJ ME/100 kg LW/d)	42.77	42.72	41.99	43.92	1.95
Ingestive behaviour					
Number of animals	12	8	11	9	
Grazing time (m/d)	537	581	550	569	19
Ruminating time (m/d)	531	529	531	529	20
Idling time (m/d)	363	331	352	343	23
Bite rate (bites/m)	54	53	55	53	1
<u>Bite weight</u>					
OMI (mg/bite)	422	393	400	416	20
DMI (mg/bite)	464	433	439	457	25

¹ Sixteen-hour-fasted liveweights.

² Organic matter intake.

³ Dry matter intake.

⁴ Megajoules metabolisable energy (see footnote of Table 2.3).

^{a, b} Means within treatment groups and within the same row with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Table 4.4 Effects of sex and sire breed of calf, and weaning time on growth performance, herbage intake and ingestive behaviour of Hereford x Friesian heifers during Experiment 2.

	Sex		Sire breed		Weaning time		Pooled SE
	Female	Male	Angus	Charolais	L84 ¹	L147 ²	
Growth performance							
Number of animals	12	8	11	9	10	10	
Initial weight ³ (kg)	420.7	412.0	422.0	410.0	415.0	417.0	16.0
Final weight ³ (kg)	434.6	425.0	433.0	426.0	429.0	430.6	17.2
Daily LWG (kg)	0.82	0.77	0.65	0.94	0.80	0.78	0.16
Herbage intake							
Number of animals	10	8	10	8	9	9	
OMI ⁴ (kg/hd/d)	13.30	14.22	13.56	13.95	12.85	14.68	0.62
DMI ⁵ (kg/hd/d)	14.44	15.23	14.87	14.79	13.97	15.69	0.63
MJ ME ⁶ /hd/d	171.78	181.18	176.92	176.04	166.24	186.72	7.49
OMI (kg/100 kg LW/d)	3.09	3.42	3.24	3.27	3.01 ^a	3.50 ^b	0.16
DMI (kg/100 kg LW/d)	3.35	3.65	3.54	3.46	3.26 ^a	3.74 ^b	0.15
MJ ME/100 kg LW/d)	39.85	43.50	42.14	41.21	38.85 ^a	44.51 ^b	1.76
Ingestive behaviour							
Number of animals	12	8	11	9	10	10	
Grazing time (m/d)	503	530	514	519	485 ^a	548 ^b	16
Ruminating time(m/d)	530	544	538	536	522	552	12
Idling time (m/d)	409	365	387	387	433 ^a	341 ^b	22
Bite rate (bites/m)	53	54	54	53	53	54	1
<u>Bite weight</u>							
OMI (mg/bite)	504	494	479	520	504	495	26
DMI (mg/bite)	539	539	526	551	549	529	29

^{1&2} Days 84 and 147 of lactation or early weaning (EW) and normal weaning (NW) times, respectively.

³ Sixteen-hour-fasted liveweights

⁴ Organic matter intake.

⁵ Dry matter intake.

⁶ Megajoules metabolisable energy (see footnote of Table 2.3).

^{a, b} Means within treatment groups and within the same row with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Carcass and Meat Quality

Carcass Quality

The slaughter and carcass weights of heifers were not affected by sex and sire breed of calf, or by weaning time (Table 4.5). Udder weight was greater in heifers rearing male v. female (4.61 v. 4.01 kg, $P < 0.05$), and those with NW v. EW (4.76 v. 3.87 kg, $P < 0.01$) calves, but no effect of calf sire breed on udder weight was observed. Similar dressing-out percentages (DO%) were recorded for heifers rearing female or male and EW or NW calves, but heifers rearing CS v. AS calves differed in DO% (49.92 v. 47.71, PSE = 0.66%, $P < 0.05$). Heifers weaned early had carcasses about 3 cm shorter ($P < 0.05$) than the NW dams, while calf sex or sire breed had no effect on the carcass length of the dam. The fatness of heifers was not affected by sex or sire breed of their calves except for intramuscular fat level which was significantly lower ($P < 0.05$) in heifers rearing CS v. AS and NW v. EW calves. Kidney and pelvic fat level ($P > 0.10$) and fat depth ($P < 0.10$) also tended to be lower in NW heifers than in the EW group.

None of heifers had erupted more than 5 permanent incisor teeth at slaughter and their carcasses were all classified as "heifer" (NZMPB 1991). A small proportion of the carcasses were classified as "K", based on the New Zealand export classification system and no carcasses were classified as "G" (Table 4.6). Thirty-three percent of the carcasses from NW heifers were classed as "L", while no carcasses of EW heifers were placed in this class. Conversely, a greater proportion of the EW heifer carcasses were classified as "P".

Table 4.5 Effects of sex and sire breed of calf, and weaning time on carcass quality characteristics of Hereford x Friesian heifers.

	Sex		Sire breed		Weaning time		Pooled SE
	Female	Male	Angus	Charolais	L84 ¹	L147 ²	
Number of animals	13	6	12	7	10	9	
Final weight (kg)	481.9	466.1	471.6	476.4	476.7	471.3	19.4
Udder weight (kg)	4.01 ^a	4.61 ^b	4.13	4.50	3.87 ^a	4.76 ^b	0.23
Carcass weight (kg)	234.00	224.55	223.11	235.43	231.35	227.19	8.92
Dressing-out% ³ (DO%)	49.05	48.59	47.71 ^a	49.92 ^b	49.03	48.61	0.66
Carcass length ³ (cm)	206.9	208.8	207.8	207.5	206.1 ^a	209.2 ^b	1.1
Rib-eye area ³ (cm ²)	60.31	56.09	59.28	57.11	59.62	56.77	1.85
Kidney+pelvic fat ³ (kg)	4.35	4.21	4.88	3.68	4.72	3.84	0.74
Fat depth ³ (mm)	4.09	4.37	4.87	3.60	5.06	3.40	0.69
Intramuscular fat ³ (%)	3.31	2.68	4.21 ^b	1.78 ^a	3.67 ^b	2.37 ^a	0.27

^{1&2} Days 84 and 147 of lactation or early weaning (EW) and normal weaning (NW) times, respectively.

³ Means are adjusted to a constant carcass weight by covariance analysis.

^{a, b} Means within treatment groups and within the same row with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Table 4.6 Proportions (%) of carcasses of heifer dams rearing female v. male, Angus-sired v. Charolais-sired and early-weaned v. normal-weaned calves in four fatness classes, based on the New Zealand export beef carcass classification system.

	Fatness class			
	L (1-3mm) ¹	P (4-7mm)	K (8-12mm)	G (13-18mm)
Sex				
Female	15	77	8	0
Male	17	83	0	0
Sire breed				
Angus-sired	17	75	8	0
Charolais-sired	14	86	0	0
Weaning time				
Early-weaned	0	90	10	0
Normal-weaned	33	67	0	0

¹ Backfat thickness range in brackets.

The weights of hind-quarter cuts were similar in heifers rearing female or male, AS or CS and EW or NW calves except for the topside which was heavier ($P < 0.01$) in heifers rearing CS v. AS calves (Table 4.7).

Table 4.7 Effects of sex and sire breed of calf, and weaning time on the hind-quarter cut weights (kg) of Hereford x Friesian heifers.

	Sex		Sire breed		Weaning time		Pooled SE
	Female	Male	Angus	Charolais	L84 ¹	L147 ²	
Number of animals	13	6	12	7	10	9	
Tenderloin ³	3.72	3.60	3.64	3.68	3.57	3.75	0.08
Striploin ³	7.08	6.66	6.67	7.07	7.10	6.64	0.25
Rump ³	12.71	13.27	13.20	12.79	13.17	12.82	0.45
Knuckle ³	8.51	8.35	8.23	8.63	8.26	8.60	0.15
Topside ³	13.17	12.83	12.56 ^a	13.44 ^b	12.97	13.05	0.17
Outside ³	12.79	12.63	12.56	12.87	12.40	13.02	0.27
3-cuts ⁴	34.33	33.66	33.37	34.63	33.62	34.38	0.48
6-Cuts ⁵	57.78	57.12	56.86	58.05	57.46	57.45	0.61

^{1&2} Days 84 and 147 of lactation or early weaning (EW) and normal weaning (NW) times, respectively.

³ Means are adjusted to a constant carcass weight by covariance analysis.

^{4&5} The sum of (knuckle, inside and outside), and the sum of all six cuts, respectively.

^{a, b} Means within treatment groups and within the same rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Meat Quality

A higher ($P < 0.05$) meat ultimate pH and a lower ($P < 0.10$) sarcomere length were observed in heifers rearing male v. female calves (Table 4.8). These factors were not affected by the calf sire breed or weaning time. The meat and fat colour were similar in heifers rearing female or male, AS or CS and EW or NW calves. Heifers weaned early had meat with lower ($P < 0.10$) expressed juice values than the NW group. A lower ($P < 0.05$) cooking loss value was recorded for meat of heifers rearing AS v. CS or EW v. NW calves.

The WB shear force patterns were generally similar in cooked meat of heifers rearing male v. female, AS v. CS and EW v. NW calves (Table 4.8). Meat of heifers rearing male calves had higher WB peak force ($P < 0.05$) and WB (PF-IY) values ($P < 0.01$) than meat of heifers rearing female calves.

As noted earlier, the quality characteristics of chilled meat were also evaluated in this study. These results, together with quality parameters on the chilled meat of heifers slaughtered in March 1993 (Chapter 5), are presented in Appendix II.

Table 4.8 Effects of sex and sire breed of calf, and weaning time on meat quality characteristics and the Warner-Bratzler (WB) shear force parameters of Hereford x Friesian heifers.

	Sex		Sire breed		Weaning time		Pooled SE
	Female	Male	Angus	Charolais	L84 ¹	L147 ²	
Number of animals	13	6	12	7	10	9	
Meat quality characteristics							
Ultimate pH	5.57 ^a	5.67 ^b	5.61	5.63	5.60	5.64	0.03
Sarcomere length (μm)	1.68	1.59	1.64	1.63	1.66	1.61	0.03
<u>Meat colour³</u>							
L*	37.60	36.57	37.40	36.75	37.27	36.90	0.81
a*	25.88	24.74	24.46	26.16	24.70	25.92	0.94
b*	12.52	11.55	11.67	12.39	11.76	12.31	0.61
Fat colour ⁴	4.69	5.52	5.24	4.98	4.78	5.44	0.61
Expressed juice (cm^2/g)	42.93	41.58	41.60	42.91	40.80	43.72	1.22
Cooking loss (%)	27.56	28.69	27.34 ^a	28.92 ^b	27.36 ^a	28.91 ^b	0.57
WB shear force parameters							
WB work-index	2.64	2.86	2.65	2.84	2.62	2.88	0.16
WB initial yield (IY, kg)	6.55	7.42	6.55	7.41	6.50	7.37	0.48
WB peak force (PF, kg)	8.02 ^a	9.68 ^b	8.36	9.33	8.30	9.40	0.55
WB (PF-IY, kg)	1.47 ^a	2.26 ^b	1.81	1.92	1.70	2.02	0.18

^{1&2} Days 84 and 147 of lactation or early weaning (EW) and normal weaning (NW) times, respectively.

³ L*, a* and b* = The brightness, redness and yellowness of meat colour, respectively, measured with a Minolta Chroma Meter II.

⁴ Based on a set of 8 coloured paddles: 1 = nearly white to 8 = bright yellow (Purchas et al. 1992).

^{a, b} Means within treatment groups and within the same row with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

DISCUSSION

The main purpose of this study was to examine whether early or normal weaning affected the performance of heifers and their calves. However, the effects of sex and sire breed of calf on the abovementioned factors were also studied. Since the calf sex and sire breed effects were apparent before the heifers were weaned at L84, these parameters will be discussed first.

Effects of Calf Sex and Sire Breed

The liveweights of 320, 455 and 475 kg recorded at mating, calving and slaughter, respectively, for heifers in this study are similar to those reported for once-bred Hereford x Friesian heifers in the United Kingdom (Keane 1988) and suggest that target liveweights similar to those recommended by Morris & Khadem (1991) are achievable for New Zealand OBH beef production systems. However, a liveweight of 543 kg at slaughter was reported for once-bred Hereford x Friesian heifers, calving at about 21 months of age, weaned at 3-4 days post-partum and finished on an autumn forage supplemented with 2 kg of barley/hd/d, in the study of Lowman & Broadbent (1987). Liveweight loss at calving recorded for heifer dams in this study (Table 4.1) was similar to that (67 kg) reported for once-calved heifers in the study of Keane (1988). The higher liveweight loss recorded here for heifers carrying CS v. AS calves was due to the heavier birth weights of CS calves.

The shorter gestation length (by 5 days) of heifers carrying AS v. CS calves and the (non-significantly) lower calving score and calf mortality rates recorded for the AS calves are in agreement with previous results (Everitt & Evans 1970; Everitt et al. 1978a; Baker et al. 1986, 1990; Morris et al. 1993a), suggesting that Angus sires may be marginally more appropriate than Charolais sires for mating yearling heifers in New Zealand. Heifers rearing male v. female calves exhibited lower daily LWG, during

L1-L84 and L1-L147, presumably reflecting the greater milk requirements of the faster growing male calves (Everitt et al. 1978a, 1978b; Barlow & O'Neill 1978, 1980; Baker et al. 1986; 1990). However, this was not consistent in heifers rearing heavier CS v. AS calves during the same periods. The greater liveweights recorded for CS calves at L84 were partly due to the differences which existed between the weights of CS v. AS calves at birth and partly due to the cumulative effects of a small difference in daily LWG.

The digestibilities recorded for the hand-plucked herbage samples in Experiments 1 and 2 (Table 4.2) are similar to those reported for late spring and mid summer Manawatu pastures (Waghorn & Barry 1987). The OM, DM and ME intakes recorded for heifers rearing female v. male or CS v. AS calves during the mid- and late-lactation periods (Experiments 1 and 2) are similar to those recommended for suckling and growing heifers under New Zealand pasture conditions (Joyce 1971; Joyce et al. 1975; Geenty & Rattray 1987) or those of overseas reports (ARC 1980; Wright & Russel 1987; Barlow et al. 1988, 1990). Growth performance of heifers in Experiments 1 and 2 was not affected by sex and sire breed of calf except daily LWG which was significantly higher in heifers rearing CS v. AS calves in Experiment 1. This may have been a chance effect as there was no corresponding difference during the main study (Table 4.1).

Calf sex and sire breed did not influence the ingestive behaviour of heifers in either Experiment 1 or Experiment 2. The grazing, ruminating and idling times recorded for heifers in this study are similar to those reported for lactating heifers in Chapter 2. Grazing times similar to those observed for heifer dams in this study were reported for pregnant or non-pregnant heifers (509 v. 482 m/d, Inwood et al. 1992) and for Friesian, Piedmontese x Friesian and Belgian Blue x Friesian bulls (497, 520 and 454 m/d, respectively, Morris et al. 1993b) when animals were set stocked on perennial ryegrass and white clover pastures in New Zealand. However, a wide range of 24 h grazing

times has been reported for mature cows grazing perennial ryegrass pastures in the United Kingdom (580-625 m/d, Forbes & Hodgson 1985; 463-501 m/d, Zoby & Holmes 1983) and for crossbred cows exposed to a mountain foothill rangeland in the United States of America (672-738 m/d, Funston et al. 1991).

The greater udder weights in heifers rearing male v. female and, to a lesser extent, in those rearing CS v. AS calves were presumably due to the higher demands from faster growing male and CS calves for milk during the suckling period. Carcass weight, DO% and fat level were similar in heifers rearing female v. male calves. Heifers rearing CS v. AS calves produced carcasses with a higher DO% and lower fat level. The lower fat level in heifers rearing CS calves might also have been due to the greater demands of their calves for milk such that these heifers deposited less energy as fat (including pelvic fat), and consequently their DO% was lower since this parameter was calculated after removal of kidney and pelvic fat.

The higher ultimate pH recorded for heifers rearing male v. female calves was associated with a shorter sarcomere length and tougher meat, possibly reflecting the fact that these heifers suffered more stress while suckling calves with higher growth rates during L1-L147. However, there was no comparable data available in literature. Heifers rearing CS v. AS calves produced meat with similar quality and WB shear force values, and the higher cooking loss recorded for heifers rearing CS v. AS calves seems likely to be a chance effect.

Effects of weaning time

Early-weaned heifers were about 23 kg lighter than NW heifers at L84 (a consequence of the random assignment of heifers to the two groups), but only about 6 kg lighter at L147, reflecting their significantly greater LWG (by about 55%) during the intervening period. In agreement with these results, Neville & McCormick (1981) reported that

heifer dams weaned at L67 or L230 and grazed on pastures had liveweight gains of 0.62 and 0.32 kg/d, respectively, during the period L67-L230. Likewise, Richardson et al. (1978) noted that dams weaned early (at day 120 of their calf age), and grazed on pastures, had 12 kg greater liveweights, at day 210 post-partum, than dams still rearing their calves.

Calves weaned early and grazed on pasture as their sole feed in this study grew at a rate 0.57 kg/d less than NW calves suckling their dams, during L84-L147. Thus at L147 the liveweight of NW calves was about 30 kg greater than that of EW calves. Growth rate of EW calves in relation to those of NW calves is expected to vary from one study to another since the relative gains depend on the milking ability of the dams and non-milk nutrients available to the EW calves. In the study of Neville & McCormick (1981), half of the calves weaned at L67 were group-fed a concentrate mix *ad libitum* while on pasture and the remainder were reared on a drylot and received a complete diet *ad libitum*. Average daily gains and weights at L230 were higher for calves weaned at L67 to the drylot than for corresponding calves on "herbage plus concentrates", and higher for calves weaned at L67 on herbage plus concentrates than for those weaned at L230. Lusby et al. (1981) reported that a group of calves weaned at L50 and reared on a drylot had similar liveweights to calves suckling their dams and weaned at L210. Richardson et al. (1978) reported that calves weaned at 120 days of age, and grazed on bluegrass pastures supplemented by concentrate meal, had 10 kg greater weight at day 210 of age than calves still suckling their dams. However, these results are not directly comparable to the present study because they involved calves fed concentrate diets.

Australian data showed that calves weaned at 5 months of age and grazed under tropical range conditions had 57.4 kg lower liveweights than their counterparts suckling grazing cows and weaned at 8 months of age (Holroyd et al. 1988). In addition, results from a 2-year study at the Whatawhata Research Centre in New

Zealand (McCall & Scott 1988) demonstrated that when groups of calves were weaned at about L100 and offered herbage with 1500-2300 kg DM/ha as the only feed source, they were on average 14 kg lighter at L150 than the calves still suckling their dams. The authors suggested that the benefits of late weaning were increased calf growth and reduced demand for quality autumn pastures, benefits which were considered to outweigh the costs of cow liveweight loss. However, the validity of this conclusion depends on the value of the cow liveweight loss, which will vary according to the production system (e.g. once-bred heifer dams v. traditional beef breeding cows).

During Experiment 2, heifers weaned at L147 had higher intakes than those weaned at L84. This was associated with longer grazing and shorter idling times in the NW than in the EW group. The higher intakes of NW heifers reflected the fact that during L84-L147 these heifers grew at a rate similar to those weaned at L84 while still rearing calves growing at a rate of about 1.3 kg/d. Bond et al. (1986) reported that once-calved heifers weaned at L7, L24 or L42 had intakes of 7.7, 9.6 and 10.7 kg DM/hd/d, respectively, averaged over the periods from calving to weaning, when a concentrate-based ration was offered. These and the results of Experiments 1 and 2 clearly demonstrate the need to provide adequate feed to lactating heifers if they are to meet the demands of their calves for milk while also continuing to grow themselves.

Heifers weaned at L84 v. L147 had different udder weights at slaughter (equivalent to "L210") suggesting that NW heifers had not completed mammary involution at this time. Normal-weaned heifers in this study produced longer carcasses than heifers of the EW group. However, this was not of great consequence because a high proportion of carcasses of NW heifers were classified as "L". In the study of Vincent et al. (1991), in which once-bred heifers were slaughtered a few days after weaning at L90, L150 or L210, the proportions of carcasses graded as class 1 (youthful) decreased as heifers suckled their calves for more than 3 months.

Compared with EW heifers, the NW group produced carcasses with lower total fat (including intramuscular fat or marbling) levels. This was presumably due to the extra energy which EW heifers deposited as fat during the period between weaning and slaughter while, during part of this period (L84-L147), NW heifers were still suckling their calves. However, OBH dams offered an *ad libitum* concentrate-based ration during the suckling period and slaughtered at later stages of lactation, had higher intramuscular fat levels than those slaughtered earlier (Vincent et al. 1991). This again illustrates the point that effects of early weaning on carcass value will depend on the nutritional conditions to which the heifers are exposed.

The similar hind-quarter cut weights recorded for heifers weaned at L84 or L147 are in agreement with the results of Vincent et al. (1991), indicating that weaning heifers of different stages of lactation does not affect the level of leanness in their carcasses. In addition, Lowman & Broadbent (1987) reported similar yields of saleable meat for OBH dams slaughtered after suckling their calves for six or twelve weeks.

Weaning time did not affect the ultimate pH, sarcomere length or colour of meat in this study. However, different ultimate pH and colour was reported for meat of once-calved heifers slaughtered immediately after weaning at L90, L150 and L210 by Vincent et al. (1991). The higher cooking loss in meat of heifers weaned at L147 v. L84 is in agreement with results of Bond et al. (1986).

CONCLUSIONS

From a management viewpoint, weaning of heifers for OBH beef production systems should occur at a time when adequate pastures are available for heifers to reach a slaughter liveweight at an appropriate time. In the present study, heifers weaned at the end of November (EW group) reached an acceptable liveweight in March and, overall, had slightly better carcass and meat quality characteristics than those of the normal

weaned group (although effects on quality were generally small). Therefore, weaning heifers at about 3 months post-partum is marginally advantageous in terms of heifer meat production. However, the greater liveweight gain and lower feed intake of EW heifers during the period L84-L147 was achieved at some cost, both in the 30 kg lower liveweights of their calves at L147 and the presumed greater herbage intake of these calves post-weaning. These issues will be discussed further in Chapter 6.

CHAPTER FIVE

GROWTH, REPRODUCTION, CARCASS AND MEAT QUALITY CHARACTERISTICS OF ONCE-BRED HEREFORD X FRIESIAN AND SIMMENTAL X FRIESIAN HEIFERS OFFERED NORMAL OR RESTRICTED HERBAGE ALLOWANCE DURING MID PREGNANCY

ABSTRACT

The growth, reproduction, carcass and meat quality characteristics of once-bred Hereford x Friesian (H x F) v. Simmental x Friesian (S x F) heifers mated to Angus sires and offered a normal (NHA) or restricted (RHA) herbage allowance during mid pregnancy (i.e. pregnancy day 114-214 = P114-P214) were compared in this study. Liveweights at mating of S x F heifers (306 ± 6 kg) were slightly higher ($P < 0.10$) than those of H x F heifers (292 ± 5 kg). From P114 until P214, NHA heifers had significantly higher ($P < 0.001$) growth rates (0.72 ± 0.03 kg/d) than the RHA group (0.16 ± 0.02 kg/d). This resulted in a higher liveweight (LW) in NHA heifers at P214 ($P < 0.001$) and P270 ($P < 0.01$) than the RHA heifers. Gestation length, calving score and LW loss at calving were not affected by dam genotype, herbage allowance or calf sex. Calf mortality rate was 7% with all dead calves being female and born to H x F and NHA heifers. Calving ease score was not significantly related to the pelvic area measured externally at P270 ($r = -0.13$, $P > 0.10$) but was related to both external ($r = -0.54$, $P < 0.01$) and internal ($r = -0.39$, $P < 0.10$) pelvic area at day 60 of lactation. Liveweight gain (LWG) of heifers was not affected by dam genotype, prior herbage allowance or calf sex during the suckling period or from weaning to slaughter (an average LWG of 0.33 kg/d). Calf birth weight, weaning weight and daily LWG during a 106-day suckling period were not influenced by genotype, prior herbage allowance

of the dam or calf sex. Final heifer LW was slightly lower ($P < 0.10$) in RHA v. NHA heifers (476.4 v. 512.7, PSE = 16.2). Dressing-out percentage was significantly ($P < 0.05$) higher in H x F heifers than in the S x F group, while herbage allowance and calf sex had no effect on dressing-out percentages. There was a tendency for H x F v. S x F or NHA v. RHA heifers to produce carcasses with greater levels of fat. However, muscularity was not affected by dam genotype or herbage allowance. Meat quality traits were not significantly affected by dam genotype or herbage allowance. Results are discussed in the context of beef production from once-bred S x F v. H x F heifers under New Zealand conditions.

INTRODUCTION

Once-bred heifer (OBH) beef production systems have been developed under New Zealand conditions using Hereford x Friesian (H x F) heifers (Keeling et al. 1991; Morris & Khadem 1991). Other research, however, suggests that the use of large European crossbred heifers could improve the performance of once-bred heifers and their calves (Roux et al. 1987; Keane et al. 1991; Morris & Khadem 1991). For example, in the United Kingdom, once-bred Charolais x Friesian heifers produced 22 kg heavier carcasses than Hereford x Friesian heifers managed under the same conditions (Keane et al. 1991). In New Zealand, when seven European and four local breeds of cattle were mated to Angus or Hereford dams in different environments, the progeny of the European breeds had higher growth rates and heavier carcasses than those of the traditional British breeds (Morris et al. 1990a, 1993a). Furthermore, offspring of high milk producing dams (e.g. Simmental crosses) were reported to have carcasses 10 kg heavier than offspring of Hereford x Angus dams (Morris et al. 1987). However, there are no data on the use of European crosses as once-bred heifers under New Zealand pastoral conditions. Therefore, Simmental x Friesian (S x F) and H x F heifers were compared in this study.

Nutrition of heifers during pregnancy can potentially influence calf birth weight and the incidence of dystocia (Morris 1980b; Bellows et al. 1991), an important issue in the development of OBH systems. One option, at least in theory, is to control the pre-calving LW of heifer dams and hence the birth weight of their calves with restricted feeding during the late pregnancy period. However, New Zealand data indicate that when 2- to 3-year-old heifers were fed a restricted herbage allowance (8 kg DM/hd/d, Nicoll 1979; or maintenance level, Pleasants & Barton 1985, 1987, 1992a, 1992b) during the last 40-60 days of pregnancy, calf birth weight was not significantly affected. Overseas studies have also shown little or no difference in birth weight of calves, and hence in the incidence of dystocia, when heifers were subjected to different feeding levels (maintenance or sub-maintenance requirements) during the last 45-150 days of pregnancy (Tudor 1972; Hodge 1976; Bellows et al. 1978, 1982, 1991; Whittier et al. 1988; Keane et al. 1991). At Massey University, once-bred heifers offered a restricted feeding level during the last 2 months of pregnancy still had unacceptable levels of dystocia and mortality rates (see Chapters 2 and 4).

Despite suggestions that early pregnancy feeding in sheep (Robinson et al. 1977) and cattle (Bond & Weinland 1978) may affect subsequent foetal growth, no information is available for New Zealand conditions on the effects of the level of heifer nutrition in early- to mid pregnancy on calf birth weight and dystocia. A second objective of this study was, therefore, to examine the effects of herbage allowance during the mid pregnancy period (i.e. from day 114 to day 214 of pregnancy) on calf birth weight, the incidence of dystocia and the performance of heifer dams and their progeny. Carcass and meat quality characteristics of the heifer dams were also studied.

MATERIALS AND METHODS

Twenty-five approximately 4-month-old H x F heifers with mean (\pm SE) LW of 103 ± 3 kg and 23 S x F heifers with a mean LW of 111 ± 3 kg were purchased in December 1990. Heifers were grazed on pastures of predominantly perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) at the Massey University Sheep and Beef Cattle Research Unit. Liveweights were recorded monthly from purchase through to slaughter in March 1992. Five heifers (2 from the H x F and 3 from the S x F groups) were removed from the trial in December 1991 as they had been mated by a stray bull in October 1991. The remaining heifers were randomly mated to 5 Angus sires at about 15 months of age commencing 21 November 1991. Liveweight at mating was 292 ± 6 and 306 ± 4 kg for H x F and S x F heifers, respectively. Heifers were mated by artificial insemination (AI) 48 hours after CIDR withdrawal (Jellie 1991). Heifers observed in oestrus at the next cycle were mated with the semen from the same bulls used at the earlier insemination. From these matings 27 heifers (15 H x F and 12 S x F) became pregnant. The 16 remaining heifers were then run with a Hereford bull and 8 of these became pregnant. Heifers mated to the Hereford bull were excluded from the analysis on the basis that they were not comparable to the Angus-mated heifers.

Pre-Calving Management

Heifer dams were managed to gain weight (0.6 kg/d) until pregnancy day 114 (P114, 12 March 1992). Following measurement of 16-hour-fasted LW, heifers were randomly assigned by weight and genotype to two herbage allowance levels - either a normal herbage allowance (NHA, to gain 0.6 kg LW/d) or a restricted herbage allowance (RHA, maintenance feeding level). The NHA heifers grazed 1 ha paddocks with pre- and post-grazing herbage masses of 2100-2450 and 1150-1450 kg DM/ha, respectively. The corresponding sward surface heights were 10-12.5 and 4-5.5 cm. The RHA group followed the NHA heifers on the grazing rotation. Sward surface

height (SSH, Barthram 1986) and compressed sward height (CSH, Earle & McGowan 1979) were assessed at 7-day intervals. Herbage mass was estimated using the method described by Earle & McGowan (1979). Unfasted liveweights were taken at 20-day intervals from P113 to P213.

On P153 (i.e. day 40 of the different nutritional treatments), the LW of the RHA group was higher than planned. Therefore, an on-off grazing system (Hodgson 1990) was used to maintain constant liveweights. Heifers grazed pastures for 2 hours per day (at an allowance of approximately 4-5 kg DM/hd/d and a similar pre-grazing herbage mass as previously described for the NHA heifers) and were then fed about 2 kg DM/hd/d of hay on a feed pad with no further access to pasture. This policy was continued until P214 when a 16-hour-fasted LW of heifers was recorded. From P214 until calving (approximately 65 days), all heifers were run together as one mob receiving a maintenance level of intake (i.e. an intake of 3-3.5 kg DM/hd/d of herbage plus about 2 kg DM/hd/d hay).

Body condition score of heifers, based on a scale of 1-5 (1 for emaciated and 5 for extremely fat heifers, Nicoll 1979; Makarechian & Berg 1983), was recorded on P114, P214 and about one week prior to calving on P270. The pelvic area of heifer dams was measured externally on P270, and both externally and internally on day 60 of lactation (L60). For the external measurement hip height from the ground (H) and hip width between the left and right tuber coxae (W) were taken by a ruler. The product of $(0.18H \times 0.36W)$ was then taken as the pelvic area based on the method of Beriao et al. (1987). The internal pelvic area was calculated by multiplying the height (the distance between the symphysis pubis and sacral vertebrae) and width (the distance between the two shaft of ilea) of the birth canal, measured using a mechanical instrument described by Price & Wiltbank (1978).

Post-Calving Management

Heifers calved between the end of August and 21 September 1992. Calf birth weight, calving ease score, pre-and post-calving LW of heifers and the heifer dam's LW loss at calving were recorded or calculated. In addition to the post-calving liveweights estimated for all heifers (see Chapter 2), the actual post-calving LW of 11 heifers was recorded immediately after calving (i.e. before heifers had access to water or pasture) to determine the correlation between the estimated and actual post-calving LW of heifers.

Two calves died of dystocia at parturition. Another calf died from misadventure but no cow mortalities occurred. Heifers which lost their calves were sold within a few months of calving and were excluded from further analysis. Twenty-four heifers suckled their calves until 14 December 1992 when the calves were weaned at an average age of 106 ± 3 days and then sold as weaners. The weaned dams were then fed to gain LW (at approximately 0.5 kg/d) until slaughter in March 1993. These heifers were also used to study the effects of temporary weaning and pre-partum nutrition on the length of the post-partum anoestrus interval (de Nava et al. 1994). They were run with two entire Friesian bulls during the last 2 months of the lactation period, and at slaughter averaged 105 ± 8 days pregnant.

Carcass and Meat Quality Measurements

Twenty-four heifers were weighed off pasture at 0800h on 7 March 1993 and transported 20 km to a slaughter plant (Weddel Feilding Ltd). Heifers were slaughtered at about 0800h the following day. Weight of the udder, uterus and foetus were recorded. Age of foetus was estimated using the equation developed by Harris et al. (1983). The number of erupted permanent incisor teeth and the weights of kidney and pelvic fat depots from both sides of the carcasses were recorded. Carcasses were

weighed and classified (NZMPB 1991; Purchas et al. 1992) while carcass length was measured using the procedure described by Purchas (1990).

A sample of the *longissimus dorsi* (LD) muscle from the 10th to 13th rib region (c. 810-1075 g) was dissected from the right side of each carcass within 90 minutes *post mortem*. Samples were placed in plastic bags, held at ambient temperature (15-18°C) for 24 h, transferred to a chiller (0-2°C) for 6 days and then frozen (at -15 to -20°C) for 5 to 16 weeks.

On the day following slaughter, the area of LD from each carcass was traced and the thickness of subcutaneous fat measured on the chilled (overnight at 1-3°C) and quartered carcasses (Purchas 1990). A high correlation ($r = 0.95-0.98$) had been found between the weight of three (i.e. the sum of knuckle, topside and outside weights) and six (i.e. the sum of these three cuts plus the tenderloin, striploin and rump weights) hind-quarter cuts taken from the carcasses of heifers used in previous trials (see Chapters 3 and 4). Hence only the weight of the three cuts from both sides of each carcass was recorded as the carcasses were prepared under normal commercial conditions (NZMPB 1991). Fat colour was measured on the subcutaneous fat over the LD samples using a Minolta Chroma Meter II (Minolta Camera Co., Meter Division, Ramsey, NJ, U.S.A.).

The femur bones from the right sides of carcasses were collected and their weights and lengths measured after removal of residual muscle and fat tissue. Muscularity was calculated from the weights (g) of knuckle, topside and outside cuts and the length (cm) of the femur bone using the equation described by Purchas et al. (1991).

In addition to the samples of LD taken from the right side of unchilled carcasses, a similar sample of LD from the left side (c. 570-940 g from the 10th to 13th rib region) was also taken at the time of boning to determine whether chilling overnight affected

meat quality characteristics. Samples were placed in plastic bags, transferred to a chiller (0-2°C) for 6 days and then frozen (at -15 to -20°C) for 5 to 16 weeks. Results from this study are shown in Appendix II.

The frozen samples of LD were thawed (ambient temperature for 1 h and in a chiller at 3-5°C, for 20-22 h), sub-sampled, and then the quality characteristics of raw meat (i.e. the pH, sarcomere length and colour of meat) and the Warner-Bratzler (WB) shear force values of cooked meat were measured as described in Chapters 3 and 4.

Statistical Analyses

Statistical analysis was performed by the General Linear Model procedure (SAS 1985). Data relating to the performance of heifer dams pre-calving (from P114 to calving), and cow and calf performance from calving through to weaning and slaughter were analysed using model 5.1 below:

[Model 5.1]

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \Theta_k + (\alpha\beta)_{ij} + (\alpha\Theta)_{ik} + (\beta\Theta)_{jk} + e_{ijkl}$$

- Where:
- Y_{ijkl} = an observation on the l^{th} dam (or its calf) of the i^{th} dam genotype, the j^{th} herbage allowance and the k^{th} calf sex
 - μ = the overall mean
 - α_i = the effect of the i^{th} dam genotype ($i = 1, 2$)
 - β_j = the effect of the j^{th} herbage allowance ($j = 1, 2$)
 - Θ_k = the effect of the k^{th} calf sex ($k = 1, 2$)
 - $(\alpha\beta)_{ij}$ = the interaction between the effects of the i^{th} dam genotype and the j^{th} herbage allowance
 - $(\alpha\Theta)_{ik}$ = the interaction between the effects of the i^{th} dam genotype and the k^{th} calf sex
 - $(\beta\Theta)_{jk}$ = the interaction between the effects of the j^{th} herbage allowance and the k^{th} calf sex
 - e_{ijkl} = the random residual associated with an observation on the l^{th} dam (or its calf) of the i^{th} dam genotype, the j^{th} herbage allowance and the k^{th} calf sex.

Data relating to the carcass and meat quality characteristics of the heifer dam were analysed using model 5.2 below.

[Model 5.2]

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \Theta_k + (\alpha\beta)_{ij} + (\alpha\Theta)_{ik} + (\beta\Theta)_{jk} + b_{ijk}(x_{ijkl} - X) + e_{ijkl}$$

This model was the same as model 5.1 except that carcass weight (X) was included as a covariate (see Chapter 3). Dressing-out percentage (DO%) was calculated as: DO% = (carcass weight ÷ final LW x 100), where final LW = [last LW - (udder weight + uterus weight + foetus weight)]. Non-significant ($P > 0.05$) interactions were excluded from the model and the model refitted.

RESULTS

Preliminary analyses showed that there was no significant effect of sire on the performance of heifer dams and calves. Individual sire effects were therefore excluded from subsequent analyses. Since no significant interactions were observed between the effects of dam genotype, herbage allowance, and calf sex, results are presented for the main treatment effects only.

Heifer and Calf Performance

Liveweights of H x F (103 ± 3 kg) heifers were marginally lower than those of S x F (111 ± 3 kg) heifers at purchase. This difference was also apparent in S x F (306 ± 6 kg) v. H x F (292 ± 5 kg) heifers at mating ($P < 0.10$). The overall conception rate for heifers over two cycles of mating was 63%, with H x F and S x F heifers having conception rates of 65% and 60%, respectively.

Liveweight and body condition score of heifers were not affected by dam genotype at

P114 (Table 5.1). From P114 until P214, NHA heifers had significantly higher ($P < 0.001$) growth rates (0.72 ± 0.03 kg/d) than the RHA group (0.16 ± 0.02 kg/d). This resulted in a higher LW of NHA heifers at P214 ($P < 0.001$) and P270 ($P < 0.01$) than for the RHA heifers (see Figure 5.1). Dam genotype had no effect on body condition scores at P214 and P270 but NHA heifers had significantly higher scores at P214 ($P < 0.01$) and P270 ($P < 0.10$) than the RHA heifers.

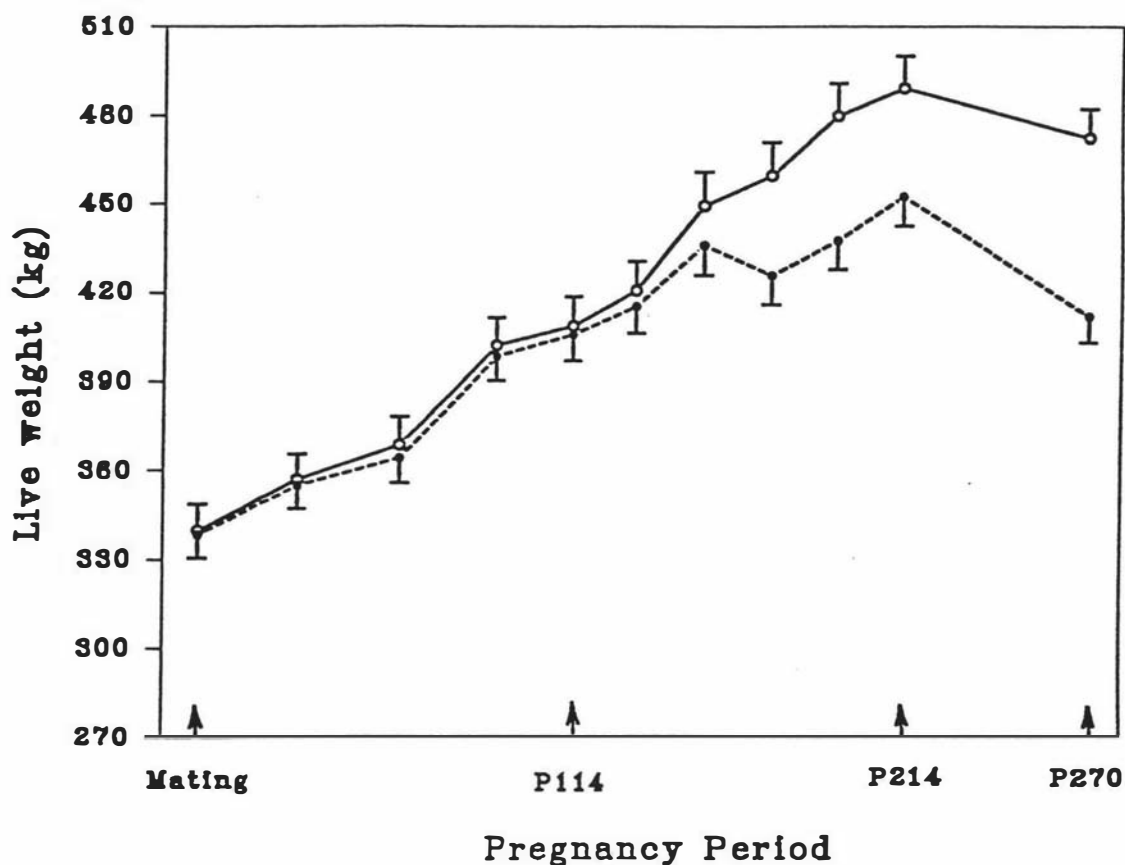


Figure 5.1 Growth performance of once-bred heifers offered restricted (*filled circles*) v. normal (*empty circles*) herbage allowance from pregnancy day 114 (P114) through to P214. Vertical bars represent the standard errors of the mean.

Table 5.1 Effects of heifer genotype and herbage allowance during mid pregnancy¹ on growth performance and body condition score of once-bred heifers.

	Genotype		Herbage allowance		Pooled SE
	(H x F) ²	(S x F) ²	Normal	Restricted	
Number of Animals	15	12	12	15	
Growth performance					
Liveweight at P114 ³ (kg)	390.3	407.8	405.5	392.6	9.0
Liveweight at P214 ³ (kg)	436.3	450.5	477.2 ^b	409.6 ^a	9.8
Daily LWG P114-P214 (kg)	0.45	0.42	0.72 ^b	0.16 ^a	0.03
Liveweight at P270 ⁴ (kg)	425.2	441.3	454.0 ^b	412.3 ^a	10.7
Body condition score⁵					
P114	3.04	3.44	3.16	3.22	0.12
P214	3.23	3.68	3.85 ^b	3.05 ^a	0.16
P270	2.19	2.27	2.65	1.82	0.26

¹ Day 114 to day 214 of pregnancy = P114-P214.

² H x F = Hereford x Friesian, S x F = Simmental x Friesian.

³ Sixteen-hour-fasted liveweights.

⁴ Unfasted liveweights.

⁵ Scoring scale: 1 = emaciated to 5 = extremely fat.

^{a, b} Means within main effects and rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Pre- and post-calving liveweights were similar for both genotypes (Table 5.2), but NHA heifers had greater ($P < 0.01$) pre- and post-calving liveweights than the RHA heifers. These variables were not affected by calf sex. The post-calving liveweights recorded for 11 heifers using either actual (382.9 ± 11.1 kg) or calculated (390.6 ± 10.1 kg) data were similar and highly correlated ($r = 0.988$, $P < 0.001$). Gestation length, calving score and LW loss at calving were not affected by dam genotype, herbage allowance or calf sex (Table 5.2).

The liveweight of heifers at weaning was not affected by genotype (Table 5.2). Heifers previously exposed to a restricted herbage allowance were lighter ($P < 0.05$) at weaning than the NHA heifers. Calf sex had no effect on the weight of dam at weaning. Growth rate of heifers was not affected by dam genotype, prior herbage allowance or calf sex during the suckling period (Table 5.2) or from weaning to slaughter (an average LWG of 0.33 kg/d).

Calf birth weight, weaning weight and daily LWG during the 106 day suckling period were not influenced by genotype, prior herbage allowance of the dam or calf sex (Table 5.2).

The incidence of dystocia (defined in this case as heifers requiring assistance at calving) was 37% across all calvings. Dystocia levels of 27 v. 50, 33 v. 40 and 43 v. 35% were recorded for H x F v. S x F, NHA v. RHA heifer dams and heifers calving female v. male calves, respectively. Calf mortality rate was 7% with all dead calves being female and born to H x F and NHA heifers. No heifer dam deaths were recorded at parturition.

Pelvic area measurements taken externally at P270 were similar for the heifer genotypes (Table 5.2), but heifers which had received the normal herbage allowance at P114-P214 had greater pelvic areas (336.1 cm^2) than the RHA heifers (315.9 cm^2 , PSE = 5.5 cm^2 , $P < 0.05$). Dam genotype and prior herbage allowance did not influence pelvic areas measured externally or internally at L60. A positive correlation ($r = 0.26$, $P > 0.10$) was observed between the pelvic areas measured externally and internally at L60 and between pelvic areas measured externally at P270 and L60 ($r = 0.54$, $P > 0.01$). Calving ease score was not significantly related to the pelvic area measured externally at P270 ($r = -0.13$, $P > 0.10$) but was related to both external ($r = -0.54$, $P < 0.01$) and internal ($r = -0.39$, $P < 0.10$) pelvic area at L60.

Table 5.2 Effects of dam genotype, herbage allowance during mid pregnancy¹ and calf sex on heifer dam and calf performance, and pelvic area of heifers.

	Genotype		Herbage allowance		Sex		Pooled SE
	(HxF) ²	(SxF) ²	Normal	Restricted	Female	Male	
Heifer performance							
Number of animals	13	11	10	14	18	6	
Gestation length ³ (d)	279.1	279.1	279.2	279.0	279.7	278.6	1.5
Pre-calving LW ³ (kg)	414.2	440.4	450.9 ^b	403.7 ^a	440.6	414.0	13.4
Post-calving LW ³ (kg)	360.5	386.8	397.1 ^b	350.2 ^a	386.7	360.5	12.9
LW loss ^{3, 4} (kg)	53.7	53.7	53.9	53.5	53.8	53.5	1.4
Calving score ³	2.0	2.1	2.0	2.1	2.1	2.1	0.6
Weaning weight (kg)	434.5	456.9	464.6 ^b	426.9 ^a	457.3	434.1	14.8
Daily LWG ⁵ (kg)	0.66	0.67	0.62	0.71	0.64	0.69	0.07
Calf performance							
Birth weight ³ (kg)	34.0	33.9	33.1	33.8	34.0	33.8	1.3
Weaning weight ⁶ (kg)	143.0	148.9	146.8	145.1	153.9	137.9	11.6
Daily LWG ⁵ (kg)	1.04	1.07	1.06	1.05	1.09	1.02	0.06
Pelvic area (cm²)							
<u>Pre-calving</u>							
Number of animals	15	12	12	15			
P270 (external) ⁷	318.4	333.6	336.1 ^a	315.9 ^b	-	-	5.5
<u>Post-calving</u>							
Number of animals	13	10	10	13	17	6	
L60 (external) ⁷	375.0	360.1	373.1	362.0	352.9	382.3	11.8
L60 (internal) ⁸	354.8	371.3	364.5	361.6	363.9	362.2	10.2

¹ Day 114 to day 214 of pregnancy = P114 - P214.

² H x F = Hereford x Friesian, S x F = Simmental x Friesian.

³ Includes data from heifers with live or dead calves (heifer performance) or from live and dead calves (calf performance).

⁴ Heifers' liveweight (LW) loss at calving.

⁵ The daily live weight gain of heifers or calves during a 106-day suckling period.

⁶ Figures are adjusted to a common calf weaning age (Nicoll & Rae 1978a, 1978b).

⁷ Externally measured pelvic area at P270 or day 60 of lactation = L60.

⁸ Internally measured pelvic area at L60.

^{a, b} Means within main effects and rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Carcass and Meat Quality Characteristics

Final heifer LW was not affected by dam genotype or calf sex, but RHA heifers had slightly lower ($P < 0.10$) final liveweights than the NHA heifers (Table 5.3). Dressing-out percentage (DO%) was significantly ($P < 0.05$) higher in H x F heifers than in the S x F group. Herbage allowance and calf sex had no effect on dressing-out percentages. Simmental x Friesian heifers had longer ($P < 0.05$) carcasses than H x F heifers, but herbage allowance did not affected carcass length. Kidney and pelvic fat weights ($P < 0.10$), fat depth ($P < 0.01$) and intramuscular fat level ($P < 0.05$) were higher in H x F than in S x F heifers. Restricted herbage allowance heifers had lower ($P < 0.05$) kidney and pelvic fat weights and higher ($P < 0.10$) intramuscular fat levels than the NHA heifers. Heifers rearing female or male calves produced carcasses with similar fatness levels (Table 5.3).

Table 5.3 Effects of dam genotype, herbage allowance during mid pregnancy¹ and calf sex on carcass quality characteristics of once-bred heifers.

	Genotype		Herbage allowance		Sex		Pooled SE
	(HxF) ²	(SxF) ²	Normal	Restricted	Female	Male	
Number of animals	13	11	10	14	18	6	
Final weight (kg)	481.6	507.5	512.7	476.4	507.2	481.9	16.2
Udder weight (kg)	4.33	5.32	5.32	4.34	4.94	4.71	0.59
Carcass weight (kg)	236.84	244.63	248.35	233.15	246.91	234.55	8.82
Dressing-out% ³ (DO%)	50.03 ^b	48.85 ^a	49.02	49.86	49.29	49.59	0.44
Carcass length ³ (cm)	208.4 ^a	212.7 ^b	209.9	211.2	210.6	210.5	1.45
Rib-eye area ³ (cm ²)	68.47	63.86	68.47	63.86	65.57	66.76	2.04
Kidney+pelvic fat ³ (kg)	9.27	7.67	9.37 ^b	7.58 ^a	8.32	8.63	0.63
Fat depth ³ (mm)	9.29 ^b	4.68 ^a	6.69	7.28	6.24	7.72	1.09
Intramuscular fat ³ (%)	5.60 ^b	2.97 ^a	3.42	5.15	3.69	4.87	0.76

¹ Day 114 to day 214 of pregnancy = P114-P214.

² H x F = Hereford x Friesian, S x F = Simmental x Friesian.

³ Means are adjusted to a constant carcass weight by covariance analysis.

a, b Means within main effects and rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

The carcasses of all heifers were classified as "heifer" in the New Zealand meat export grade schedule because in each case fewer than 5 permanent incisor teeth had erupted by the time of slaughter. No carcasses were classified into the "L" or "G" fat class. All carcasses from the S x F heifers were classified into the "P" grade while H x F heifers produced carcasses that graded either "P" (77%) or "K" (23%, Table 5.4). Twenty percent of carcasses from NHA heifers were in the "K" fat class, but only 7% of carcasses from RHA heifers were in this class. Sex of calf had no effect on carcass fat classes.

Table 5.4 Effects of dam genotype, herbage allowance during mid pregnancy¹ and calf sex on the proportion (%) of heifer dams carcasses in four fatness classes, based on the New Zealand export beef carcass classification system.

	Fatness class			
	L (1-3mm) ¹	P (4-7mm)	K (8-12mm)	G (13-18mm)
Genotype				
Hereford x Friesian	0	77	23	0
Simmental x Friesian	0	100	0	0
Herbage allowance				
Normal	0	80	20	0
Restricted	0	93	7	0
Calf Sex				
Female	0	89	11	0
Male	0	83	17	0

¹ Day 114 to day 214 of pregnancy = P114-P214.

² Backfat thickness range in brackets.

Simmental x Friesian heifers had heavier and longer ($P < 0.01$) femur bones with higher ($P < 0.05$) weight to length ratios than the H x F heifers (Table 5.5). A higher ($P < 0.01$) weight and ($P < 0.05$) weight to length ratio were recorded for the femur bones of NHA heifers v. RHA heifers. Muscularity was not affected by dam genotype or herbage allowance. The three hind-quarter cut weights of heifer dams were affected by dam genotype ($P < 0.001$) and herbage allowance ($P < 0.05$). Femur bone characteristics, muscularity and the hind-quarter cut weights of heifers were not influenced by calf sex.

Meat quality characteristics and the WB shear force values of heifers are summarised in Table 5.6. Meat quality traits were not significantly affected by dam genotype or herbage allowance with the exception of meat ultimate pH which was slightly higher ($P < 0.10$) in S x F heifers than in the H x F group. Calf sex had no effect on meat quality traits or WB shear force parameters.

Table 5.5 Effects of dam genotype, herbage allowance during mid pregnancy¹ and calf sex on femur bone characteristics, muscularity and the hind-quarter cut weights of once-bred heifers.

	Genotype		Herbage allowance		Sex		Pooled SE
	(HxF) ²	(SxF) ²	Normal	Restricted	Female	Male	
Number of animals	13	11	10	14	18	6	
Femur bone characteristics³							
Femur weight (g)	1907.7 ^a	2123.3 ^b	2107.0 ^b	1923.9 ^a	2034.6	1996.2	51.4
Femur length (mm)	394.1 ^a	406.9 ^b	402.4	398.6	401.3	399.7	3.3
FW/FL ³	5.26 ^a	5.62 ^b	5.64 ^b	5.24 ^a	5.48	5.40	0.11
Muscularity⁴							
	0.54	0.53	0.54	0.53	0.53	0.53	0.01
Hind-quarter cut weights⁴ (kg)							
Knuckle	8.43 ^a	8.93 ^b	8.77	8.60	8.71	8.65	0.19
Topside	13.50 ^a	15.07 ^b	14.51	14.06	14.27	14.30	0.20
Outside	13.02 ^a	14.03 ^b	13.81 ^b	13.23 ^a	13.71	13.34	0.23
3-cuts ⁶	34.95 ^a	38.04 ^b	37.09 ^b	35.89 ^a	36.69	36.29	0.47

¹ Day 114 to day 214 of pregnancy = P114-P214.

² H x F = Hereford x Friesian, S x F = Simmental x Friesian.

³ The ratio of femur weight (FW) to femur length (FL).

⁴ Means are adjusted to a constant carcass weight by covariance analysis.

⁵ Muscularity = (square root (weight of 3-cuts/femur length))/femur length, Purchas et al. (1991).

⁶ The sum of knuckle, topside and outside cuts.

a, b Means within main effects and rows with superscripts that do not contain a common letter are significantly different ($P < 0.05$).

Table 5.6 Effects of dam genotype, herbage allowance during mid pregnancy¹ and calf sex on meat quality characteristics and the Warner-Bratzler (WB) shear force parameters of once-bred heifers.

	Genotype		Herbage allowance		Sex		Pooled SE
	(HxF) ²	(SxF) ²	Normal	Restricted	Female	Male	
Number of animals	13	11	10	14	18	6	
Meat quality characteristics							
Ultimate pH	5.48	5.75	5.63	5.61	5.66	5.58	0.11
Sarcomere length (µm)	1.69	1.67	1.71	1.65	1.70	1.66	0.02
Cooking loss (%)	29.93	29.71	29.21	30.44	29.96	29.69	1.08
<u>Meat colour³</u>							
L*	37.88	36.73	36.45	38.15	38.02	36.59	1.36
a*	25.96	22.76	23.82	24.91	24.65	24.08	1.19
b*	15.77	14.68	13.78	16.68	12.38	18.07	3.54
<u>Fat colour³</u>							
L*	73.98	72.21	72.22	73.96	73.04	73.14	1.52
a*	1.25 ^a	4.19 ^b	3.28	2.16	2.67	2.78	0.72
b*	20.44	22.28	22.08	20.63	21.32	21.39	1.25
WB shear force parameters							
WB work	2.36	2.78	2.42	2.71	2.65	2.49	0.29
WB initial yield (IY,kg)	6.58	6.94	6.41	7.12	6.41	7.11	0.84
WB peak force (PF, kg)	7.82	9.05	7.99	8.88	8.49	8.37	1.02
WB (PF-IY, kg)	0.62	1.05	0.79	0.88	1.04	0.63	0.23

¹ Day 114 to day 214 of pregnancy = P114 - P214.

² H x F = Hereford x Friesian, S x F = Simmental x Friesian.

³ L*, a* and b* = The brightness, redness and yellowness, respectively, of meat or fat colour measured with a Minolta Chroma Meter II.

^{a, b} Means within main effects and rows with superscripts that do not contain a common letter are significantly different (P < 0.05).

DISCUSSION

As noted earlier, the main purpose of this study was to examine the possible effects of dam genotype and herbage allowance during mid pregnancy on performance of heifer dams and their progeny. No significant effects of calf sex on performance of heifers and calves were observed and hence calf sex will not be discussed further.

Effects of Dam Genotype

Simmental x Friesian heifers in this study were marginally heavier at purchase (4 months of age) and had greater liveweights than the H x F heifers at mating, calving, weaning and slaughter. These and the faster growth rates reported for Simmental x Friesian v. Hereford x Friesian (Everitt et al. 1975, 1978a, 1978b, 1980) and Simmental v. Hereford (Kress et al. 1990; Sawyer et al. 1991a, 1991b; Burns et al. 1992; Tierney et al. 1992) heifers and steers confirm that, under the same conditions, Simmentals and their crosses grow faster than Herefords or their crosses. However, the efficiency of growth should be considered from the viewpoint of the amount of feed eaten and the weight changes achieved. These attributes were not estimated in this study and there are no comparable data available for Simmental v. Hereford heifers and their crosses. Southgate et al. (1982b) found that Hereford x Friesian steers had significantly lower daily feed intakes than Simmental x Friesian steers (4.4 v. 5.2 kg dry organic matter intake (DOMI)/hd/d). However, there was no significant difference in food conversion efficiency between the two groups of steers in that study (a ratio of 217 v. 201 g LWG/kg DOMI for the former and latter groups, respectively). Andersen et al. (1977) also found that Simmental x Danish dairy or Hereford x Danish dairy steers had similar feed conversion ratios, while growth rate was higher in the former v. latter group (0.685 v. 0.639 kg/d). Likewise, More O'Ferrall & Keane (1990) reported that Charolais x Friesian (as a representative of large European crossbreds) had higher growth rate and daily feed intake than Hereford

x Friesian steers, but the two groups of steers consumed similar amounts of feed when the intakes were converted to a per unit LW basis (19.7 v. 20.2 g intake/kg LW/d, for the former and latter groups, respectively). However, a report from the United Kingdom (Anon 1977) suggested that Hereford x Friesian steers had better feed conversion efficiencies than Simmental x Friesian steers when the results were expressed based on the LW at slaughter, cold carcass weight or lean meat weights.

Simmental x Friesian heifers suffered higher levels of dystocia at parturition than the H x F heifers, but no calf mortality was observed in the former group. This might be associated with the marginally greater internal pelvic area in S x F (371.3 cm²) v. H x F (354.8 cm²) heifers at L60 since heifers with a greater pelvic area will cause less damage to the calf at parturition than those with a smaller pelvic area (Bellows et al. 1991). However, it is not clear why the incidence of dystocia was higher, but mortality not different, in S x F heifers since other studies have reported that heifer dams or older cows with greater pelvic area had both lower mortality rates and lower levels of dystocia at parturition (Axelsen et al. 1981; Bellows et al. 1991).

The 6 kg greater weaning weight of calves reared by S x F v. H x F heifers was partly due to the cumulative effects of a small difference in daily LWG between these two groups of calves (see Table 5.2). This, in turn, could have been due to a higher level of milk produced by S x F v. H x F heifers, since dam milk production influences the weaning weight of calves in cow-calf rearing systems (Barton 1970; Cundiff et al. 1974; Nicol 1976; Wright & Russel 1987; Jenkins et al. 1991, 1992; Marston et al. 1992). However, the two heifer genotypes had similar udder weights at slaughter and the possibility that the calf weaning weight difference reflected solely a difference in calf genotype (i.e. capacity of the calf for rapid growth) cannot be discounted.

The slightly greater slaughter and carcass weights recorded for S x F v. H x F heifers in this study are in agreement with the results of Everitt et al. (1980) who found that

Simmental x Friesian steers produced carcasses 14 kg heavier than Hereford x Friesian steers. Morris et al. (1990a) also reported greater carcass weights for 20- to 31-month-old steer progeny derived from Simmental v. Hereford sires. There is no information in the literature comparing carcasses of Simmental v. Hereford straightbred or crossbred heifers. However, Keane et al. (1991) reported 22 kg heavier carcasses for Charolais x Friesian (as a representative of large European crossbreds) v. Hereford x Friesian once-bred heifers slaughtered at the same age.

The lower DO% recorded for S x F v. H x F heifers in this study is in agreement with the results of Everitt et al. (1980) where DO% in Simmental x Friesian steers (49.9%) was lower than that in Hereford x Friesian steers (50.8%). In addition, in the study of Morris et al. (1990a), Hereford x Angus steers had higher DO% than Simmental x Angus steers (52.5% v. 51.7%). Thus, lower DO% seem to be a characteristic of the progeny of Simmental v. Hereford sires.

Simmental x Friesian heifers produced longer carcasses than the H x F heifers, a difference which was associated with longer and heavier femur bones in the former group. In agreement with these results, Simmental x Friesian steers had heavier bones than Hereford x Friesian steers in the studies of Everitt et al. (1980) and Morris et al. (1990a). However, the lower fatness level (which was associated with a higher proportion of carcasses graded "P") and heavier hind-quarter cut weights in S x F v. H x F heifers suggest that the later maturing S x F heifers have the ability to grow to heavier weights while still producing valuable carcasses based on the New Zealand beef export grading system. The different intramuscular fat (marbling) levels recorded for dam genotypes in this study are in agreement with the findings of Bailey et al. (1991). Since some of the New Zealand export beef markets (e.g. the Japanese market) value meat with higher marbling levels (Hogg et al. 1992), meat of H x F once-bred heifers might be superior to that of S x F heifers for those markets.

In agreement with the results of this study, Bailey et al. (1991) reported that dam

genotype had no effects on meat quality traits and WB shear force values of heifers.

Effects of Herbage Allowance

Heifers offered a restricted herbage allowance at P114-P214 had about 68 kg lower liveweights and a lower body condition score than the NHA heifers at P214. While these differences were still apparent at calving (but reduced in magnitude to c. 42 kg), there were no differences between the groups in calf birth weight, calving difficulty score or dystocia level (with the exception that all calf deaths were in calves born to the NHA heifers). Other New Zealand investigations, which involved different restrictions in feeding level of 2- to 3-year-old pregnant heifers during the last 2 months of pregnancy, have shown similar results (Nicoll 1979; Anderson et al. 1981; Pleasants & Barton 1987, 1992a). In overseas studies, Keane et al. (1991) reported no effect of pre-calving feeding level of once-bred heifers on the incidence of calving difficulty or on calf birth weight, while Fiems et al. (1987) found that restricted feeding in late pregnancy reduced birth weight of calves, calving difficulties and early calf mortalities. In the studies of Drennan (1979) and Tudor (1972), calf birth weight was reduced by restricted feeding of dams, but there was no effect on calving difficulty except in the case of excessive restriction which increased calving difficulties. Hight (1966, 1968a) also reported that, in comparison with the calves born to the normal-fed 3-to 8-year old cows, a severe restriction during the last 120 days of pregnancy reduced the birth weights of calves by 20%. However, severely restricted herbage allowances are not recommended for heifers in OBH systems since one important aim of the system is to maximise carcass weights.

Normal herbage allowance heifers had greater pelvic area at P270 and L60 than the RHA heifers which is consistent with the findings of Bellows et al. (1991). The 17% (2 out of 12 calvings) v. 0% calf mortality rates in NHA or RHA heifers, in this study, is not consistent with the findings of Bellows et al. (1991) where calf survival levels were 91% v. 93% for normal-fed and restricted-fed heifers, respectively. However,

this might be a chance effect since the number of animals was too low to adequately test for treatment differences in dystocia levels. Thus while restricted feeding in mid pregnancy altered pelvic area, it did not influence calf birth weight, the incidence of dystocia or mortality.

Differences in LW between RHA and NHA heifers generated between P114 and P214 persisted through to weaning and slaughter, and resulted in the RHA heifers producing about 15 kg lighter carcasses than the NHA heifers. Similar results were reported for the carcass weights of once-bred heifers offered high or medium v. low feeding levels during the last 41 to 72 days of pregnancy in the study of Keane et al. (1991). Heifers receiving the normal herbage allowance during P114-P214 in this study deposited more kidney and pelvic fat than the RHA heifers, which is consistent with the findings of Keane et al. (1991)

Heifers on a normal herbage allowance in this study had heavier femur bones and hind-quarter cut weights than those of RHA heifers. However, they produced meat which had similar quality traits and WB shear force values to the meat of RHA heifers. No comparable study was found in the literature.

CONCLUSIONS

Results from this study indicate that the use of Simmental x dairy heifers in a OBH beef production system will increase carcass weights of heifer dams, and to some extent the weaning weight of their progeny, in comparison to those of heifers derived from traditional British beef x dairy cross animals. The gross margins associated with use of these two dam genotypes are considered in Chapter 6. However, feeding heifers at maintenance levels during mid pregnancy did not reduce the birth weight of calves and was detrimental to the overall performance of the OBH system. This management practice is, therefore, not recommended.

CHAPTER SIX

ECONOMIC EVALUATION AND GENERAL DISCUSSION

OVERVIEW

The main objective of this research programme was to investigate issues related to the development of "Once-Bred Heifer" (OBH) beef production systems. The development of appropriate OBH systems, which are new to New Zealand, would encourage dairy farmers to mate cows due to be culled, or those of low genetic merit, to beef breed sires in order to produce heifer (and bull) calves suitable for beef production. Heifer calves would then be reared on dairy farms up to about 3 months of age and sold to sheep and beef cattle farmers for OBH beef production. Under this system heifers are mated at about 15 months of age and rear their calves for 3 to 5 months before being slaughtered at 30-33 months of age. The meat of once-bred heifers (classified as "heifer", Kirton 1989) could be exported to the North Asian beef markets, such as South Korea and Japan, where beef quotas have recently been increased (Thomson 1989a; Joyce 1992; Forgie 1993; NZMPB 1993). Alternatively, the beef could be sold to the local trade which is expected to increase significantly through population and tourism growth to the year 2000 (NZMPB 1993). The 3-way cross progeny of once-bred heifers would also have the ability to grow rapidly and produce meat to increase national beef production.

There are several selling strategies available for the cattle of OBH systems. The system provides three types of animals for sale, namely: dry heifers (i.e. heifers which have failed to conceive or to calve, or those which calved but did not suckle due to the death of the calf); the progeny from the calved heifers; and heifer dams which suckled their calves up until a few months prior to slaughter. The dry heifers are a source of management flexibility within the system. They can be sold at any time after pregnancy diagnosis (February-March, for non-conceived heifers) or shortly after

calving (November-December, for heifers whose calves die at birth). The progeny can be sold at a similar time to the dairy beef sales in November, or in March-April at the time of weaner fairs for traditional beef cow progeny. Alternatively the female calves can be retained as another source of breeding animals for OBH beef production systems. The heifer dams from OBH systems can be weaned when their calves reach about 3-5 months of age and slaughtered at any time, depending on pasture availability and meat schedule values, after being finished for 2-3 months post-weaning (see later discussion).

As noted in Chapter 1, among different beef production policies in New Zealand, only bull beef finishing enterprises have higher gross margins than OBH beef production systems (Keeling et al. 1991). However, a survey of schedule prices (excluding premiums) published by the AFFCO New Zealand Ltd for steer or heifer, bull, cow and manufacturing beef grades in the 220-245 kg carcass weight range showed a steady decline in the price of bull beef during the July 1991 to July 1993 period (see Figure 6.1). This is presumably due to bull beef being highly dependent on the North American beef market, with more than 80% of bull beef being exported to the United States of America (NZMPB 1993; Wright et al. 1993), and/or to changes in the exchange rate (\$ NZ against \$ US). In contrast, fluctuations in the published schedule price of beef from heifers or steers were small (Figure 6.1), and the "heifer" beef price exceeded that of bull beef during the 1993 season. While the absence of reliable information on premiums paid for various meat grades makes it difficult to establish the true relative values of alternative meat production systems, the baseline data shown in Figure 6.1 does provide a reasonably strong incentive to New Zealand farmers to produce profitable "heifer" beef through the adoption of OBH beef production systems.

Results from the first trial of the present 3-year research programme at Massey University indicated that once-bred heifers are biologically able to produce meat comparable to that from maiden heifers (see Chapters 2 and 3). However, genotype, nutritional management and weaning time are the major factors affecting the

performance of heifer dams and their progeny' in OBH beef production systems (see Chapter 1). These matters were investigated in the second and third trials of this programme and results are presented in Chapters 4 and 5. The purpose of this Chapter is to evaluate the financial implications of OBH systems in a commercial farming environment, based on the results already achieved, and to offer some further recommendations for the future development of OBH beef production systems in New Zealand.

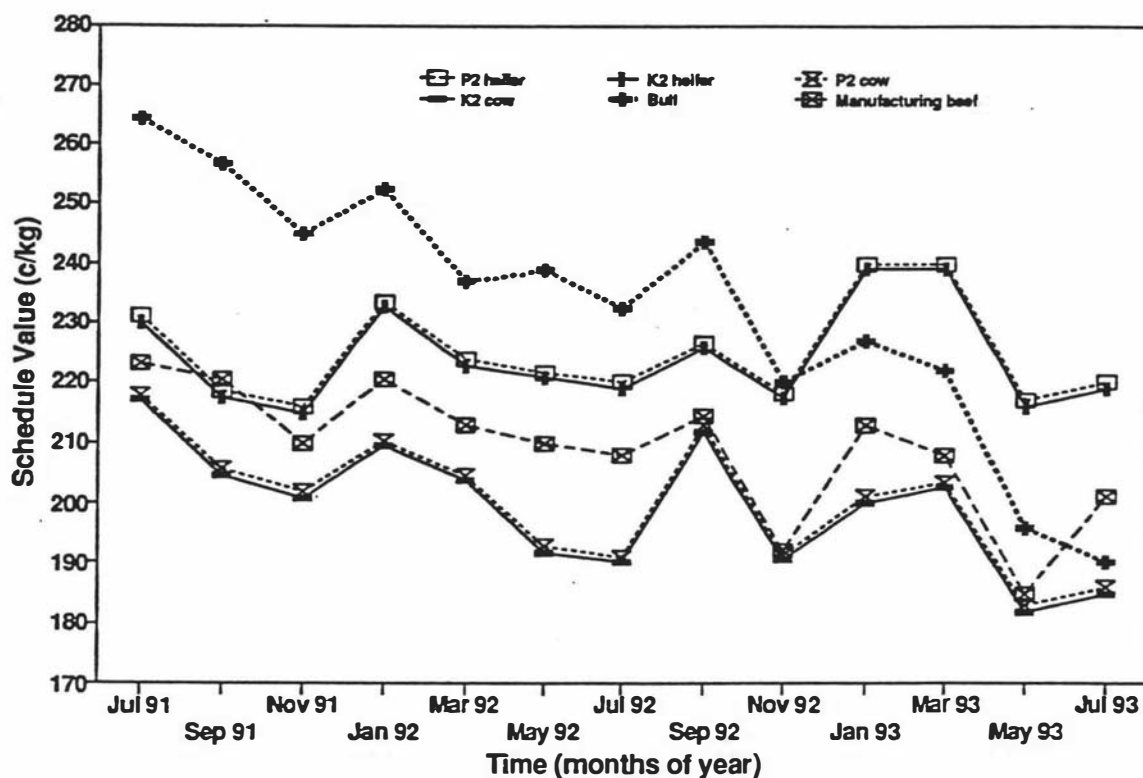


Figure 6.1 Schedule prices (excluding premiums) published by the AFFCO New Zealand Ltd for steer or heifer, bull, cow and manufacturing beef grades in the 220-245 kg carcass weight range between July 1991 and July 1993.

ECONOMIC EVALUATION

Animal production in New Zealand is based on use of pasture as the main source of feed (Taylor & Scales 1985; Nicol & Nicoll 1987). Pasture production is highly dependent on the seasonal conditions within a year (Radcliffe 1974) and good managerial skills are required to maintain a balance between herbage allowance, herbage quality and the demand of animals. This is because animal intake and productivity generally increase with herbage allowance but, if pasture becomes long and rank, its digestibility is decreased, the performance of animals declines and, consequently, the overall profitability of the farm enterprise may be reduced (Taylor & Scales 1985; Waghorn & Barry 1987). For adoption of a OBH beef production system it is, therefore, essential that the managerial and financial implications of the system are fully investigated before the system is established.

The costs incurred in, and returns achieved from, once-bred heifer beef production systems trialled at Massey University in this programme are presented in Table 6.1. Some of these figures (e.g. costs for animal health, oestrus synchronisation or artificial insemination) were constant for the alternative OBH systems (e.g. early- or normal-weaning policies or different dam genotypes) through the years, but others (e.g. purchase prices of heifers or sale prices of different classes of animals) were different due to the diversity in beef sale markets (see the footnote to Table 6.1). Therefore, in order to permit fair comparisons between the final outputs of different OBH systems, gross margin (GM) analyses were performed as described below.

Table 6.1 The costs incurred in, and returns achieved from, once-bred heifer beef production systems at Massey University during 1989-1993.

	Values (\$)
Costs (Per head)	
Heifer purchase price ¹	95-500
Animal health	8-10
Oestrus synchronisation	11.50
Artificial insemination	13.50
Pregnancy test	2.00
Natural mating	4.50
Returns (per head)	
Sale of unbred heifers ²	519-621
Sale of dry heifers ³	519-615
Sale of once-bred heifers ⁴	510-688
Sale of progeny ⁵	330-400

¹ A value of \$95, \$300 and \$450, respectively, for 4-day-old, 3-month-old and yearling Hereford x Friesian heifers. The corresponding values were \$110, \$330, and \$500 for Simmental x Friesian heifers of similar ages (T.G. Harvey 1993, personal communication).

² Unbred and bred but not pregnant, heifers sold at 27 months of age.

³ Bred but not pregnant heifers and those which calved but did not rear a calf and were sold at about 27-32 months of age.

⁴ Once-bred heifers calved at about 24 months of age, rearing their calves for 3-5 months and slaughtered at 30-33 months of age.

⁵ Male and female progeny from once-bred heifers sold at 4-5 months of age, at a price of \$1.85-3.00 per kg liveweight (LW) (i.e. calves of more than 200 kg LW = \$1.85/kg LW; calves of 175-200 kg LW = \$2/kg LW; calves of 125-175 kg LW = \$2.33/kg LW; and calves of 90-125 kg LW = \$3/kg LW). (Source: T.G. Harvey 1993, personal communication).

Gross Margin Analyses

According to the definition of Thomson (1989b) and Parker (1991) a gross margin (GM) represents the total returns from a particular enterprise less the direct costs associated with that enterprise. A simulation model, established by Parker (1991) and presented in Appendix III, was used to estimate the gross margins of alternative OBH systems studied in this research programme. The assumptions made in this exercise were as follows:

- (1) Number of heifers purchased: All gross margins were calculated on a SU basis for a herd derived from 100 4-day-old, 3-month-old or yearling heifers.
- (2) Calving percentages: Heifers mated (only once) through the use of AI coupled with CIDR-synchronisation in the first year of this research programme (Chapter 2) had low calving percentages, but when bulls were used to follow AI (Chapters 4 and 5) the calving performance was increased to more than 85% calves born per cow mated. This figure, which should be achievable under commercial farming conditions, was used as the standard for GM calculations.
- (3) Loss of purchased heifer calves to yearling stage: This was assumed to be 5% for the 4-day-old calves and 2% for the 3-month-old calves. The higher calf loss assumed for 4-day-old calves was due to them being smaller and more sensitive to changing the environment (from dairy farm to OBH farm). However, if these calves were reared on dairy farms (under a profit share contract between the OBH and dairy farmers) the calf loss might be reduced. This latter assumption was not considered in the present GM calculations.
- (4) Loss of heifers from yearling to calving: This was assumed to be 2% of the whole mob.

- (5) Loss of calved and dry heifers: Dam mortality at calving was high in the first two trials when heifers were inseminated with the semen of Limousin or Charolais sires (see Chapters 2 and 4) but it decreased to 0% when the semen of Angus sires was used (Chapters 4 and 5) or when heifers were mated to Hereford "tail-up" bulls (Chapter 5). Therefore, mortality rates to sale of 3% and 2% for calved and dry heifers, respectively, were assumed.
- (6) Loss of progeny from once-bred heifers to sale: Calf mortality was high when calves were sired by Limousin and Charolais bulls (Chapters 2 and 4), but it was substantially decreased in Angus-sired (Chapter 5) calves. A mortality rate to sale of 5% was assumed for the progeny of once-bred heifers in the present GM calculations.
- (7) Mating heifers through the use of artificial insemination (AI) coupled with CIDR-synchronisation and use of cover bull(s): All gross margins reported for alternative OBH systems in Table 6.2 were calculated based on oestrus of heifers being synchronised by use of CIDRs, heifers being mated for the first cycle or two cycles by AI and a sound bull being used to mate the heifers not pregnant to AI. A herbage intake of about 12 kg DM/hd/d (Geenty & Rattray 1987) at \$0.041/kg DM (i.e. an opportunity cost, Newman et al. 1992) was estimated for the fertile bull while grazing with heifers. This bull was sold after being with the heifers for about 2 months.
- (8) Costs: These were assumed to be the figures presented in Table 6.1. An extra cost for purchased hay (\$ 0.15/kg DM, T.G. Harvey 1993, personal communication) was considered for the periods in which the feed intake of heifers was restricted for the few months prior to calving (see Chapters 2, 4 and 5). While herbage intake of pregnant and never-pregnant heifers was assumed to be similar (Chapter 2), an extra herbage intake was considered for lactating rather

than never-pregnant (Chapter 2), or dry or early-weaned (Chapters 4 and 5) heifers during the periods equivalent to the calf rearing periods for lactating heifers. Early-weaned calves (Chapter 4) were assumed to consume 4.8 kg DM/hd/d of herbage (Geenty & Rattray 1987; Wright & Russel 1987) whereas no herbage consumption was assumed for calves reared on their dams (Newman et al. 1992). An opportunity feed cost of \$0.041/kg DM herbage was considered for herbage consumed by the abovementioned animals (Newman et al. 1992).

- (9) Sale of progeny: These were based on the performance (weaning weights) of calves presented in Chapters 2, 4 and 5, and on the sale values for calves summarised in Table 6.1.
- (10) Sale of unbred, dry and once-bred heifers: The schedule price (week beginning 11/7/93, excluding premiums) published by the AFFCO New Zealand Ltd for steer or heifer, bull, cow and manufacturing beef grades (see Appendix III) was used to determine the sale price of heifers according to carcass weight and grade. The carcass weights of once-bred heifers and their associated carcass grades, as presented in Chapters 3, 4 and 5, were used. Unbred heifers slaughtered at about 27 months of age had an average carcass weight of about 242 kg with the grading distributions showed in Chapter 3. However, since once-bred heifers were slaughtered 6 months later than the unbred group, in that particular trial, the comparison between the slaughter performance of once-bred and unbred heifers was thought not to be precise unless an additional liveweight gain (LWG) of about 0.5 kg/d was considered for these and the dry heifers of alternative OBH systems described in Chapters 4 and 5. Therefore, greater carcass weights with grading distributions similar to those listed in Appendix III, were assumed (R.W. Purchas 1993, personal communication) for unbred and dry heifers when the gross margins shown in Tables 6.2 and 6.3 were calculated.

- (11) Double suckling: A double suckling policy based on the performance of early-weaned heifers and their progeny (Chapter 4) was developed based on assumptions that: 1) the second calves were 2-day-old H x F crossbred females with a purchase price similar to that for 4-day-old calves shown in Table 6.1; 2) the weaning weight of heifer's original calf was about 10% lower than the weaning weights of early-weaned calves (similar to the early-weaned calves in Chapter 4); 3) the weaning weight of the second calf was about 10% lower than the weaning weight of original calf; and 4) the carcass weight of the heifer dam was about 10% lower than that of similar heifers weaned early in Chapter 4. No extra feed was assumed for heifer dams rearing twin calves.
- (12) Natural mating of heifers: Two grade bulls (each for mating of 50 heifers in 2 to 3 cycles of oestrus (McMillan 1989)) were "used" with the assumption that the weaning weights of their progeny would be about 10% lower (see McCall 1989) than those of the early-weaned calves sired by highly selected bulls through use of AI (see Chapter 4). This was examined both with and without the use of CIDRs for oestrus synchronisation (see Table 6.2). The herbage intake of bulls and its cost was estimated as described in item 7 above.

The effects of various animal parameters and management policies on the gross margins of OBH beef production systems are discussed in the next section.

CONSIDERATIONS FOR ON-FARM ADOPTION OF OBH BEEF PRODUCTION SYSTEMS

Breeding of Heifers

A major reason for establishing OBH beef production systems is to increase national exports of table beef. Animal sex (heifer, steer or bull), weight (fatness) and age (cull cows or old entire sires from the beef and dairy industries) are factors that determine the classification of, and hence the price received for, beef in both the local and export beef markets (Barton 1982; Kirton 1989). A priority for once-bred heifer systems therefore is to ensure that beef is classified as "heifer" because carcasses classified as "heifer" normally have a higher schedule value than those graded as "cow" (see Figure 6.1). "Heifer" meat is defined as that produced by animals which have erupted not more than 3 pairs of their permanent incisor teeth. Teeth counting, therefore, is necessary to prevent any mistakes in determining the correct price schedule at the abattoir. The carcasses of all heifers slaughtered in this research programme were classified as "heifer" (see Chapters 3, 4 and 5), and mostly graded within the "P" and "K" fat, classes based on the New Zealand beef export carcass classification system (NZMPB 1991).

Unbred and empty heifers had greater carcass weights and, consequently, higher dressing-out percentages (DO%) than once-bred heifers, a difference which was associated with higher level of fatness in the former groups (see Chapter 3). However, the differences between other carcass and meat quality traits of the heifer breeding groups were minor. Thus, once-bred heifers produced meat which was comparable in quality to that of unbred and empty heifers. The carcass weight and DO% of once-bred heifers was improved by weaning heifers early (end of November) and giving them the opportunity to grow rapidly to reach the target slaughter weight by March (see Chapters 2, 3 and 4).

Breeding the heifers and allowing them to calve once and rear their calves for about 5

months (Chapters 2 and 3) resulted in gross margins of \$43.82, \$35.70 and \$41.09/SU when the replacements were purchased as 4-day-old calves, 3-month-old calves or yearlings, respectively. The corresponding values were \$37.36, \$30.17 and \$31.14/SU for the unbred heifers (see Table 6.2). As noted earlier, unbred or empty heifers (Chapters 2 and 3), and dry or "calved but not suckled" heifers (Chapters 4 and 5) were sold earlier with lower carcass weights than those assumed for this analysis (Appendix III). Although heavy carcasses (more than 275 kg) from once-bred heifers have graded as "P" or "K" in this research programme, it is not clear whether unbred heifers finished to heavier weights would also be classified within these grades as assumed in this GM analysis. Further research is required to address this issue. If unbred heifers are able to produce heavy carcasses within the highest priced grades, OBH beef production systems would still be more profitable (\$5-10/SU, Table 6.2) than the traditional heifer finishing system in New Zealand where heifers are typically slaughtered at only 180-210 kg carcass weights at 16-26 months of age (W.J. Parker 1993, personal communication).

Once-bred or unbred heifers purchased as yearlings had higher \$GM/SU than the 3-month-old purchase group with 4-day-old heifers having intermediate values (Table 6.2). The higher gross margins achieved for OBH systems buying replacements as yearlings were due to the lower costs (e.g. animal health) for this group v. 3-month-old heifers. Lower purchase prices were assumed for calves purchased at 4 days of age (\$230-245, including the costs for rearing up to 3 months of age; Parker 1993, personal communication) v. 3 months (\$300-330, purchased from a dairy farmer where rearing costs (including labour) are incorporated in the price). These results were achieved even though a 3% higher weaner loss was assumed for the heifer calves purchased as 4-day-old than for 3-month-old or yearling heifers. Although 4-day-old purchase policies offers lower capital costs (by about 50%) and a higher number of calves available for OBH systems (i.e. there would be fewer 8 month and older calves traded on store markets) use of these calves in OBH systems is less attractive to farmers because of the extra labour required for rearing over the spring months when there is usually already a high workload on farm staff.

Table 6.2 The effects of breeding, dam genotype, weaning time, herbage allowance during mid pregnancy, double suckling and mating system on the gross margin (\$/SU) of once-bred heifers purchased as 4-day-old calves, 3-month-weaners or yearlings. If a premium of 20¢/kg was included on carcass price, the gross margin (e.g. for 3-month-old early-weaned heifers, see below) would increase by \$5.74 to \$47.42/SU.

	Age at Purchase		
	4-day-old	3-month-old	Yearling
Breeding			
Unbred	37.36 ¹	30.17	31.14
Once-bred	43.82	35.70	41.09
Dam genotype			
Hereford x Friesian	46.54	38.48	45.98
Simmental x Friesian	47.97	38.20	42.18
Weaning time			
Early-weaned	49.80	41.68	51.62
Normal-weaned	50.08	42.00	52.17
Herbage allowance			
Restricted	43.55	37.29	41.61
Normal	50.22	42.18	50.85
Double suckling ²	59.72	51.60	68.71
Natural mating			
Use of bull plus CIDRs ²	47.73	39.47	47.59
Use of bull only ²	48.80	40.68	49.85

¹ Gross margin calculations are based on the assumptions described in the text under "Gross Margin Analyses". An example template is in Appendix III.

² These groups should be compared with the "Early-weaned" group above.

The gross margins achieved through mating heifers using grade bulls coupled with CIDR-synchronisation (see point 12, page 147) were \$2-4/SU lower than those obtained for comparable early-weaned heifers through the use of AI coupled with CIDR-synchronisation plus "tail-up" bull(s) (see Table 6.2). Thus the use of CIDRs for oestrus synchronisation and mating once-bred heifers using semen of selected sires (AI) plus "tail-up" bull(s) is more profitable and is therefore recommended for future OBH systems in New Zealand.

Dam Genotype

A wide range of breeds have been used in overseas OBH beef production systems (see Chapter 1). The choice of breed is normally based on the predominant breed used for dairy production within a particular country. As described in Chapters 2, 3 and 4, Hereford x Friesian (H x F) heifers, which are the most common beef x dairy heifers available to the New Zealand beef industry (McMillan 1989), were used in first 2 years of this research programme. Overall, these crossbred heifers reared calves with high weaning weights in comparison to the other New Zealand data reported for 2-way (Everitt et al. 1975; 1978a, 1978b; Baker et al. 1990) or 3-way (McCall 1989; Morris et al. 1993a) cross progeny. They also produced carcasses with acceptable weights for the New Zealand beef industry and proved to be suitable as a crossbred heifer for OBH beef production under New Zealand conditions.

Simmental x Friesian (S x F) crosses were compared in terms of their productivity with the H x F heifers (see Chapter 5), because New Zealand (Everitt and Jury 1980; Baker et al. 1982, 1990; Morris et al. 1990a, 1993a) and British (Kempster et al. 1982; Keane 1988; More O'Ferrall & Keane 1990; Keane et al. 1991) research showed that large European x dairy crossbred steers or once-bred heifers produced heavier carcasses than crossbred animals of British origin. Marginally greater weaning weights of progeny and a higher slaughter weight of heifer dams were achieved from the once-bred S x F

heifers than from the H x F groups in this study. Meat quality traits were not affected by dam genotype, but it was concluded that the use of Simmental x dairy heifers in a OBH beef production system increases carcass weights of heifer dams (by about 8 kg) in comparison to those of heifers derived from traditional British beef x dairy animals (see Chapter 5). However, given similar feed conversion efficiencies in the two genotype groups (Southgate et al. 1982b), and when the higher (per head) purchase price of S x F heifers - about \$15, \$30 and \$50 more expensive than the H x F heifers at 4 days, 3 months and one year, respectively (see Table 6.1) - was taken into account, gross margins were similar for H x F and S x F heifer groups (Table 6.2). Thus, there is little incentive for farmers to use heifers sired by large European breeds (e.g. Simmental) rather by Hereford (or other small British beef sires) which are commonly used to mate first-calving heifers in the dairy industry.

Hereford x Jersey females with (per head) purchase prices of \$75, \$290 and \$410 for 4-day-old, 3-month-old and yearling calves, respectively (T.G. Harvey 1993, personal communication), are another source of animals potentially suitable for OBH beef production systems. About 26% of the dairy cows in New Zealand are Jersey (LIC 1991) and the use of beef x Jersey females, with their lower purchase prices (see above) than beef x Friesian crossbreds (Table 6.1), might enable sheep and beef cattle farmers to establish OBH systems with low capital costs and high profitability. However, Smith et al. (1976) and Baker et al. (1990) reported that, although Jersey cross cattle generally grew faster than straightbred Jerseys, their growth rates were significantly lower than those of comparable crosses with other breeds. In addition Jerseys and Jersey crosses have traditionally been regarded as animals producing carcasses with low fat cover, high kidney fat, poor hind-quarter conformation, yellow subcutaneous fat and high meat tenderness (Purchas & Barton 1976; Purchas et al. 1992). A research programme similar to that reported in this thesis will be required to compare the lifetime productivity (i.e. growth rate, reproductive performance, weaning weight of progeny, feed conversion efficiency, and carcass and meat quality traits) of

once-bred beef x Jersey heifers before definitive recommendations can be made regarding the use of Jersey cross heifers in OBH systems.

Management and Nutrition

Heifers in OBH beef production systems require a high degree of management skill to achieve target liveweights at mating, calving and slaughter under all-pasture conditions (Chapter 1; Harvey & Burnham 1991; Morris & Khadem 1991). A daily LWG of 0.6-0.7 kg is recommended for female calves (purchased at a minimum liveweight (LW) of 85 kg at 3 months of age) to reach target liveweights of 300-330 kg at mating at about 15 months of age. Mating should occur in late November to enable heifers to calve during August-September when adequate pasture is available under New Zealand conditions for heifer dams to graze and produce adequate milk to support the growth of their calves. Heifers should also be fed at well above-maintenance levels post-weaning (i.e. late spring - early summer, during the period of rapid pasture growth (Pleasants & Barton 1978; Smeaton 1983b)), to achieve a carcass weight of at least 220 kg by 30 months of age (see below).

Once-bred heifers or traditional replacement heifers mated as yearlings normally have lower conception rates and suffer higher levels of dystocia and mortality at parturition than do older cows (Morris 1980b; McMillan 1989; Keane et al. 1991; Morrison et al. 1992; Morris et al. 1993a). The pre-calving LW, nutritional level during pregnancy and pelvic area of the dam, and the sex and sire breed of the calf, are reportedly the major factors affecting dystocia and cow-calf mortalities in heifers calving at 2 years of age (Tudor 1972; Morris 1980b; Bellows et al. 1991; Keane et al. 1991). It is therefore recommended that semen from easy-calving sires be utilised through AI (coupled with CIDR-synchronisation) to reduce the level of dystocia in once-bred heifers. While this mating programme involves additional costs, compared to natural mating, it can be justified for OBH systems if the higher productivity of heifer dams

and their progeny offsets the extra costs. Semen from British Milk Marketing Board Limousin and Charolais sires, identified through progeny testing as "easy-calving" animals, was used to mate H x F heifers in the 1989 breeding season but high cow and calf mortalities were observed, particularly in the Limousin-sired progeny and their dams (see Chapter 2). The Limousin sires were, therefore, not used in the 1990 and 1991 trials and heifers were mated (by AI) to local Charolais and Angus sires. Sire evaluation was not a primary focus of this research programme (because of the limited number of sires and progeny in each year). However, H x F (Chapters 2, 4 and 5) and S x F (Chapter 5) heifers mated to Angus sires had shorter gestations, lower calf birth weights and lower rates of cow and calf mortalities at calving than heifers mated to Limousin or Charolais (Chapters 2 and 4) sires. Based on this admittedly limited evidence, the Angus would seem preferable to the Limousin or Charolais as a sire breed for once-bred heifers in New Zealand. Hereford, Beef Shorthorn, Murray Grey and Santa Gertrudis (a *Bos indicus* breed) have also been recommended as easy calving sires that produce progeny with high growth performance (McMillan 1989; Thomson 1989b; Morris et al. 1993a). Much more extensive investigation is, however, needed before the easy-calving sire breeds most suitable for use with once-bred heifers in New Zealand can be identified. This research would also be directly applicable to the wider beef breeding cow industry.

The pelvic area of heifers, as an indicator of potential calving difficulties at parturition, was measured only in the last group of heifer dams (i.e. heifers mated to Angus semen, Chapter 5). Simmental x Friesian heifers had greater pelvic areas than H x F heifers and low calf mortality rates. It might be possible to measure the pelvic area of heifers prior to mating at 15 months of age and to mate only heifers with a suitable pelvic area (based on the average pelvic area of the whole mob) to reduce the level of dystocia and cow-calf mortalities at calving. However, this assumes a high correlation between pre-mating pelvic area and the incidence of dystocia, a relationship not examined in this study. Other studies (Basarab et al. 1993) suggested that the ratio of the heifer's pelvic

area to her body weight can be used to select heifers that have relatively greater pelvic area per kilogram of body weight and so reduce the incidence of difficult births by about 10%.

The herbage intake trials (Chapter 2) showed that once-bred and never-pregnant (unbred and bred but not pregnant) heifers required similar amounts of herbage to maintain their weight during the period equivalent to late pregnancy in the former group. In addition, herbage intake and the growth rate of non-pregnant and pregnant heifers was similar during the mid-pregnancy period for the latter group (see Inwood et al. 1992). Vanzant et al. (1991) also found no difference between pregnant and non-pregnant heifers in their forage consumption twelve days prior to parturition in the former group. Thus, pregnancy did not markedly affect the feed consumption of heifers. However, during the calf rearing period, lactating heifers consumed up to 24% more herbage per day than the never-pregnant (Chapter 2) and dry (i.e. early-weaned, Chapter 4) heifers. These results, which are consistent with the results of other studies (Hunter & Siebert 1986; Havstad et al. 1986; Vanzant et al. 1991), indicate that the extra feed consumed by once-bred heifers during the lactation period was converted to milk to support calves growing at 1.0-1.3 kg per day rather than being converted to higher liveweight. The very good milking ability of the crossbred heifers, exhibited in the high growth rates of their progeny (see Chapters 2, 4 and 5), suggests that double suckling may be possible for New Zealand OBH systems, at least for the first few months of the post-partum period. The second calf could be obtained from dairy farmers and suckled for 3-4 months (late August to mid December) before both calves were weaned early to allow time for the heifer dams to be finished on reasonably good quality December-February pastures in preparation for slaughter by mid March (see later sections).

The longer grazing time, and associated higher herbage intake, of once-bred v. unbred heifers during early lactation (Chapter 2) and that of heifers weaned early v. late

(Chapter 4), showed that ingestive behaviour studies are useful for improving the interpretation of herbage intake data. In particular, increased herbage intakes were associated with longer grazing and ruminating, and shorter idling, times per day in heifers rearing calves, than those of dry heifers, in the second trial (Chapter 4). This indicates that these heifers expended more effort in eating to support the growth of their calves, as well as themselves.

The nutrition of heifers during pregnancy, as a potential factor affecting the birth weight of calves and hence the incidence of dystocia and mortality at calving, was considered in this research programme. High feeding levels were continued from mating through to mid pregnancy in heifers used for the first two years (see Chapters 2 and 4). Heifers were then fed at a restricted (maintenance) level during the last two months of pregnancy, but calf birth weights (37-41 kg) and consequently the levels of dystocia and mortality at calving, were high. In the third year of study (Chapter 5), therefore, the nutrition of heifers was restricted from an earlier stage of pregnancy. One group of heifers was fed as in the previous years and the another group was offered a restricted (maintenance) herbage allowance from mid March through to late June, after which time both groups were fed at a maintenance level through to calving. Feeding level did not affect the calf birth weight but no dead calves were observed in the heifers restricted in early to mid pregnancy. Heifers fed at a high level in early pregnancy may have deposited more fat in the birth canal, and maintained this through to calving, thus causing a higher level of calf mortality than in the restricted group (see Chapter 5). Bond & Weinland (1978) found that heifers fed at a level equivalent to 140% of their TDN requirements for growth and reproduction, from 7 months of age through to calving at about 28 months of age, were the heaviest dams at calving but had a lower level of calf survival than heifers fed at 60, 80 and 100% levels during the same period. Roux et al. (1987) noted that once-bred heifers managed to grow 0.9 v. 0.7 kg/d, pre-mating and during the first 5 months of pregnancy, had calving rates of 90.6 v. 78.5 percent at about 20 months of age. Heifer groups in that study were

grazed to grow at 0.4-0.5 kg/d during the last 4 months of pregnancy and produced calves with similar birth weights (32.6 v. 31.5 kg).

These findings suggest that if once-bred heifers on New Zealand hill country were to be fed adequately (a growth rate of 0.6-0.7 kg/d) post-weaning through to mating and for the first 4-5 months of pregnancy, and then moderately (slightly above maintenance level while grazing in hilly areas) through to calving, they would be able to maintain adequate liveweights (in terms of carcass value) while avoiding excess fat deposition in the birth canal and hence have relatively few dystocia problems. These heifers should then be fed above maintenance, post-calving through to slaughter, to produce heavy carcasses while rearing calves with high weaning weights (Hutton & Parker 1973; Hodge et al. 1976; Pleasants & Barton 1978; Nicoll 1979; Taylor & Scales 1985). Although the ideal nutritional programme for OBH is yet to be developed, heifers with restricted v. normal herbage allowance (Chapter 5) had returns of \$37.29 v. \$42.18/SU (assuming purchase at 3 months, see Table 6.2). This indicates that the feed restriction imposed in that study was a cost in terms of dam weight loss and hence decreased carcass weights. Thus restricting feed intake to heifers during pregnancy reduces their profitability unless it substantially improves calf and heifer dam survival rates.

Weaning Time

The availability of feed, dam genotype and the stage of lactation all affect the amount of milk produced by suckling cows (Hight 1968b; Wright & Russel 1987) and hence the weaning weights of their calves. In a traditional cow-calf system, especially when animals are fed solely on pasture, late weaning is preferred by farmers because heavier calves attract higher prices. Based on this information, heifer dams in the 1990 season (Chapter 2) were allowed to rear their calves to five months of age (an average weaning weight of 211 kg). This was achieved, however, at the expense of LWG in the once-bred heifers so that unbred heifers slaughtered at 27 months of age had higher

slaughter weights than once-bred heifers slaughtered at about 33 months of age (see Chapter 3). This was partly due to the weaning of heifers at the end of January when pasture quality did not allow the heifers to exhibit their potential daily growth rates, and hence to achieve target liveweights even by about 110 days post-weaning.

To investigate a practical strategy for overcoming this constraint, an early v. normal-weaning study was undertaken (Chapter 4). Heifers weaned after about 3 months of suckling (early-weaned or "EW" group) grew about 55% faster than those weaned of their calves at about 5 months post-partum (normal-weaned or "NW" group), during the period between the two weaning dates. The EW group gained about 29 kg more than the NW group between early weaning and slaughter. This was achieved at the expense of lower weaning weights (by c. 30 kg) in the EW calves, but early weaning has some managerial advantages (e.g. calves sold earlier usually earn a premium and pasture can be conserved to achieve better growth in the heifer dams (Harvey & Burnham 1991; Chapter 4)). The other advantage of weaning heifers early was a marginal improvement in meat quality characteristics compared to those of heifers weaned 5 months post-partum.

However, the similar gross margins achieved for early-weaned v. normal-weaned heifers (see Table 6.2) indicate that OBH farmers may choose either early or late weaning policies with little financial penalty. As noted earlier, one of the most important factors in this regard is the availability of good quality pastures. Taylor & Scales (1985) noted that twice the herbage allowance is required for a given LWG in late summer - early autumn as in spring - early summer. This and the summer dry conditions experienced by OBH heifers in the first trial of this series (see Chapters 2 and 3) indicate that, if calves in OBH systems were weaned early (between 3-4 months of age), there would be an opportunity for heifer dams to grow rapidly on late spring to early summer pastures and reach acceptable weights for slaughter by March (see Chapters 4 and 5). The progeny of early-weaned heifers could be sold as weaners at a

premium in the late November/mid December weaner sale markets (T.G. Harvey 1993, personal communication) or reared to greater weights and sold at the end of January.

Double Suckling

A double suckling policy could potentially be used to increase the income from OBH beef production systems. Results of experiments in which beef cows and calves reared two calves as a consequence of fostering have indicated that the total weight of calf weaned per cow is about 1.6 times that of a cow rearing a single calf (Wyatt et al. 1977; Nicoll 1982a, 1982b; Russel et al. 1985; Wright et al. 1987; McMillan et al. 1993a). Significantly higher milk yields were produced by Hereford x Friesian cows rearing twin (10.1-13.5 kg/hd/day) v. single (8.3-9.1 kg/hd/d) calves in the study of Nicoll (1982a). The original and fostered calves of the abovementioned cows consumed different amounts of milk (7.9-9.0 v. 5.2-6.5 kg/hd/d) and had different growth rates (0.87-0.94 v. 0.61-0.72 kg/d, Nicoll (1982b)). McMillan et al. (1993a) also found that 2-10 year old single- (cows reared only a single calf) and double- (cows reared their own calf plus a foster calf) suckled Hereford x Friesian cows had weaning weights of 452 v. 437 kg, after rearing their calves for 5-6 months on pasture. Calf weaning weight was lowest in the foster calf group, but comparable in the own calf and single calf groups (140 v. 194 v. 202 kg, respectively), with most of the foster calves being male Friesians. Wright et al. (1987) noted that, during a c. 134 day suckling period, twin-rearing cows consumed significantly more herbage than single-rearing cows (16.5 v. 15.1 g OM/kg LW/d), and took 55 days longer to reach slaughter condition. However, double suckling is becoming more common because of the introduction of embryo-transfer technology to the beef industry (de Rose & Wilton 1991; Morris et al. 1992; McMillan et al. 1993b). In the study of de Rose & Wilton (1991), twin births were associated with increased profit for traditional cow-calf rearing systems, in the United States of America, but overhead costs were higher for twin calves than for singles in feedlots. Under New Zealand conditions, Thomson

(1989b) suggested that net income could be doubled if a traditional straightbred beef breeding cow system was replaced by a system in which dairy cross weaner heifers were reared to calve at 2 years of age and an extra bull calf was suckled on each cow. The GM analysis of double suckling (see point 11, page 147) indicates that this system would be 19-25% (\$10-17/SU) more profitable than a single-suckling policy in New Zealand OBH systems (see Table 6.2). However, whether double suckling would influence the feed consumption of heifers, milk production and hence growth rate of their calves, and the performance (growth and hence carcass and meat quality traits) of heifers, under New Zealand pastoral conditions, is unknown. The ready availability of extra calves from the dairy industry, and the opportunity to significantly improve returns to farmers, supports the case for research to investigate these factors together with the possible extra labour needed for fostering the second calf onto the heifer dam.

Sensitivity of Gross Margins for OBH Beef Production Systems

As is summarised in Table 6.3, the returns for OBH beef production systems are mostly sensitive to the cost at which heifers are purchased, the calving percentage, sale price of progeny, the carcass weights of both calved and dry heifers and meat schedule values. A decrease of 20% in calf purchase price increased the GM by about 17% per stock unit. The GM increased by about 8% per stock unit when the calving percentage of heifers was increased by 20%. A substantial increase in GM occurred when heifers produced heavy carcasses (an increase of c. \$20/SU) or when the meat schedule price (an increase of c. \$11/SU) was increased (see Table 6.2). However, the gross margin was not changed markedly by changes in mortality rates of progeny, non-pregnant or pregnant/calved heifers. These results suggest that farmers need to carefully monitor calf purchase prices and optimise carcass weights and meat schedule values if the best possible returns are to be achieved from OBH beef production systems.

Table 6.3 Sensitivity of the gross margin for a once-bred heifer beef production system to changes in parameters listed below. The normal values (assumed to be the gross margin for an early-weaned OBH policy with replacements purchased at 3 months of age, i.e. \$41.68/SU) are shown in brackets.

Parameters	- 20%	Normal	+ 20%
Heifers' purchase price	48.50	(\$300/head)	34.58
Loss of 3-month-old weaners	42.12	(2%)	41.87
Loss of 1- to 2-year-old heifers	42.12	(2%)	41.87
Loss of non-pregnant heifers	41.68	(2%)	41.68
Loss of pregnant/calved heifers	42.12	(3%)	41.68
Calving percentage	38.02	(85%)	45.06
Loss of progeny to sale	41.68	(5%)	40.74
Sale price of progeny	35.22	(\$368/head)	47.86
Heifers' carcass weight	26.93	(241 kg)	62.03
Meat schedule price	30.41	(215 ¢/kg) ¹	52.66
Capital interest	42.56	(6%)	40.53

¹ A value of 215, 220, 219, 211 and 205 ¢/kg for L, P, K, G and T grades of meat from once-bred heifers, and a value of 230, 241, 240, 232 and 211 ¢/kg for the corresponding grades of unbred or empty heifers.

SUMMARY

The following is a summary of the results of this research programme:

1. There is an opportunity for dairy farmers to mate cows due to be culled, or those of low genetic merit, to beef breed sires to produce heifer calves suitable for profitable once-bred heifer (OBH) beef production systems in New Zealand. The widespread adoption of OBH systems would likely increase the demand for beef x dairy heifers and hence the price which dairy farmers received for them.
2. It is clearly possible to produce carcasses and meat with desirable quality attributes from once-bred heifers, although carcass weights and DO% were lower in calved heifers than in unbred heifers. The table meat ("heifer" beef) from heifers in OBH systems could be exported to the North American and North Asian markets (where beef quotas have recently been increased). Alternatively, this beef could be sold to the local trade which is expected to increase significantly through population and tourism growth to the year 2000.
3. No significant differences was observed between unbred v. pregnant heifers in herbage consumption or ingestive behaviour when both groups were offered a limited herbage allowance during the late pregnancy period in the latter group. However, when offered *ad libitum* allowances during different stages of the calf rearing period, lactating heifers had greater intakes associated with longer grazing times and bite weights than unbred heifers or than comparable heifers weaned of their calves at an earlier stage.

4. Feeding heifers at a maintenance level during mid pregnancy did not reduce the birth weight of calves, or level of dystocia, and was detrimental to the overall performance of the OBH system. Although the ideal nutritional programme for OBH systems is yet to be developed, heifers with a previously restricted herbage allowance had lower returns (\$/SU) than those given a normal herbage allowance during pregnancy.
5. Heifers mated to Angus sires had lower gestation lengths, calf birth weights and rates of cow and calf mortalities at calving than heifers mated to Limousin or Charolais sires. Based on this limited evidence, the Angus is, therefore, preferable to the Limousin or Charolais as a sire breed for once-bred heifers in New Zealand.
6. Use of Hereford x Friesian heifers in New Zealand OBH beef production systems is slightly more profitable than use of Simmental x Friesian heifers unless the purchase price of latter group decreases.
7. Although similar gross margins were estimated for early- and normal-weaning policies, there are managerial advantages in weaning heifers for OBH beef production systems at 3-4 months of calf age (November-December) because adequate pasture is likely to be available for heifers to reach an acceptable slaughter weight in mid March.
8. Gross margin analysis showed that double suckling will increase the profitability of OBH beef production systems by 19-25% (\$10-17/SU) in heifers purchased at 4 days old, 3 months old or as yearlings. The use of the AI technique coupled with CIDR-synchronisation plus "tail-up" bull(s) is preferable to the use of bulls only or use of bulls plus CIDRs for oestrus synchronisation, in terms of achievable gross margins, in New Zealand pastoral OBH beef production systems.

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APPENDICES

APPENDIX I

Faecal Output, Herbage Intake and Metabolisable Energy Estimation in Once-Bred Heifers Using Chromium Controlled Release Capsules

FAECAL OUTPUT

Chromium content of dried faecal samples (Cr/g faeces, see Chapters 2 and 4) was determined using the equation:

$$\text{Cr/g faeces} = (\text{AA} \times 1.0416 \times 0.05) \div (\text{WFS}) \quad (\text{EQ 1})$$

Where: AA = the atomic absorption spectrophotometer reading of Cr concentration in solution, 1.0416 = the recovery factor for chromium content of faeces, 0.05 = the dilution factor, and WFS = the weight of faecal sample.

Daily FO was calculated using the equation:

$$\text{FO} = (\text{RR}) \div (\text{Cr/g faeces}) \quad (\text{EQ 2})$$

Where: RR = the daily release rate (mg/d) of chromium from the CRC (for cattle in this trial, the RR was assumed to be 1150 mg Cr/d (Hirschberg et al. 1990)), and Cr/g faeces is the chromium content of faeces as defined and calculated above.

HERBAGE INTAKE

Herbage intake, in terms of organic matter (OMI, kg/hd/d), dry matter (DMI, kg/hd/d), and megajoules of metabolisable energy (MJ ME/hd/d) were calculated as described below:

Organic matter intake was calculated using the equation:

$$\text{OMI} = (\text{FOM}) \div (1 - \text{OMD}) \quad (\text{EQ 3})$$

Where: FOM = faecal organic matter calculated by subtracting the ash content of faeces from the daily FO, and OMD = the (*in vitro*) organic matter digestibility of hand-plucked herbage samples collected during the experimental period.

Dry matter intake was determined using the equation:

$$\text{DMI} = \text{OMI} + (\text{OMI} \times \text{Ash}\%) \quad (\text{EQ 4})$$

Where: OMI was computed from EQ 3, and Ash% = the ash content of hand-plucked herbage samples.

METABOLISABLE ENERGY

Metabolisable energy was calculated using the equation:

$$(\text{MJ ME}) = (\text{DMI} \times 0.163 \times \text{DOMD}) \quad (\text{EQ 5})$$

Where: DMI was calculated from EQ 4, 0.163 = the correction factor (ARC, 1980), and DOMD = the digestible (*in vitro*) organic matter in the dry matter of hand-plucked herbage samples.

APPENDIX II

Effects of Removing *Longissimus Dorsi* Samples Before and After Chilling on Meat Quality Characteristics

BACKGROUND

In New Zealand abattoirs, boning of prime carcasses usually occurs after holding carcasses in a chiller (0-3°C) for 24 hours. In this research programme samples of *longissimus dorsi* (LD) muscle were taken from carcasses at about 90 minutes *post-mortem* and held at 15-18°C for 24 h so as to minimise the likelihood of cold-induced contractions which can cause a severe increase in the eventual toughness of the meat after cooking (Locker & Hagyard 1963). In order to compare the quality of these samples with that of samples that had remained on the carcass for 24 h or more, additional samples were taken from some carcasses at the time of boning (see below).

DATA COLLECTION

As described in Chapters 3, 4 and 5, samples from LD muscle (c. 750-1075 g, from the 10th to 13th rib region) were dissected from the right side of each carcass within c. 90 minutes *post mortem* (pre-chill samples). For the second and third trials (Chapters 4 and 5), in addition to the pre-chill samples, similar LD samples from the 10th to 13th rib region of the left side of each carcass were taken at the time of boning (c. 24 h *post-mortem*, post-chill samples) to determine whether chilling overnight affected the quality characteristics of meat. The same procedure described for meat quality assessment in Chapter 3 was used to evaluate the meat quality traits of both the pre- and post-chill samples (see Chapters 4 and 5). Data from heifers in the second (19 LD samples, Chapter 4) and third (9 LD samples, Chapter 5) trials were combined and analysed using the paired *t-test* comparison method described in SAS (1985).

RESULTS AND DISCUSSION

Results of this validation trial are presented in Table AII.1. Moderate to high correlations existed between the meat quality characteristics of pre- and post-chill samples. The higher pH ($P < 0.001$) and sarcomere length ($P < 0.01$) recorded for post-chill rather than pre-chill samples in this study is in agreement with the findings of Koohmaraie et al. (1988) who noted that LD samples from steers stored at 0°C had higher pH than those stored at 26°C . While sarcomere length was not affected by chilling in the study of Koohmaraie et al. (1988), Taylor et al. (1981) found higher sarcomere lengths in hot-boned rather than cold-boned LD samples, unlike the results of the present study. However, Joseph & Connolly (1977) noted that chilling had no effect on the ultimate pH and sarcomere length of LD samples from Hereford-cross heifers. The brighter meat colour recorded for the pre-chill LD samples in this study is in agreement with the findings of Taylor et al. (1981) indicating that hot-boned beef (corresponding to the pre-chill samples in Table AII.1) had better consumer acceptance. While the pre-chill samples tended to have lower shear force values in this study, Koohmaraie et al. (1988) noted that chilling did not influence the shear force values of LD samples stored at 0°C or 26°C . Dransfield et al. (1976) noted that in commercial practice, the rate of cooling depends upon the size, composition and packing of the meat as well as the operating temperature and the delay before chilling. As a conclusion, the present study suggests that pre-chill sampling has a marginal advantage over post-chill sampling in terms of meat quality values, but the correlations indicated that measurements on the two samples were similar.

Table All.1 Means for quality characteristics of samples from *longissimus dorsi* muscle removed from heifer carcasses within either 90 minutes (pre-chill) or 24 h (post-chill) *post-mortem*.

	Pre-chill	Post-chill	Difference	Sig. ¹	Cor. ²
Number of animals	28	28			
Meat Quality Characteristics					
Meat ultimate pH	5.68	5.78	0.10 (±0.01) ³	***	0.94
Sarcomere length (µm)	1.64	1.73	0.09 (±0.03)	**	0.22
Cooking loss (%)	27.78	27.66	0.12 (±0.49)	NS	0.41
Meat colour⁴					
L*	36.97	35.43	1.54 (±0.36)	***	0.69
a*	22.87	22.59	0.28 (±0.49)	*	0.58
b*	11.38	10.35	1.03 (±0.29)	**	0.65
WB Shear Force Parameters					
WB work index	2.81	2.97	0.16 (±0.30)	NS	0.55
WB initial yield (IY, kg)	7.28	8.19	0.91 (±0.81)	*	0.64
WB peak force (PF, kg)	9.11	10.01	0.90 (±1.05)	*	0.69
WB (PF-YI, kg)	1.49	1.59	0.10 (±0.17)	NS	0.91

¹ Levels of significance: NS = P > 0.05, * = P < 0.05, ** = P < 0.01 and *** = P < 0.001.

² Cor. = The simple correlation coefficient.

³ Standard error of difference in brackets.

⁴ L*, a* and b* = The brightness, redness and yellowness of meat colour, respectively, measured with a Minolta Chroma Meter II.

APPENDIX III

An Example of Gross Margin Analyses for Alternative Once-Bred Heifer Beef Production Systems

Tables 1-5 illustrate an example of gross margin analysis for once-bred Hereford x Friesian heifers purchased as 3 months weaners, mated at about 15 months of age and slaughtered at 32-33 months of age after suckling their calves for about 5 months (see Chapters, 2, 3 and 6).

Table AIII.1 **The assumptions made were as follows¹:**

Number of replacements (R) purchased	100
Calving performance (% of whole mob)	85
Losses: (% of whole mob)	
Purchase to yearling (yr)	2
R 1 yr to R 2 yr	2
R 2 yr non-pregnant heifers to sale	2
R 2 yr calved heifers to sale	3
Progeny of once-bred heifers	5

¹ See Chapter 6 for further explanation.

Table AIII.2 **Number and capital value of livestock wintered (i.e. at 30 June)**

Animal status	Number of animals	Stock units¹		Value (\$)	
		Per head	Sub-total	Per head	Sub-total
Yearlings	98	4.0	392	300	29400
Pregnant/calved	82	5.5	451	500	41000
Non-pregnant	14	5.0	70	475	6650
Total			913		77050

¹ A Stock Unit (SU) is a 55 kg ewe rearing one lamb to weaning with a feed requirement of 550-600 kg DM herbage per year (Coop 1965).

Table AIII.3 Gross margin calculation (note: values have been rounded to the nearer \$).
(I - Total Income, \$).

Animal status	Number of animals	Carcass weight (kg)		Value (\$)	
		kg/hd ¹	\$/kg ²	\$/hd	Sub-total
Calved heifers	79	211	2.09	441 ¹	34875
Dry heifers	14	285	2.34	667 ¹	9339
Progeny	78	(\$1.85/kg LW)		390 ³	30420
Tail-up bull(s)	1	280	2.09	585	585
Total					\$75219

(II - Total costs, \$).

Items	Number of animals	Per head	Sub-total
Heifers' purchase price	100	300	30000
Tail-up bull(s)' purchase price	1	800	800
Animal health			
Purchase to yearling	98	10	980
Dry heifers	14	8	112
Calved heifers	82	10	820
Synchronisation and artificial insemination	98	25	2450
Pregnancy diagnosis	96	2	192
Feed (hay or herbage)	82	32.3 ⁴	2649
Interest on capital	(6% of capital, see Table 1 above)		4623
Total			\$42626

Gross margin = (total income - total costs) ÷ 913 = \$35.70/SU

¹ Derived from Table 4.

² An average schedule price for heifer meat derived from table 4 below and a fixed value of \$2.09/kg of carcass for the tail-up bull.

³ Derived from the performance (weaning weight) of calves in Chapters 2 and 3, and the price for progeny (see Chapter 6).

⁴ All extra costs related to the use of different feeding policies for pregnant v. unbred heifers during the last 2 months of pregnancy in former group, or for unbred v. lactating heifers while the latter group were rearing their calves (see Chapters 2 and 6) or the cost for herbage consumption by tail-up bull (see Chapter 6) are added to this item.

Table AIII.4 The number of calved/dry heifers, their carcasses weight, proportion of carcasses in each grade, the schedule price for each grade and the income (\$, per head/total) from calved and dry heifers in a OBH system.

			Calved		Dry			
Number of animals			79 ¹		14 ¹			
Carcass weight			211 ²		285 ²			
Grade	Percent of carcasses		Price (\$/kg)		Price (\$/hd)		Total Income	
	Calved ²	Dry ³	Calved ⁴	Dry ⁴	Calved	Dry	Calved	Dry
M	-	-	-	-	-	-	-	-
L	13	-	205	-	433	-	4453	-
P	74	15	210	241	443	687	25964	1455
K	13	35	209	240	441	684	4540	3380
G	-	40	-	232	-	661	-	3734
T	-	10	-	211	-	601	-	849
E	-	-	-	-	-	-	-	-
Average income per head							\$441	\$667

¹ Derived from Table 3.

^{2&3} Derived from Chapter 3 and assumptions made in Chapter 6.

⁴ Derived from Table 5.

Table AIII.5 Schedule price for different grades and weights of heifer carcasses (¢/kg, excluding premiums) published by the AFFCO New Zealand Ltd for the week beginning 11/7/93.

Weight range (kg)	Grades				
	L	P	K	G	T
160.0 - 195	198	203	202	194	180
195.1 - 220	205	210	209	201	187
220.1 - 245	215	220	219	211	196
245.1 - 270	225	232	231	223	206
270.1 - 295	230	241	240	232	211
295.1 - 320	232	248	247	239	213
320.1 - 345	237	263	262	254	218
Over 345	237	269	268	260	218