Development of a Carcass Merit Prediction Equation For Beef Cattle Breeding Stock

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DEVELOPMENT OF A CARCASS MERIT PREDICTION EQUATION FOR BEEF CATTLE BREEDING STOCK

BY

ELIZABETH SALLY

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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ABSTRACT

Analyses were conducted using regression procedures to develop a set of equations predicting carcass values on a total and per kilogram of carcass weight basis using measurements that could be taken from the live animal using ultrasound technology. These measurements consisted of average backfat thickness, longissimus dorsi muscle area, marbling score and live weight. Also heritabilities and phenotypic and genetic correlations were estimated for the carcass values, live animal measurements and individual wholesale cuts. The data-set consisted of records from a carcass cut-out study conducted by Agriculture and Agri-food Canada, representing 2008 steer and heifer carcasses combined with Montreal wholesale cut prices reported by Agriculture and Agri-food Canada. The prediction equations were tested to see whether high or low price ranges would affect the equation and the significance of variables used to predict carcass value. Similarly, the equations were tested for breed of dam effects. It was found that neither price differences nor breed of dam had a significant effect on the prediction equations. No difference was found between high and low valued carcasses with respect to proportions of wholesale cuts as a percentage of total carcass weight. The heritabilities calculated for carcass value, live-animal measurement traits and wholesale cut traits were consistently lower than similar estimates found within the literature. In addition, comparisons of the phenotypic and genetic correlations between live-animal measurements in the present study and those found in the literature were questionable. As a result, the correlations between the

individual wholesale cuts are under some suspicion. The unpredictability of the estimated genetic parameters is believed to be a result of small sample size.

DEDICATION

I would like to dedicate this thesis to my Grandfather, Carvel Reyno.

"Although, my eyes see waves of tall grain on a prairie ocean, my heart remembers the salty, wet spray of the sea."

E.F.S., 1995.

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TABLE OF CONTENTS

Page

ABSTRACT i
DEDICATION iii
ACKNOWLEDGEMENT iv
LIST OF TABLES vii
LIST OF APPENDIX TABLES viii
LIST OF FIGURES ix
LIST OF ABBREVIATIONS x
INTRODUCTION 1
LITERATURE REVIEW 4
1. Predicting Carcass Yield 4
2. Breed Effects on Carcass Traits 8
3. Genetic Parameters for Carcass Traits 12
4. Derivation of Carcass Value 16
MATERIALS AND METHODS 19
1. Carcass Data 19
2. Price Data 22
3. Determination of Carcass Value 25
4. Statistical Analysis 26
RESULTS AND DISCUSSION 33
1. Characterization of Data 33
1.1 Correlations 37
1.1a Correlations Between the Carcass Values 39
1.1b Correlations Between Carcass Values and "Live Animal" Measurements 39
1.1c Correlations Between Carcass Values and Wholesale Cuts 43
1.1d Correlations Between "Live Animal" Measurements 47
1.1e Correlations between "Live Animal" Measurements and Wholesale Cuts 49
1.1f Correlations Between the Wholesale Cuts 52
2. Prediction Equation 52
3. Breed of Dam Effects 59
4. Price Sensitivity 64
5. Carcass Cut Characteristics 70
6. Genetic Parameters 73
CONCLUSIONS 80
LIST OF REFERENCES 83
APPENDIX 88

LIST OF TABLES

Table — Page

1. Weighted mean heritability for carcass traits 14
2. Weighted mean genetic (above diagonal) and phenotypic (below diagonal) correlations of carcass traits 15
3. Dam groups by breed composition 20
4. List of factors in the model 28
5. Means of variables used across breeds 34
6. Analysis of variance for carcass values 35
7. Analysis of variance for carcass measurements that could be taken on the live animal 36
8. Analysis of variance for individual cuts taken from the carcass (half-carcass weights) 38
9. Correlations of calculated carcass value residuals 40
10. Correlations of calculated carcass value residuals and residuals of "live animal" measurements 42
11. Correlations of calculated carcass value residuals and wholesale cut residuals 44
12. Correlations of "live animal" measurement residuals 48
13. Correlations of "live animal" measurement residuals and wholesale cut residuals 50
14. Correlations of wholesale cut residuals 53
15. Regression coefficients for carcass value 1 and carcass value 1 per kilogram of carcass weight 55
16. Regression coefficients for each breed of dam group with carcass value 1 being the dependent variable 61
17. Regression coefficents for each breed of dam group with carcass value 1 per kilogram of carcass weight being the independent variable 65
18. Regression coefficients for carcass values derived using different price sets 68
19. Regression coefficients for carcass values per kilogram of carcass weight derived using different price sets 69
20. Proportion of individual cuts as a percentage of cold carcass weight 72
21. Heritabilities of calculated carcass values, "live animal" measurements and wholesale cuts 74
22. Genetic and phenotypic correlations between variables 76
23. Comparison of phenotypic correlations 77
24. Comparisons of genetic correlations 78

LIST OF APPENDIX TABLES

Table Page
1. Breed of dam effects for 010202 88
2. Breed of dam effects for 010501 89
3. Breed of dam effects for 010601 90
4. Breed of dam effects for 020502 91
5. Breed of dam effects for 020602 92
6. Breed of dam effects for 030503 93
7. Breed of dam effects for 030603 94
8. Breed of dam effects for 050303 95
9. Breed of dam effects for 050501 96
10. Breed of dam effects for 050502 97
11. Breed of dam effects for 050503 98
12. Breed of dam effects for 060303 99
13. Breed of dam effects for 060601 100
14. Breed of dam effects for 060602 101
15. Breed of dam effects for 060603 102
16. Limousin sires used in this study and number of offspring of each sire 103
17. Montreal wholesale primal and sub-primal beef prices 104
18. Correlations of calculated carcass value residuals and residuals of "live animal" measurements 105
19. Correlations of "live animal" measurement residuals 106
20. Correlations of calculated carcass value residuals and wholesale cut residuals 107
21. Correlations of "live animal" measurement residuals and wholesale cut residuals 108
22. Correlations of wholesale cut residual 109
23. Correlations of calculated carcass value residuals 110

LIST OF FIGURES

Figure Page

1. Wholesale cuts of the beef carcass 23
2. Montreal wholesale cuts monthly averages for 1994 24
3. Variation among breed of dam groups for the regression coefficients for four variables used to predict carcass value 1 63
4. Variation among breed of dam groups for the regression coefficients for four variables used to predict carcass value 1 per kilogram of carcass weight 66

LIST OF ABBREVIATIONS

Terms used and definitions for variables used in the analysis.

Variable	Description	Units	Residual
avgbf	Average backfat thickness	mm	avgbfr
lma	Longissimus dorsi muscle area	cm^2	lmar
lwt	Live weight (unshrunk)	kg	lwtr
marb	Marbling Score	Index (1-10)	marbr
shloin	Shortloin (commercial trim)	kg	shloinr
rib	Rib (commercial trim)	kg	flankr
sbutt	Sirloin Butt (commercial trim)	kg	ribr
round	Round (commercial trim)	kg	shankr
chuck	Chuck (rough trim)	kg	chuckr
brisk	Brisket (rough trim)	kg	roundr
shank	Shank (rough trim)	kg	briskr
flank	Flank (rough trim)	kg	sbuttr
Cvalue1	Carcass value 1	$	cv1r
Cvalue2	Carcass value 2	$	cv2r
Cvalue3	Carcass value 3	$	cv3r
Cvalue4	Carcass value 4	$	cv4r
Cvalue5	Carcass value 5	$	cv5r
Cvalue6	Carcass value 6	$	cv6r
cvpkcw	carcass value per kilogram carcass weight	$ per kg	cvpkcwr

INTRODUCTION

The beef cattle industry is on the verge of major change. The emphasis for change focuses on two rather broad issues. First, is the preference of end product users. Consumers today want lean, high quality beef on a consistent basis. National consumer surveys from both Canada and the United States have identified that beef has a problem with consistent eating quality and excess fat. Total beef consumption has declined over the past number of years as a result of consumer concerns and competition from other meats such as poultry and pork. To prevent further decline in beef consumption and to regain some of its original market share, the producers of beef must address and react to the preferences of their customers. The second issue which faces the beef industry and is expected to create much change is the incorporation of previously unused technologies into the grading and evaluation systems. For example, video image analysis systems are being tested and promoted to increase the efficiency and accuracy of evaluating individual carcasses on the basis of yield and quality , ultrasound technology has been fine-tuned enough to make accurate predictions about carcass characteristics of the live animal and identification systems are being developed that can be used to follow the live animal from its herd of origin, complete with pedigree information, all the way to the packer where carcass information may be recorded.

In an effort to improve the consistency of production of high quality beef selection of cattle which perform well and have suitable breeding values for carcass

traits is needed. The development and implementation of estimated progeny differences (EPD's) for carcass traits will be an important tool for producers in making selection decisions regarding breeding stock to improve their herds. The concept of carcass merit should be utilized and understood at this stage. The definition of "ideal" carcass merit was stated by Rex Butterfield as "one which yields a maximum percentage of muscle, a minimum percentage of bone and enough fat to meet the minimum quality requirements of the market place. It must be produced economically within the limits of functionally efficient cattle." (Green et al., 1994). It has been shown in research results that genetic variation exists between and within cattle breeds for traits relating to carcass merit. The levels of heritability for many carcass traits are sufficiently high that genetic improvement is possible for these traits if pursued in selection programs.

The move towards a "value-based" marketing system would definitely encourage producers to become more aware of the carcass performance of the cattle they raise but also would serve as an economic incentive to select for cattle with superior breeding values for carcass traits. Technological advances, especially with unique identification of animals, make the move towards this type of marketing system foreseeable in the near future. In light of the direction the beef industry is taking this project was undertaken to address a number of objectives. The first objective was to use carcass cut-out data and current whole-sale beef prices, to determine an individual carcass value for each carcass in the data set. Secondly, a prediction equation will be developed to predict carcass values using measurements that could be easily attained from the live animal using ultrasound technology. Thirdly, price sensitivity of the

prediction equation would be tested to see whether the prediction equation would be affected according to higher or lower prices. Fourthly, the prediction equation would be tested to see if breed of dam had any effect on its value. Fifthly, examination of higher-valued carcasses compared to lower-valued carcasses with respect to differences in proportion of individual cuts relative to the total carcass. The sixth and last objective was to estimate the genetic parameters for the variables used in this project, including carcass values, individual wholesale cuts and those measurements taken on the live animal using ultrasound technology pertaining to carcass characteristics. The parameters to be estimated are heritabilities and phenotypic and genetic correlations.

LITERATURE REVIEW

1. Predicting Carcass Yield

The basis for the yield grade in the Canadian beef grading system is an estimate of lean meat yield based on measurements taken on the carcass at the 12-13th rib site for backfat thickness and longissimus dorsi muscle area. Measurements are taken from the left side of the chilled carcass using a grade ruler. The actual fat thickness measurement is used to assign the carcass to a particular fat class. Length and width of the loin eye area are then measured and these are used to determine a muscling score. Together fat class and muscling score are combined on a yield grid to estimate the lean meat yield.

The use of these predictors has a sound basis in the scientific literature. There is a strong negative relationship between fat thickness and lean meat yield. May et al. (1992) found correlations between back fat thickness and boneless subprimal yield and percentage of trimmable fat to be -0.69 and 0.84 respectively. A positive relationship exists between longissimus dorsi muscle area and lean meat yield. Reiling et al. (1992) concluded that longissimus dorsi muscle area was an important variable in predicting the percentage of retail product.

It is important to be able to estimate the components of the carcass. Whether it is lean meat yield, retail product or some other measurement describing the valuable components of the carcass, the two most important predictors are measurements taken

for backfat thickness and longissimus dorsi muscle area. It would be extremely useful to the industry to be able to predict carcass composition using similar measurements taken from the live animal. This would aid in grouping together physiologically similar animals at the beginning of the finishing period prior to slaughtering in order to market a uniform group of animals. Also, there would be opportunity to evaluate live animals on the basis of predicted carcass composition to aid in selection decisions of potential breeding stock. Fortunately the technology to take carcass measurements from the live animal is available with the use of real-time ultrasound.

Ultrasound is perhaps the most useful tool available to measure and subsequently estimate carcass attributes on the live animal. There are several benefits to using ultrasound as a means to evaluate potential breeding stock. First, the animal need not to be slaughtered to attain carcass measurements. Second, the time and expense from a traditional progeny test can be avoided since records from the individual being evaluated are available. Ultrasound measurements can be taken easily with a minimum of stress on the animal. The measurement is taken on the exterior of the animal, is quick, painless and causes no after effects. The ultrasound machines available now are made to be easily transported thereby allowing on farm scanning to be performed. The accuracy and repeatability of ultrasound measurements to actual carcass measurements are high.

Backfat thickness, longissimus dorsi muscle area and an estimation of intramuscular fat (marbling) at the 12-13th rib site are predominantly the measurements taken since they are the most important traits to predict yield grade and quality grade.

The relationship between ultrasound carcass measurements and actual carcass measurements is strong. Evidence from several studies have indicated that measurements from either ultrasound or the carcass are strongly correlated. In two experiments conducted by Smith et al. (1992), assessment of the relationships between ultrasound measurements of fat thickness and longissimus dorsi muscle area to the corresponding carcass measurements from yearling steers was conducted. Correlations of 0.81 and 0.43 were found for fat thickness and longissimus dorsi muscle area, respectively, in the first experiment. A similar correlation was found for fat thickness in the second experiment while that for Longissimus muscle area was 0.63. Faulkner et al. (1990) also concluded that ultrasound measurements of 12-13 rib fat accurately predicted actual 12-13 rib fat measurements in mature cows. Similar findings were recorded by Robinson et al. (1993), Perkins et al. (1992), Smith et al. (1992) and Turner et al. (1990).

It was found throughout most studies, there is a general tendency to underestimate fat thickness in fatter cattle. Longissimus dorsi muscle area was overestimated for lighter muscled cattle and underestimated for heavier muscled cattle (Waldner et al. 1992; Smith et al. 1992 and Herring et al. 1994).

It follows that since ultrasound measurements are good predictors of actual carcass measurements that they would be useful in predicting carcass composition and subsequently lean meat yields and retail product. Herring (1994) concluded that measurements taken using ultrasound is a valid means for predicting carcass composition. Robinson et al. (1993) showed that carcass traits measured using

ultrasound and predicted meat yields are moderately heritable and exhibit genetic variation.

Evaluation of young breeding stock for carcass merit in their progeny requires consideration of these two issues. Young animals evaluated as breeding stock, typically yearling bulls, are physiologically not the same animals produced for slaughter. For example, there is a sex difference between bulls and slaughter steers or heifers. Bulls have a different growth pattern with respect to growth rate and fat deposition than do steers or heifers. Studies where yearling bulls have been measured indicate that the levels of backfat thickness are very small and have little variation, therefore making any type of significant difference between animals difficult to detect (Arnold et al. 1991). This is not because differences do not exist, simply that at this particular stage in growth most bulls tend to be physiologically similar. Young bulls are also typically leaner than a finished steer due possibly in part to an age effect since bulls are measured as yearlings and steers typically are measured as finished animals at 15 to 17 months of age. Similarly, when considering levels of marbling in young bulls, they tend to exhibit low levels within a small range (Wilson et al., 1994). If ultrasound measurements taken on young stock are used as a selection tool, it is recommended that for longissimus dorsi muscle area adjustment for age, weight and backfat thickness should occur (Turner et al. 1990).

2. Breed Effects On Carcass Traits

A review of papers focussing on carcass characteristics indicates that there are significant differences between breeds with respect to carcass traits. Individual studies differed in the number and varieties of breeds used with the evaluation of cross-bred cattle being dominant. In general, comparisons were made between breed types; British (the more traditional breeds such as Hereford, Angus and Shorthorn), Continental (the dual-purpose breeds from Europe such as Charolais, Simmental and Limousin), Dairy (breeds specialized in milk production such as Holstein, Friesian and Brown Swiss) and Bos indicus (the "humped" cattle such as Brahman, Santa Gertrudis and Zebu). These four types of cattle are used in beef production systems across the world and are often used in crossbreeding programs to combine favorable traits (whether growth, carcass composition, hardiness, etc.) in diverse environments. This thesis focuses on the carcass traits exhibited by three of these types of cattle (Bos indicus types are not included).

The British breeds are characterized as being small to medium in size on a live and carcass basis. Angus cattle had lower carcass weight than Brown Swiss, a dairy type in a study by Marshall et al. (1987). In a similar study comparing Angus cattle to Simmental, the Simmental-sired progeny were significantly ($P < .05$) heavier at slaughter than Angus-sired progeny (Urick et al., 1991). British types had higher marbling scores and more fat with less lean in the carcass compared to the Continental types. Urick et al. (1991) reported that Angus-cross progeny had higher marbling

scores than Continental breeds (Simmental, Tarentaise and Pinzgauer). Similarly, Comerford et al. (1988) reported Polled Hereford progeny had higher marbling scores and more carcass fat than progeny from Limousin-, Brahman- and Simmental-crossed dams and Paschal et al. (1995) found Angus-cross progeny more desirable ($P < .05$) in marbling score and quality grade compared to Bos indicus crosses. In another project using progeny from Polled Hereford dams it was found they had greater hind-quarter fat weight and more fat as a proportion of carcass weight than progeny from Limousin dams and Brahman dams, (Arnold et al. 1990). A similar result was found by Jenkins et al. (1981) comparing British types to dairy and Brahman types. Another study by Urick et al. (1989) found Angus-sired progeny had higher marbling scores than progeny from Charolais sires. DeRouen et al. (1992) reported Angus and Hereford breeds had increased fat thickness, marbling score and meat tenderness. Another study looking at the effects of using British breeds of cattle, in particular Angus, in a cross-breeding program with Brown Swiss, a dairy type, found the Angus would increase carcass quality grade and tenderness because of higher marbling score but would decrease the carcass weight, rib eye area and cutability of the carcass (Marshall et al. 1987). The British breed types are classified as early maturing cattle. Berg and Butterfield (1976), stated that, "generally early maturing cattle have a lower mature size and they enter the fattening phase at lighter weights".

The Continental type of cattle are made up of breeds which originate in Europe and were selected and used for draft work. Some of these breeds were further selected to be dual-purpose animals, fit for draft work and milk production. These breeds are

typically larger-framed and heavier-muscled than the other types of cattle. The Continental breeds are also classified as late-maturing in contrast to the British breeds. They have larger mature sizes (which vary according to individual breed) and tend to enter the fattening phase at higher live weights and older ages than the other three types of cattle. They tend to produce large, lean, heavily muscled carcasses, with little fat.

Marbling scores tended to be lower for Continental breeds compared to British and dairy breeds in a number of studies: Urick et al. (1989); Urick et al. (1991); Comerford et al. (1988); El-Hakim et al. (1986) and DeRouen et al. (1992). Wheeler et al. (1989) indicated that lean beef with desirable palatability could be produced by Continental breeds (late-maturing). Throughout the literature it has been reported that the Continental breeds produce leaner and heavier carcasses. Several studies have reported that Continental-cross progeny had higher proportions of their muscle in the hind quarter than other cattle types. Keane and More O'Ferrall, (1992) reported Simmental-Friesian crosses had a higher proportion of their muscle in the higher-valued joints of the hind quarter, while having a lower proportion of their muscle in the forequarter when compared to straight bred Friesian and Hereford-Friesian crosses. Similar results on the Continental breeds having higher proportions of meat and total carcass weight in the hindquarter have been reported by El-Hakim et al. (1986) and Arnold et al. (1990). There is evidence that the Continental breeds exceed the other types of cattle for weight of specific muscles found in the hindquarter. Urick et al. (1991) reported Simmental and Pinzgauer steers had larger longissimus dorsi muscle area and cutability ($P < .05$) than Angus or Red Poll. Comerford et al. (1988) and

Marshall et al. (1985) found a similar result with Limousin and Simmental crosses having larger rib-eye area ($P < .05$) compared with calves from British, Brahman and dairy breeding respectively. Using progeny from Limousin and Brahman dams, Arnold et al. (1990), found calves from the Limousin dams had greater round weight and loin weight than the Brahman calves. Since the Continental breeds generally have heavier carcasses with more lean and less fat than the other types of cattle they tend to exhibit greater cutability. Studies by Urick et al. (1989), Urick et al. (1991), Comerford et al. (1988) and DeRouen et al. (1992) support this finding.

Male offspring from dairy herds are often raised for the production of beef. Typically, the dairy breeds are large-framed animals but do not exhibit a tremendous amount of muscle. Studies comparing dairy cattle to Continental and British types found significant differences between the types with respect to carcass composition. El-Hakim et al. (1986) found dairy animals deposited more fat and bone in the carcass than the Continental breeds. As well, they tended to have more meat in the brisket, shank and flank when compared to the Continentals. Using Brown Swiss in a cross-breeding system with Angus increased carcass weight, rib eye area and cutability in a study by Marshall et al. (1987). In another study comparing muscle proportions between dairy and British-dairy crosses it was found there were similar proportions of total muscle in the hind quarter, Keane and More O'Farrell (1992).

The Bos indicus cattle in tropic and subtropic climates have adapted well to extreme heat and are used extensively in cross-breeding systems in the these types of climates. Bos indicus cattle are typically smaller than the other three types of cattle.

Comerford et al. (1988) reported progeny from Limousin dams had significantly ($P < .05$) heavier carcasses and higher dressing percentages than progeny from Brahman dams. Similarly Arnold et al. (1990) found calves from Limousin dams had greater hind quarter weight than those from Brahman dams, due mostly to differences in round and loin weight. Brahman crossed cattle ranked lowest behind Limousin, Simmental and Hereford cattle with respect to loin eye area, Comerford et al. (1988).

Throughout the literature there has been substantial evidence that there are differences found between the four types of cattle used for beef production. These differences are expressed in a number of different traits which pertain to growth, reproduction and carcass characteristics. For this study, the differences of carcass traits between the four types of cattle was important to show that significant variation does exist within the entire cattle population.

3. Genetic Parameters For Carcass Traits

Throughout the literature there have been numerous reports of genetic parameters for carcass traits in beef cattle. In particular heritabilities and correlations (genetic and phenotypic) have been estimated for different cattle populations. Heritability is an important parameter since it describes the relationship between an animals phenotype and its breeding value. It is defined in the narrow sense, as the ratio of the additive genetic variance to the phenotypic variance of a particular trait being considered (Van Vleck 1987). In simpler terms, heritability can be described as

the proportion of the total variance that is due to differences among the breeding values of individuals in the population. An estimate of heritability is specific for the particular trait under consideration and the population being evaluated. Heritability is important and useful when estimating breeding values and predicting a response from selection programs. Generally speaking, heritability estimates for carcass traits tend to be moderate to high. Koots et al. (1994b), undertook an extensive review of the literature, from 1940 to 1990, of genetic parameters for growth, reproductive and carcass traits in beef cattle. They compiled and pooled results from the literature and published weighted estimates for heritabilities for a variety of carcass traits as shown in Table 1. Estimates of heritability for carcass traits from studies published since 1990 by Johnston et al. (1992);Veseth et al. (1993); Woodward et al. (1992) and Wilson et al. (1993) are consistent with those reported by Koots et al. (1994b).

Correlations, both genetic and phenotypic have also been estimated for carcass traits. The genetic correlation describes the relationship between two traits which is the result of additive genetic effects by common genes. This relationship can be either positive, non-existent or negative. If there is a positive correlation between two traits, selection on one trait will have a similar effect on the other trait. If the correlation is negative, selection on one trait will have an opposite effect on the other trait. Correlations are useful when predicting the effects of selection on traits that are not actively being selected for. Again, Koots et al. (1994a), in their review paper, published weighted correlation estimates, both genetic and phenotypic. These results are shown in Table 2.

Table 1. Weighted mean heritability for carcass traits.[1]

	Heritability (h^2)	Standard Error[2]
Backfat thickness	0.44	0.019
Cutability	0.47	0.024
Carcass weight	0.23	0.011
Dressing percentage	0.39	0.021
Lean/Bone ratio	0.63	0.041
Lean percentage	0.55	0.028
Marbling	0.38	0.034
Market weight	0.41	0.011
Rib eye area	0.42	0.023
Tenderness	0.29	0.038

[1] Constant age.
[2] Standard error of the estimate of the pooled mean.
Koots et al. (1994).

Table 2. Weighted mean genetic (above diagonal) and phenotypic (below diagonal) correlations of carcass traits.

	1	2	3	4	5	6	7	8
1. Backfat thickness		-0.56	0.29	0.30	0.35	0.00	0.01	
2. Cutability	-0.51		0.00		-0.25	-0.19	0.45	
3.Carcass weight	0.37	-0.17		0.04	0.25	0.96	0.48	
4. Dressing percent	0.16		0.43		0.23	-0.23	0.36	0.14
5. Marbling	0.24	-0.25	0.15	0.05		0.34	-0.21	
6. Market weight	0.19	-0.22	0.94	0.06	0.15		0.43	
7. Rib eye area	-0.11	0.33	0.45	0.08	0.06	0.33		
8. Lean percent				0.21				

Koots et al. (1994)

There is some question whether heritability and correlation estimates from different sample populations can be compared since these parameters are unique in describing the populations from which they were derived. In much of the literature, estimated genetic parameters came from herds that had been subject to some form of artificial selection. It is believed that populations under selection for a specific trait will exhibit a lower additive genetic variation for that trait than a population that has not undergone selection (Falconer 1989). A study by Veseth et al. (1993), compared estimates of genetic parameters from an unselected herd with those from populations that had been subjected to selection pressure. The results indicated that heritabilities and correlations from the herd undergoing no selection were in good agreement with results published from herds that had undergone selection. Koots et al. (1994b) reported similar results that heritabilities estimated from field data and experimental data did not differ for growth traits. Therefore it seems that the genetic parameters presented in Tables 1 and 2 are good estimators for carcass traits in the current cattle population.

4. Derivation Of Carcass Value

The value of a beef carcass is based upon the components that make up the carcass, the quality of the carcass and the current market prices of the components which can be sold. The components making up the carcass include muscle, bone and

fat. The yield of muscle in relation to fat and bone is a primary factor in the value of the carcass. At similar weights, carcasses which tend to have more saleable lean meat and less fat have higher values than those with less saleable lean and more trimmable fat. Fat that is sold along with an individual cut, is valued the same as the lean meat comprising that cut. Therefore that fat adds value to the carcass. Excess fat which is trimmed from the carcass adds no value to the carcass. Carcasses which exhibit high lean meat yield produce more saleable lean meat with less fat trim when compared to carcasses of similar weight but less lean meat yield. These higher yielding carcasses again have a higher value because they produce more saleable product, at the same cost of processing as the lower yielding carcasses. The size of the carcass also reflects the value of that carcass. Carcasses which may have the same yield percentage will differ in value on the basis of size. Larger carcasses will produce more meat than a smaller carcass, resulting in more product which can be marketed which in turn increases the value of carcass. This relationship holds true up to a particular weight and size. Carcasses can become too large, which makes processing more difficult and these over-weight carcasses are penalized with substantial price discounts.

The quality of the carcass also influences the value of the carcass. High quality carcasses which are youthful, exhibit some degree of marbling, have minimum fat cover and desirable muscle texture and fat colour receive a premium price whereas carcasses of lesser quality are heavily discounted in price.

The relationship between live cattle prices and carcass values is not as close as would be expected when analyzed on an individual basis (de Matos et al. 1994).

Commercial cattle are generally sold live in groups which are similar in weight, size, conformation and age. The price for a group is determined based on the expected average value of the carcasses that the group will produce after being processed. The animals making up the group will vary according to carcass performance, so in effect, since the entire group is valued by an average price, the buyer will pay too much for some cattle and too little for others. De Matos et al. (1994) reported the live purchase price of some cattle compared to the value of their carcasses were in some cases too high and in others too low. There was a bias towards steers receiving higher live prices than heifers while heifers tended to have comparatively higher carcass values. In their report, it was concluded that purchase values of live cattle were independent of the final yield grade but the value of the cuts were closely related to yield grade. The discrepancies between steer and heifer live prices and the values of their respective carcasses, although biased, is equalized because of the pricing system which is based on averages.

Prices for live cattle are connected to the value of carcasses and wholesale and retail beef, however not so much on an individual basis. Owen et al. (1991) looked at the imputed carcass value (ICV) otherwise known as the "boxed beef cut-out" which is reported by the U.S. Department of Agriculture, Market News Service. This is a weighted average price which is based upon prices for 11 different primal cuts. They examined which cuts were most apt to influence the prices for live fed cattle. They found that the striploin price was a leading indicator of fed cattle prices, and that the price of the striploin influenced the direction of fed cattle prices for following day.

This study acknowledged that fabricated cut beef prices could be useful in forecasting fed cattle prices and trends.

The relationship between live cattle prices and carcass values is clouded because of the pricing system which is based on averages. There is movement within the beef industry to move towards a value-based marketing system where the price received per animal is based on the carcass performance of that animal. Carcass-tracking technologies are becoming more accessible and the incorporation of this technology into the beef processing sector will give the entire industry an opportunity to improve beef quality and consistency of product.

MATERIALS AND METHODS

The economic values of beef carcasses from steers and heifers of diverse genetic make-up were calculated for this project. These values were calculated using detailed carcass cut-out information along with price information on individual cuts.

1. Carcass Data

The carcass data for this project was supplied by the Research Branch of Agriculture and Agrifood Canada. It came from a comprehensive study evaluating cross-bred beef cattle consisting of various Continental European beef breeds and British beef breeds. The breeds included Charolais, Simmental, Limousin, Angus, Hereford and Shorthorn. The carcass information used in this project came from steers and heifers sired by Limousin bulls and born to cows representing European X British F1 and backcross genotypes and one all- British F1 cross (Hereford X Angus) as shown in Table 3. The cows calved between 2 and 5 years of age and cows with calves were raised either under semi-intensive management at Brandon, Manitoba or under extensive range management at Manyberries, Alberta in 1981-1986. Rahnefeld et al. (1990), describes in detail the development and management of these two cattle

Table 3. Dam groups by breed composition.

Code	Breed Composition	# of offspring
010202	Hereford (Angus)	248
010501	Hereford (Charolais X Hereford)	108
010601	Hereford (Simmental X Hereford)	129
020502	Angus (Charolais X Angus)	115
020602	Angus (Simmental X Angus)	136
030503	Shorthorn (Charolais X Shorthorn)	100
030603	Shorthorn (Simmental X Shorthorn)	132
050303	Charolais (Shorthorn)	107
050501	Charolais (Charolais X Hereford)	86
050502	Charolais (Charolais X Angus)	103
050503	Charolais (Charolais X Shorthorn)	95
060303	Simmental (Shorthorn)	278
060601	Simmental (Simmental X Hereford)	113
060602	Simmental (Simmental X Angus)	136
060603	Simmental (Simmental X Shorthorn)	121

First breed listed represents the breed of dam's sire. The next breed represents the breed of dam's dam.

populations. Calves were weaned between 5 and 6.5 months of age and were then placed in feedlots. Brandon calves remained in Brandon, while Manyberries calves were moved to Lacombe, Alberta. While in the feedlot calves were fed in a manner consistent with normal procedures for commercial cattle. Designation for slaughter occurred when unshrunk live weight was a minimum 400 kilograms for heifers and 450 kilograms for steers. In addition, at Lacombe, cattle were required to have a minimum four millimetres rib fat depth on visual appraisal. In Brandon, cattle were slaughtered weekly in groups of up to 35 at a large commercial abattoir. In Lacombe, cattle were slaughtered weekly in groups of up to 25 at a small commercial abattoir (1982, 1983) or at the Lacombe Meat Research Centre abattoir (1984-1987). After slaughter, carcasses were chilled for 24 hours then ribbed, scored and graded. In Brandon (1982) the ribbing site was between the 11th-12th rib in accordance with the grading regulations of that time, while at Lacombe, during this time it was either at the 11th-12th or the 12th-13th rib. In 1983 at both Brandon and Lacombe the rib site was both the 11th-12th rib and 12th-13th rib. From 1984 to 1987, the rib site was at the 12th-13th rib at both Brandon and Lacombe. The change in ribbing site corresponds with the change that occurred in the National Beef Grading System. At the 12th-13th rib, the muscle area (cm^2) of the longissimus dorsi muscle cross section was measured, along with the depth of fat cover (cm) at three locations over the longissimus dorsi

muscle. A marbling score was also determined at this location. Marbling was scored on a 10 point scale with 1 representing the maximum (very abundant) and 10 the minimum (devoid). After two days chilled storage (Brandon) and six days (Lacombe) the carcasses were cut into wholesale cuts and "preferred" cuts (shortloin, rib, sirloin butt and round (Newman et al. 1994). The cuts used in this project included the shortloin, rib, sirloin butt, round, chuck, brisket, shank and flank as shown in Figure 1. The weight (kg) for each cut taken from one of the halves of each carcass was used in the analysis.

2. Price Data

The price data for this project came from the Market Information Service, Red Meat Development Division, Market and Industry Services Branch of Agriculture and Agrifood Canada (Canada Livestock and Meat Trade Report). It is published monthly and the price information used in this project is recorded as the Montreal Wholesale Prices - Primal and Subprimal Beef Cuts, A1 and A2 averages with prices recorded in dollars per kilogram. The 1994 monthly averages shown in Figure 2 were used in this project as they were the most current. The Montreal wholesale price represents prices received for sales of a small proportion of Canadian sales but they were the only

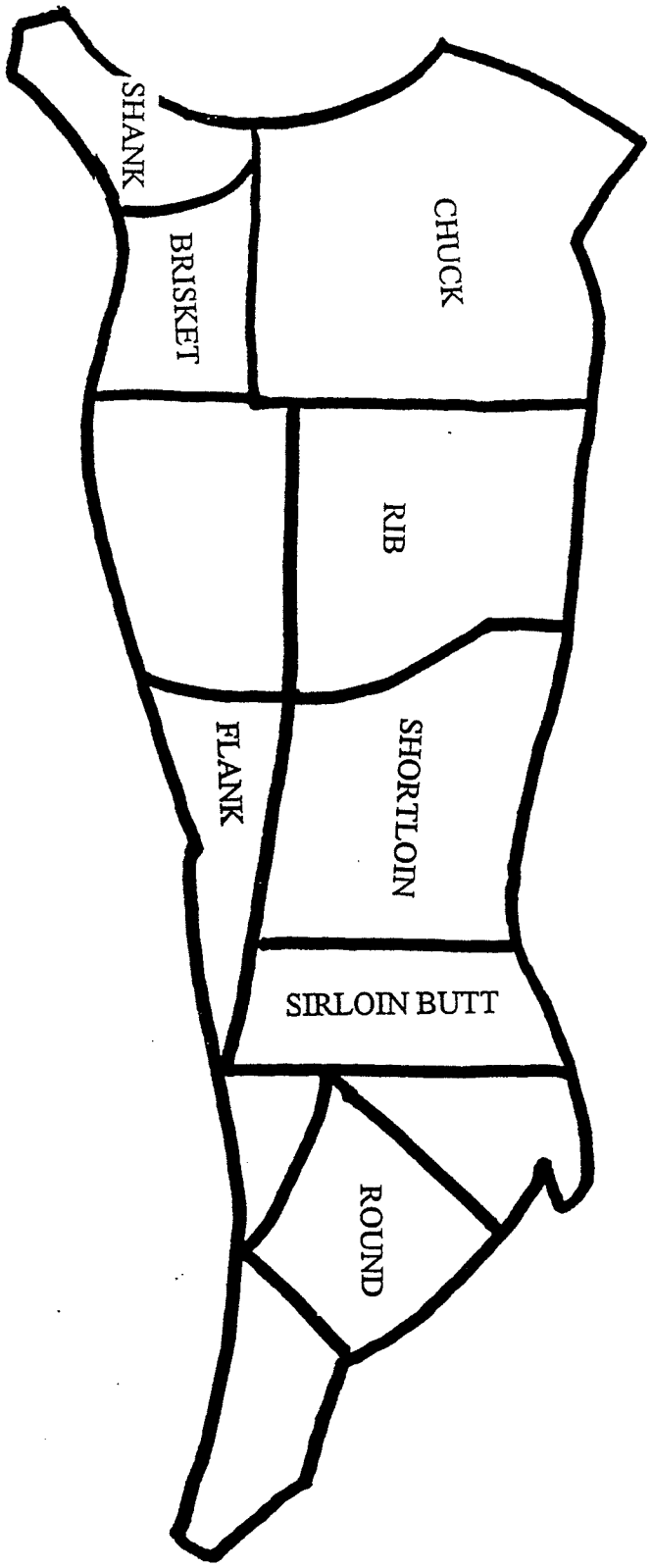

Figure 1. Wholesale cuts of the beef carcass.

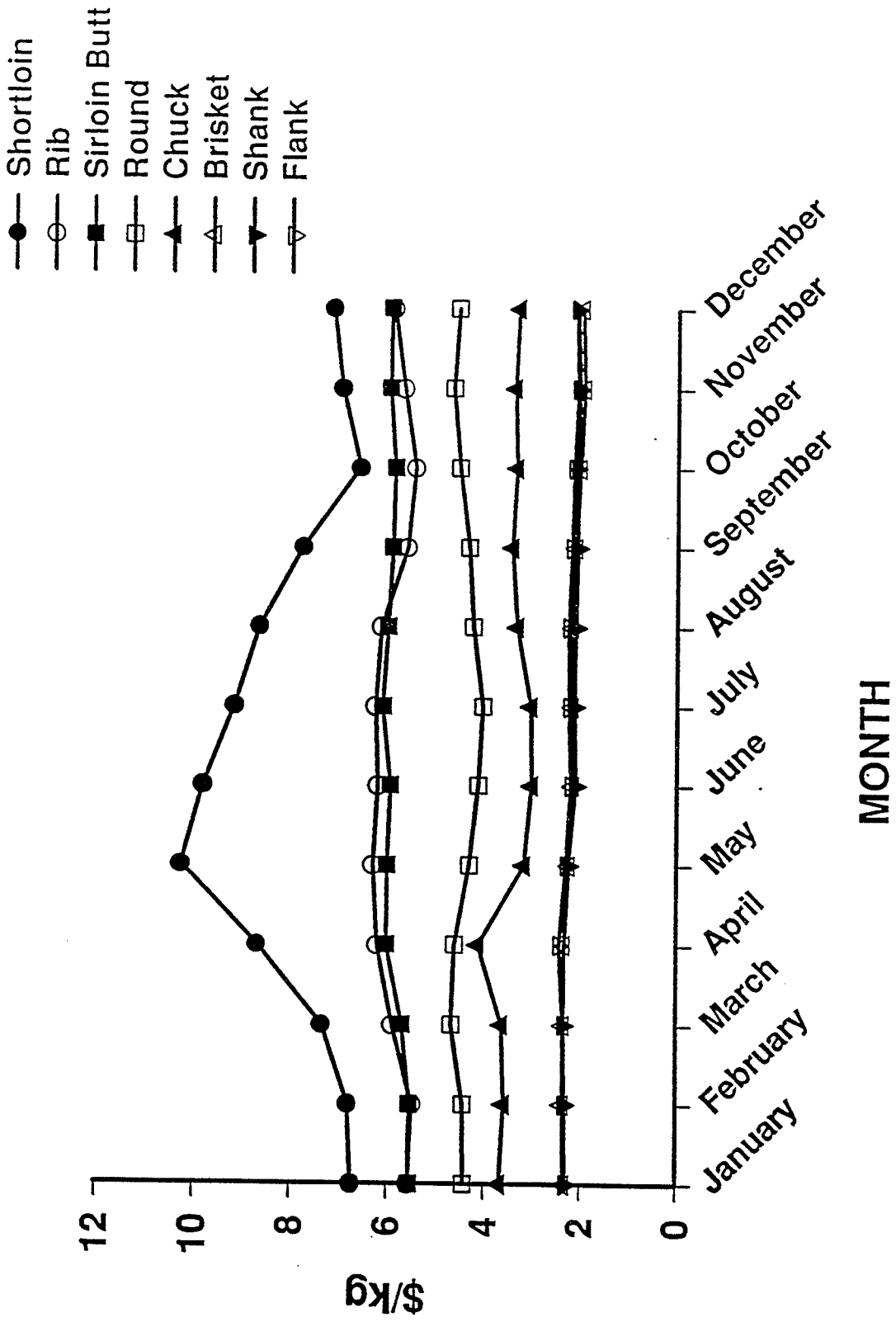

Figure 2. Montreal wholesale cuts monthly price averages for 1994.

consistent, public source of this type of information. Though absolute prices may vary among markets the relationships between prices of cuts tends to be relatively stable across markets and the Montreal wholesale prices are considered good indicators of these relationships (John Ross, Agriculture and Agrifood Canada, personal communication, 1994). Comparison between the Canadian prices and those from the United States also displayed similar relationships between the prices of cuts.

3. Determination of Carcass Value

A carcass value was estimated for each individual animal used in the project. Carcass values were created by combining cut-out data with the price data. The price of each wholesale cut was multiplied by the weight of the corresponding cut for each steer and heifer record. The cuts that were included in this calculation were as follows: shortloin, rib, sirloin butt, round, chuck, brisket, shank and flank. The sum of all cuts was then multiplied by two, resulting in an estimated carcass value. The plate was not included in the estimate of carcass value because a price for this cut was not available. The plate is a low value cut. It was agreed after consultation with Agriculture Canada officials that exclusion of the plate in the estimated carcass value would not affect the integrity of the data.

Several carcass values were created using the same procedure described above but with different price sets. Carcass Value 1 was created using the overall average price for each wholesale cut price in 1994. Carcass Value 2 was created using front and hind quarter prices. The front and hind quarter prices were applied to the sum of the individual cuts found in the front quarter and those cuts found in the hind quarter. Carcass Values 3 and 4 were created using the lowest price for each cut regardless of month (3) and the highest price regardless of month (4). Carcass Values 5 and 6 were created using prices from the months that cumulatively had the lowest prices (October) and the highest prices (May). Carcass value per kilogram of carcass weight was also calculated by dividing carcass value 1 by the cold carcass weight. Carcass Value 1 was used predominantly in this project. Carcass Values 3, 4, 5 and 6 were used to analyze price sensitivity.

4. Statistical Analysis

All the statistical analyses carried out in this project was completed using SAS Version 6.09, 1988. The first step in the analysis was to create the carcass values and assign a carcass value to each animal record. The GLM procedure of SAS was used to

adjust the data and remove environmental effects. Initially all two- and three-way interactions of the independent variables (the factors in the model) were included in the model. Those variables and interactions which were non-significant ($P > .05$) for all variables were dropped from the model, and those included in the model are shown in Table 4.

The final model which was used for all variables is as follows:

$$Y_{ijkl} = \mu + t_i + m_j + s_k + ms_{jk} + bX_{ijkl} + c_iX_{ijkl} + d_kX_{ijkl} + r_{ijkl} \qquad (1)$$

where Y_{ijkl} represents a response variable. Response variables included Carcass Values 1 through 6, carcass value per kilogram carcass weight, average backfat thickness, longissimus dorsi muscle area, marbling score, live weight and the cuts: chuck, rib, shortloin, sirloin butt, round, brisket, shank and flank, μ represents the population mean, t_i represents the station-year effect, m_j represents breed group of dam effects, s_k represents the effect of sex, ms_{jk} represents the effect of breed group of dam by sex interaction, bX_{ijkl} represents the overall regression coefficient for slaughter age, c_iX_{ijkl} represents the regression coefficient for slaughter age for the i'th station-year, d_kX_{ijkl} represents the regression coefficient for slaughter age for each sex and r_{ijkl} represents residual or error term.

Table 4. List of Factors in the model.

Factor	Description
StYr	Combination of station and year born
BreeDam	Breed group of dam
Sex	Sex of animal (steer or heifer)
StYr * Sex	Interaction between station-year and sex
Sex * BreeDam	Interaction between sex and breed group of dam
Slage	Slaughter age of animal
Slage * StYr	Interaction between slaughter age and station-year
Slage * Sex	Interaction between slaughter age and sex

Residuals (r_{ijkl}) for each variable were calculated for further analysis. These residuals represent animal performance for each character adjusted for environmental effects (station-year and age) and genetic effects (breed group of dam and sex). For the purpose of further analyses the breed of dam effects were added back into each residual record. Correlations between residuals of all characters were calculated with and without breed of dam effects .

The next step of the analysis was the development of a prediction equation where carcass value was predicted using the variables that could, in theory, be measured on the live animal. These included average backfat thickness, longissimus dorsi muscle area, live weight and marbling were measured on each carcass. All of these variables and their interactions were tested, with only those independent variables and their interactions which were significant kept in the model. The variables used in this analysis were corrected for all fixed effects (station-year, sex and slaughter age) except for breed of dam, since this was a genetic effect which was included as part of the variation among the animals.

The final model was:

$$CVR = b_0 + b_1AVGBFR + b_2LMAR + b_3LWTR + b_4LMAR^2 + b_5AVGBFR*LMAR + e \quad (2)$$

where CVR represents a carcass value residual (carcass values 1 through 6 or carcass value per kilogram carcass weight), b_0 represents the intercept, b_1 represents the regression coefficient for the average backfat thickness residual, b_2 represents the regression coefficient for longissimus dorsi muscle area residual, b_3 represents the regression coefficient for live weight residual, b_4 represents the regression coefficient for the square of the longissimus dorsi muscle area residual, b_5 represents the regression coefficient for the interaction of average backfat thickness and longissimus dorsi muscle area and e represents the variation in carcass value unaccounted for by the model.

The coefficients for each variable were used as the weights in the index estimating carcass value. Using the same model, regression analyses were carried out for each breed of dam group. The intention was to see if breed of dam had an effect on the equation for estimating carcass value. The variables along with their

coefficients were compared to see if there were changes in significance and magnitude.

A profile of the animals that made up the top 10% and bottom 10% of carcass values was carried out. Using the Z table, it was established that to separate off the top or bottom 10% of carcass values the cut off point was 1.28 standard deviation units. This weighting factor was multiplied by the standard deviation of carcass value to determine the cut off point. The mean weights of the individual cuts and the total cold carcass weight were then calculated for each group. The percentage of each individual cut relative to the total carcass weight was calculated for the top and bottom 10% of the population and for the overall population. The percent of each individual cut relative to the total carcass weight was compared between the top and bottom 10% and the overall mean to see if there were anatomical differences between the groups which affected the carcass value. These differences were assessed using t-tests.

The final set of analyses was directed at estimation of variance and covariance components using GLM and VARCOMP procedures (SAS, Inc. 1988) which could be used to calculate phenotypic and genetic correlations and heritabilities. In order to calculate phenotypic and genetic correlations between traits it was necessary to create variables representing sums of all the combinations of dependent variables.

The residuals from Model 1 were analyzed for genetic and environmental effects using a model containing sire, dam and breed of dam effects as follows:

$$Y_{ijkl} = \mu + b_i + s_j + d_{ik} + e_{ijkl} \quad (3)$$

where Y_{ijkl} represents the residuals from Model 1, μ represents the mean, b_i represents the ith breed group of dam, s_j represents the jth individual sire, d_{ik} represents the individual dam within the breed group and e_{ijkl} represents environmental effects on the individual animal.

Breed of dam was considered a fixed effect while sire, and dam within the breed group of dam were considered random effects. Genetic and environmental covariances between variables (example: between longissimus dorsi muscle area [X] and average backfat thickness [Y] were estimated by applying the same model to the sum [X + Y]). Covariance components were derived from these analyses using the following relationship:

$$\sigma^2_{x+y} = \sigma^2_x + \sigma^2_y + 2\sigma_{xy} \quad (4)$$

The three variance components: σ^2_{x+y}, σ^2_x, σ^2_y are all calculated in the analysis of variance, so that the covariance component (σ_{xy}) can be calculated as follows:

$$\sigma_{xy} = \frac{\sigma^2_{x+y} - \sigma^2_x - \sigma^2_y}{2}$$

RESULTS AND DISCUSSION

1. Characterization Of Data

Means and standard deviations of the variables used in the analysis are given in Table 5. The data were adjusted to remove such environmental effects as station-year, slaughter age, sex, breed group of dam and their interactions. The end result could be considered a large contemporary group of animals. Since breed group of dam was a genetic effect, it was added back into the data set (see Appendix) before further analysis was conducted. After the environmental effects were removed, the relationships between the variables could be assessed more clearly. Table 6 shows that for all the carcass value variables, station-year and the interaction of slaughter age and station-year contributed the most variation (approximately 7%). Breed group of dam contributed to a lesser degree in being a significant source of variation (approximately 3%), with the exception of carcass value per kilogram of carcass weight (approximately 8%). The results seen in Table 7 indicate that breed of dam was a significant source of variation when analyzing average backfat thickness (11%). Station-year and the interaction of slaughter age and station-year were also significant sources of variation but to a lesser extent (3 and 2% respectively). Station-year, breed group of dam and the interaction of slaughter age and station-year each accounted for approximately 5%

Table 5. Means of variables used across breeds.

Variable	N	Mean	Standard Deviation
avgbf (mm)	2001	1.183	0.379
lma (cm^2)	1996	77.542	8.701
lwt (kg)	2007	460.269	36.213
marb (index score)	2007	6.149	1.053
shortloin (kg)	2006	8.082	1.234
rib (kg)	1929	15.026	1.540
sirloin butt (kg)	2006	11.147	1.112
round (kg)	2002	31.782	3.267
chuck (kg)	1951	33.852	3.468
brisket (kg)	1950	5.160	1.308
shank (kg)	1950	4.426	0.688
flank (kg)	2007	8.073	1.489
Cvalue 1 ($)	1921	1030.207	87.309
Cvalue 2 ($)	1921	1017.350	84.812
Cvalue 3 ($)	1921	929.68	78.467
Cvalue 4 ($)	1921	1153.18	98.489
Cvalue 5 ($)	1921	993.58	84.126
Cvalue 6 ($)	1921	1060.46	90.038
cvpkcw ($/kg)	1686	3.96	0.075

Table 6. Analysis of Variance for Carcass Values.

Source	DF[a]	Percent Sums of Squares[b]						
		Carcass Value 1	Carcass Value 2	Carcass Value 3	Carcass Value 4	Carcass Value 5	Carcass Value 6	Cvpkcw
StYr	10	7.19 **	8.84 **	7.16 **	7.30 **	7.12 **	7.16 **	7.14 **
Breedam	14	3.02 **	2.47 **	3.10 **	2.81 **	3.25 **	2.82 **	8.23 **
Sex	1	0.58 **	0.53 **	0.58 **	0.57 **	0.59 **	0.57 **	0.25 *
StYr*Sex	10	1.64 **	1.55 **	1.62 **	1.65 **	1.68 **	1.62 **	0.55 **
Breedam*Sex	14	1.26 **	1.24 **	1.26 **	1.27 **	1.26 **	1.27 **	1.52 **
Slage	1	8.45 **	9.03 **	8.36 **	8.66 **	8.28 **	8.53 **	6.89 **
Slage*StYr	10	0.71	0.77	0.70	0.73	0.69	0.73	0.40
Slage*Sex	1	0.02	0.01	0.02	0.02	0.02	0.02	0.27
Residual	1859	77.14	75.56	77.19	76.99	77.09	77.28	74.74
Mean		1030.207	1017.350	929.683	1153.184	993.582	1060.463	3.961
Residual SD		52.645	51.344	47.488	59.051	50.76	54.372	0.051
Units		$	$	$	$	$	$	$/Kg

** P<0.01, * P<0.05

[a] degrees of freedom for variable cvpkcw was 8 for StYr and StYr interactions.

[b] sums of squares expressed as a percentage of the total.

Table 7. Analysis of Variance for Carcass Measurements that could be taken on the live animal.

		Percent Sums of Squares[b]			
Source	DF[a]	Average Backfat Thickness	Longissimus Dorsi Muscle Area	Live Weight Unshrunk	Marbling Score
StYr	11	3.56 **	5.48 **	10.82 **	1.60 **
Breedam	14	11.04 **	5.19 **	1.58 **	3.75 **
Sex	1	0.13	0.45 **	0.53 **	0.19 *
StYr*Sex	11	0.43 **	0.05	1.52 **	0.30 *
Breedam*Sex	14	0.66	1.18 **	1.25 **	2.69 **
Slage	1	2.57 **	5.06 **	11.51 **	1.70 **
Slage*StYr	11	0.60	0.37	0.59	0.47
Slage*Sex	1	0.06	0.32 **	0.01	0.15
Residual	1942	80.97	81.90	72.20	89.16
Mean		1.183	77.542	460.269	6.149
Residual SD		0.318	7.514	20.607	0.82
Units		mm	cm^2	kg	index 1-10

** P<0.01, * P<0.05

[a] degrees of freedom for average backfat thickness and longissimus dorsi muscle area were 1936 and 1931 respectively, for the residual degrees of freedom.

of the variation found in the longissimus dorsi muscle area. For the variable live weight, station-year and the interaction of slaughter age and station-year accounted for approximately 11% each of the total variation. Breed group of dam and the interaction of station-year and sex accounted for approximately 3 and 4% of the total variation in marbling score. In Table 8, station-year accounted for between 3-9% of the variation for all of the wholesale cuts. Similarly, breed group of dam accounted for 0-10%, the interaction of station-year and sex accounted for 1-2% of the variation across all cuts, and the interaction of slaughter age and station-year accounted for 3-10% of the variation among the wholesale cuts.

1.1 Correlations

All of the variables were analyzed to determine out the nature of the correlations that existed between each variable. Correlation analysis was performed on the data before and after breed group of dam effects were added back into the data set. Whether the breed group of dam effects were present did not alter most of the correlations. For the purpose of discussion and continuity, the correlations derived from the data containing the breed of dam effects has been used. Correlations derived from the data before breed of dam effects had been reintroduced to the data set can be found in the Appendix Tables 18-23.

Table 8. Analysis of Variance for Individual Cuts taken from the carcass (half-carcass weights).

Source	DF[a]	Percent Sums of Squares[b]							
		Shortloin (comm. trim)	Rib (comm. trim)	Sirloin Butt (comm. trim)	Round (comm. trim)	Chuck (rough trim)	Brisket (rough trim)	Shank (rough trim)	Flank (rough trim)
StYr	11	6.07 **	4.20 **	5.06 **	3.09 **	9.10 **	6.12 **	8.75 **	8.27 **
Breedam	14	0.73	1.20 *	5.01 **	10.47 **	1.23 **	2.57 **	3.98 **	5.78 **
Sex	1	0.23 *	0.21*	0.20 *	0.74 **	0.29 **	0.04	1.28 **	0.02
StYr*Sex	11	0.41 **	0.00	0.00	2.09 **	1.16 **	0.10	2.61 **	0.03
Breedam*Sex	14	1.86 **	1.07 **	1.03 *	1.23 **	1.04 **	1.06 **	0.18 **	1.53 **
Slage	1	8.18 **	5.55 **	4.34 **	3.34 **	10.26 **	8.07 **	0.67 **	5.59 **
Slage*StYr	11	0.75	0.69	0.64	0.37	0.78	0.67	0.01	0.97 *
Slage*Sex	1	0.02	0.02	0.00	0.08	0.01	0.21 *	0.28 *	0.02
Residual	1942	81.75	87.06	83.71	78.59	76.13	81.16	82.24	77.79
Mean		8.082	15.026	11.147	31.782	33.852	5.16	4.426	8.073
Residual SD		0.667	1.07	0.798	2.078	2.047	0.725	0.401	0.888
Units		kg	kg	kg	kg	kg	kg	kg	kg

** P<0.01, * P<0.05

[a] degrees of freedom for the variables chuck, rib, brisket and shank were 10 for StYr and StYr interactions. The residual degrees of freedom for shortloin and sirloin butt were 1941, for the round was 1937, for the rib was 1867, for the chuck was 1889 and for the brisket and shank were 1888.

[b] sums of squares expressed as a percentage of the total.

1.1a Correlations between the carcass values

The correlations between the carcass values 1 through 6 and carcass value per kilogram of carcass weight can be found in Table 9. The correlations between carcass values 1 through 6 were quite high and ranged from 0.97 to 1.00. The correlation between carcass value 1 and carcass value 2 was 0.97 and significant ($P < .01$). The correlations between the carcass values 1 through 6 and carcass value per kilogram of carcass weight were comparatively low, 0.15 to 0.26. The low correlation between carcass value per kilogram carcass weight and carcass value indicates that high or low carcass values could have high or low values per kilogram.

1.1b) Correlation between carcass values and "live animal" measurements.

Comparisons of the correlations before and after breed of dam effects were added back into the data set resulted in changes for the variables average backfat thickness and marbling score. Before breed of dam effects were added to the data set the correlations between average backfat thickness and carcass values 1 through 6 were positive but not significant ($P > .05$). After the breed of dam effects were added back into the data the correlations became negative, but again were nonsignificant ($P > .05$).

Table 9. Correlations of calculated carcass value residuals.

	cv2r	cv3r	cv4r	cv5r	cv6r	cvpkcwr
cv1r	0.986**	1.000**	1.000**	1.000**	1.000**	0.244**
cv2r		0.986**	0.985**	0.986**	0.983**	0.121**
cv3r			0.999**	1.000**	0.998**	0.243**
cv4r				0.998**	0.999**	0.243**
cv5r					0.997**	0.246**
cv6r						0.250**

** P<0.01, * P<0.05

The n for these correlations ranged from 1686 to 1921.

Correlations were calculated after breed of dam effects were added back into the data set.

Similarly, for marbling score prior to breed of dam effects being added back to the data, the correlations were negative and after the breed of dam effects were added back the correlations became positive. The absolute values of the correlation coefficients remained consistent whether breed of dam effects were in the data set or not. Also, the correlations between average backfat thickness and marbling score to the carcass values 1 through 6 were not significant ($P > .05$).

Table 10 shows the correlations between carcass values and "live animal" measurements. Live weight showed a strong and significant correlation with each of the carcass values 1 through 6 (0.81-0.82). This relationship indicated that an increase in live weight would correspond to an increase in carcass value. The general rule that the heavier animals will produce the heavier carcasses can be applied. Based on how the carcass values are derived, it follows that the heavier the carcass, the heavier the cuts will be and thus the higher the value of the carcass. Longissimus dorsi muscle area also showed a significant and positive correlation with the carcass values 1 through 6 (0.44-0.47). The interpretation was that an increase in longissimus dorsi muscle area would result in an increase in carcass value.

The correlations between the measurements that could be taken on the live animal and the carcass value per kilogram carcass weight presented a different picture. All the variables representing live animal measurements were significantly correlated

Table 10. Correlations of calculated carcass value residuals and residuals of "live animal" measurements.

	cv1r	cv2r	cv3r	cv4r	cv5r	cv6r	cvpkcwr
avgbfr	-0.017	0.022	-0.019	-0.012	-0.028	-0.007	-0.365**
lmar	0.446 **	0.422**	0.461**	0.467**	0.462**	0.464**	0.333**
lwtr	0.815**	0.844**	0.815**	0.818**	0.814**	0.814**	-0.085**
marbr	0.014	-0.010	0.014	0.007	0.020	0.009	0.218**

** P<0.01, * P<0.05
The n for these correlations ranged from 1680 to 1921.
Correlations were calculated after breed of dam effects were added back into the data set.
"live animal" measurements were taken from the carcass but could be measured from the live animal by the use of ultrasound.

to carcass value per kilogram. There was a negative correlation with average backfat thickness (-0.37). This negative correlation may be explained by considering that increased backfat thickness would result in less lean which in turn would result in less carcass value. Average backfat thickness and longissimus dorsi muscle area were negatively correlated. An increase in average backfat thickness would result in an decrease of longissimus dorsi muscle area and vice versa.

It has been shown longissimus dorsi muscle area was positively correlated with carcass value. This also held true for carcass value per kilogram carcass weight (0.33). There was a small negative but significant correlation between live weight and carcass value per kilogram of carcass weight (-0.08). Marbling score had a positive relationship with carcass value per kilogram carcass weight (0.22).

1.1c) Correlations between carcass values and wholesale cuts.

The correlation coefficient for each wholesale cut and carcass values 1 through 6 are shown in Table 11. It is apparent that significant positive correlations exist between the variables. The chuck and the round cuts were most highly correlated with carcass values 1 through 6, each with a correlation coefficient of 0.83. These two cuts were the largest cuts from the carcass with means of 33.85 and 31.78 kilograms respectively. Since these cuts were much larger in comparison to the other cuts of the

Table 11. Correlations of calculated carcass value residuals and wholesale cut residuals.

	cv1r	cv2r	cv3r	cv4r	cv5r	cv6r	cvpkcwr
shloinr	0.676**	0.642**	0.665**	0.697**	0.658**	0.705**	0.281**
ribr	0.694**	0.655**	0.698**	0.687**	0.687**	0.698**	0.090**
sbuttr	0.709**	0.681**	0.714**	0.702**	0.715**	0.704**	0.357**
roundr	0.825**	0.814**	0.827**	0.818**	0.837**	0.813**	0.368**
chuckr	0.836**	0.842**	0.834**	0.842**	0.837**	0.824**	0.028
briskr	0.333**	0.361**	0.332**	0.323**	0.328**	0.335**	-0.112**
shankr	0.450**	0.465**	0.452**	0.441**	0.455**	0.448**	0.113**
flankr	0.321**	0.409**	0.321**	0.332**	0.311**	0.327**	-0.421**

** $P<0.01$, * $P<0.05$

The n for these correlations ranged from 1686 to 1921.

Correlations were calculated after breed of dam effects were added back into the data set.

carcass, they had the most influence on carcass value. Although the round was a higher priced cut than the chuck, the price difference did not affect the carcass value. The sirloin butt (0.71), rib (0.68) and shortloin (0.67) were also strongly correlated with carcass values 1 through 6. Again, these are higher priced cuts but their high correlations with the carcass values can be attributed to the weight of these cuts in comparison to other cuts since they compose a large part of the whole carcass. The mean weights for the sirloin butt, rib and shortloin were 11.15, 15.03 and 8.08 kilograms respectively. The shank (0.46), brisket (0.33) and flank (0.32) were positively correlated with the carcass values but not to the same extent as some of the other cuts. Again, this is due to the small weights attributed to these cuts 4.43, 5.16 and 8.07 kilograms respectively. Within the smaller cuts there was a small price effect on the carcass value with respect to the weight of the cut. For example, both the shortloin and flank had a mean weight of 8 kilograms, yet the correlation coefficient for shortloin was 0.67 and that for flank was 0.32. The difference in correlation coefficients can be attributed to the difference in price of the two cuts. The shortloin was a higher priced cut than the flank, thus it contributed more to the value of the carcass while contributing the same weight in kilograms to the carcass.

The correlations between the wholesale cuts and carcass value per kilogram of carcass weight were somewhat different than the relationships found between the cuts and the carcass values 1 through 6. The absolute values of the correlation coefficients

were generally smaller than those for the other carcass values. The chuck, which had a strong positive correlation with the carcass values 1 through 6 had a very small correlation coefficient (0.04), ($P > .05$). The higher priced cuts, shortloin (0.28), rib (0.10), sirloin butt (0.36) and round (0.37) had a positive correlation with carcass value per kilogram of carcass weight. The lower priced cuts, in particular brisket (-0.12) and flank (-0.42) had negative correlation coefficients which were found to be significant ($P < .05$). The shank (0.11) was positively correlated with carcass value per kilogram of carcass weight and this correlation as significant as well. The higher priced cuts tended to be positively correlated with carcass value per kilogram of carcass weight, whereas the lower priced cuts were negatively correlated. In the case of the shank and chuck, there was a small positive relationship which was significant for only the shank. It seems that for the variable carcass weight per kilogram of carcass weight, price had an influence on the correlation. An increase in the weight of the higher priced cuts (shortloin, rib, sirloin butt and round) tended to increase the carcass value per kilogram of carcass weight. On the other hand, an increase in the lower priced cuts would tend to decrease the carcass value per kilogram carcass weight and vice versa.

1.1d) Correlations between "live animal" measurements.

The correlations calculated between the four variables; average backfat thickness, longissimus dorsi muscle area, live weight and marbling score were consistent to those found in the literature and are shown in Table 12. These records can be measured on the live animal with a high degree of accuracy using real-time ultrasound technology. The measurements of these variables, with the exception of live weight, were taken from the carcass of each animal rather than the live animal using ultrasound. Since the measurements, whether taken from the live animal or the carcass are very similar, comparison of the correlation coefficients to those found in the literature using actual live animal measurements are valid.

Average backfat thickness was negatively correlated with longissimus dorsi muscle area (-0.24). This was consistent to the results found by Johnston et al. (1992), of -0.35. This may be explained in that as the average backfat thickness becomes greater, the longissimus dorsi muscle area lessens. Average backfat thickness had a small positive correlation with live weight. Again, this was consistent to the literature and to normal growth patterns in cattle. An increase in fat is associated with an increase in live weight. The correlation coefficient between average backfat thickness and marbling score was -0.19. This compares to -0.24 found by Johnston et al. (1992). The negative correlation suggests an antagonistic relationship exists between backfat thickness and marbling score. An increase in backfat thickness did not correspond to

Table 12. Correlations of "live animal" measurement residuals.

	lmar	lwtr	marbr
avgbfr	-0.235**	0.091**	-0.185**
lmar		0.262**	0.098**
lwtr			-0.044**

** $P<0.01$, * $P<0.05$

The n for these correlations ranged from 1996 to 2007.

Correlations were calculated after breed of dam effects were added back into the data set.

"live animal" measurements were taken from the carcass but could be measured from the live animal by the use of ultrasound.

an increase in the amount of intramuscular fat (determined by marbling score). Longissimus dorsi muscle area was positively correlated with both live weight (0.27) and marbling score (0.10). Veseth et al. (1993) found similar results between longissimus dorsi muscle area and slaughter weight (0.53) and marbling score (0.16). Johnston et al. (1992) using carcass weight rather than live weight, found correlations between longissimus dorsi muscle area and slaughter weight to be 0.51 and between longissimus dorsi muscle area and marbling to be -0.09. Live weight was negatively correlated to marbling score (-0.04), however the relationship was quite small. Again, this was consistent to results found in the literature. Johnston et al. (1992), found a correlation of -0.03, Koots et al. (1994a) found a correlation of 0.07. Veseth et al. (1993) reported a correlation of 0.28 between slaughter weight and marbling score.

1.1e) Correlations between "live animal" measurements and wholesale cuts.

Table 13 shows the correlations between measurements that can be taken on the live animal and the wholesale cuts. Correlations between live weight and all the wholesale cuts were positive and significant, ranging from 0.36 for the brisket to 0.75 for the chuck. This was probably a result of the weight of these cuts. The chuck and the round were the largest cuts from the carcass with means of 33.85 and 31.78

Table 13. Correlations of "live animal" measurement residuals and wholesale cut residuals.

	avgbfr	lmar	lwtr	marbr
shloinr	0.084**	0.365**	0.553**	-0.018**
ribr	0.159**	0.301**	0.565**	-0.133**
sbuttr	-0.089**	0.367**	0.543**	0.089**
roundr	-0.276**	0.463**	0.626**	0.155**
chuckr	0.039	0.309**	0.745**	-0.012
briskr	0.136**	0.034	0.359**	-0.105**
shankr	-0.168**	0.206**	0.384**	0.057*
flankr	0.435**	-0.022	0.433**	-0.223**

** P<0.01, * P<0.05

The n for these correlations ranged from 1918 to 2007.

Correlations were calculated after breed of dam effects were added back into the data set. "live animal" measurements were taken from the carcass but could be measured from the live animal by the use of ultrasound.

kilograms respectively. They each exhibited the highest absolute correlation coefficients, 0.75 and 0.63 respectively. The brisket and shank were the smallest cuts , 5.16 and 4.43 kilograms and also had the lowest correlation values with live weight, 0.36 and 0.39. All the cuts exhibited a significant correlation with average backfat thickness with the exception of the chuck. There were positive correlations with the rib, shortloin, brisket and flank, while negative correlations existed with the round and shank. The absolute values of these correlation coefficients were not high, therefore, the relationships that existed were not strong.

The correlations between longissimus dorsi muscle area and the wholesale cuts were significant and positive with the exception of the brisket and shank (0.04 and -0.03). The correlation coefficient ranged from 0.20 for the shank to 0.47 for the round. It was interesting that the coefficient for the rib was 0.30. It was expected that the correlation between the wholesale rib cut would be higher since the longissimus dorsi muscle area is a direct measurement of the muscle area of the rib cut.

The chuck (-0.01) and shortloin (-0.02) exhibited negative correlations with marbling score, however, they were not significant ($P > .05$). The brisket (-0.11), rib (-0.13) and flank (-0.23) were negatively correlated to marbling and significant ($P < .05$). The round (0.16) and sirloin butt (0.09) were positively correlated to marbling. The correlation coefficients for all of the wholesale cuts with marbling score

were quite low indicating that there was not a strong relationship between those variables.

1.1f) Correlations between the wholesale cuts.

Table 14 shows the correlations between the wholesale cuts. All of the correlations between the wholesale cuts are significant and positive, with the exception of the correlation between shank and flank (-0.03). The correlations involving the chuck and the higher priced cuts; shortloin (0.49), rib (0.52), sirloin butt (0.52) and round (0.62) were the highest. Round and sirloin butt (0.58) and the round and shank (0.54) were also high. This could be a result of the weight factor of the chuck and the round since these were the two largest cuts. It can be rationalized that the larger the round or the chuck, the larger would be the carcass. Since the carcass would be larger it follows that the rest of the cuts would be larger as well.

2. Prediction Equation

A regression equation was calculated relating variables representing measurements that could be taken on the live animal to carcass value 1. All variables were adjusted for environmental effects. Only variables that had a significant effect

Table 14. Correlations of wholesale cut residuals.

	ribr	sbuttr	roundr	chuckr	briskr	shankr	flankr
shloinr	0.350**	0.388**	0.453**	0.489**	0.213**	0.287**	0.240**
ribr		.0372**	0.376**	0.521**	0.246**	0.182**	0.374**
sbuttr			0.573**	0.519**	0.199**	0.292**	0.156**
roundr				0.618**	0.170**	0.541**	0.013
chuckr					0.220**	0.266**	0.284**
briskr						0.180**	0.200**
shankr							-0.040

** P< 0.01, *P< 0.05
The n for these correlations ranged from 1924 to 2007.
Correlations were calculated after breed of dam effects were added back into the data set.

$P < .05$) on carcass value were included, those being average backfat thickness, longissimus dorsi muscle area, live weight (unshrunk), and the interaction between average backfat thickness and longissimus dorsi muscle area. A second regression equation was calculated for carcass value per kilogram of carcass weight. The variables used were the same as in the first equation with the exception of marbling being included and the interaction was dropped. The purpose of the regression equations was to see if using live animal measurements could predict carcass values with an acceptable degree of accuracy.

Table 15 contains the regression coefficients from two prediction equations, one which predicted carcass value 1 and the other, carcass value 1 per kilogram of carcass weight. The variables that were regressed on carcass value 1, were average backfat thickness (-3.971 \$/mm), longissimus dorsi muscle area (1.938 \$/cm^2), live weight (1.986 \$/kg) and the interaction between average backfat thickness and longissimus dorsi muscle area (-0.954 \$/$mmcm^2$). These variables were all significant ($P < .05$) with the exception of average backfat thickness ($P > .05$) which was not significantly different from zero. This prediction equation accounted for 76% of the variation found in carcass value 1 for this data set. Shackleford et al. (1995), reported a R^2 value of 0.72 for an equation predicting retail product yield, which included the variables; adjusted fat thickness, marbling score, rib eye area and estimated kidney, pelvic, heart

Table 15. Regression coefficients for carcass value 1 and carcass value 1 per kilogram of cold carcass weight.

	cv1r	s.e.		cvpkcwr	s.e.
intercept	-1.227	0.673	intercept	-0.0009	0.0012
avgbfr ($/mm)	-3.971	1.999	avgbfr ($/mm)	-0.0394**	0.0035
lmar ($/cm^2)	1.938**	0.093	lmar ($/cm^2)	0.0020**	0.0002
lwtr ($/kg)	1.986**	0.035	lwtr ($/kg)	-0.0004**	0.0001
bflma($/mmcm^2)	-0.954**	0.225	marbr ($/unit)	0.0078**	0.0013
r^2	0.76		r^2	0.2367	
√MSE	26.222		√MSE	0.0457	

** P<0.01, * P<0.05

fat. The retail product used in their study was a measure of meat product and should, except for differential pricing of cuts, be similar to carcass value used in this study.

The regression coefficients may be interpreted as a unit increase in the variable which corresponds to either an increase or decrease in carcass value 1. The magnitude of the change depends upon the value of the coefficient. Average backfat thickness (-3.971 $/mm) was not significant ($P > .05$) in this equation, but it is interesting to note the sign of the coefficient. Since it is negative, it is understood that an increase in fat thickness would cause a decrease in carcass value, while all other variables are held constant. In a similar study by Shackleford et al. (1995), adjusted backfat thickness (-5.8402) was found to have a negative effect on retail product. This negative effect may be explained by considering that animals with more fat would tend to have less muscle since all other variables were held constant. Because the wholesale cuts used to calculate carcass value 1 were subject to trimming , the fatter animals would have produced more waste fat with less lean , subsequently this would be reflected in lower carcass value. Mies et al. (1992) reported fatter carcasses were lower in value due to loss of product yield as fat was trimmed whereas leaner carcasses increased in value.

Longissimus dorsi muscle area (1.938 $/cm^2) was a significant variable ($P < .05$) in this equation. A one cm^2 increase in muscle area would result in a $1.938 increase in carcass value 1. Shackleford et al. (1995) reported a coefficient for rib eye

area of 0.1018 in their prediction equation for retail product yield. Since an increase in longissimus dorsi muscle area corresponds to an increase in carcass value it suggests that longissimus dorsi muscle area is an indicator of either the amount of muscle in the carcass or the size of the carcass. Several studies have found that longissimus muscle area is a function of carcass weight Cole et al. (1962); Fitzhugh et al. (1965) and Powell and Huffman (1973).

The variable, live weight, (1.986 $/kg) had a significant ($P < .05$) and positive effect on predictions of carcass value 1. The carcass value 1 in this study was derived using a summation of the weights of individual primal cuts which were then multiplied by their appropriate price. Therefore animals with a larger weight of their cuts will have a higher carcass value. These results suggest a 1 kilogram increase in live weight will correspond to a $1.986 increase in carcass value. This is plausible since a higher live weight will result in a heavier carcass, which in turn will result in larger primal cuts with heavier weights. It is apparent for this data set , evaluating carcass value 1, that larger, heavier animals have higher carcass values.

The interaction between average backfat thickness and longissimus dorsi muscle area (-0.954) was significant ($P < .05$) and had a negative influence on carcass value 1. The role of the interaction depends upon the level of average backfat thickness. At backfat thicknesses which are below average and longissimus dorsi muscle areas that

are above average carcass value is increased which is expected. However at high levels of backfat thickness the affect on carcass value is reversed.

The regression equation using these variables accounted for 76% of the variation in carcass value 1. This indicates that these variables may be useful in predicting carcass values from measurements taken from live animals. Carcass value 1 primarily measures the quantity of the cuts taken from the carcass and therefore reflects the size of the carcass which in turn is an indicator of size in the live animal.

The other prediction equation studied was similar to the regression on carcass value 1. This equation was used to predict carcass value 1 per kilogram of carcass weight using the variables, average backfat thickness, longissimus dorsi muscle area, live weight and marbling score. These four variables were significant ($P < .05$) in the equation and there were no significant interactions among the variables.

Average backfat thickness (-0.0394 $/mm) had a negative influence on carcass value 1 per kilogram of carcass weight. This result was expected since fatter animals tended to have less muscle at a constant weight as explained previously.

Longissimus dorsi muscle area (0.0020 $/cm^2) had a positive influence on carcass value 1 per kilogram of carcass weight. Again, this effect was expected since longissimus dorsi muscle area describes the musculature of the animal and the carcass.

Increased muscle area relates to heavier muscled animals, thus increased carcass values.

Live weight (-0.0004 $/kg) had a negative influence on carcass value 1 per kilogram of carcass weight. Because this carcass value was measured on a per kilogram basis, the effects of size were removed. Therefore, unlike in the previous prediction equation where larger animals translated to higher carcass values, in this equation that relationship does not exist.

Marbling score (0.0078 $/unit) had a positive influence on carcass value 1 per kilogram of carcass weight. This effect can not be explained since marbling score was not a factor in the pricing system used.

The R^2 value for this prediction equation was 0.2367. The smaller R^2 value may be attributed to the additional variation due to differential prices applied to the different cuts. Low R^2 were also found in similar equations which predict percent of lean meat from the total carcass weight rather than yield (Shackleford et al. 1995 and Reiling et al. 1992).

3. Breed of dam effects

Regression procedures were used to estimate the accuracy of predicting carcass value 1 and carcass value 1 per kilogram of carcass weight using the variables; average backfat thickness, longissimus dorsi muscle area, live weight, marbling score and the

interaction between average backfat thickness and longissimus dorsi muscle area. A summary of the regression coefficients are presented in Tables 16 for each of the fifteen breed of dam groups and also across all breed of dam groups. The analysis for carcass value 1 by breed of dam group resulted in two variables (longissimus dorsi muscle area and live weight) being significant ($P < .05$) and the other two variables (average backfat thickness and the interaction between backfat thickness and longissimus dorsi muscle area) being for the most part non-significant ($P > .05$). For the variables which were significant, the values for the coefficients and their standard errors were similar for each breed of dam group. The variables which were non-significant tended to vary substantially in their values and signs. As well, the standard errors were quite large in comparison to the value of the coefficients. The R^2 values for each breed of dam group averaged 0.80 with a range of 0.83 to 0.68. The R^2 value for the model across all breed of dam groups was 0.76.

It has already been determined that carcass value 1 is an indicator of the size of the carcass. Therefore having live weight and longissimus dorsi muscle area as significant variables for each breed of dam group is expected. The fact that average backfat thickness was not a significant variable ($P > .05$) suggests that for this data set, there were no significant differences for average backfat thickness between breed of dam groups. The interaction between average backfat thickness and longissimus dorsi

Table 16. Regression coefficients for each breed of dam group with carcass value 1 being the dependant variable.

Breed	avgbfr		lmar		lwtr		bflma		R^2	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.		
overall	-3.791	1.999	1.938**	0.093	1.986**	0.035	-0.954**	0.225	0.760	26.222
H(A)	0.478	5.047	2.764**	0.240	1.996**	0.090	-2.333**	0.460	0.825	25.357
H(CH)	15.873	9.332	1.680*	0.384	1.982**	0.128	1.009	0.967	0.758	28.186
H(SH)	12.870	7.429	1.851**	0.437	1.991**	0.120	-1.763	1.162	0.829	23.569
A(CA)	3.940	5.997	2.190**	0.345	1.777**	0.127	-1.547*	0.627	0.760	24.431
A(SA)	2.464	8.738	1.128*	0.517	2.184**	0.175	0.617	1.293	0.700	29.563
Sh(CSh)	-3.926	11.622	2.282**	0.446	2.031**	0.178	0.063	1.475	0.723	26.701
Sh(SSh)	11.172	9.321	1.616**	0.393	1.866**	0.141	2.383	1.249	0.720	26.874
C(Sh)	4.052	7.820	2.060**	0.345	1.894**	0.109	0.100	0.931	0.823	22.737
C(CH)	1.102	8.371	0.731	0.461	1.844**	0.143	-4.149**	1.160	0.716	22.202
C(CA)	-18.111	9.782	1.655**	0.456	1.873**	0.173	-0.462	1.249	0.684	25.844
C(CSh)	-11.891	8.878	1.732**	0.378	1.999**	0.138	-0.429	0.846	0.790	25.560
S(Sh)	3.373	5.904	1.687**	0.246	2.010**	0.095	1.256	0.758	0.774	24.026
S(SH)	1.129	8.813	1.170**	0.413	1.930**	0.126	-0.767	1.214	0.829	24.653
S(SA)	-14.273	10.331	1.213**	0.427	2.280**	0.138	-1.505	1.170	0.779	27.247
S(SSh)	0.516	10.230	1.673**	0.481	1.809**	0.160	-0.415	1.365	0.684	28.503

muscle area was for the most part nonsignificant as well. Figure 3 depicts the value of the coefficients and their standard errors. For both longissimus dorsi muscle area and live weight the coefficients are very similar. In many cases when the standard errors are taken into consideration, the coefficients could often be considered the same. This indicates for this study, breed group of dam did not effect the prediction equation when estimating carcass value 1.

Further evidence supporting the idea that breed group of dam did not interfere with the prediction of carcass value 1 is found when comparing R^2 values. The overall R^2 value across all breed of dam groups for the regression equation was 0.76. The data set used for that regression was adjusted for breed of dam, then the breed of dam effects were added back to the data set. Another model was created which included breed group of dam, the live animal measurement variables and the interactions between breed group of dam and live animal measurement variables. This model was analyzed using GLM procedures with the resulting R^2 value being 0.76. Therefore whether breed of dam was incorporated into the model or not did not change the R^2 value and thus did not add or detract from the accuracy of the prediction equation.

A similar regression analysis was done for carcass value 1 per kilogram of carcass weight using the variables; average backfat thickness, longissimus dorsi muscle area, live weight and marbling score. Across breeds, all four of these variables were

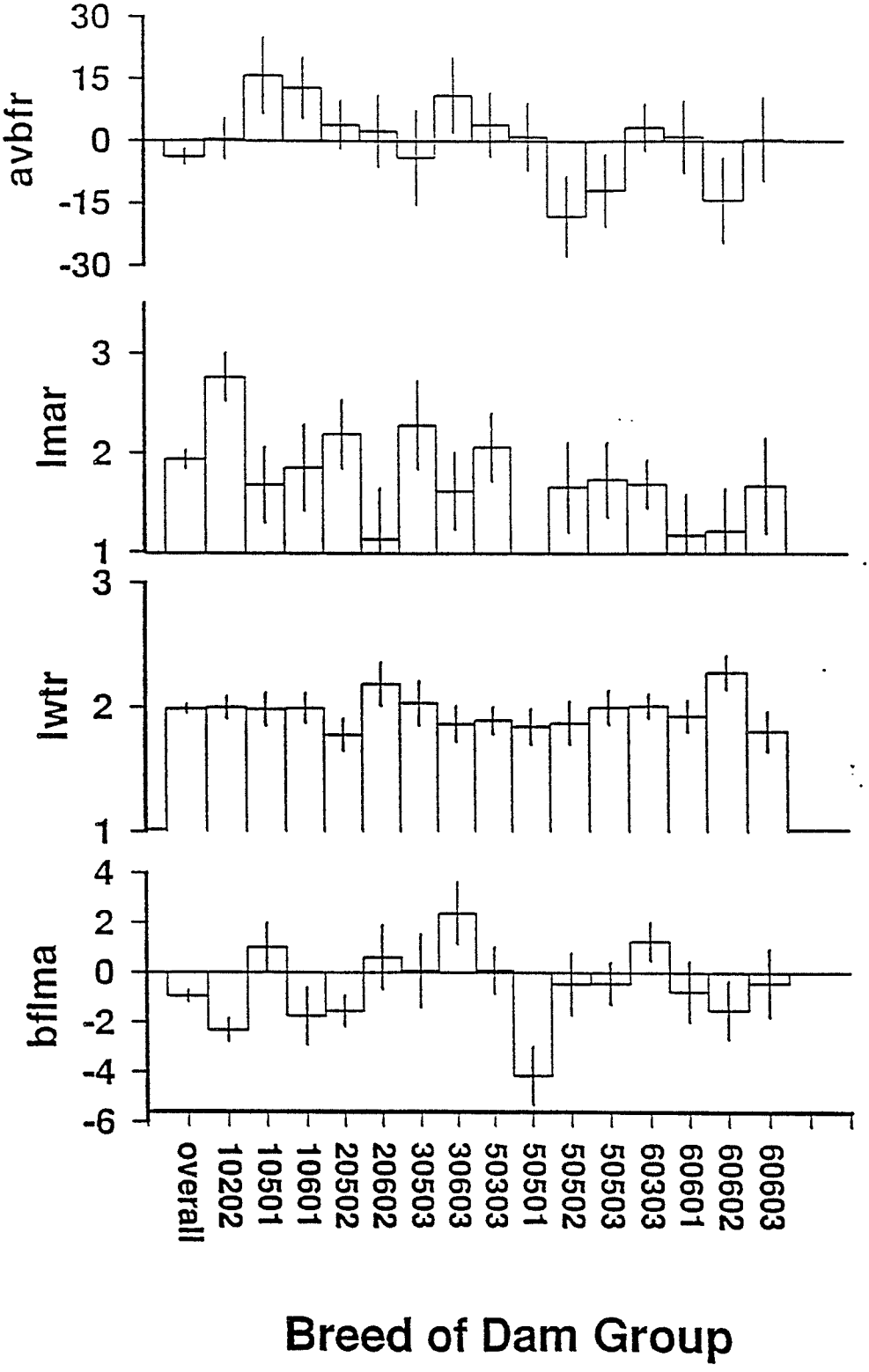

Figure 3. Variation among breed of dam groups for the regression coefficients for four variables used to predict carcass value 1.

significant ($P < .05$) but when the equation was run by each breed of dam group some of the variables were significant for some breed groups but not others. Table 17 summarizes the regression coefficients and their respective standard errors for each breed of dam group. Average backfat thickness and longissimus dorsi muscle area were both significant ($P < .05$) for most breed groups whereas live weight and marbling score were for the most part non-significant for most breed groups. There did not seem to be a particular pattern between those variables which were significant and non-significant for each breed of dam as is shown in Figure 4.

4. Price Sensitivity

Regression analysis was carried out on eight separate carcass values which were derived using different price sets. Four of the carcass values were created in a similar fashion to carcass value 1 with the sum of each individual primal cut multiplied by its respective price making up the carcass value. The other four carcass values were created by dividing each of the four carcass values by the cold carcass weight to get a carcass value per kilogram of carcass weight. The explanatory variables used in the regression were: average backfat thickness, longissimus dorsi muscle area, live weight, marbling score and the interaction between average backfat thickness and longissimus dorsi muscle area.

Table 17. Regression coefficients for each breed of dam group with carcass value 1 per kilogram of carcass weight being the dependant variable.

Breed	avgbfr		lmar		lwtr		marbr		R^2	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.		
overall	-0.0394**	0.0035	0.0020**	0.0002	-0.0004**	0.0001	0.0078**	0.0013	0.2367	0.0457
H(A)	-0.0425**	0.0097	0.0026**	0.0005	-0.0004*	0.0002	0.0036	0.0050	0.2812	0.0478
H(CH)	-0.0242	0.0136	0.0016**	0.0006	-0.0008**	0.0002	0.0042	0.0046	0.2253	0.0441
H(SH)	-0.0264*	0.0132	0.0018**	0.0008	0.0000	0.0002	0.0022	0.0058	0.1066	0.0443
A(CA)	-0.0293*	0.0119	0.0023**	0.0007	-0.0005	0.0003	0.0096*	0.0045	0.2233	0.0488
A(SA)	-0.0173	0.0132	0.0008	0.0007	0.0002	0.0003	0.0125	0.0066	0.0851	0.0451
Sh(CSh)	-0.0510**	0.0164	0.0020*	0.0008	-0.0003	0.0003	0.0058	0.0051	0.2556	0.0455
Sh(SSh)	-0.0386**	0.0146	0.0024**	0.0006	-0.0003	0.0002	0.0119*	0.0058	0.2971	0.0415
C(Sh)	-0.0300*	0.0148	0.0021**	0.0007	-0.0005*	0.0002	-0.0035	0.0044	0.1694	0.0452
C(CH)	-0.0247	0.0155	0.0018**	0.0006	-0.0006*	0.0003	0.0079	0.0048	0.2520	0.0415
C(CA)	-0.0693**	0.0149	0.0017**	0.0006	-0.0004	0.0003	0.0050	0.0040	0.3237	0.0404
C(CSh)	-0.0615**	0.0151	0.0010	0.0006	-0.0001	0.0002	0.0046	0.0056	0.2366	0.0438
S(Sh)	-0.0280*	0.0119	0.0019**	0.0005	-0.0002	0.0002	0.0063	0.0045	0.1312	0.0485
S(SH)	-0.0293*	0.0140	0.0028**	0.0007	-0.0005	0.0002	0.0098	0.0054	0.3093	0.0400
S(SA)	-0.0197	0.0169	0.0009	0.0006	-0.0003	0.0002	0.0134	0.0053	0.1466	0.0427
S(SSh)	-0.0118	0.0172	0.0015	0.0007	-0.0007**	0.0003	0.0080	0.0059	0.1546	0.0479

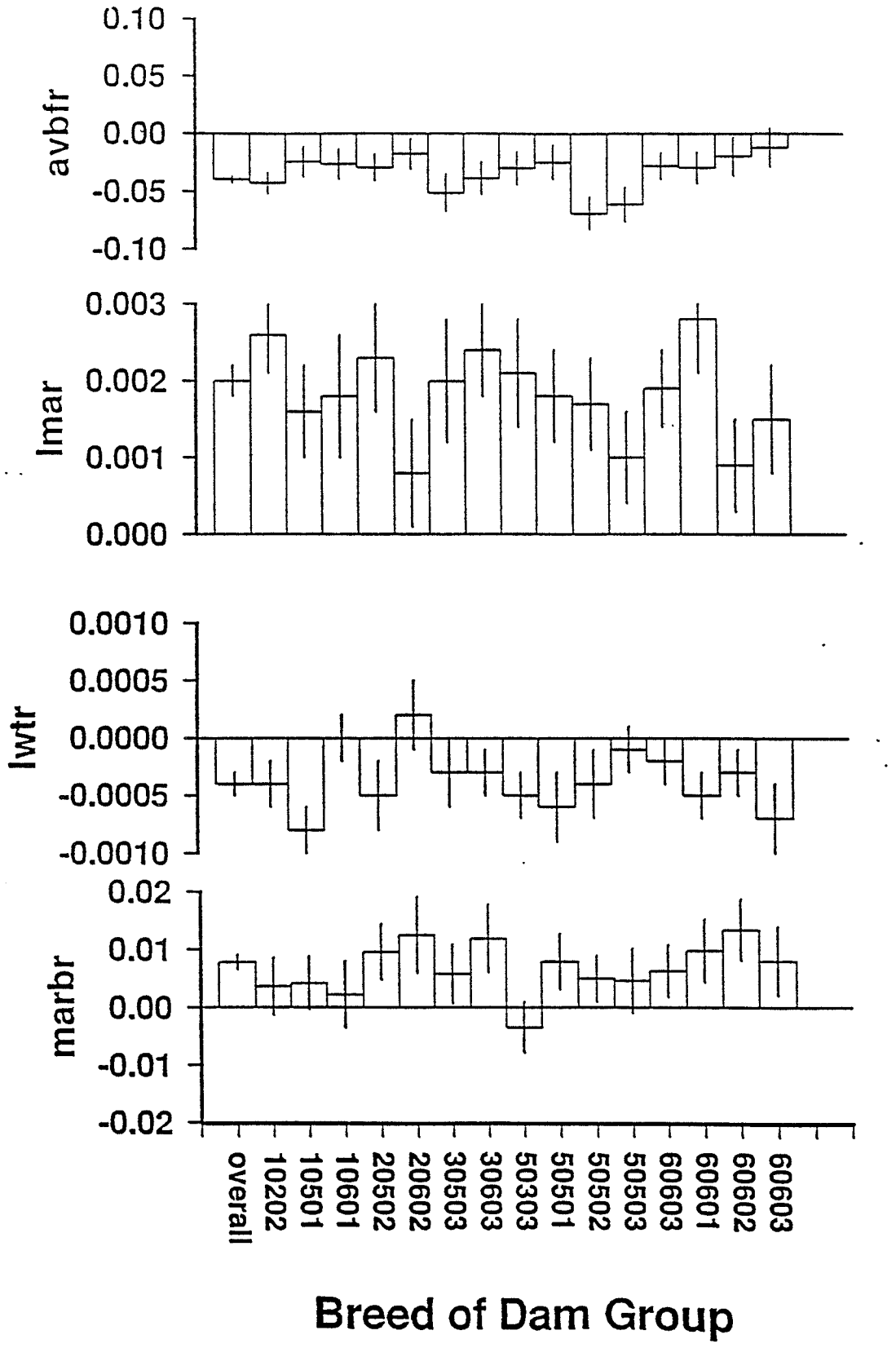

Figure 4. Variation among breed of dam groups for the regression coefficients for four variables used to predict carcass value 1 per kilogram of carcass weight.

The regression coefficients for carcass values and carcass values per kilogram of carcass weight and their respective standard errors are presented in Tables 18 and 19. Average backfat thickness was a significant ($P < .05$) variable in predicting carcass values 3 and 5 which represented carcass values determined using lower price sets. It was not a significant ($P > .05$) variable in predicting carcass value 4 and 6 which were determined using the higher price sets. This is explained by the relationship between backfat thickness and amount of muscle in the carcass. At a constant weight it has been determined that higher levels of backfat correspond to lower amounts of muscle in the carcass and particularly in the higher valued cuts. The greatest range of prices in the price sets used for this study were found to be in the higher priced cuts. Therefore the carcass values created using with price sets (3 and 5) were influenced by the levels of backfat thickness because this variable is correlated with the amount of meat in the carcass. Differences in the quantity of cuts at low prices is more significant on the overall carcass value than differences at high prices. The coefficients for longissimus dorsi muscle area, live weight and the interaction between average backfat thickness and longissimus dorsi muscle area were significant ($P < .05$) for all carcass values 3 through 6 and were similar in both sign and value across each carcass value. The R^2 values for each regression analysis was the same (0.76) for each carcass value 3

Table 18. Regression coefficients for carcass values derived using different price sets.

	cv3r		cv4r		cv5r		cv6r	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.
intercept	-1.131	0.608	-1.311	0.752	-1.242	0.653	-1.197	0.696
avgbfr ($/mm)	-3.746*	1.806	-3.089	2.232	-5.482**	1.938	-2.121	2.066
lmar ($/cm^2)	1.744**	0.084	2.165**	0.104	1.856**	0.090	2.040**	0.096
lwtr ($/kg)	1.791**	0.031	2.229**	0.039	1.918**	0.034	2.037**	0.036
bflma ($/mmcm^2)	-0.881**	0.203	-1.024**	0.251	-0.974**	0.218	-0.907**	0.232
r^2	0.760		0.762		0.759		0.759	
$\sqrt{MSE}$	23.69		29.291		25.426		27.112	

** P<0.01, * P<0.05

Table 19. Regression coefficients for carcass values per kilogram of carcass weight derived using different price sets.

	cvpkcw3r		cvpkcw4r		cvpkcw5r		cvpkcw6r	
	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.	coefficient	s.e.
intercept ($)	-0.0005	0.0010	-0.0005	0.0013	-0.0005	0.0011	-0.0009	0.0012
avgbfr ($/mm)	-0.0362**	0.0031	-0.0394**	0.0039	-0.0439**	0.0033	-0.0336**	0.0037
lmar ($/cm^2)	0.0018**	0.0001	0.0023**	0.0002	0.0019**	0.0002	0.0023**	0.0002
lwtr ($/kg)	-0.0003**	0.0001	-0.0004**	0.0001	-0.0003**	0.0001	-0.0004**	0.0001
marbr ($/unit)	0.0071**	0.0012	0.0082**	0.0015	0.0085**	0.0013	0.0072**	0.0014
r^2	0.2372		0.2140		0.2586		0.2040	
$\sqrt{MSE}$	0.0413		0.0516		0.0442		0.0499	

** P<0.01, * P<0.05

through 6. The correlations between these same carcass values were high, ranging from 0.997 to 1.000, indicating that these carcass values were very similar.

Since the prediction equations for carcass values 3 through 6 were much the same, it is apparent that within the restricted price sets used, the differences in prices of individual cuts did not affect the variables used to predict the carcass values. Perhaps if the price sets used had a wider range between high and low prices there may have been differences in the prediction equations but within the price ranges for 1994 this did not occur.

Examination of the regression coefficients for the carcass values on a per kilogram of carcass weight basis gave similar results. The four variables used, average backfat thickness, longissimus dorsi muscle area, live weight and marbling score were significant ($P < .05$) and similar in value and sign for all the price sets used. The R^2 values ranged from 0.2040 to 0.2586. These results lend further support that within the price sets used, whether high or low prices, did not seem to effect the prediction equation when predicting carcass value per kilogram of carcass weight.

5. Carcass Cut Characteristics

In theory, if cattle displayed a large amount of variation in the distribution of individual muscles it could be possible that this would affect carcass value. Suppose a

type of cattle were identified which had a higher proportion of muscle mass in one area of the carcass and this represented the area where most of the higher priced cuts originate. These animals, at the same weight and age as an average type of cattle, then would have a higher carcass value simply because more of its muscle mass is located within the higher priced cuts.

Analysis of the top and bottom 10% of the carcass value data was performed to see if there was a difference in the weights and proportions of cuts according to carcass value. Did the higher valued carcasses have a greater proportion of higher valued cuts? In Table 20 the proportion of each cut as a percentage of the total cold carcass weight can be seen. The mean weights of the individual cuts for each sub-group; top, bottom and overall average were used to calculate the percentages. The proportion of each cut relative to the carcass is the same for higher valued, lower valued and the overall average carcass valued groups. The carcasses with the higher values were those which were the largest. It was apparent that size was important in determining the value of the carcass. There was no evidence that higher-valued carcasses had increases in the proportions of higher priced cuts in relation to any of the other carcasses. The similarity seen between the percentages of individual cuts in relation to the whole carcass regardless of carcass value group agree with the findings of Berg and Butterfield, (1976) who claimed that muscle distribution was quite constant within sex

Table 20. Proportion of individual cuts as a percentage of cold carcass weight

Wholesale cut	Carcass Value 1					
	Top 10%		Bottom 10%		Overall Average	
	Mean (kg)	Percent	Mean (kg)	Percent	Mean (kg)	Percent
Shortloin	18.198	6.4	15.708	6.5	16.164	6.2
Rib	32.722	11.5	27.688	11.4	30.052	11.5
Sirloin Butt	24.502	8.6	20.136	8.3	22.294	8.6
Round	71.266	25.0	58.472	24.1	63.564	24.4
Chuck	74.374	26.0	62.862	25.9	67.704	26.0
Brisket	11.738	4.1	10.498	4.3	10.320	4.0
Shank	9.600	3.4	8.368	3.4	8.852	3.4
Flank	17.126	6.0	14.834	6.1	16.146	6.2
Other	52.262	18.2	49.174	20.2	50.578	19.4
Carcass Weight	285.655		243.153		260.385	
Cvalue1 ($)	1138.060		942.471		1030.210	

and slaughter weight groups and is little influenced by breed. In this data set there were no over-weight cattle marketed. The design of the experiment was to analyze cattle at appropriate slaughter weights and degrees of finish to achieve A1,A2 grades. The entire aspect of price discounting on overweight market animals is not applicable in this analysis but it should be considered that the heavier the animal the higher its carcass value applies only up to a certain weight. If this is exceeded, the value of the carcass will be penalized and subjected to substantial price discounts.

All breed groups of dam were present in the top 10% of the carcass values and also the bottom 10%. It did not appear that any one breed group achieved consistently higher carcass values over another.

Since a consistent relationship between muscles exist, prediction equations can be used to predict composition and muscle weights on those muscles that can not be measured directly.

6. Genetic Parameters

Table 21 shows the estimated heritability for carcass trait measurements and fabricated wholesale cuts. The heritabilities calculated for average backfat thickness, longissimus dorsi muscle area, live weight and marbling score were much lower than

Table 21. Heritabilities of calculated carcass values, "live animal" measurements and wholesale cuts.

Variable	Heritability (h^2)
CV1R	0.160
CV3R	0.160
CV4R	0.160
CV5R	0.160
CV6R	0.160
CVPKCW1R	0.170
CVPKCW3R	0.180
CVPKCW4R	0.170
CVPKCW5R	0.190
CVPKCW6R	0.170
AVGBFR	0.180
LMAR	0.200
LWTR	0.100
MARBR	0.140
SHLOINR	0.150
RIBR	0.140
SBUTTR	0.290
ROUNDR	0.120
CHUCKR	0.20
BRISKR	0.060
SHANKR	0.27
FLANKR	0.180

those calculated by Koots et al. (1994) in their review of genetic parameters found in the literature over the past fifty years. Heritability estimates for the individual cuts used in this study were not found in the literature therefore comparisons could not be accommodated. It is believed that carcass traits are highly heritable. The heritabilities calculated from this data set are moderate to low. Caution should be exercised when interpreting these heritabilities. They appear to be substantially lower than other published results.

Genetic and phenotypic correlations were calculated for the same set of variables as the heritabilities and are shown in Table 22. Comparisons with the literature could be made for the correlations involving combinations of average backfat thickness, longissimus dorsi muscle area, live weight and marbling score. Tables 23 and 24 show a summary of the genetic and phenotypic correlations for which comparisons could be found in the literature. Of the genetic correlations, that between longissimus dorsi muscle area and marbling score was the only result found to be similar to literature results. The phenotypic correlations on the other hand compared much more favourably to results found in the literature, especially with the review paper by Koots et al. (1994b). Again, caution should be used when interpreting these results especially for correlations involving the cuts since examples of similar estimates could not be found. For three genetic correlations, live weight and chuck (1.134), live weight and brisket (2.369) and live weight and shank (1.648) the value of the

Table 22. Genetic and phenotypic correlations between variables.[1]

	1	2	3	4	5	6	7	8	9	10	11	12
1. AVGBFR		-0.301	-0.063	0.161	0.256	0.340	-0.271	-0.126	0.063	0.303	-0.266	0.541
2. LMAR	-0.197		-0.094	-0.163	0.619	0.639	0.216	0.097	0.057	0.128	0.366	-0.244
3. LWTR	0.131	0.264		-0.184	0.544	0.218	0.402	0.309	1.134	2.369	1.648	-0.080
4. MARBR	-0.155	0.072	-0.038		-0.237	-0.458	-0.153	0.015	-0.373	-0.280	-0.103	-0.090
5. SHLOINR	0.102	0.371	0.557	-0.018		0.588	0.313	0.402	0.389	0.155	0.376	0.302
6. RIBR	0.181	0.327	0.248	-0.120	0.337		0.185	0.143	0.308	0.557	0.227	-0.191
7. ROUNDR	-0.207	0.437	0.639	0.128	0.466	0.380		0.487	0.531	0.286	0.859	-0.281
8. SBUTTR	-0.028	0.345	0.551	0.067	0.393	0.360	0.552		0.331	0.301	0.295	-0.126
9. CHUCKR	0.074	0.311	0.666	-0.005	0.486	0.500	0.623	0.516		0.738	0.564	-0.082
10. BRISKR	1.944	0.066	0.134	-0.076	0.205	0.243	0.196	0.205	0.219		-0.051	0.332
11. SHANKR	-0.112	0.203	-0.017	0.065	0.271	0.173	4.326	0.256	0.254	0.196		-0.159
12. FLANKR	0.410	0.016	0.446	-0.192	0.252	0.380	0.071	0.200	0.297	0.266	-0.023	

[1] Genetic correlations above the diagonal, phenotypic correlations below the diagonal.

Table 23. Comparisons of phenotypic correlations.

	Present Study	Koots	Johnston	Wilson	Veseth
AVGBFR &LMAR	-0.197	-0.110		-0.080	
AVGBFR & LWTR	0.131	0.190			
AVGBFR & MARBR	-0.155	0.240		0.120	
LMAR & LWTR	0.264	0.330			0.340
LMAR & MARBR	0.072	0.060	-0.090	-0.010	0.280
LWTR & MARBR	-0.038	0.150			0.240

Table 24. Comparisons of genetic correlations.

	Present Study	Koots	Johnston	Wilson	Veseth
AVGBFR &LMAR	-0.301	0.010		-0.060	
AVGBFR & LWTR	-0.063	0.000			
AVGBFR & MARBR	0.161	0.350		-0.130	
LMAR & LWTR	-0.094	0.430			0.710
LMAR & MARBR	-0.163	-0.210	0.240	-0.040	0.510
LWTR & MARBR	-0.184	0.340			0.470

correlation exceeded one which is theoretically impossible. Similarly for two phenotypic correlations, average backfat thickness and brisket (1.944) and round and shank (4.326) the value of the correlation exceeded one. The validity of the genetic and phenotypic correlations is under question. It is believed that the genetic parameters estimated using pre-adjusted, Proc Varcomp-REML procedures to this data set were unusual compared to those found in the literature. A possible reason for this occurrence is thought to be the small sample size with regards to the number of sires used (38).

CONCLUSIONS

In this study, a value was assigned for each carcass in the data set based on the quantity and price of the individual wholesale cuts that make up the carcass. The derived carcass values and other variables describing carcass traits were analyzed using correlation analysis to compare the data set to other studies. The relationships between measurements that could be taken from the live animal using ultrasound technology (average backfat thickness, longissimus dorsi muscle area, live weight and marbling score) were consistent to results found from similar studies throughout the literature.

Regression analysis was used to construct an equation predicting carcass value using measurements that could be taken from the live animal using ultrasound technology. The prediction equation explained 76% of the variation found in carcass value which was comparable to similar estimates found in the literature. The equation using the same variables, with the exception of the interaction between backfat thickness and longissimus dorsi muscle area being replaced with marbling score, when used to predict carcass value per kilogram of carcass weight accounted for only 24% of the variation found in that value. Although the R^2 was lower for the carcass value when expressed as a proportion of the total carcass, this result too, was consistent to that found in the literature.

The differences in prices used to calculate the carcass values did not seem to have an effect on the accuracy or significance of the prediction equation. Whether high or low prices were used the prediction equation was altered little. Similarly, breed of dam did not have a significant effect on the prediction equation as it did not generally change between breed of dam groups. Also, when the coefficient values were compared across all breed of dam groups and taking into consideration the standard errors, there were no significant differences between the breeds. In fact, the breed of dam groups were more similar than different.

A comparison between the top and bottom 10% of the data set with respect to carcass values was made to see if there were any differences in body composition between animals producing high valued carcasses and those with low valued carcasses. As expected, there were no differences in the percentage of weight for each individual cut with respect to the weight of the entire carcass for the higher valued carcasses or the lower valued carcasses.

Estimates for genetic parameters such as heritabilities and phenotypic and genetic correlations were calculated for carcass values, "live animal" measurements and individual wholesale cuts. The heritabilities which were calculated were consistently lower than other reported heritabilities found throughout the literature for similar traits (live animal measurements). The phenotypic correlations between live animal traits

compared favourably to other published estimates, however, the genetic correlations did not seem to compare as well. Caution was exercised in interpreting the genetic parameters, and it is felt that the sample size of the data set was too small to accurately make genetic assessments for the data.

The overall results found in this study are generally consistent to those found in the literature from similar studies. The prediction equation that was calculated compares favourably to other prediction equations that have been developed. The heritabilities and correlations (particularly the genetic), should regarded with some caution, since they were somewhat different from those reported in the literature.

An equation that can accurately predict carcass merit in the live animal would be of great value to the cattle industry. Currently, animals are evaluated for slaughter on the basis of a visual appraisal. With the implementation of a privatized grading system in Canada and the move towards auotomated grading technology the human error and bias in subjective evaluations will be reduced if not eliminated. Thus it is logical that evaluation of the live animal throught the use of ultrasound technology and development of prediction equations be implemented as well. Further research into the relationships between carcass measurements taken on live animals using ultrasound technology and carcass quality and value need to be conducted to develop a standard prediction equation across the industry.

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Appendix Table 1. Breed of dam effects for 010202.

Hereford (Angus)		
Variable	Unit	Breed Effect
cv1r	$	-16.66
cv2r	$	-14.77
cv3r	$	-15.30
cv4r	$	-17.86
cv5r	$	-17.01
cv6r	$	-16.18
cvpkcw1r	$/kg	-0.02
cvpkcw3r	$/kg	-0.02
cvpkcw4r	$/kg	-0.02
cvpkcw5r	$/kg	-0.02
cvpkcw6r	$/kg	-0.02
avgbfr	mm	+0.21
lmar	cm^2	-2.61
lwtr	kg	-5.11
marbr	index	-0.11
shloinr	kg	-0.01
ribr	kg	+0.01
sbuttr	kg	-0.34
roundr	kg	-0.42
chuckr	kg	-0.41
briskr	kg	-0.05
shankr	kg	-0.15
flankr	kg	+0.32

Appendix Table 2. Breed of dam effects for 010501.

Hereford (Charolais X Hereford)		
Variable	Unit	Breed Effect
cv1r	$	-12.80
cv2r	$	-14.51
cv3r	$	-11.63
cv4r	$	-14.12
cv5r	$	-12.61
cv6r	$	-12.91
cvpkcw1r	$/kg	0.000
cvpkcw3r	$/kg	-0.001
cvpkcw4r	$/kg	0.000
cvpkcw5r	$/kg	-0.001
cvpkcw6r	$/kg	+0.001
avgbfr	mm	-0.06
lmar	cm^2	-1.74
lwtr	kg	-2.71
marbr	index	+0.16
shloinr	kg	-0.06
ribr	kg	-0.13
sbuttr	kg	-0.10
roundr	kg	-0.68
chuckr	kg	-0.35
briskr	kg	+0.07
shankr	kg	-0.10
flankr	kg	-0.16

Appendix Table 3. Breed of dam effects for 010601.

Hereford (Simmental X Hereford)		
Variable	Unit	Breed Effect
cv1r	$	-17.61
cv2r	$	-16.73
cv3r	$	-15.89
cv4r	$	-19.62
cv5r	$	-17.12
cv6r	$	-18.02
cvpkcw1r	$/kg	-0.004
cvpkcw3r	$/kg	-0.004
cvpkcw4r	$/kg	-0.004
cvpkcw5r	$/kg	-0.004
cvpkcw6r	$/kg	-0.004
avgbfr	mm	+0.09
lmar	cm^2	-2.31
lwtr	kg	-5.26
marbr	index	-0.08
shloinr	kg	-0.16
ribr	kg	-0.18
sbuttr	kg	-0.21
roundr	kg	-0.82
chuckr	kg	-0.61
briskr	kg	-0.14
shankr	kg	-0.04
flankr	kg	-0.03

Appendix Table 4. Breed of dam effects for 020502.

	Angus (Charolais X Angus)	
Variable	Unit	Breed Effect
cv1r	$	-5.72
cv2r	$	-3.67
cv3r	$	-5.29
cv4r	$	-5.90
cv5r	$	-5.70
cv6r	$	-6.02
cvpkcw1r	$/kg	-0.01
cvpkcw3r	$/kg	-0.01
cvpkcw4r	$/kg	-0.01
cvpkcw5r	$/kg	-0.01
cvpkcw6r	$/kg	-0.01
avgbfr	mm	+0.10
lmar	cm^2	+0.50
lwtr	kg	-0.28
marbr	index	-0.20
shloinr	kg	-0.04
ribr	kg	-0.11
sbuttr	kg	-0.18
roundr	kg	-0.47
chuckr	kg	+0.22
briskr	kg	+0.02
shankr	kg	-0.11
flankr	kg	+0.28

Appendix Table 5. Breed of dam effects for 020602.

	Angus (Simmental X Angus)	
Variable	Unit	Breed Effect
cv1r	$	-7.70
cv2r	$	-5.16
cv3r	$	-7.15
cv4r	$	-7.97
cv5r	$	-8.15
cv6r	$	-7.22
cvpkcw1r	$/kg	-0.02
cvpkcw3r	$/kg	-0.02
cvpkcw4r	$/kg	-0.02
cvpkcw5r	$/kg	-0.02
cvpkcw6r	$/kg	-0.02
avgbfr	mm	+0.18
lmar	cm^2	-1.37
lwtr	kg	-0.10
marbr	index	-0.20
shloinr	kg	+0.08
ribr	kg	+0.14
sbuttr	kg	-0.30
roundr	kg	-0.75
chuckr	kg	-0.10
briskr	kg	-0.07
shankr	kg	-0.08
flankr	kg	+0.30

Appendix Table 6. Breed of dam effects for 030503.

Shorthorn (Charolais X Shorthorn)		
Variable	Unit	Breed Effect
cv1r	$	-6.76
cv2r	$	-2.65
cv3r	$	-6.22
cv4r	$	-7.16
cv5r	$	-6.66
cv6r	$	-7.11
cvpkcw1r	$/kg	-0.03
cvpkcw3r	$/kg	-0.02
cvpkcw4r	$/kg	-0.03
cvpkcw5r	$/kg	-0.03
cvpkcw6r	$/kg	-0.03
avgbfr	mm	+0.01
lmar	cm^2	-3.00
lwtr	kg	-0.30
marbr	index	-0.09
shloinr	kg	-0.05
ribr	kg	-0.23
sbuttr	kg	-0.17
roundr	kg	-0.47
chuckr	kg	+0.10
briskr	kg	+0.19
shankr	kg	-0.05
flankr	kg	+0.31

Appendix Table 7. Breed of dam effects 030603.

Shorthorn (Simmental X Shorthorn)		
Variable	Unit	Breed Effect
cv1r	$	-3.27
cv2r	$	-1.90
cv3r	$	-3.10
cv4r	$	-3.24
cv5r	$	-3.65
cv6r	$	-2.90
cvpkcw1r	$/kg	-0.02
cvpkcw3r	$/kg	-0.02
cvpkcw4r	$/kg	-0.02
cvpkcw5r	$/kg	-0.02
cvpkcw6r	$/kg	-0.02
avgbfr	mm	+0.06
lmar	cm^2	-1.25
lwtr	kg	+2.61
marbr	index	-0.20
shloinr	kg	+0.06
ribr	kg	+0.01
sbuttr	kg	-0.03
roundr	kg	-0.57
chuckr	kg	+0.04
briskr	kg	+0.28
shankr	kg	-0.02
flankr	kg	+0.24

Appendix Table 8. Breed of dam effects 050303.

Charolais (Shorthorn)		
Variable	Unit	Breed Effect
cv1r	$	+14.20
cv2r	$	+14.63
cv3r	$	+12.99
cv4r	$	+15.44
cv5r	$	+13.85
cv6r	$	+14.43
cvpkcw1r	$/kg	0.000
cvpkcw3r	$/kg	0.000
cvpkcw4r	$/kg	-0.002
cvpkcw5r	$/kg	0.000
cvpkcw6r	$/kg	-0.008
avgbfr	mm	-0.01
lmar	cm^2	-0.34
lwtr	kg	+4.02
marbr	index	-0.20
shloinr	kg	+0.03
ribr	kg	+0.33
sbuttr	kg	+0.19
roundr	kg	+0.51
chuckr	kg	+0.30
briskr	kg	+0.03
shankr	kg	+0.03
flankr	kg	+0.15

Appendix Table 9. Breed of dam effects for 050501.

Charolais (Charolais X Hereford)		
Variable	Unit	Breed Effect
cv1r	$	+10.05
cv2r	$	+6.67
cv3r	$	+9.28
cv4r	$	+10.62
cv5r	$	+10.22
cv6r	$	+10.01
cvpkcw1r	$/kg	+0.03
cvpkcw3r	$/kg	+0.02
cvpkcw4r	$/kg	+0.03
cvpkcw5r	$/kg	+0.03
cvpkcw6r	$/kg	+0.03
avgbfr	mm	-0.18
lmar	cm^2	+0.40
lwtr	kg	-0.84
marbr	index	+0.25
shloinr	kg	+0.01
ribr	kg	+0.08
sbuttr	kg	+0.28
roundr	kg	+0.79
chuckr	kg	+0.04
briskr	kg	-0.12
shankr	kg	+0.06
flankr	kg	-0.29

Appendix Table 10. Breed of dam effects for 050502.

Charolais (Charolais X Angus)		
Variable	Unit	Breed Effect
cv1r	$	+14.36
cv2r	$	+10.99
cv3r	$	+13.06
cv4r	$	+15.68
cv5r	$	+14.33
cv6r	$	+14.52
cvpkcw1r	$/kg	+0.03
cvpkcw3r	$/kg	+0.02
cvpkcw4r	$/kg	+0.03
cvpkcw5r	$/kg	+0.03
cvpkcw6r	$/kg	+0.03
avgbfr	mm	-0.15
lmar	cm^2	+3.74
lwtr	kg	-1.06
marbr	index	+0.32
shloinr	kg	+0.09
ribr	kg	+0.09
sbuttr	kg	+0.22
roundr	kg	+1.03
chuckr	kg	+0.25
briskr	kg	-0.13
shankr	kg	+0.14
flankr	kg	-0.35

Appendix Table 11. Breed of dam effects for 050503.

Charolais (Charolais X Shorthorn)		
Variable	Unit	Breed Effect
cv1r	$	+11.46
cv2r	$	+8.62
cv3r	$	+10.40
cv4r	$	+12.49
cv5r	$	+11.66
cv6r	$	+11.44
cvpkcw1r	$/kg	+0.03
cvpkcw3r	$/kg	+0.03
cvpkcw4r	$/kg	+0.03
cvpkcw5r	$/kg	+0.03
cvpkcw6r	$/kg	+0.03
avgbfr	mm	-0.17
lmar	cm^2	+2.97
lwtr	kg	-1.53
marbr	index	+0.34
shloinr	kg	+0.08
ribr	kg	-0.10
sbuttr	kg	+0.20
roundr	kg	+1.09
chuckr	kg	+0.17
briskr	kg	-0.13
shankr	kg	+0.10
flankr	kg	-0.36

Appendix Table 12. Breed of dam effects for 060303.

Simmental (Shorthorn)		
Variable	Unit	Breed Effect
cv1r	$	-1.26
cv2r	$	+0.91
cv3r	$	-1.12
cv4r	$	-1.46
cv5r	$	-1.24
cv6r	$	-1.32
cvpkcw1r	$/kg	-0.01
cvpkcw3r	$/kg	-0.01
cvpkcw4r	$/kg	-0.02
cvpkcw5r	$/kg	-0.01
cvpkcw6r	$/kg	-0.01
avgbfr	mm	+0.05
lmar	cm^2	-0.01
lwtr	kg	+1.79
marbr	index	-0.13
shloinr	kg	-0.003
ribr	kg	-0.06
sbuttr	kg	+0.03
roundr	kg	-0.10
chuckr	kg	-0.03
briskr	kg	+0.15
shankr	kg	-0.04
flankr	kg	+0.13

Appendix Table 13. Breed of dam effects for 060601.

Simmental (Simmental X Hereford)		
Variable	Unit	Breed Effect
cv1r	$	+1.57
cv2r	$	-0.11
cv3r	$	+1.62
cv4r	$	+1.14
cv5r	$	+2.01
cv6r	$	+1.18
cvpkcw1r	$/kg	+0.01
cvpkcw3r	$/kg	+0.01
cvpkcw4r	$/kg	+0.01
cvpkcw5r	$/kg	+0.01
cvpkcw6r	$/kg	+0.01
avgbfr	mm	-0.06
lmar	cm^2	+1.91
lwtr	kg	+1.61
marbr	index	+0.13
shloinr	kg	-0.09
ribr	kg	+0.03
sbuttr	kg	+0.08
roundr	kg	+0.52
chuckr	kg	-0.14
briskr	kg	-0.15
shankr	kg	+0.03
flankr	kg	-0.28

Appendix Table 14. Breed of dam effects for 060602.

Simmental (Simmental X Angus)		
Variable	Unit	Breed Effect
cv1r	$	+7.22
cv2r	$	+5.56
cv3r	$	+6.56
cv4r	$	+7.89
cv5r	$	+7.26
cv6r	$	+7.15
cvpkcw1r	$/kg	+0.01
cvpkcw3r	$/kg	+0.01
cvpkcw4r	$/kg	+0.01
cvpkcw5r	$/kg	+0.01
cvpkcw6r	$/kg	+0.01
avgbfr	mm	-0.10
lmar	cm^2	+1.73
lwtr	kg	+1.31
marbr	index	+0.01
shloinr	kg	+0.03
ribr	kg	+0.02
sbuttr	kg	+0.10
roundr	kg	+0.50
chuckr	kg	+0.22
briskr	kg	-0.04
shankr	kg	+0.08
flankr	kg	-0.20

Appendix Table 15. Breed of dam effects for 060603.

Simmental (Simmental X Shorthorn)		
Variable	Unit	Breed Effect
cv1r	$	+12.91
cv2r	$	+12.10
cv3r	$	+11.76
cv4r	$	+14.07
cv5r	$	+12.81
cv6r	$	+12.94
cvpkcw1r	$/kg	+0.01
cvpkcw3r	$/kg	+0.01
cvpkcw4r	$/kg	+0.01
cvpkcw5r	$/kg	+0.01
cvpkcw6r	$/kg	+0.01
avgbfr	mm	-0.09
lmar	cm^2	+1.38
lwtr	kg	+5.86
marbr	index	+0.02
shloinr	kg	+0.04
ribr	kg	+0.10
sbuttr	kg	+0.24
roundr	kg	+0.83
chuckr	kg	+0.29
briskr	kg	+0.09
shankr	kg	+0.15
flankr	kg	-0.07

Appendix Table 16. Limousin sires used in this study and number of offspring of each bull.

Sire	Sire ID	Number of Offspring
1.	64	1
2.	130	17
3.	129	26
4.	128	32
5.	127	25
6.	14	114
7.	29	96
8.	31	109
9.	44	19
10.	69	105
11.	78	28
12.	4	43
13.	84	49
14.	97	11
15.	5	18
16.	19	44
17.	21	42
18.	26	104
19.	27	27
20.	28	50
21.	52	43
22.	84	37
23.	100	52
24.	101	49
25.	32	18
26.	45	71
27.	107	70
28.	108	64
29	109	74
30.	110	61
31.	111	75
32.	112	41
33.	113	57
34.	114	47
35.	115	77
36.	116	70
37.	117	73
38.	123	68

Appendix Table 17. Montreal wholesale primal and sub-primal beef prices.

1994	Shortloin	Rib	Sirloin Butt	Round	Chuck	Brisket	Shank	Flank
January	6.74	5.56	5.55	4.42	3.67	2.34	2.31	2.32
February	6.81	5.48	5.53	4.44	3.58	2.36	2.33	2.35
March	7.35	5.89	5.69	4.68	3.63	2.35	2.35	2.36
April	8.69	6.21	6.02	4.62	4.13	2.34	no quote	2.45
May	10.26	6.30	6.01	4.32	3.18	2.25	2.26	2.31
June	9.82	6.21	5.95	4.14	3.03	2.17	2.12	2.22
July	9.18	6.26	6.12	4.05	3.05	2.19	2.15	2.26
August	8.67	6.15	6.01	4.25	3.34	2.19	2.13	2.27
September	7.77	5.61	5.92	4.34	3.45	2.12	2.09	2.21
October	6.60	5.45	5.88	4.54	3.36	2.04	2.12	2.17
November	6.98	5.69	5.99	4.68	3.40	1.96	2.06	2.10
December	7.17	5.91	5.97	4.57	3.33	2.00	2.11	2.13
Average	8.00	5.89	5.89	4.42	3.43	2.19	2.18	2.26

Source: Agriculture and Agrifood Canada (Canada Livestock and Meat Trade Report).
Prices quoted in Canadian dollars per kilogram.

Appendix Table 18. Correlations of "live animal" measurement residuals.

	lmar	lwtr	marbr
avgbfr	-0.191**	0.112**	-0.147**
lmar		0.261**	0.073**
lwtr			-0.039

** P<0.01, * P<0.05
The n for these correlations ranged from 1996 to 2007.
Correlations were calculated before breed of dam effects were added back into the data set.
"live animal" measurements were taken from the carcass but could be measured from the live animal by the use of ultrasound.

Appendix Table 19. Correlations of wholesale cut residuals.

	ribr	sbuttr	roundr	chuckr	briskr	shankr	flankr
shloinr	0.348**	0.392**	0.469**	0.487**	0.215**	0.287**	0.249**
ribr		0.373**	0.386**	0.522**	0.254**	0.179**	0.391**
sbuttr			0.550**	0.519**	0.211**	0.266**	0.208**
roundr				0.630**	0.198**	0.517**	0.083**
chuckr					0.220**	0.259**	0.301**
briskr						0.195**	0.281**
shankr							0.00

** P< 0.01, *P< 0.05
The n for these correlations ranged from 1924 to 2007.
Correlations were calculated before breed of dam effects were added back into the data set.

Appendix Table 20. Correlations of calculated carcass value residuals.

	cv2r	cv3r	cv4r	cv5r	cv6r	cvpkcwr
cv1r	0.986**	1.000**	1.000**	1.000**	0.999**	0.214**
cv2r		0.986**	0.985**	0.987**	0.983**	0.094**
cv3r			0.999**	1.000**	0.998**	0.213**
cv4r				0.998**	0.999**	0.212**
cv5r					0.997**	0.214**
cv6r						0.221**

** P<0.01, * P<0.05
The n for these correlations ranged from 1686 to 1921.
Correlations were calculated before breed of dam effects were added back into the data set.

Appendix Table 21. Correlations of calculated carcass value residuals and residuals of "live animal" measurements.

	cv1r	cv2r	cv3r	cv4r	cv5r	cv6r	cvpkcwr
avgbfr	0.037	0.069**	0.035	0.042	0.027	0.045*	-0.307**
lmar	0.446**	0.410**	0.445**	0.445**	0.445**	0.449**	0.292**
lwtr	0.821**	0.847**	0.820**	0.822**	0.819**	0.819**	-0.095**
marbr	-0.003	-0.020	-0.002	-0.005	0.003	-0.007	0.175**

** P<0.01, * P<0.05
The n for these correlations ranged from 1680 to 1921.
Correlations were calculated before breed of dam effects were added back into the data set.
"live animal" measurements were taken from the carcass but could be measured from the live animal by the use of ultrasound.

Appendix Table 22. Correlations of calculated carcass value residuals and wholesale cut residuals.

	cv1r	cv2r	cv3r	cv4r	cv5r	cv6r	cvpkcwr
chuckr	0.681**	0.645**	0.670**	0.699**	0.663**	0.709**	0.285**
ribr	0.698**	0.656**	0.702**	0.692**	0.691**	0.702**	0.084**
shloinr	0.701**	0.675**	0.705**	0.692**	0.706**	0.696**	0.322**
sbuttr	0.827**	0.821**	0.829**	0.819**	0.838**	0.815**	0.310**
roundr	0.838**	0.843**	0.836**	0.844**	0.840**	0.826**	0.018
briskr	0.348**	0.372**	0.348**	0.345**	0.343**	0.350**	-0.087**
shankr	0.434**	0.453**	0.435**	0.430**	0.438**	0.432**	0.063**
flankr	0.368**	0.449**	0.368**	0.369**	0.360**	0.372**	-0.375**

** P<0.01, * P<0.05

The n for these correlations ranged from 1686 to 1921.

Correlations were calculated before breed of dam effects were added back into the data set.

Appendix Table 23. Correlations of "live animal" measurement residuals and wholesale cut residuals.

	avgbfr	lmar	lwtr	marbr
shloinr	0.097**	0.368**	0.555**	-0.020
ribr	0.175**	0.304**	0.564**	-0.134**
sbuttr	-0.028	0.346**	0.546**	0.067**
roundr	-0.198**	0.431**	0.645**	0.124**
chuckr	0.065**	0.303**	0.745**	-0.013
briskr	0.131**	0.053*	0.357**	-0.090**
shankr	-0.166**	0.177**	0.383**	0.035
flankr	0.398**	0.024	0.452**	-0.187**

** P<0.01, * P<0.05

The n for these correlations ranged from 1918 to 2007.

Correlations were calculated before breed of dam effects were added back into the data set.

"live animal" measurements were taken from the carcass but could be measured from the live animal by the use of ultrasound.