THE UNIVERSITY OF ALBERTA

THE ONCE-CALVED HEIFER IN A BEEF PRODUCTION SYSTEM

by

BERNARD CLEMENT VINCENT

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

ANIMAL GROWTH AND DEVELOPMENT

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

SPRING 1990

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ISBN 0-315-60237-6

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RELEASE FORM

NAME OF AUTHOR BERNARD CLEMENT VINCENT

TITLE OF THESIS THE ONCE-CALVED HEIFER IN A BEEF PRODUCTION SYSTEM

DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED SPRING 1990

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DEDICACE

Cette thèse est dédiée à mon père, Charles Clément Vincent.
Si je peux devenir seulement une partie de ce qu'il est,
ma vie sera bien comblée.

This thesis is dedicated to my father, Charles Clément Vincent.
If I become but a part of what he is, my life shall be a worthy one.

Abstract

Three uniform groups formed from 120 crossbred heifers (270 ± 3.0 kg) were fed a cereal silage/grain diet, and exposed to bulls for six weeks when their average age was 385 days. This resulted in 96 heifer-calf pairs (OCH) and 18 heifers which failed to wean a calf (NC). The calves were weaned and heifers slaughtered at three, five and seven months after calving (OCH 3, 5, 7, respectively). A similar group (C) of 32 conventionally managed heifers was also fed to slaughter weight (432 ± 6.4 kg at 457 days of age). All heifers were regularly weighed and pen feed consumption was recorded. Following slaughter all carcasses were graded and the left sides dissected into fat, lean and bone.

Efficiencies were calculated on a combined cow-calf unit for the OCH system and on the C heifers. On a carcass weight basis, C heifers required significantly less digestible energy than the OCH 3, 5 and 7 groups (210.9 vs 245.7, 236.6, 233.2 MJ.kg^{-1}, respectively). C heifers required less dry matter, protein and digestible energy per kg of liveweight gain than OCH 3, 5 and 7 heifers (100.6 vs 121.0, 124.9, 125.8 MJ.kg^{-1}, respectively). The OCH 3, 5 and 7 heifers had dressing percentages similar to conventionally reared heifers (58.9, 59.1, 59.0 vs 59.8 respectively) but significantly lower than NC (62.2).

The carcass weights of the C heifers were significantly less (231 ± 3.71 kg) than those of OCH7 (288± 6.62 kg), CCH5 (298 ± 6.41 kg), OCH3 (274 ± 5.08 kg) and NC (292±6.02 kg.). All of the C and NC heifer carcasses graded maturity I whereas seven OCH carcasses graded maturity II or III. There was no significant difference in the amount of lean yielded among treatments when adjusted using total bone as covariate.

Conventionally reared heifers had higher steak moisture losses than NC, OCH 3, 5 and 7 heifers (9.44 vs 7.01, 5.23, 6.71, 6.85 $g.kg^{-1}$, respectively) and higher ultimate L* values (38.4 vs 35.6, 34.5, 34.7 and 34.8 respectively). The OCH3 heifers had significantly higher shear muscle values than all other groups. Electrical stimulation decreased shear values of OCH 3, 5,7 heifers to make them significantly lower than those of non-stimulated C heifers (6.58, 5.69, 5.42 vs 7.78 kg respectively).

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to Drs. Steve Morgan-Jones and Mick Price for their sage advice and guidance throughout my program. I also thank Drs. Berg, Hawrysh and Mathison for their suggestions and criticisms.

I am extremely grateful to Mr. Ray Weingard for his generous help with statistical analysis and timely humour.

Thanks are due to Mr. Ian Turnbull and staff at the beef unit for the care and management of the heifers and calves, as well as Mr. Don Brereton and staff at the Meats Facility for their excellent work on the slaughtering and carcass dissection operations.

Special thanks to Wayne Robertson, Terry Osko and Dave Best for their technical assistance at the Lacombe Meats Facility.

I express my deepest gratitude to my family and friends for all their patience, encouragement and support throughout this program of study.

Table of Contents

List of tables

List of figures

Chapter I

A ROLE FOR THE ONCE-CALVED HEIFER IN BEEF PRODUCTION

The role of the heifer as a source of beef has begun to increase. In 1981, Canadian producers raised about 833,000 heifers for beef production (Statistics Canada, 1982), almost twice that of 25 years ago (Agriculture Canada, 1963). In 1987, heifers accounted for 27% of slaughter animals in Canada in contrast to the 49% market share represented by steers (Agriculture Canada, 1987). As the productivity of the cowherd increases, more heifers become available for meat.

The industry has achieved a gradual increase in cow productivity during the past few decades with more kilograms of beef being produced per cow in the breeding herd (Gracey, 1981). The importation of European cattle initiated in 1967 along with the inauguration of new beef carcass grading standards in 1972 (Fredeen, 1980) were major contributors to this trend. Results from a life-time production study conducted at the University of Alberta indicate that new breed crosses made available to the industry by the influx of the "exotic" breeds may substantially out-produce traditionally favoured breeding females (Berg, 1984).

Consumer demand has encouraged the production of leaner beef to such an extent that in 1987, 58.3% of the "A" carcasses were Canada A1 (Agriculture Canada, 1987). This improvement in lean content due largely to the adoption of faster growing breeds has been paralleled by a gradual increase in carcass weight.

The average warm carcass weight has increased by about 42 kg (from 246 to 289 kg) during the past 25 years (Agriculture Canada, 1963, 1987). Producers are also increasing the reproductive performance of cows, with a progressive improvement of management and selection skills. As well, a higher proportion of producers are calving heifers at two rather than three years of age, consequently reducing the proportion of females required for herd perpetuation. As a result of the increased production of lean beef from cows, fewer females are required to yield the same amount of product, suggesting that a higher proportion of heifers could be used for meat production.

Heifers are slower growing and less efficient than males when compared at a standard body weight (Neumann, 1977; Ensminger, 1978). They not only commence fattening at a lighter carcass muscle weight than males but also undergo more rapid fat deposition relative to muscle weight (Berg et al., 1979). Heifers, however, have a lower proportion of muscle weight in the neck and thoracic muscles which gives them a better muscle distribution for beef purposes than either steers or bulls (Berg and Butterfield, 1976). In general, results indicate that the animal gender may exert only a minimal (certainly undetectable) influence on its eating quality (Hood and Allen, 1970; Prost et al., 1975). Exploration into production methods which are better suited to the slower growth patterns of heifers may be of merit.

An alternative to the traditional method of raising and marketing heifers may be a once-calved heifer system. An example of this system would be one where the heifer produces a calf when she is about 22 months of age and a quality carcass shortly afterwards. This system would have a higher efficiency of feed utilization than the present system because the dam herself would become the source of meat production and the conventional maternal overhead cost of producing a calf would be reduced by becoming part of productive growth (Taylor et al., 1985). This system would allow for possibilities of increasing beef slaughter numbers without increasing the national cow herd. In addition to the calf, there would be a substantial increase in the output of lean meat obtained from each heifer compared to maiden heifers slaughtered at the same degree of fatness (Crowley, 1973). This would be particularly advantageous in Canada since carcass weight is not a grading criterion. There is however, a shortage of information in the scientific literature on the production efficiency of once-calved heifers compared to conventional feeding of heifers for meat production.

Depending on the intensity of management, the once-calved heifer production system could have some additional advantages to those already outlined. Since the heifers would be handled in much the same way as replacement heifers, its simplest application could be as an added selection tool for reproductive females. The once-calved system could be used to improve selection for reproductive performance and maternal ability to a limited degree. Assuming all heifers would calve within a narrow time period, their milking ability could be evaluated early in lactation using the calf-nursing-method (Butson and Berg, 1984). Butson and Berg (1984) found that one measurement of either milk yield or any constituent yield was a sufficient indicator of the pre-weaning average daily gain of the calf and therefore reflected the production ability of the dam.

With this information the producer could assess the benefits of different breeding and marketing strategies. Based on the calving results and current beef prices, the producer could determine the number of replacement heifers required to fulfill his goal, be it herd expansion or cash flow. An economic benefit of this system would be that the producer would only have to predict what the prices would be in a couple of months time rather than several months or even years in advance as is necessary in a cow-calf operation. An advantage which would eventually have a repeating financial effect would be the potential extra productivity of having more accurately selected the superior producing heifers.

An option available within a cow-calf operation could be a once-calved double suckling system. In such a system, the calves born to the heifers would be fostered on to the mature cows from the foundation herd. The heifers could then be marketed for slaughter. In theory, the system would allow all mature cows to be double suckled if all heifer calves were kept as once-calved heifers. There would still be a high overhead cost of maintaining the cow herd. This system would offer an alternative method of rearing the calf. It would have promise in the more intensively oriented cattle operations in the European countries (Lowman and Broadbent, 1987). The high labour requirements needed for fostering young calves would however discourage many Canadian producers. In addition, the consequences of the added milking demand on the mature cows would be of concern and would have to be investigated.

Another level of application of the once-calved system would be to raise heifers solely for meat production. Since all animals are destined for meat production this system has little to gain by being in synchrony with the regular calving period. It may even be economically advantageous to time production with low-season supply, therefore the only time restraint becomes the availability of facilities and labour. This approach may have potential in the industry as a marketing scheme for out-of-season heifers. For example, proper planning with late heifer calves could result in matching feed requirements with times when less expensive feeds are available and also marketing during the off-season when demands may be higher. The feasibility of this system is greatly dependent on the supply of suitable heifers from other sources.

Developments in the control of fetal sex determination by techniques such as spermatozoon sexing (Dziuk and Bellows, 1983), may contribute to a self-perpetuating once-calved system. In such a system every heifer produces a heifer calf which in turn produces a heifer calf. The age at first calving could be two years as is the present practice in heifer management or it could perhaps be reduced thus improving efficiency even further. The seasonal variations in Canada encourage cattle production to follow a cycle which takes either one, one and a half or two years to complete. The ultimate would be to calve heifers near one year of age. Obviously, such heifers would be of a different type than those presently desired by the industry. They would have to be very early maturing and therefore likely much smaller. Accounts of heifers calving near a year of age arise on occasion (Price, M.A., pers. comm.) which suggests that these traits do exist within the cattle genetic pool. The challenge would be to locate and assemble a large enough group which could eventually become self-sustaining. The short generation interval would greatly accelerate genetic progress. Although we cannot foresee when techniques such as sex control of offspring will become commonplace, it is important that researchers study its potential and determine its merit or limitations.

To date the once-calved heifer system has not been adopted by the industry since producers do not wish to calve out a high proportion of heifers and the quality of meat from 30 month old heiferettes has not been subjected to detailed research. With the advent of beef sires tested for ease of calving, some of the problems of calving heifers should be resolved. In the Canadian context, the critical information to collect is the carcass grade and quality information for once-calved heifers as well as an estimate of the efficiency of such a system. The ratio of output to input for the entire herd is more important than the performance of individual animals in assessing the efficiency of cattle production. To avoid the effects of varying costs and prices, efficiency in animal production can be assessed solely in biological terms (Dickerson, 1978). The compilation and evaluation of this information is essential for determining the financial viability of the once-calved heifer system.

Chapter II

THE BIOLOGICAL EFFICIENCY OF A ONCE-CALVED HEIFER SYSTEM

A. INTRODUCTION

Western Canada is a major beef producing area and most of the cattle are produced from traditional cow-calf systems. In such a system, a foundation cow herd is maintained year-round to produce calves. Calves are weaned at about seven months of age. With the exception of some replacement heifers, most are fed in feedlots and eventually slaughtered. The once-calved heifer system, where heifers produce a calf prior to slaughter may be beneficial to Western producers. However few studies have attempted to evaluate the once-calved heifer system as a replacement for the traditional cow-calf system due to the complexity and high requirement of resources and time. Researchers have preferred to evaluate a segment of the system (e.g. carcass quality of bred heifers) and then combine these with other results to extrapolate to the complete system. Thus the efficiency of the once-calved heifer system has, to date, been evaluated using various combinations of actual and derived data, resulting in dissimilar conclusions among researchers (Boucqué et al., 1980, Brethour, 1987). Therefore the objective of the present work was to compare the biological efficiency of the once-calved system with conventionally reared heifers.

B. MATERIALS AND METHODS

1 - Setup and management

One hundred and twenty heifers ranging from 7/16 to 14/16 British breed composition were selected at weaning from the Lacombe beef research herd and sorted into three uniform groups of 40. Many breeds were represented. The most prevalent being Charolais, Simmental, Hereford, Angus and Red Angus. Each group of 40 was then sorted by weight into four groups of increasing average weight. Each of these groups of ten heifers was then randomly allocated to a pen. These calves were fed a varying combination of silage and beef ration (Table II.1) which would allow them to attain the desired target weight of 350 kg at breeding. Four days prior to commencement of the breeding season the heifers were allocated within the three large groups of forty according to their genetic composition. One half of each group was composed of twenty heifers between 7/16 and 9/16 British breeding (low British) and the remaining twenty ranged between 9/16 and 7/8 British. Heifers containing 9/16 British breeding were randomly allocated to the low and high British groups. Each group of twenty was then allocated to two pen groups of ten composed of equal mean weights (Figure II.1)

Two breeds of bulls were used for breeding. Red Angus bulls, a popular choice of easy calving sires were used along with Corriente bulls, a breed of Criollo descent which is a new Mexican breed available to the industry and is considered to be extremely easy calving. One bull of each breed was randomly allocated to each low and high British breeding group within each treatment. To guard against the possibility of infertility, bulls were rotated among pens every week throughout the six-week breeding period. The heifers were pregnancy tested in September by a veterinarian, approximately 90 days after the last breeding date, and non-pregnant heifers were separated and placed on the feeding regime shown in Table II.2. They became the fourth treatment.

Table II.1 - Feeding regime of once-calved heifers from start of test to trial completion.

Period	Ontest to breeding		Breeding		Breeding to preg test		Pregnancy test to 2wks pre-calving	
Duration (days)	134		44		81		106	
Feedstuffs (%):	As fed	DM	As fed	DM	As fed	DM	As fed	DM
silage	82.2	63.8	85.7	69.1	99.9	91.6	100	100
beef ration	17.8	36.2	-	-	-	-	-	-
magnesium pellets	-	-	14.3	30.9	0.1	8.4	-	-
Daily intake ($kg.d^{-1}$)	15.2	6.04	19.4	7.08	35.5	10.9	20.3	5.9

Period	2 wks pre-calving to end calving		End calving to 3 mth wng		3 months to 5 mths wng		5 months to 7 mths wng	
Duration (days)	71		50		56		56	
Feedstuffs (%):	as fed	DM	as fed	DM	as fed	DM	as fed	DM
silage	84.4	64.0	51.0	25.7	80.6	58.0	98.0	98.0
beef ration	15.6	36.0	49.0	74.3	19.4	42.0	2.0	5.0
magnesium pellets	-	-	-	-	-	-	-	-
Daily intake ($kg.d^{-1}$)	23.3	8.9	26.8	15.7	37.9	15.3	45.0	13.5

FIGUREII.1 - ONCE-CALVED HEIFER BREEDING ALLOCATIONS.

n=10 animals/pen

	GROUP 1	GROUP 2	GROUP3	
pen#=	PEN A	PEN C	PEN E	
weight (kg)=	366.0	367.3	360.0	
breed of bull=	Corriente	Red Angus	Corriente	
mean weight= 364.0 kg				7/16 - 9/16 BRITISH
pen#=	PEN B	PEN D	PEN F	
weight (kg)=	365.7	364.4	360.0	
breed of bull=	Red Angus	Corriente	Red Angus	
pen#=	PEN G	PEN I	PEN K	
weight (kg)=	347.0	350.1	359.0	
breed of bull=	Red Angus	Corriente	Red Angus	
mean weight = 351.2 kg				9/16 - 14/16 BRITISH
pen#=	PEN H	PEN J	PEN L	
weight (kg)=	345.6	349.2	356.1	
breed of bull=	Corriente	Red Angus	Corriente	
mean weight=	356.1	357.8	358.7	

overall mean weight =357.5

Table II.2 - Feeding regime of non-pregnant, lost calf and conventionally reared heifers.

Non-pregnant

duration (days)	21		53		47	
feedstuffs (%)	as fed	DM	as fed	DM	as fed	DM
silage	100.0	100.0	78.7	53.7	61.0	34.0
beef ration	-	-	21.3	46.3	39.0	66.0
daily intake (kg)	23.3	6.5	24.6	10.0	16.9	9.0

Lost calf

duration (days)	60	
feedstuffs (%)	as fed	DM
silage	65.5	39.7
beef ration	34.5	60.3
daily intake (kg)	33.5	17.3

Conventionally reared

duration (days)	39		195	
feedstuffs (%)	as fed	DM	as fed	DM
silage	83.6	61.5	61.0	34.0
beef ration	16.4	38.5	39.0	66.0
daily intake (kg)	10.2	3.9	14.3	7.6

At this time a fifth group was formed from 32 newly weaned heifer calves (C). Two groups of 16 heifers were assembled according to their breed composition. All calves were sired by Red Angus bulls. The high British group had Hereford x Angus dams whereas the low British calves had Charolais dams. These groups were managed as conventional feedlot heifers and fed as shown in Table II.2.

2 - Calving

All pregnant heifers received an *Escherichia coli* bacterin (Vynugen II, M.T.C. Pharmaceuticals, Cambridge, Ont.) approximately nine and six weeks prior to calving, in an attempt to limit scour problems often encountered by calving in close quarters. Calving took place within pens accessible to sheltered handling facilities. Calves were permanently identified as soon as possible following calving. The calf data recorded included calf birth weight, calving ease and presentation. Calvings were scored from 0 to 5, 0 indicating normal birth, 1 slight assistance, 2 puller used easy, 3 puller used hard, 4 required a veterinarian and 5 caesarian.

In order to minimize the variation among calving dates within the treatment groups, the heifers were divided into either early or late calving groups and penned accordingly as shown by Figure II.2. Breed of sire was stratified among pens to allow replication. Twelve new pens were filled with half the total expected number of heifer-calf pairs (early group) and then the remaining heifer-calf pairs (late group) were stratified among the existing pens as [illegible] Figure II.3. Two days per week were designated as allocation [illegible] newly calved heifers. On the allocation day following calving, the heifer and calf were moved to their new pen. Heifers were fed a diet consisting of 64% silage and 36% beef ration (DM basis) to allow

FIGUREII.2 - ONCE-CALVED HEIFERS CALVING ALLOCATIONS
EARLY STAGE (UNTIL 1/2 OF THE HEIFERS HAVE CALVED).

CO=Corriente RA=Red Angus

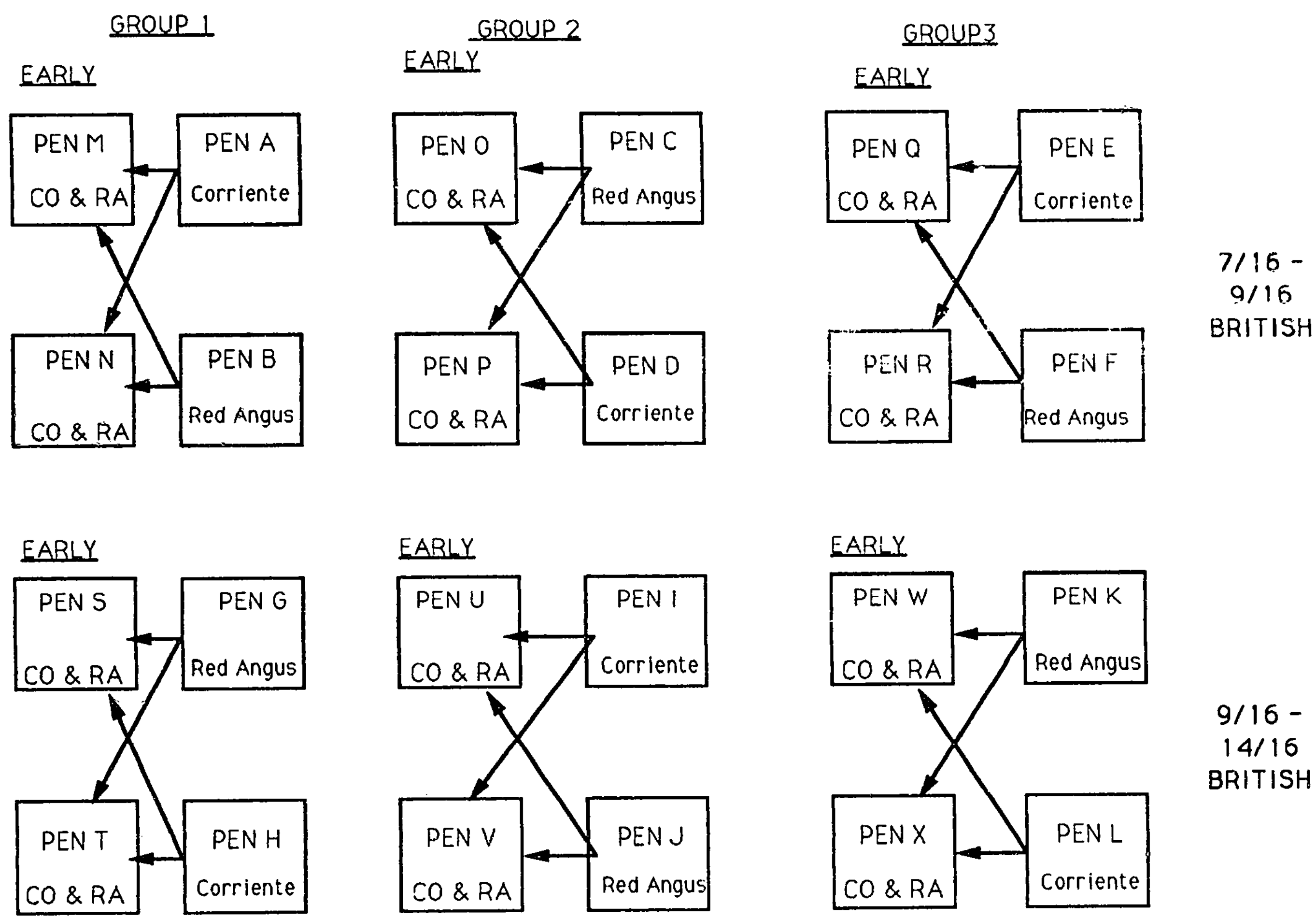
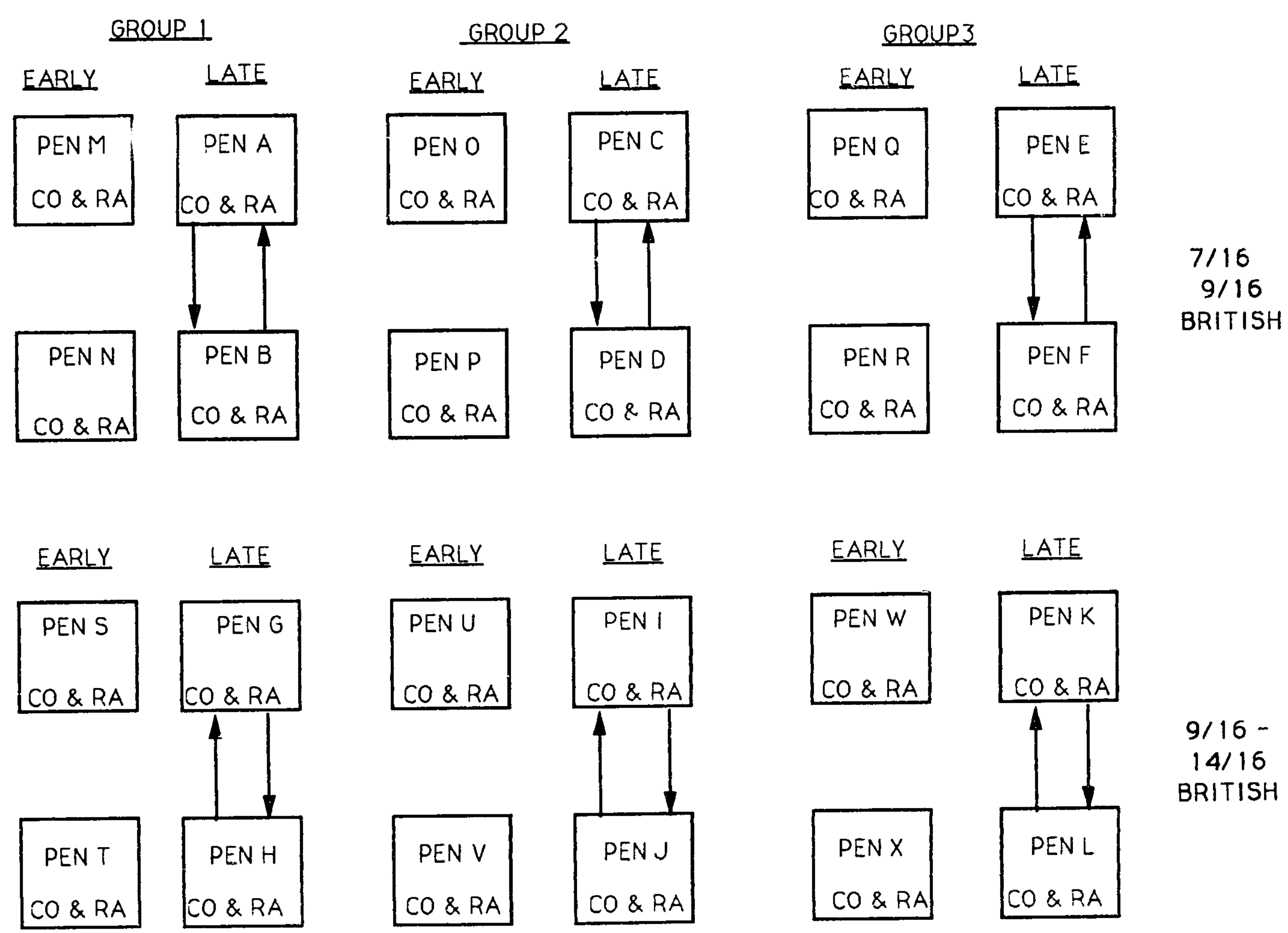


Figure II.3 - ONCE-CALVED HEIFER CALVING ALLOCATIONS
LATE STAGE (REMAINING 1/2 OF THE HEIFERS).



maximum milk production and ideally encourage an improvement in condition. Calves had creep feed available throughout the trial to alleviate the demands on the heifers and to prepare them for early weaning (Table II.3).

Heifers which lost their calves at or shortly after parturition were penned separately, fed a high barley based diet (Table II.2) and slaughtered after an average of 60 days. Preliminary analysis of data did not reveal a significant difference between this group and the heifers which did not conceive. In the context of the once-calved system, these two groups were comprised of animals which would be removed from the system so their data were pooled and analysed as one group which did not rear a calf (NC).

3 - Weaning and slaughter

Calves from the three large groups were weaned at different ages: three, five and seven months (OCH3, OCH5 and OCH7, respectively). On the morning of the specified weaning date, the designated pens of heifers and calves were weighed. The calves were returned to their pens and the heifers were placed in pens without access to feed or water and later transported to the meats facility, where they remained until their slaughter time the next day.

All animals were weighed immediately prior to slaughter (plant weight). They were stunned by captive bolt and weighed before and after exsanguination which was performed by severing the major blood vessels in the neck. All internal organs (tongue, blood, bladder, pancreas, adrenals, reproductive tract, diaphragm, kidneys, liver, heart, spleen, lungs, small intestine, large intestine, rumen, reticulum, omasum and abomasum), fat depots (kidney, mesenteric and omental) along with the head, tail, hide,

Table II.3 - The formulation of the creep feed.

Composition $g.kg^{-1}$			Analysis (dry matter basis $g.kg^{-1}$)		
Calf weight (kg)	150	200	Calf weight (kg)	150	200
Barley grain	250.0	250.0	Crude protein	18.7	16.7
Canola meal	100.0	100.0	Digestible energy ($MJ.kg^{-1}$)	14.5	14.5
Molasses, beet	30.0	30.0			
Oats, grain	350.0	400.0			
Soybean meal	100.0	50.0			
Wheat	150.0	150.0			
Calcium phosphate*	6.0	6.0			
Calcium carbonate~	8.0	8.0			
Salt	3.5	3.5			
Vitamin ADE	2.5	2.5			

* $CaPO_4$
~ $CaCO_3$

udder and feet were weighed on the slaughter floor. The gastro-intestinal tract was weighed full and empty of digesta. Empty body weight was defined as the live weight of the animal less the weight of the digesta and urine. All carcasses were weighed warm before and following trimming.

4 - Feed conversion efficiency

Feed consumption was monitored daily on a pen basis. Silage of cereal and forage origin was the source of roughage for the heifers throughout the trial. The levels of beef ration, a 73% barley-based concentrate (Table II.4), were adjusted to meet the nutritive requirements of the heifers for the varying stages. Magnesium pellets (Table II.5) were fed during the breeding period. Feed samples were collected on a monthly basis and analysed to determine dry matter and protein levels. These results were used to calculate the dry matter and protein intakes of the heifers. The digestible energy value for each feed was calculated from the tabulated Alberta average values (Alberta Agriculture, 1988).

Feed efficiencies were calculated on a combined cow-calf unit for the once-calved system and on a heifer only basis for the conventionally reared heifers. Efficiency was calculated using two approaches. The first method was the ideal situation including only those heifers which successfully conceived, raised a calf and were slaughtered. The second approach was to evaluate the actual situation where the efficiency of each treatment was calculated including those heifers which failed to conceive or raise a calf. Efficiencies were calculated on a liveweight, carcass weight and lean weight basis. Liveweight gain was the difference between the final and initial liveweights. In order to estimate carcass and lean gain, a value for the initial body composition of the heifers and the final composition of the calves

Table II.4 - The formulation of the beef ration.

Composition $g.kg^{-1}$		Analysis (dry matter basis $g.kg^{-1}$)	
Barley	732.50	Crude protein	11.9
Oats	150.00	Digestible energy ($MJ.kg^{-1}$)	14.6
32% protein supplement	50.00		
Beet pulp	50.00		
Calcium-phosphorus supplement	2.50		
Salt (cobalt-iodized)	4.25		
Ground limestone	10.00		
Vitamin A	.75		

Table II.5 - The formulation of the magnesium pellets.

Composition $g.kg^{-1}$		Analysis (dry matter basis $g.kg^{-1}$)	
Barley	877.0	Crude protein	13.1
Calcium phosphate*	62.5	Digestible energy (MJ.kg-1)	13.0
Magnesium oxide	41.0		
Perma pel ~	12.5		
Salt (cobalt-iodized)	5.0		
Trace minerals	1.0		
Selenium	1.0		

* $CaPO_4$
~ binding agent

was required. This was obtained from a similar group of 30 heifers slaughtered at the Lacombe Research Station (Aalhus and Jones, unpublished). The carcasses averaged 51.3% of the liveweight and the lean was equivalent to 30.7% of the liveweight. Efficiency was therefore calculated as the amount of feed input (dry matter, protein, digestible energy) per unit of animal gain (carcass, lean, liveweight).

5 - Data analysis

Dressing percentage was calculated using the warm carcass weight expressed as a proportion of plant weight. The plant weight, was taken after a constant 24 hours of water and feed deprivation. The performance, efficiency and dressing percentage data were analysed using a General Linear Model procedure (GLM; Statistical Analysis System, 1985). Sources of variation for the calf performance consisted of breed of sire, breed of dam, sex of calf and the 2-way and 3-way interactions. Sources of variation for efficiency consisted of heifer group, pen and the heifer group x pen interaction. Mean separation of significant main effects was by single degree of freedom linear contrast. The calving ease data were analysed using Fisher's Exact Test (Steele and Torrie, 1980).

C. RESULTS

1 - Calving and weaning

From the original 120 heifers, nine were diagnosed as being non-pregnant when pregnancy tested in the fall. Another five were detected non-pregnant at calving time. Data from these five heifers were removed from the project.

a - breed of sire

All Corriente calves were born unassisted, whereas 20% of the Red Angus calves required slight manual assistance and 11% of the Red Angus calves required more than a slight assist (Table II.6). There were two calvings involving abnormal presentations in the Red Angus group, and none in the Corriente group. Both groups suffered the same net calf loss except the Red Angus calves died at calving whereas the Corriente calves died after birth. One heifer bred to a Red Angus bull died due to calving. Corriente calves had sigificantly lower birth weights and higher ease of calving than Red Angus sired calves (Table II.7).

Differences in growth performance (Table II.7) were apparent at the early weaning period and remained throughout the different weaning times. Red Angus calves were 36, 38 and 22% heavier than the Corriente calves when weaned at three, five and seven months of age respectively.

b - breed of dam

There was no significant difference in birth weight or in the frequency of calving difficulties between the low and high British breeding heifer groups (Table II.8). The only significant difference in performance (P=.041) was at the 3 month weaning stage where the calves from the high British heifers were heavier than those of the low British heifers (111.3 vs 97.2).

c - sex of calf

Although male calves were assisted at calving more often than females this difference was not statistically significant (Table II.9). Male weights exceeded females but the differences were not significant at birth or

Table II.6 - Calving ease of Red Angus and Corriente sired calves from heifers.

Breed of Sire	n	birth weight (kg)	number unassisted	slight manual assist	other assist (puller, caes.)	malpre-sentation	calf losses	cow losses
Red Angus	54	34.7	37	11	6	2*	5	1
Corriente	52	28.6	52	0	0	0	5	0

*backwards

Table II.7 - Calf performance summary - breed of sire.

	Breed of sire			
	Corriente	Red Angus	SEM	Probability
Calving ease frequency				
Some difficulty	0	17		
No difficulty	52	37	-	0001
Birth weight				
number	52	54		
mean (kg)*	28.6	34.7	.71	.0001
Growth performance				
3 month weaning wt				
number	17	15		
mean (kg)*	89.3	121.3	3.79	.0001
5 month weaning wt				
number	16	17		
mean (kg)*	132.5	182.8	6.22	.0001
7 month weaning wt				
number	14	17		
mean (kg)*	217.2	263.6	5.56	.0001

*Least square mean

Table II.8 - Calf performance summary - breed of dam.

	Breed of dam			
	Low British	High British	SEM	Probability
Calving ease				
Both sexes				
Some difficulty	7	10		
No difficulty	20	17	-	.279
Male calves				
Some difficulty	5	5		
No difficulty	8	8	-	.656
Female calves				
Some difficulty	2	5		
No difficulty	12	9	-	.192
Birth weight				
number	53	53		
mean (kg)*	31.3	32.1	.71	.590
Growth performance				
3 month weaning wt				
number	16	16		
mean (kg)*	97.2	111.3	3.78	.041
5 month weaning wt				
number	16	17		
mean (kg)*	165.8	151.5	6.22	.138
7 month weaning wt				
number	17	14		
mean (kg)*	239.6	246.4	5.56	.292

* Least square mean

Table II.9 - Calf performance summary - sex of calf.

	Sex of calf			
	Male	Female	SEM	Probability
Calving ease				
Some difficulty	10	7		
No difficulty	16	21	-	.220
Birth weight				
number	46	60		
mean (kg)*	32.5	31.1	.72	.375
Growth performance				
3 month weaning wt				
number	13	19		
mean (kg)*	107.4	102.1	3.85	.845
5 month weaning wt				
number	14	19		
mean (kg)*	174.6	146.5	6.29	.034
7 month weaning wt				
number	12	19		
mean (kg)*	255.7	234.4	5.68	.003

* Least square mean

at 3 months weaning. Males were significantly heavier than the females in the 5 and 7 months weaning groups.

2 - Feed conversion efficiency

In the ideal situation (Table II.10), there were no significant differences ($P>0.05$) among treatments for estimated carcass feed efficiency (kg carcass gain.kg DM^{-1}) or estimated carcass lean efficiency (kg lean gain.kg DM^{-1}). The conventional heifers required less dry matter per kg of liveweight gain than those slaughtered at 3, 5 and 7 months after calving (9.17 vs 10.6, 10.3, 10.0 respectively). The same trend was repeated for the estimated efficiency of protein intake. No differences were found ($P>0.05$) among treatments for estimated carcass feed efficiency (kg carcass gain.kg $protein^{-1}$) or estimated carcass lean efficiency (kg carcass gain.kg $protein^{-1}$). The conventionally reared heifers, however required significantly less protein per kg of liveweight gain than the heifers slaughtered after 3, 5 and 7 months of lactation (.94 vs 1.16, 1.14, 1.11 respectively). As well, conventionally reared heifers required less digestible energy than the once-calved heifers to yield the same amount of carcass and liveweight gain. On a lean gain basis the conventionally reared heifers required less digestible energy than the OCH3 and OCH5 heifers (410.67 vs 496.12, 493.39 $MJ.kg^{-1}$, espectively) and not significantly less digestible energy to the OCH7 heifers (456.33 $MJ.kg^{-1}$).

In the actual situation (Table II.11) feed efficiency results were similar to those obtained in the ideal situation. The differences which favoured the C heifers for carcass feed efficiency (kg carcass gain.kg DM^{-1}) were not statistically significant. The conventionally reared heifers required less digestible energy per kg carcass gain than the OCH3 heifers.

Table II.10 - Estimated feed conversion efficiency of the once-calved system (ideal)*.

	Treatment					
	conventional	OCH3~	OCH5~	OCH7~	SEM	Prob.
Carcass efficiency						
kg dry matter.kg^{-1} carcass	18.92	20.55	19.57	19.32	.540	.2014
kg protein.kg^{-1} carcass	1.98	2.24	2.15	2.14	.060	.0692
MJ DE.kg^{-1} carcass	210.85^{a}	245.69^{b}	236.57^{b}	233.17^{b}	6.548	.0222
Lean efficiency						
kg dry matter.kg^{-1} lean	37.46	41.48	40.82	37.80	1.555	.1764
kg protein.kg^{-1} lean	3.85	4.53	4.50	4.19	.168	.0568
MJ DE.kg^{-1} lean	410.67^{a}	496.12^{b}	493.39^{b}	456.33^{ab}	18.410	.0243
Liveweight efficiency						
kg dry matter.kg^{-1} livewt	9.17^{a}	10.60^{b}	10.33^{b}	10.04^{b}	.278	.0227
kg protein.kg^{-1} livewt	.94^{a}	1.16^{b}	1.14^{b}	1.11^{b}	.030	.0011
MJ DE.kg^{-1} livewt	100.60^{a}	126.82^{b}	124.96^{b}	121.20^{b}	3.284	.0003

* = all heifers wean a calf
~ = once-calved heifers which nursed calves for 3, 5 or 7 months

Table II.11 - Estimated feed conversion efficiency of the once-calved system (actual)*.

	Treatment					
	conventional	OCH3~	OCH5~	OCH7~	SEM	Prob.
Carcass efficiency						
kg dry matter.kg^{-1} carcass	18.92	21.55	20.42	20.32	.720	.1292
kg protein.kg^{-1} carcass	1.98^{a}	2.36^{b}	2.25^{b}	2.25^{b}	.080	.0357
MJ DE.kg^{-1} carcass	210.85^{a}	258.61^{b}	246.98^{ab}	245.29^{ab}	8.598	.0172
Lean efficiency						
kg dry matter.kg^{-1} lean	37.46	42.82	42.15	39.80	2.528	.3979
kg protein.kg^{-1} lean	3.85	4.68	4.65	4.41	.262	.1259
MJ DE.kg^{-1} lean	410.67	513.90	509.88	480.53	27.910	.0718
Liveweight efficiency						
kg dry matter.kg^{-1} livewt	9.17^{a}	11.43^{b}	10.89^{b}	10.76^{b}	.344	.0078
kg protein.kg^{-1} livewt	.94^{a}	1.25^{b}	1.20^{b}	1.19^{b}	.035	.0014
MJ DE.kg^{-1} livewt	100.60^{a}	137.15^{b}	131.69^{b}	129.96^{b}	4.012	.0011

* = includes those heifers which did not raise a calf
~ = once-calved heifers which nursed calves for 3, 5 or 7 months

They required less protein per kg carcass gain than all OCH groups. On a lean gain basis there were no significant differences among treatments in the amount of dry matter, digestible energy or protein required to yield the same amount of carcass lean. The conventionally reared heifers required significantly less dry matter, digestible energy and protein to yield the same amount of liveweight gain.

3 - Dressing percentage and body components

Those heifers which did not rear a calf (NC) had a significantly higher dressing percentage (P>.0001) than the conventional and once-calved heifers (Table II.12). No significant differences in dressing percentages were found between the once-calved heifers and the conventional heifers or among the groups of once-calved heifers.

Preliminary analysis of weights of the various body components revealed that although there were significant differences among body component weights, most were not of real importance. The exceptions were kidney fat and udder weights. When adjusted to a common empty body weight, conventionally reared heifers had significantly more kidney fat than NC, OCH3, OCH5 and OCH7 heifer groups (12.56 vs 8.70, 8.56, 9.10, 9.66 kg respectively). The conventionally reared and no calf heifer groups had significantly lower adjusted udder weights than the OCH3, OCH5 and OCH7 heifers (5.04, 4.87 vs 10.20, 10.60, 10.16 kg respectively). The least squares means and standard errors for the individual body components are presented in the Appendix Tables 1a, 1b and 2.

Table II.12- Dressing percentages of once-calved, no calf and conventionally reared heifers.

	conventional	no calf	OCH3	OCH5	OCH7	SEM	Probability
Dressing percentage*	59.8^{a}	62.2^{b}	58.9^{a}	59.1^{a}	59.0^{a}	.003	.0001

^{ab} means in the same row with different superscripts are significantly different ($P<0.05$)
* based on 24h shrunk weight and warm carcass weight

D. DISCUSSION

1 - Calving and weaning

Calf losses were very similar for both breeds of sire. Although the Corriente calves were born with less difficulty than the Red Angus sired calves, an equal number died shortly after birth. Although not subject to scientific validation, the Corriente calves seemed to have less resistance to disease. In the case of calf scours for example, Corriente calves seemed to dehydrate rapidly and not respond as readily to treatment as Red Angus calves. Overall calf losses were higher than the 4% level accepted by the industry (Alta Ag., 1988). These losses may have been less if the experiment had not required that the heifers and calves remain in closed confinement at all times. This suggests that the once-calved system requires a higher level of management than the conventional system which directly influences its profitability.

The calving and growth performance results closely follow those reported for other trials. Lighter birth weights are closely associated with decreased calving difficulty (Makarechian and Berg, 1983). Therefore the lower frequency of calving difficulty from Corriente sired calves is consistent with their lower birth weights. The average birth weight of the Corriente sired calves has been reported to be very similar to that of Jersey sired calves (28.6 vs 28.3 kg; Laster and Gregory, 1973). The percentage calving difficulty in Jersey calves is also reported to be low (6.6%; Laster and Gregory, 1973).

Breed of dam has been associated with dystocia (Laster et al., 1973). There is generally a reduction in easy calving in heifers from large sized beef breeds resulting from both an increase in size and muscle development (Petit, 1975). Although increasing size increases the pelvic opening of the dams, it also brings about a rise in birth weight which may lead to dystocia.

Results suggest that the low British breed of dam group was not adversely affected by calving nor was it significantly different from the high British group for calving ease.

Gregory and coworkers (1978) found significant interactions of breed of sire with sex of calf and breed of dam with sex of calf for calving difficulty. This suggests that the higher the average level of calving difficulty observed for a breed of sire or breed of dam group, the greater the difference observed between their male and female progeny in the level of calving difficulty (Gregory et al., 1978). Our results failed to show a sex of calf by breed of sire interaction even though there was a 31% calving assistance in this group. It is possible that the smaller sample size of the present study did not allow enough sensitivity to detect these differences. Since residual error was not reported by Laster and Gregory (1978), this cannot be confirmed.

As expected the results of this trial support the concept of a strong relationship existing between birth weight and weaning weight. The growth rate of the heavier Red Angus sired calves was higher than that of the Corriente sired calves at all stages measured. Birth weight has a reported phenotypic correlation of 0.46 with weaning weight (Lasley, 1978). Thus the advantage of easy calving offered by Corriente bulls was compromised by a reduced growth rate in the calves evident at the early growth stages.

2 - Feed conversion efficiency

Results from this study generally show that heifers reared in the conventional system require less feed per unit of gain than those reared as once-calved heifers. All efficiency calculations based on liveweight gain showed the conventionally reared heifers had a better efficiency of feed conversion than the once-calved heifers. There were fewer significant differences when feed efficiency was calculated on a carcass or lean basis. The present experiment effectively compared the two methods of rearing heifers by having the same initial (post-weaning) and final end-points (carcass). Few other experiments have followed similar procedures consequently direct comparisons of the results of this study with others are difficult.

Boucqué et al. (1980) compared the lifetime feed efficiency of maiden and once-calved heifers in France. They concluded that although the latter enhanced meat production, the system was neither biologically nor economically efficient. Detailed examination of their experimental data showed numerous shortcomings such as a high number of infertile heifers (16%), caesarian deliveries (35%) and calf losses (19.4%) which would have had a major impact on overall efficiency. Feed efficiency estimates were based on small numbers of heifers and only calculated on a liveweight basis rather than the actual composition of the carcasses. Bond et al. (1986) found that daily gains in heifers were higher during both the 170 days prior to, and the 7, 21, and 42 days after calving compared to non-bred heifers of the same age. Feed efficiency was better for the bred heifers before parturition but poorer when calculated using a 24 h post-partum body weight. Again, efficiency was calculated on a liveweight and not a carcass weight basis. Efficiency calculations did not take into account the live calf and consequently are of limited value. Waggoner and coworkers (1988) also conducted a study on once-calved heifers at Kansas State University, and found that during the 112 day post-partum period, feedlot average-daily-gains were higher for two year old open heifers than for calved heifers. This result is in contrast to that reported by Bond et al. (1986), but the length of the feeding periods differed in the two trials.

Brethour (1987) looked at the economic feasibility of a once-calved system using models based on four years of research data collected at the Fort Hays Experiment Station. He concluded that returns could be increased by 41% when surplus heifers were retained, bred and fed out rather than selecting replacements in the fall and selling the remainder. Actual efficiency data were not included and conclusions were dependent upon the economic values used in the models.

In the present study there was a trend for efficiency among the once-calved groups to increase with increased suckling time. The differences were not significant and support the conclusions reached by Taylor et al. (1985) that variations in the time of slaughter had little implication in the decline in overall efficiency. This suggests that other criteria such as carcass quality, market price and feed costs could be allowed to determine when progeny would be slaughtered without incurring a severe efficiency-of-feed-utilization penalty.

The different rations and times on feed influenced the efficiency of the systems. The OCH7 were on test for 598 days and the diet of all once-calved heifers averaged 90% silage (as fed) whereas the conventionally reared heifers were on test for an average of 234 days and were fed a diet averaging 65% silage. The maintenance requirement must be fulfilled before any energy can be diverted to growth. The energy cost of maintenance is substantial since the amount of maintenance energy is a function of the metabolic size (National Research Council, 1984). Therefore the feed costs of production of muscle increase as the animal becomes more mature. Maintaining the once-calved heifers for 598 days was an energy sink which made them biologically less efficient then the conventional system. In addition, the feeding regime of the experiment resulted in the once-calved heifers being heavy at the start of the trial therefore raising their overall maintenance costs.

The once-calved heifer and conventional production systems have been compared on a biological basis. However, the outcome may be different if evaluated on an economic basis. Firstly, energy derived from silage and beef ration are not necessarily equivalent on an economic scale. The once-calved system, being a high roughage based production system may become economically advantageous over the conventional system if the price of grain is substantially more than roughage. The method of calculating efficiency in this paper underestimates the economic value of the calf. Calculating the value of the calf as a carcass is less than the live calf would obtain at the market place. To accurately assess the economic efficiency of the two production system, factors such as labour costs, interest rates, feed costs and beef prices must be taken into consideration. The economic merit of the once-calved system could only be determined by the establishment of a working model.

3 - Dressing percentage and body components

The present study found that conventionally reared heifers had similar dressing percentages to once-calved heifers. This contradicts other researchers who have found the dressing percentage of once-calved heifers to be lower than yearling heifers (Lalande et al.,1981; Roux et al., 1987). Results from the present study show that the dressing percentage of calved heifers is lower than open heifers of the same age. This concurs with other studies (Lalande et al., 1981; Bond et al., 1986; Roux et al., 1987; Waggoner et al. 1988). Comparison with other studies may not be valid since some included kidney fat in the calculations of dressing percentage. The body component results of the present study show that conventionally reared heifers had significantly higher levels of kidney fat than the no calf and once-calved groups. It is clear that a different amount of kidney fat among conventional and once-calved heifers would influence dressing percentage. It appears from the body composition data, that the heavier kidney fat weight of the conventional heifers is balanced by the heavier udder weights of the once-calved heifers to yield a similar dressing percentage.

In summary, the once-calved heifers were on test for up to 600 days, gaining .5 kg /day and attaining a final live weight of about 500 kg. The conventionally reared heifers gained .9 kg/day throughout the 230 day feed period thus attaining a final liveweight of 400 kg.

E. CONCLUSION

Once-calved heifers slaughtered a few days after weaning had dressing percentages similar to conventionally reared heifers.

The once-calved system yielded carcasses which were significantly heavier than carcasses from the conventionally managed system.

Feed efficiency on a live weight, carcass and lean basis generally tend to be poorer for the once-calved heifers than the conventionally reared heifers. On an economical basis, the efficiency would vary with feed costs, labour costs and calf prices.

Chapter III

CARCASS CHARACTERISTICS AND MEAT QUALITY OF ONCE-CALVED HEIFERS

A. INTRODUCTION

In the first part of the study (Chapter II), it was found that the once-calved system yielded heifer carcasses which were significantly heavier than heifer carcasses from the conventionally managed system. This may make the once-calved heifer system attractive to producers since heifer carcasses of the same grade are usually discounted compared to their counterparts from steers due to their lower carcass weight at the same fat level. The composition of these carcasses and their meat quality are consequently of scientific and commercial interest. Carcasses are composed of various cuts of meat reflecting differences in tenderness, taste, shape and size (Swatland, 1984). These different cuts return different value to people involved in the meat industry. The value of the different cuts are directly determined by the composition of the carcass, the distribution of the carcass tissues and the quality of the meat. No study conducted under Canadian conditions has evaluated these parameters for once-calved heifers compared to conventionally reared heifers. The aim of the present study was to establish the differences between carcasses of conventional and once-calved heifers and to compare the meat quality of the different animal types.

B. MATERIALS AND METHODS

1 - Carcass evaluation

The carcasses used were obtained from the growth trial described earlier (Chapter II). Muscle pH and temperature were taken on the cut surface of the longissimus muscle at the 13th rib using a Corning pH meter (Corning Glassworks, Medfield, Mass., U.S.A.) equipped with an Ingold spear-type combination electrode (Ingold Electronics, Andover, MA, U.S.A.) at 45 minutes and a second temperature at six hours post-slaughter. All carcasses were shrouded and chilled for 24 hours at 1°C at which time the shrouds were removed and the carcasses were cut between the 12th and 13th ribs. When meat is exposed to air, the purple myoglobin absorbs oxygen to become a bright red oxymyoglobin (Forrest et al., 1975). Since this process requires time, a 30 minute bloom time was allowed after which the longissimus muscle pH and colour in the C.I.E., L* a* b* scale (using a Minolta Croma meter II, Minolta Camera Company, Meter Division, Ramsey, New Jersey, U.S.A.) were recorded. At this time the amount of marbling was determined by a two-membered panel using a 9 point scale (1=abundant, 9=traces) and the carcass grades were assessed by Agriculture Canada graders.

The left sides of each carcass were then sequentially removed from the cooler, weighed and separated into primal cuts. These cuts were each weighed and then dissected into fat, lean and bone. The longissimus muscle portions between the 1st and 5th lumbar vertebrae from both sides of all carcasses were removed for meat quality evaluation. A 25 mm steak was cut from the anterior end of the longissimus muscle, weighed and packaged with oxygen permeable wrap (oxygen transmission 8600 cc.m-

^{2}.24h^{-1}, Vitafilm Choice Wrap, Goodyear Canada Ltd. Toronto) in a display tray. The packaged steaks were then refrigerated at 1°C for 96 hours after which drip losses were calculated using the "before" and "after" steak weights. The remaining portions of the longissimus muscles was shrink wrapped and stored at 1°C for 96 hours (144 h postmortem).

2-Meat quality determinations

At 144 hours postmortem, the packaged longissimus muscles were removed from refrigeration and unwrapped. One 25 mm steak was cut from the anterior end of each muscle. Three pH measurements were taken on each steak and after 30 minutes, three colour measurements were taken at the same sites using the Minolta Chroma meter. These same steaks were cooked in a microwave oven (Litton menumaster XLC-20) to an internal temperature of 80°C as measured with an electronic temperature probe (Technoterm 1100, West Germany) and left to cool for a minimum of three hours. At this time, three cylindrical 20 mm cores were removed from each steak by pressing vertically on the steak with a hand corer. These were then sheared once using an Ottawa Texture Measuring System (OTMS, Canners Machinery, Simcoe, Ont.) fitted with a Warner-Bratzler test cell and the peak shear force recorded. An average of the three readings was used in the statistical analysis of all pH, colour and shear test determinations.

The remaining portion of the longissimus muscle was trimmed of any surface fat and ground through a 3.2 mm plate three times. The ground muscle was used for determinations of expressible juice, moisture content and intramuscular fat. For expressible juice, exactly 20 grams of ground sample was centrifuged at 3-4°C and 37000 X g for 60 minutes. The amount of juice which precipitated from the sample was determined. For the moisture analysis, 100 grams of ground sample was dried in a gravity convection oven at 110°C for 24 hours. Moisture content was then calculated from the "before" and "after" dried weights. The dried sample was crushed and used for intramuscular fat determination using petroleum ether as an extraction solvent on a Soxtec apparatus. This value was corrected for moisture content and presented in the results on a fresh muscle weight basis.

The carcass composition data were firstly analysed on a non-adjusted weight basis. Covariance analysis was performed with carcass weight and then total bone as covariate. The growth coefficients for each carcass fat depot relative to total carcass fat were calculated by transforming all weights into log form and using the allometric equation (Huxley, 1932). Since the difference among slopes was not significant (P<0.05), the pooled regression coefficient was used for adjustment. If the difference among adjusted means of the fat depots was significant, the adjusted anti-log means were compared.

A general linear model which included heifer group, replicate, the heifer group x replicate interaction and residual error was used to identify sources of experimental error. The least squares means were compared using the treatment x replicate mean square as an error term.

C. RESULTS

1-Carcass evaluation

The proportion of carcasses assessed as maturity class 1 (youthful) decreased as age at slaughter advanced from 692-883 days (Table III.1). The younger conventional heifers and heifers which did not raise a calf

Table III.1 - Carcass maturity and grades from the heifer groups.

	conventional	no calf	OCH3~	OCH5~	OCH7~	SEM	Probability
Number of carcasses	32	18	32	33	31	-	-
age at slaughter (days)	457	692	765	821	883	-	-
Youthful (Canada A and B)	32	18	31	31	27	-	-
Intermediate (Canada C)	0	0	1	1	3	-	-
Mature (Canada D)	0	0	0	1	1	-	-
Grade fat depth (mm)	9.1^{a}	11.3^{ab}	8.8^{a}	12.8^{b}	12.0^{b}	.798	.0003
Marbling score*	6.7^{a}	6.7^{a}	6.2^{b}	6.3^{b}	6.4^{c}	.044	.0001

^{abc} means in the same row with different superscripts are significantly different ($P<0.05$)
* (1=abundant, 9=traces)
~ OCH = once-calved heifers which nursed calves for 3, 5 or 7 months

produced carcasses which all remained in the maturity class 1 category (Canada A and B grades). One of the 32 OCH3 heifers fell into the maturity class 2 category (Canada C grade). There was one maturity class 2 (Canada C grade) and one maturity class 3 (Canada D grade) among the OCH5 heifers. Of OCH7, three fell into the maturity class 2 and one into the maturity class 3 categories. The OCH5 and OCH7 heifer groups had significantly thicker fat at the grading site than the conventional and OCH3 groups. Marbling scores showed that at 24 hours the once-calved heifers had more visible marbling fat than the conventional and no calf groups (Table III.1). The 3 month and 5 month weaning groups had more marbling than those weaned at 7 months.

An evaluation of the composition of the carcasses showed that the conventionally reared heifers yielded significantly less lean and bone than all other heifer groups and also significantly less fat than the three once-calved groups (Table III.2). The no calf heifer group yielded significantly more bone and lean than other heifer groups, but was similar to the conventional and OCH3 groups in amount of fat.

When adjusted to a common total carcass weight, the once-calved system yielded carcasses with similar amounts of fat and lean to those reared in the conventional system (Table III.3). The conventionally reared heifers had significantly less bone weight than all other groups. On a carcass weight adjusted basis, the no calf heifer group yielded significantly less fat and more lean than all other heifer groups and were similar to the OCH3 group in the amount of bone. The OCH5 and OCH7 groups were similar for all three carcass components. The OCH3 group had significantly less fat and more lean than the OCH5 group and had more bone than either the OCH5 and OCH7 groups.

Table III.2 - Least square means of carcass characteristics.

	conventional	no calf~	OCH3*	OCH5*	OCH7*	SEM	Probability
Number of animals	32	18	31	33	31	-	-
Carcass wt (kg)	231.0^{a}	291.9^{bc}	274.0^{b}	297.6^{c}	288.4^{bc}	5.76	.0001
Fat (side) kg	35.3^{a}	39.3^{ab}	41.4^{b}	50.3^{c}	46.7^{c}	1.70	.0001
Bone (side) kg	17.6^{a}	24.1^{b}	22.2^{c}	22.5^{c}	22.3^{c}	.44	.0001
Lean (side) kg	62.3^{a}	82.4^{b}	73.5^{c}	75.9^{c}	75.6^{c}	1.73	.0001

^{abc} means in the same row with different superscripts are significantly different ($P<0.05$)

Table III.3 - Carcass composition of heifer groups adjusted to side weight (137.7 kg) as covariate.

	conventional	no calf	OCH3	OCH5	OCH7	SEM	Probability
Number of animals	32	18	31	33	31	-	-
Fat (side) kg	44.7^{ac}	35.9^{b}	41.4^{c}	45.7^{a}	43.8^{ac}	1.21	.0001
Bone (side) kg	20.1^{a}	23.2^{b}	22.4^{b}	21.3^{c}	21.6^{c}	.29	.0001
Lean (side) kg	72.9^{ac}	78.6^{b}	73.9^{ad}	70.7^{c}	72.3^{cd}	1.08	.0002

abc means in the same row with different superscripts are significantly different ($P<0.05$)

All heifer groups yielded similar proportions of lean when analysed using total bone as covariate (Table III.4). The conventional, no calf and OCH3 heifer groups yielded carcasses with significantly less total fat than the OCH5 and OCH7 groups. More specifically, they had significantly less subcutaneous and intermuscular fat than OCH5 and OCH7. The once-calved groups had similar amounts of body cavity fat to the conventional heifers. The no calf group yielded significantly less body cavity fat than all but the OCH3 heifer groups.

The analysis of fat depot accumulation relative to that of total carcass fat showed that the subcutaneous fat depot had an allometric growth coefficient greater than 1.0, whereas coefficients for body cavity and intermuscular fat were less than 1.0 (Table III.5). The treatment differences among slopes were not significant ($P<0.05$) for any of the fat depots and the adjusted means were not significant for the subcutaneous and intermuscular fat depots. The no calf, OCH3 and OCH7 groups yielded carcasses with significantly less body cavity fat than the conventional heifer group. The OCH5 group yielded similar amounts of body cavity fat to all other heifer groups except OCH7 which had the least.

2 - Meat quality determinations

The conventional heifers, compared to all other groups, had significantly lower 45 minute pH readings (Table III.6). The 45 minute temperatures of conventional, no calf and OCH3 carcasses were significantly lower than those of the OCH5 and OCH7 groups. The OCH3 heifer group had a six hour temperature which was similar to the no calf group, but significantly lower than all other heifer groups. The only difference at 24 hours was that the conventional and OCH5 heifers had a

Table III.4 - Carcass composition of heifer groups using total bone as covariate.

	conventional	no calf	OCH3*	OCH5*	OCH7*	SEM	Prob.
Lean (side) kg	73.5	75.0	71.5	73.3	73.3	1.20	.4379
Total fat (side) kg	39.3^{a}	36.7^{a}	40.5^{a}	49.4^{b}	45.9^{b}	1.65	.0001
body cavity (side) kg	3.4^{ad}	2.8^{b}	3.1^{ab}	3.6^{cd}	3.3^{a}	.12	.0002
subcutaneous (side) kg	12.5^{a}	12.1^{a}	13.1^{a}	16.3^{b}	15.7^{b}	.67	.0001
intermuscular (side) kg	23.4^{a}	21.8^{a}	24.3^{a}	29.4^{b}	26.9^{c}	.95	.0001

* = once-calved heifers which nursed calves for 3, 5 or 7 months

abc means in the same row with different superscripts are significantly different ($P<0.05$)

Table III.5 - Growth coefficients (b), adjusted means and F-values in the analyses of covariance of weights of fat depots using log of total carcass dissectable fat as the independent variable.

fat depots	common		residual	adjusted means antilog (kg)					F values	
	b	s.e.	CV	conv.	no calf	OCH3*	OCH5*	OCH7*	among slopes	among adjusted means
body cavity	0.723	0.06	11.265	3.45[a]	3.17[bc]	3.18[bc]	3.27[ab]	3.05[c]	0.10	0.02
subcutaneous	1.165	0.03	3.070	13.67	13.78	13.41	13.34	13.86	0.55	0.29
intermuscular	0.946	0.02	1.218	24.54	24.76	25.09	25.08	24.75	0.09	0.19

* = once-calved heifers which nursed calves for 3, 5 or 7 months
abc Adjusted means in a row bearing different superscripts differ significantly at $P<0.05$.

Table III.6 - Least square means of muscle pH, temperature and moisture loss of heifer groups.

	conventional	no calf	OCH3	OCH5	OCH7	SEM	Probability
pH							
45m	6.53^{a}	6.69^{b}	6.79^{b}	6.72^{b}	6.77^{b}	.043	.0001
24h	5.67^{a}	5.66^{a}	5.71^{a}	5.69^{a}	5.80^{b}	.036	.0227
6d	5.48^{a}	5.62^{b}	5.61^{b}	5.61^{b}	5.65^{b}	.028	.0001
Temperature (°C)							
45m	39.46^{a}	39.18^{a}	39.23^{a}	39.73^{b}	39.57^{b}	.15	.0201
6h~	16.75^{ac}	14.49^{bc}	13.93^{b}	15.65^{c}	15.44^{c}	.431	.0001
24h~	3.51^{a}	3.26^{ab}	3.30^{ab}	3.46^{a}	3.06^{b}	.128	.0421
Steak drip loss ($g\ kg^{-1}$)	9.44^{a}	7.01^{b}	6.23^{b}	6.71^{b}	6.85^{b}	.552	.0002
Expressible juice ($g\ kg^{-1}$)	252.4^{a}	240.3^{ab}	229.7^{bc}	227.8^{bc}	211.8^{c}	5.83	.0001

^{abc} means in the same row with different superscripts are significantly different ($p<0.05$)
~adjusted for side weight

significantly higher temperature than the OCH7 group. Conventional heifers had significantly higher moisture losses than other heifer groups as measured by steak drip loss (Table III.6). They also had significantly higher expressible juice values than all heifer groups except the no calf group. The conventional heifers had significantly higher L* colour values after 24 hours and the difference was still significant at 6 days postmortem (Table III.7). The conventional heifers had a* and b* colour values similar to the other treatments. The only significant difference being a lower a* value for the conventional heifers compared to the OCH5 group. The OCH5 group had an a* value which was significantly higher than all other groups and a b* value which was higher than all but the conventional group. There were no differences among any of the groups for six day a* and b* colour values.

The OCH3 group yielded meat which had significantly higher shear values than any of the other treatments. All other heifer groups yielded meat of similar tenderness. The percentage intramuscular fat as measured by ether extraction showed no significant difference between the conventional group and the others. The intramuscular fat percentages of the OCH5 and OCH7 groups were significantly higher than the no calf group.

D. DISCUSSION

1 - Carcass evaluation

The carcass grading results from this experiment suggest that as animals age chronologically beyond 25 months, an increasing proportion are assessed as being physiologically older than the maturity class 1 category (Canada A and B). The carcass grade would have a major

Table III.7 - Least square means of muscle colour, shear test and intramuscular fat of heifer groups.

	conventional	no calf	OCH3	OCH5	OCH7	SEM	Probability
Colour							
24h							
L*	36.6^{a}	34.7^{b}	33.8^{b}	34.8^{b}	33.7^{b}	.41	.0001
a*	21.2^{a}	20.8^{a}	20.3^{a}	22.8^{b}	21.7^{a}	.41	.0001
b*	9.6^{ab}	9.4^{a}	9.0^{a}	10.4^{b}	9.2^{a}	.28	.0022
6D							
L*	38.4^{a}	35.6^{b}	34.5^{b}	34.7^{b}	34.8^{b}	.47	.0001
a*	21.1	20.8	21.6	21.8	21.9	.40	.267
b*	9.9	9.5	9.7	9.9	9.4	.30	.620
Shear value, kg	7.8^{a}	7.8^{a}	9.4^{b}	7.5^{a}	7.2^{a}	.32	.0001
Intramuscular fat ($g\ kg^{-1}$)	49.9^{ab}	42.4^{b}	53.9^{ab}	62.6^{a}	62.7^{a}	1.50	.0034

abc means in the same row with different superscripts are significantly different ($p<0.05$)

influence on the profitability of a once-calved system since the highest prices are paid for those in the youthful categories with optimal fat cover (Canada A1). The grade fat depth results show that all heifer groups were able to attain the minimum 4 mm fat depth required to grade A1. The constraints of the experiment resulted in some heifer groups reaching higher fat levels than would be desired by producers. In the practical situation, this could be avoided by earlier slaughtering or changing the management so that a lower quantity of grain was fed following calving.

The results of this study showed that the once-calved system produced meat which was judged to be significantly more marbled than the conventional system but chemical analysis showed no significant effect on intramuscular fat content. Marbling is not a grading criterion in Canada at the present time. It is included in the grading systems of Japan and the United States and is consequently a factor which affects Canadian beef exported to those countries. Results from this experiment show that the majority of the carcasses from the once-calved heifer system could be classified as A1 and may even be favoured for markets where a premium is paid for higher marbled meat.

The Canadian grading system could not distinguish between carcasses from the once-calved heifer system and those from the conventional system. A detailed evaluation of the composition of the carcasses was nevertheless performed. Since the conventional heifers were slaughtered earlier and at a lighter liveweight than the other heifer groups, it was expected that they would yield lighter carcasses, with less lean and bone then the other heifer groups. When adjusted to a common weight the carcasses from the once-calved system did not differ in fat or lean weight compared to those of the conventional system. The once-calved heifer groups did have more bone than the conventional system suggesting a difference in stage of maturity. In order to bring all heifer groups to a similar stage of maturity, the carcasses were adjusted to a common total bone weight. This showed that no differences existed among the heifer groups in the adjusted quantity of lean yield, thus indicating that calving did not influence the lean:bone ratio of the once-calved heifer carcasses. The OCH5 and OCH7 groups tended to have more fat in the subcutaneous and intermuscular depots, but overall the differences found in composition were minor and probably not of commercial importance.

The growth coefficients of all three fat depots relative to total carcass fat were not significantly different ($P<0.05$) suggesting that over the growth range studied the fattening patterns were similar for all heifer groups. Results show that subcutaneous fat had an allometric growth coefficient greater than 1.0 indicating it was the last fat depot to be deposited and increased as a proportion of total dissectable fat as weight increased. Body cavity fat had a growth coefficient less than 1.0 suggesting that it was an early deposited fat and relative to total dissectable fat , its size decreased as liveweight increased. Intermuscular fat had a growth coefficient which was slightly below 1.0 indicating it would decrease as a proportion of total dissectable fat as weight increased. These results agree with those of Kempster (1981) who found that intermuscular fat was early developing and subcutaneous fat late developing.

No significant differences existed among the adjusted means for the subcutaneous and intermuscular fat depots. This indicates that there were no differences among the heifer groups in the relative rates at which they deposited subcutaneous and intermuscular fat, nor was there a difference in the amounts deposited when adjusted to a common total fat level. The proportion of carcass fat deposited in the body cavity is relatively small and variable (Berg and Butterfield, 1976). When adjusted to a common carcass fat level, there were differences in fat partitioning with the conventional heifer group having more body cavity fat than the no calf, OCH3 and OCH7 groups. However, the differences were small and probably not of economic importance. Carcass dissection results therefore show the once-calved system yielded carcasses which were of similar composition to conventional heifers.

2 - Meat quality determinations

This study showed that the older once-calved heifers had significantly higher longissimus muscle pH values than the younger conventional heifers. The once-calved system may produce meat with different characteristics than that from conventionally reared heifers, since these animals are older and have undergone calving and lactation. Other studies comparing once-calved heifers and open heifers of the same age have shown that meat pH was not influenced by pregnancy and calving (Petit, 1973; Dumont et al., 1987). Tuma et al. (1963) showed that the ultimate pH of the longissimus muscle decreased with increasing animal age. The small difference between the pH value of the conventional group and the other groups is not readily explainable. The rate of pH decline is affected by muscle temperature which in turn is influenced by the fatness of the carcass (Smith et al. 1977). In this study however, differences in muscle temperature did not explain variations in pH measurements. It is possible that the stress of weaning may have contributed to the higher pH perhaps by a decrease in stored glycogen. Other work performed on heifers has reported pH values ranging from 5.61 (Dumont et al., 1987) to 5.73

(Petit, 1973). This compares favourably with the pH values obtained by the older heifer groups (5.61-5.65) but not with the pH values of the conventional heifers (5.48). All groups had muscle pH values which fall within the normal range reported for commercial conditions (Murray, 1989).

The present experiment showed higher water losses in the conventional than once-calved heifers, as measured by expressible juice and steak drip loss. Although this contradicts results from Dumont et al. (1987), it is consistent with the lower pH values. The water holding capacity of meat is mainly influenced by pH. As the pH of meat approaches the isoelectric point of the protein (pH 5.0-5.1), the water-binding capacity of that protein also decreases (Swatland, 1984). Previous research has shown that calving prior to slaughter results in higher meat water losses (Dumont et al., 1987). This difference was found even though there was no difference in six hour pH. It is not surprising that many researchers have failed to find a difference in cooking losses between maiden and once-calved heifers (Dumont et al.,1987; Bond et al., 1986; Waggoner et al., 1988) since the same studies have not found a difference in pH. A disparity was found when actual water losses were measured. Petit (1973) found no difference in water retention between maiden and once-calved heifers. Dumont et al. (1987) found that calving produced significantly higher mean water losses.

Results from this experiment showed that the once-calved and no calf heifer groups yielded slightly darker meat (lower L*) than the conventional group. There was little difference in the muscle redness (a* value) or yellowness (b* value) of the different heifer groups at 24 hours and no significant differences at six days.

It is not clear from the literature what effect calving has on the colour of meat. In a study undertaken by Dumont et al. (1987) calving tended to result in lighter meat colour in Charolais X Friesian heifers. In the same trial, however, the meat of once-calved heifers of Friesian breeding was somewhat darker than the meat of maiden heifers (Dumont et al., 1987) suggesting an interaction between genotype and calving. Waggoner et al. (1988) found that one year old open heifers yielded significantly lighter coloured lean than once-calved heifers. However, they found no difference between once-calved and two year old open heifers which agrees with findings by Petit (1973), Bond et al. (1986) and the present study. The darker meat of the older animals is probably due to an increased myoglobin concentration. The concentration of myoglobin increases rapidly until about 36 months of age (Lawrie, 1979).

The lower pH of the meat from conventionally reared heifers could have resulted in more free water at the surface of the meat. This may have increased the reflectance and accounted for the significantly higher L* values. The lower pH may have also affected the spacial structure of myoglobin (Asghar and Pearson, 1980), thus increasing the light scattering properties of the muscles and influencing its colour.

Results from the present study showed that all heifer groups yielded meat of similar tenderness to that of conventionally reared heifers, except the OCH3 heifers which had the highest shear values. Meat tenderness is the main determinant of consumer eating satisfaction and thereby has the greatest influence on acceptablility (Jeremiah, 1981). Dumont et al. (1987) found that the influence of calving on tenderness varied according to the muscle considered. For example the longissimus muscle was more tender in calved heifers but the semitendinosus muscle was tougher compared to maiden heifers of the same age. Evidence also presented by Dumont et al. (1987) suggested a genotype influence.

The tenderness of meat from once-calved heifers and maiden heifers of the same age has been found to be similar using both shear test (Petit, 1973; Bond et al., 1986; Waggoner et al., 1988) and taste panel evaluation (Joseph and Crowley, 1971; Bond et al., 1986). Waggoner et al. (1988) however found that meat from two year old once-calved heifers had higher shear values than those from one year old open heifers.

The shear test results obtained in the present study show that time of slaughter after calving significantly influenced meat tenderness. Bond et al. (1986) found that taste panel tenderness scores decreased and shear force values increased for heifers slaughtered between 21 and 42 days post-partum. Results suggest that increased toughness is not due to chronological maturation as suggested by Bond and coworkers (1986), but is related to the time interval between calving and slaughter.

Merkel and Pearson (1975) suggested that even under conventional chilling methods the major differences in tenderness between fat and thin beef are due to fat retarding the rate of heat dissipation during carcass chilling. The significantly higher shear value of the OCH3 heifer group may be due to its lower fat cover over the longissimus muscle. This lack of thermal insulation is reflected by the lower muscle temperature of the OCH3 group measured at six hours post mortem. Although the conventional heifers had less fat cover, their younger age may contribute to their lower shear values. The carcass results would suggest that the no calf heifers should have shear results similar to those of the OCH3 group due to their similar fat levels. This was not the case.

The higher marbling scores obtained for the OCH5 heifer group may be a reflection of the higher carcass fat content. This agrees with Cianzio et al. (1982) that intramuscular fat increases in proportion to total fat. This does not seem to be the case for the OCH3 group which had less total fat but higher marbling scores. The significantly higher shear values and marbling scores of the OCH3 group cannot be clearly explained by differences in pH, temperature, fat levels or age. It is possible that there is a physiological link between early lactation and meat quality. During pregnancy there is a marked increase in prolactin secretion, however its action is inhibited by estrogen and progesterone during pregnancy (Ganong, 1979). After parturition, prolactin secretion continues due to a reflex action on the hypothalamus caused by nipple stimulation. A study by Zinn et al. (1986) showed that heifers exposed to short-day photoperiods had higher intramuscular fat content in the longissimus muscle than heifers exposed to long-day phtoperiod. Since prolactin levels are depressed during short-day photoperiods (Zinn et al., 1986) it is possible that prolactin is responsible for the change in body composition. Prolactin may influence the meat quality of once-calved heifers slaughtered at early stages of lactation. The once-calved system may produce animals with a higher degree of marbling which is favoured in some markets though not in Canada, but the physiological activities which take place during early lactation may also reduce meat quality.

Although the heifers weaned at 7 months of age received the highest proportions of Canada C and D grades, their meat was more tender and more marbled than the meat from conventionally reared heifers. The meat from heifers whose calves were weaned at 3 months, of which only one carcass was assessed with intermediate maturity, had the highest marbling, but also the highest shear values. The once-calved heifer appears to undergo changes in meat quality with delayed slaughter time after calving. These changes do not follow those of conventionally reared heifers and consequently challenge some of the meat quality "rules of thumb" involving marbling and meat tenderness. Results from this study do not explain the reason for these higher values. However they suggest that the endocrinology of the post-calving heifer with its possible relationship with meat quality should be investigated.

E. CONCLUSION

The majority of carcasses from the once-calved system remained in the youthful Canada A and B grades. Once-calved heifers were able to attain A1 fatness levels within 3 months post-calving and all once-calved heifer groups had significantly higher marbling scores than the conventional heifers.

Once-calved heifers produced carcasses of similar composition to conventionally managed heifers. When all carcasses were adjusted to the same level of maturity, once-calved heifers produced similar amounts of lean to conventional heifers. Once-calved heifers also had similar fattening patterns to conventionally reared heifers.

Most once-calved heifers yielded meat of a similar quality to that of conventionally reared heifers. Meat from once-calved heifers had lower moisture losses and was a darker colour than conventional heifers. It did have similar intramuscular fat and similar shear values except for the OCH3 group which was tougher.

Chapter IV

THE EFFECTS OF ELECTRICAL STIMULATION ON THE MEAT QUALITY OF ONCE-CALVED HEIFERS, NON-PREGNANT TWO - YEAR-OLD AND CONVENTIONALLY REARED BEEF HEIFERS

A. INTRODUCTION

Results from the previous experiment (Chapter III) showed that once-calved heifers yield meat of more variable quality (tenderness and colour) than meat obtained from conventionally reared heifers. Those heifers which were slaughtered after nursing their calves for 3 months had meat with higher shear values than meat from conventionally reared heifers. Meat tenderness is the main determinant of consumer eating satisfaction and thereby has the greatest influence on acceptability (Jeremiah, 1981). However, visual characteristics per se are poorly related to meat tenderness. Consumers nevertheless rely on visual cues such as meat colour, fat cover and marbling as selection criteria of beef cuts at retail outlets. Thus the once-calved heifer system must consistently produce meat of similar visual quality and tenderness to conventionally reared heifers or be agressively marketed as special in order to be adopted by the industry. Present research results (Chapter III), however show that meat from once-calved heifers may have greater variation in both tenderness and colour compared to meat from feedlot fed non-pregnant heifers.

Electrical stimulation has been shown to increase the tenderness of young beef as well as to improve a number of other meat quality factors such as colour and, marbling score (Cross et al., 1984). It is a relatively inexpensive method of improving the appearance and palatability of meat.

Experiments using high voltage electrical stimulation have shown improvements in meat quality of grain-fed or range-fed heifers and aged cows (Stiffler et al., 1982). Other trials using low voltage electrical stimulation of young and mature cows showed no differences in the cooking and quality attributes of roasts (Hawrysh and Wolfe, 1985). There has not been any work performed on once-calved heifers. Not only is it important that electrical stimulation tenderize meat produced from the once-calved heifer system, but also that it makes it comparable to meat produced in the conventional system. The purpose of this study was to determine if electrical stimulation could be used to improve the meat quality of once-calved heifers and consequently make them part of a viable meat production system.

B. MATERIALS AND METHODS

The carcasses used were obtained from the efficiency trial described in Chapter II. They represented five groups of heifers (Table III.1). Ninety-six heifers had been fattened while raising a calf and slaughtered at three different times, either at three (OCH3), five (OCH5) or seven (OCH7) months post-calving. A fourth group was a set of heifers which did not raise a calf (no calf). The fifth group was comprised of conventionally managed feedlot heifers. Alternate sides of each carcass were electrically stimulated at 475 volts for one minute (20 pulses.min^{-1}, 60 Hz) at 45 min post-stunning. Carcass evaluation and meat quality determinations were done as previously described (Chapter III).

Differences among heifer groups were analysed using a general linear model which included treatment, replicate, stimulation, the treatment by stimulation interaction and the residual error. Treatment by stimulation interactions were presented when significant. Mean separation of significant main effects was by single degree of freedom linear contrast.

C. RESULTS

The stimulated carcasses had significantly lower pHs than the unstimulated carcasses at all times of measurement (Table IV.1). There was a significant treatment x stimulation interaction for pH readings taken at 45m, 6h and 24 h, but not at 6d post-mortem. Electrically stimulated carcasses had a significantly higher temperature at the 45m reading which was taken immediately after stimulation. Electrical stimulation did not affect the temperatures at 6h and 24h.

Electrically stimulated meat was significantly brighter (higher L*); redder (higher a*) and yellower (higher b*) than unstimulated meat (Table IV.1). These changes were evident at both 24 h and 6 d post-mortem. The only significant treatment x stimulation interactions were present at 24h for the a* and b* values (Table IV.2). All electrically stimulated once-calved heifer groups yielded meat of a redder colour than the unstimulated conventional heifers. The stimulated no calf, OCH3 and OCH5 groups yielded meat with more yellow (higher b*) than the unstimulated conventional group (Table IV.2).

There were no significant differences in drip losses between stimulated and unstimulated sides (Table IV.3). However, electrically stimulated meat did have significantly more expressible juice. The treatment x stimulation effect was not significant.

Electrical stimulation significantly reduced the amount of shear force required to cut a 20 mm cylindrical cooked meat sample core (Table IV.3). There was a significant treatment x stimulation effect indicating

TableIV.1 - pH, temperature and colour at various times post-mortem for unstimulated and electrically stimulated sides.

	unstimulated		stimulated		
	mean	S.E.	mean	S.E.	probability
pH					
45m	6.70	.009	6.33	.006	.0001
6h	6.14	.020	5.68	.020	.0001
24h	5.70	.005	5.63	.005	.0001
6d	5.60	.006	5.58	.006	.0312
Temperature (°C)					
45m	39.39	.033	39.48	.018	.0329
6h~	15.16	.099	15.34	.098	.1638
24h~	3.31	.021	3.30	.021	.5830
Colour					
24h L*	34.7	.11	36.2	.11	.0001
a*	21.4	.11	23.2	.11	.0001
b*	9.5	.09	10.8	.09	.0001
6d L*	35.6	.11	36.7	.11	.0001
a*	21.4	.11	22.5	.11	.0001
b*	9.7	.07	10.5	.07	.0001

~adjusted to common side weight (kg)

Table IV.2 - Interaction effects of treatment by stimulation.~

	pH			colour (24h)			shear values
	45m	6h	24h	L*	a*	b*	kg
	mean ± S.E.	mean ± S.E.	mean ± S.E.	mean ± S.E.	mean ± S.E.	mean ± S.E.	mean ± S.E.
Unstimulated							
conventional	6.55a ± .02	6.25a ± .04	5.67ab ± .01	36.6 ± .23	21.2ab ± .23	9.6ab ± .18	7.78a ± .22
no calf	6.68ab ± .02	6.31a ± .06	5.66a ± .02	34.7 ± .30	20.8ac ± .30	9.4ab ± .24	7.83a ± .29
OCH3	6.80c ± .02	6.32a ± .04	5.71b ± .01	33.8 ± .23	20.3c ± .23	9.0a ± .18	9.38b ± .22
OCH5	6.71b ± .02	5.95b ± .04	5.69ab ± .01	34.8 ± .23	22.8de ± .23	10.4cd ± .19	7.45a ± .21
OCH7	6.75c ± .02	5.99b ± .04	5.80c ± .01	33.7 ± .23	21.7bf ± .23	9.2a ± .19	7.19ac ± .22
Stimulated							
conventional	6.20d ± .01	5.71c ± .04	5.58d ± .01	38.7 ± .23	23.5e ± .23	11.4e ± .18	5.49d ± .22
no calf	6.34ef ± .02	5.72c ± .06	5.59d ± .02	35.8 ± .30	22.2df ± .30	10.3cd ± .25	6.44c ± .29
OCH3	6.36ef ± .01	5.69c ± .04	5.59d ± .01	35.6 ± .23	22.9de ± .23	10.9de ± .18	6.58c ± .22
OCH5	6.32c ± .01	5.53d ± .04	5.65ad ± .01	35.7 ± .23	24.4g ± .23	11.2e ± .19	5.69d ±.21
OCH7	6.40f ± .01	5.78c ± .04	5.75e ± .01	35.3 ± .23	22.9de ± .23	10.0bc ± .19	5.42d ± .22
Probability	.0433	.0001	.001.	.0649	.0077	.0025	.0292

~mean separation performed across all groups

TableIV.3 - Quality analysis of unstimulated and electrically stimulated sides.

	unstimulated		stimulated		
	mean	S.E.	mean	S.E.	probability
steak drip loss ($g.kg^{-1}$)	7.53	.85	8.23	.845	.0556
expressible juice ($g.kg^{-1}$)	232.4	.92	236.4	.91	.0025
shear value, kg	7.9	.10	5.9	.10	.0001
marbling score*	6.5	.03	6.4	.03	.0283
intramuscular fat ($g.kg^{-1}$)	54.2	.47	55.1	.47	.2094

* (1=abundant, 9=traces)

that some treatments responded differently to stimulation than others (Table IV.2). Meat from all heifer groups except for OCH3, had similar shear values prior to stimulation. Stimulation resulted in decreased shear values in all heifer groups, but the no calf and OCH3 groups remained significantly tougher than all other groups. All stimulated heifer groups were more tender than the non-stimulated conventionally reared heifer carcasses.

Electrically stimulated carcasses had significantly lower marbling scores than unstimulated carcasses Table IV.3). The treatment x stimulation interaction was not significant. There were no differences in the amount of intramuscular fat in the longissimus muscle as measured by petroleum ether extraction.

D. DISCUSSION

In this study electrical stimulation caused a rapid reduction in muscle pH while carcass temperatures were still elevated. This agrees with other studies in the literature (Dutson et al., 1980; Hawrysh et al., 1986). The rapid fall in pH as a result of electrical stimulation is caused by an accelerated glycolysis and leads to earlier development of rigor mortis (Asghar and Henrickson, 1982). These changes influence both the appearance and tenderness of electrically stimulated meat.

Since the colour of fresh meat has a major influence on consumer selection it is an important quality factor. Electrical stimulation resulted in brighter and redder (higher L*, a* and b* values) meat for all the heifer groups. Other studies have found that meat from stimulated carcasses evaluated at 18-24 hours post-mortem is generally brighter than that from unstimulated carcasses (Calkins et al., 1980; Hawrysh et al., 1986). The lower pH obtained in the electrically stimulated sides could cause more denaturation of muscle proteins and result in more free water at the surface of the meat. This greater content of free water may have increased the reflectance and would account for the significantly higher L* values of the stimulated meat. It has also been suggested (Asghar and Pearson, 1980) that pH affects the spacial structure of myoglobin, increasing the light scattering properties of the muscles, and influencing its colour. However, researchers have found that meat from electrically stimulated beef carcasses had more oxymyoglobin than meat from unstimulated carcasses (Tang and Henrickson, 1980) which may also explain the higher a* values.

This improvement in meat colour on the day after slaughter is considered to be mainly a transient effect since carcasses judged at 48 hours or longer after slaughter have not shown a similar improvement in muscle colour (Smith et al., 1977; Calkins et al., 1980). The present study showed that these colour differences were still present after 6 days. Other researchers have also reported a permanent colour change in electrically stimulated beef (Eikelenboom et al., 1981). Results from the present study suggest that electrical stimulation could be used to improve the colour of meat from once-calved heifers by making it more similar to that yielded from conventionally reared heifers. This would enhance the attractiveness of retail cuts from once-calved heifers to the consumers.

Results from this study indicate that electrical stimulation of once-calved heifers and conventional heifer sides prior to chilling exerts little influence on drip loss. Such results concur with the reports of other workers (Morgan, 1979; Hall et al., 1980; Jeremiah and Martin, 1982) who found that electrical stimulation did not alter the amount drip in the packages during retail display. Electrical stimulation did, however, significantly increase the amount of expressible juice. This is consistent with the lower pH of stimulated meat since water holding capacity is reduced as the isoelectric point of meat is approached (Swatland, 1984). This suggests that electrical stimulation reduced the ability of meat to bind water, but this was only measurable when an external force (pressure) was applied. The amount of moisture loss is partially responsible for many of the physical properties, such as colour, texture, and firmness of raw meat and the eventual juiciness and tenderness of cooked meat.

The present experiment showed that electrical stimulation could be used to tenderize meat from once-calved heifers by 26% overall and up to 30% for the OCH3 group. Since the stimulated meat of all once-calved heifer groups was significantly more tender than that of the unstimulated conventionally reared heifers, the adoption of electrical stimulation would ensure that the eating satisfaction obtained from eating meat from once-calved heifers would be at worse similar to that obtained from conventionally reared heifers. However, with the exception of OCH3 the once-calved heifer meat was as tender as the conventional without stimulation.

Although the mechanisms involved are still being researched, results of this study agree with many studies that post-mortem stimulation of beef carcasses does produce a tenderizing effect on the meat (George et al., 1980; Bouton et al., 1980; Medeiros et al., 1989). This situation results in favourable conditions for the naturally occurring lysosomal enzymes to degrade muscle proteins and cause rapid tenderization (Asghar and Henrickson, 1982). Dutson and coworkers (1980) have shown that the lysosomal enzymes in electrically stimulated carcasses are released sooner as a result of the lysosomal membrane rupturing and work at a faster rate than lysosomal enzymes in unstimulated carcasses. It is suggested that collagen thermal stability in electrical stimulated muscles is lessened perhaps by the disruption of heat-stable intermolecular crosslinks (Judge et al., 1981). The thermal stability of the intermolecular cross-links in collagen play an important part in determining the toughness of meat (Bailey and Sims, 1977). Structural damage to the actual myofibrils has also been detected in electrically stimulated meat (Savell, 1979). The dissarray of protein filaments observed in the contracture bands of electrically stimulated muscle fibers suggests that structural damage may result in tenderization (Savell, 1979) particularly with high voltage stimulation. A very rapid fall in pH should be avoided however, since this could result in heat shortening and consequent meat toughening (Marsh et al., 1987).

At the present time marbling is not a grading criterion in Canada, but in the United States and Japan, the degree of marbling is used to grade carcasses in each maturity group and consequently has economic significance. Although grading is normally done following a 24 hour chill period, longer periods of chill increase marbling scores (Calkins et al., 1980). This same degree of marbling score enhancement can be achieved within a few hours by electrical stimulation. In the present study electrical stimulation significantly increased the marbling score of the heifer meat. The increase in marbling score was however quite small and probably without commercial consequence.

It is not known if the human eye can perceive ranges in degrees of marbling which are linearly related to the relative area of marbling fat (Swatland, 1984). Fat content estimated using chemical determinations is related to marbling scores (Cooper et al., 1968) and is often used as an objective measurement of intramuscular adipose tissue, although it also includes structural lipids. Results from the present study show that intramuscular fat as measured by petroleum ether extraction was not influenced by electrical stimulation. Thus the increases in marbling scores due to electrical stimulation probably resulted from acceleration of the postmortem processes and are a reflection of the more advanced state of carcass conditioning.

E. CONCLUSION

The use of electrical stimulation on meat from once-calved heifers resulted in:

(1) A rapid pH drop while carcass temperatures remained elevated.

(2) A significant improvement in meat tenderness, colour and marbling.

(3) An increased amount of expressible juice but not retail drip loss after 6 days.

It can therefore be concluded that electrical stimulation improved the quality characteristics of meat produced from once-calved heifers to make it not significantly different to that yielded from unstimulated conventionally reared heifers.

Chapter V

THE ONCE-CALVED HEIFER SYSTEM: CONCLUSIONS

From the results of the present study, it can be concluded that the once-calved system may have a role in today's cattle industry. The system could be used to produce meat of similar quality as from a conventional system and yet be predominately based on a roughage diet. As a result of breeding, calving and maintaining heifers for an extra year, the once-calved heifer system yielded an extra 60 kg of carcass weight and also a live calf. In the present study, all once-calved heifer groups were able to attain the minimum four mm fat depth required to grade A1. However, as the animals got older than 25 months, an increasing proportion were classified as Canada C or D. Although the carcasses were heavier than those produced from the conventional system, they were of similar composition. The use of electrical stimulation ensured that the meat was of comparable quality to that produced from the conventional system.

In the present study it was shown that on a biological basis the once-calved heifer system required about 10% more digestible energy to yield the same unit of carcass weight as the conventional system. Various explanations presented in Chapter II suggest that biological efficiency calculations may underestimate the true value of the system. The high roughage utilization of the once-calved heifer system might make it an advantageous system to use in conjunction with forage production on marginal quality land. It would make use of different feed inputs to yield meat comparable to that from conventionally reared heifers. Its adoption by the industry depends on whether the added value of the heavier carcass weight and calf warrant the extra labour and expenses incurred by managing a once-calved heifer system. The financial viability of the once-calved system can only be determined from a thorough economic analysis.

The once-calved heifer system may have advantages over the conventional cow-calf system in its responsiveness to market demands. The cow-calf system requires a considerable lag time to adjust to changes in the demands of the supply of beef. Large shifts in the cow inventory would have to occur to accomodate fluctuations in demands. Consequently, beef production levels tend to be of a longer term, cyclical nature with little sensitivity to immediate industry demand. The heavier carcasses from the once-calved system show this system could produce an increase in meat production with little effect on population dynamics. The once-calved heifer system would allow the industry to respond quicker to shifts in beef demands. There would be a decreased dependence of the beef supply on the cattle cycle resulting in an increased efficiency at the industry level.

This leads us to two research areas deserving further attention. Firstly, feeding regimes to minimize maintenance costs should be developed. Heifers in the once-calved system should be fed to meet the optimal weight and body condition levels required for breeding, calving and slaughter. A refinement of the feeding regime utilized in the present study could improve the efficiency of the system. Secondly, economic modelling should be performed at both the farm and industry levels. The economic consequences resulting from the adoption of the once-calved system could be simulated using data collected from this experiment. The implications to both the producer and the cattle industry as a whole could therefore be predicted and addressed.

The full merit of the once-calved heifer system will only be realized if it replaces the cow herd and becomes responsible for both meat production and herd perpetuation. The present study evaluated the biological efficiency of one complete cycle of the once-calved system. To accurately compare this system with the cow-calf system, efficiency data from both systems must be compared. A working model should be developed to compare both systems under varying economic scenarios. Data from the present trial could be used to test the model and simulate other situations. Modelling would also allow the industry to anticipate changes resulting from the new developments such as twinning and sexed embryos. These developments are essential for the realization of a self-sustained once-calved system.

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Appendix Ia- Internal body component weights using empty body weight as covariate. (Warm carcass and gastro-intestinal tissues)

body component	Treatment						
	conventional	no calf	OCH3	OCH5	OCH7	SEM	Probability
1 - warm carcass	282.30^{a}	290.04^{b}	281.31^{a}	281.93^{a}	281.56^{a}	1.216	0.0001
2 - GIT tissues							
rumen and reticulum	8.33^{a}	9.31^{b}	9.80^{c}	9.30^{b}	9.08^{b}	0.159	0.0001
omasum	2.73^{a}	3.65^{b}	4.08^{c}	3.55^{b}	3.70^{b}	0.111	0.0001
abomasum	1.61^{a}	1.88^{b}	2.29^{c}	1.71^{ab}	1.77^{ab}	0.073	0.0001
intestine	11.98^{a}	10.66^{b}	11.24^{b}	12.37^{a}	11.92^{a}	0.207	0.0001
GIT fat	21.97^{a}	16.34^{b}	18.38^{bc}	19.53^{c}	19.15^{c}	0.705	0.0001

^{abc} Adjusted means in a row bearing different superscripts differ significantly at $P<0.05$.

Appendix.Ib- Internal body component weights using empty body weight as covariate.
(Non digestive and non-carcass parts)

body component	Treatment						
	conventional	no calf	OCH3	OCH5	OCH7	SEM	Probability
3 - remaining offals							
kidney fat	12.56^{a}	8.70^{b}	8.56^{b}	9.10^{b}	9.66^{b}	0.471	0.0001
adrenals	0.02^{a}	0.02^{a}	0.02^{a}	0.02^{ab}	0.01^{c}	0.07	0.0001
heart	1.61^{a}	2.04^{b}	1.89^{b}	1.87^{b}	1.96^{b}	0.049	0.0001
spleen	0.66^{a}	0.73^{b}	0.67^{a}	0.67^{a}	0.64^{a}	0.019	0.0379
lungs and trachea	6.45^{ab}	6.56^{ab}	6.70^{b}	6.55^{b}	6.14^{a}	0.153	0.0879
blood	18.02	14.83	17.73	18.24	17.44	0.960	0.0961
bladder	0.14^{a}	0.21^{c}	0.18^{b}	0.16^{ab}	0.17^{b}	0.010	0.0007
pancreas	0.42^{ab}	0.49^{c}	0.49^{c}	0.46^{ac}	0.40b	0.018	0.0008
reproductive tract	0.51^{a}	1.20^{b}	0.98^{c}	0.79^{ac}	0.84^{c}	0.098	0.0010
diaphragm	1.01^{a}	1.00^{a}	1.14^{b}	1.12^{b}	1.13^{b}	0.034	0.0097
kidney	0.81^{ab}	0.89^{cd}	0.91^{c}	0.84^{abd}	0.79^{a}	0.020	0.0001
liver	5.96^{a}	6.24^{a}	7.19^{b}	6.73^{c}	6.11^{a}	.117	0.0001

^{abc} Adjusted means in a row bearing different superscripts differ significantly at $P<0.05$.

Appendix II- External body component weights using empty body weight as covariate.

body component	Treatment						
	conventional	no calf	OCH3	OCH5	OCH7	SEM	Prob.
head and tongue	13.60^{ab}	14.12^{bc}	13.56^{a}	13.82^{a}	14.39^{c}	0.171	0.0037
hide and tail	32.78^{ab}	34.02^{a}	30.36^{cd}	28.98^{c}	31.48^{bc}	0.622	0.0001
feet	7.19^{a}	8.06^{b}	7.70^{bc}	7.43^{ac}	7.51^{ac}	0.125	0.0007
udder	5.04^{a}	4.87^{a}	10.20^{b}	10.60^{b}	10.16^{b}	0.341	0.0001

abc Adjusted means in a row bearing different superscripts differ significantly at $P<0.05$.