

ECONOMICS OF LEPTIN GENOTYPING
OF FINISHED CATTLE

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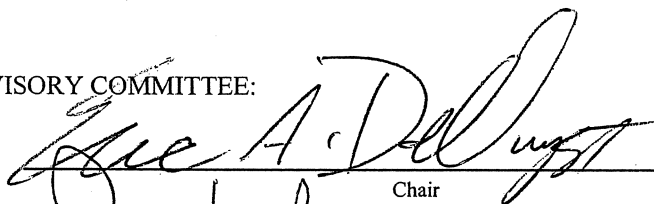
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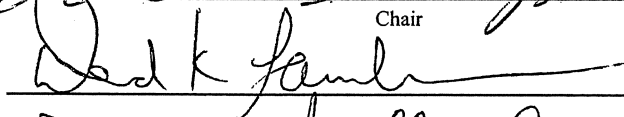
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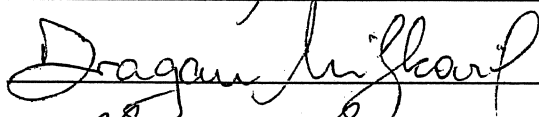
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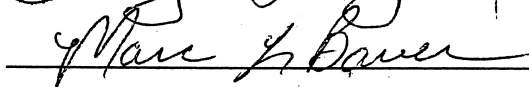
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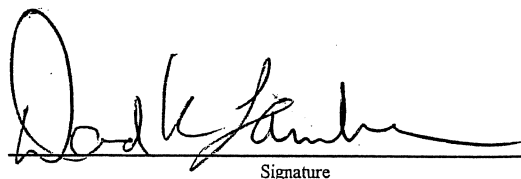






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ABSTRACT

Bullinger, Jared Ray; M.S. Department of Agribusiness and Applied Economics, College of Agriculture, Food Systems, and Nature Resources, North Dakota State University; May 2005. Economics of Leptin Genotyping of Finishing Cattle. Major Professor: Dr. Eric A. DeVuyst.

Previous research regarding the value a beef animals analyzes market values of phenotypic expression of genes. The heritability of this phenotypic information varies from characteristic to characteristic. As the functions of individual genes are identified, it becomes possible more accurately predict progeny phenotypes. Hence, genotypic knowledge should have economic value in the market place. Here, we assess the value of a highly-marketed genetic polymorphism, the leptin gene.

Using data from 180 predominantly Angus cross cattle from a feedlot in Britton, South Dakota, econometric estimations were made to estimate economically-relevant carcass traits for varying days-on-feed. A simulation model was used to determine profit for each day-on-feed throughout the finishing phase. Finally, an optimization was employed to determine the profit-maximizing day-on-feed for each calf. Profitability was then compared with and without knowledge of leptin genotype.

Contrary to literature presented in marketing campaigns, our results indicate that this single polymorphism has no managerial value when marketing feedlot cattle.

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INTRODUCTION

In today's beef industry, producers are faced with a wide range of issues and a wealth of knowledge previously unavailable to address these issues. While a producer's ultimate goal is to maximize profits, many decisions in how to generate that profit-maximizing product must be made. Brester (2002) characterizes the beef industry as one with wide genetic variation, making production of a consistent product difficult.

Brester (2002) argues that the beef industry faces two major disadvantages compared to pork and poultry, beef's major competitors. First, both the pork and poultry industries have used integration and coordination to reduce cost and thus gain market share at the expense of beef. While beef is still marketed as a commodity, poultry and pork markets have become dominated by branded products. Second, the pork and poultry industries have been more receptive in creating convenient, consistent products demanded by consumers; the beef industry has been less receptive. The separation of key elements in the production and processing sectors has led to a lack of coordination between consumers and producers (Hennessy et al. 2004). In order to maintain competitiveness, steps need to be taken to decrease the information gap between producers and consumers.

The quality and consistency of beef are affected by environment, genetics, and management. Both the pork and poultry industries have identified a common environment, management practices, and genetic prototypes most suitable for the production of their desired end products. With beef production, environments differ uncontrollably, while management practices generally vary depending on location, available resources, and operator characteristics. Genetics, however, offer the opportunity for producers to find

certain traits that are superior to others in their quest to produce a consistent, highly desirable product.

The use of genetic information may allow producers to decrease the variation found in beef despite production taking place in a wide variety of environmental and managerial situations. As such, genetic information can be considered an input into the production process. The price a producer would be willing to pay for an input is equal to “the sum of the money values of the input’s characteristics to the purchaser (Ladd and Martin 1976).” Ladd and Gibson (1978) describe economic value as “the amount by which net profit may be expected to increase for a single unit of improvement in that trait.” Investigation is necessary to establish the value of identifying certain inputs.

There are several elements that play a role in determining the value of finished cattle, with the single biggest factor being weight. Quality grade and yield grade are also important determinants. Fat content affects all these factors. A carcass containing more fat will have more total weight, a higher quality grade, and a higher numeric yield grade. As a result, the amount of fat a carcass contains will play a significant role in determining its value.

With fat’s direct effect on value, the amount of fat an animal possesses affects how and when it is marketed. Consequently, feedlot operators are constantly looking for ways to better predict fat content. Polymorphisms of the leptin gene have been shown to affect several traits associated with carcass composition. Buchanan et al. (2002) discusses how polymorphisms of the leptin gene affect 12th rib fat, while Bierman et al. (2001) notes how the polymorphism’s affect both 12th rib fat and marbling in feedlot cattle. With leptin’s

indirect affect on value, the question arises of whether or not feedlot cattle could be more profitably marketed using genetic information.

This paper examines the economic benefit of the knowledge of leptin genotype. Econometric estimations determine carcass traits affecting quality and yield grade. Preliminary estimations are made utilizing the knowledge of leptin genotype. A second econometric model ignoring genetic information is developed. A simulation and optimization model is then utilized to determine the profit maximizing days-on-feed (DOF) for each calf and truck-load lots. A pair-wise t-test is used to compare returns and determine the value of leptin genotyping.

LITERATURE REVIEW

Previous Research

Leptin is a protein hormone produced by white adipose (fatty) tissue. It is released into the blood and transported to the brain. The brain then determines the amount of energy the body will expend (Rodriguez et al. 2002). Rodriguez et al. discuss the relationship between serum leptin levels in the blood and body fat in both humans and rodents.

Leptin has been shown to have several effects on animals. Mice, with a naturally occurring mutation on the leptin gene, produce biologically inactive leptin (Kemp 2003). When leptin was administered to these mice, reduced food intake, increased metabolism, and body weight loss resulted (Kemp 2003). Kemp also notes that an increase in reproductive performance also occurred, indicating that leptin is involved with functions other than fat deposition. The energetic status of beef cattle has also been linked to serum leptin levels. Animals with higher levels seem to maintain an energetic homeostasis (Sansinanae et al. 2001). Due to its coordinating effect on whole body metabolism, “leptin may be classified as a ‘metabolism modifier’ (Houseknecht et al. 1998).”

A nucleotide switch at the 252nd base (single nucleotide protein (SNP)) in exon 2 of the leptin gene has been linked to variation in carcass composition (Buchanan et al. 2002, Geary et al. 2003, Yamada et al. 2003) and feed intake (Lagonigro et al. 2003). An A to T polymorphism at 305 in exon 2 has been shown to increase carcass fat thickness in cattle (Buchanan et al. 2002). In Bierman et al. (2001), the leptin gene’s effect on hot carcass weight and ribeye area were found to be insignificant but was significant for traits such as marbling and 12th rib fat.

A nucleic acid base switch from cytosine (C) to thymine (T) causes a change in the amino acid incorporated in serum leptin. An animal can have one of three possible genotypes. According to Kemp (2003), “They can carry two copies of the T allele (T/T or homozygous T), two copies of the C allele (C/C or homozygous C), or one copy of each allele (C/T or heterozygous).” Between genotypes, significant differences were observed for both 12th rib fat and marbling score (Buchanan et al. 2002). Fatter carcasses have been associated with the T allele while the C allele was associated with leaner carcasses (Kemp 2003; Thue et al. 2001). Kemp also notes that the animals with two copies of the T allele deposited 12th rib fat earlier in the finishing process and at lighter weights.

Certain breeds of cattle (e.g., Hereford and Angus) are often associated with higher fat levels (Fitzsimmons et al. 1998). Fitzsimmons et al. found that these ‘fat’ breeds had the greatest frequency of the ‘fat’ (T) allele. Similarly, they note that breeds generally accepted as ‘lean’ breeds (e.g., Charolais and Simmental) possessed a greater frequency of the ‘lean’ (C) allele.

Serum leptin levels have also been shown to have a significant impact on growth and carcass characteristics of swine. While serum leptin levels were not significantly different between breeds, they were among genotypes (Berg et al. 2003). Berg et al. note that breeds known for high growth, high-percent fat-free carcasses had low serum leptin levels. On the other hand, high serum leptin levels were found in breeds not known for growth or leanness, but for carcass quality.

Leptin gene polymorphisms have been shown to affect fat deposition in beef carcasses (Bierman et al. 2003, Bierman and Marshall 2001, Buchanan et al. 2002, Fitzsimmons et al. 1998, Geary et al. 2002, Oprzadek et al, 2003, Tessanne et al. 2003,

Thue et al. 2001, Wegner et al. 2001, Yamada et al. 2003). Many researchers have conducted studies to investigate this correlation. While the studies have varied considerably in nature, the results all seem to follow the same basic trend: cattle with two copies of the T allele have higher carcass fat content.

Economic Relevance

Hennessy et al. (2004) discuss three main points about genetic information. While production of a consistent product is difficult, more information about genetics would aid in the production of a more homogeneous product. Second, a processor will not differentiate their product unless they know that a purchased raw material will be consistent during processing. Finally, information on raw materials can allow managers to operate more efficiently.

Chvosta et al. (2001) and Dhuyvetter et al. (1996) discuss the economics of information at breeding bull auctions. Analysis of who bears the cost of presale trait measurement is conducted using SPMs (birth weight, weaning weight, and yearling weight) and EPDs (information inclusive of individual performance and the performance of the animal's relatives used to predict future performance). Chvosta et al. use a hedonic pricing model which determines the price paid for a bull as a function of the bull's perceived attributes, expected market conditions, and sale terms. Similarly, Dhuyvetter et al. evaluate the price paid for a bull utilizing physical and genetic characteristics, EPDs, and market conditions.

The value of a carcass is determined by three main factors: weight, quality grade, and yield grade. Since quality and yield grade are based, at least in part, upon fat content, leptin's genetic effect on carcass value may be considerable. Increased fat deposition

improves quality grade while negatively impacting yield grade. Ladd and Gibson (1978) discuss the economics of single trait selection when traits are negatively correlated. A trade-off must be made between the improvement of one trait and the degrading of another. Literature directly addressing the economic impact of leptin genotyping, however, is lacking. Leptin's impact on economically relevant carcass characteristics are discussed below.

Quality Grade

Leptin has been linked to carcasses containing higher fat content, causing higher marbling scores. Marbling affects the flavor, juiciness, and eating satisfaction in beef (Johnston 2001). The quality grade a carcass receives is assigned based on the amount of marbling in the longissimus muscle on the cut surface between the 12th and 13th ribs (Brester 2002). The four different quality grades for young cattle are prime, choice, select, or standard, with prime representing the highest marbling scores. Emphasis is placed on quality grade because higher marbling scores attract higher prices. Bindon (2004) refers to marbling as the 'gold standard' for quality grade. He notes that marbling satisfies a special consumer preference. Countries such as Canada, the United States, and especially Japan pay a premium for these higher quality carcasses. Consequently, marbling has considerable economic value when marketing finished cattle (Johnston 2001).

Marbling is a complex phenomenon that has been studied quite intensely. Although the degree of marbling is a highly heritable trait (Shackelford et al. 1994), the individual genes that contribute to marbling still remain unclear (Wegner et al. 2001, Barendse et al. 2004). Wegner et al. argue that breeding strategies could be greatly simplified if the ability to predict future marbling in young cattle existed.

Yield Grade

With leptin's tie to fat content, leptin should have an affect on yield grade. Yield grade estimates the amount of boneless, closely trimmed retail cuts contained in the more valuable parts of the carcass (i.e., round, loin, rib, and chuck) (Hale et al. 2002). Yield grade utilizes measurements for hot carcass weight, ribeye area, 12th rib fat, and percent kidney, pelvic, and heart fat. There are five numerical classifications of yield grade (1-5), with a yield grade 1 representing the leanest carcasses.

Leptin's effect on fat deposition creates several economic implications. Wegner et al. discuss the need for further investigation to clarify the association between the leptin gene and potential use in the beef cattle industry. Differences in carcass composition suggest it may validate genotyping entire herds that contain a high percentage of finished animals with marbling scores near a quality grade/price threshold (any day-on-feed when an animal attains a new quality grade) (Bierman et al. 2003). This paper will evaluate the economic benefit associated with utilizing genetic information (leptin genotype) when developing a marketing strategy for finished cattle.

METHODS

An economic model was developed to evaluate the value of the knowledge of leptin genotype. Preliminary estimations were made with and without leptin genotypic information to predict economically relevant carcass traits that vary with days-on-feed. A simulation model was then used to predict carcass traits for each day-on-feed, and the profits associated with those traits. Finally, a grid search optimization model was employed to find the profit maximizing day-on-feed for each calf. Statistical analysis was performed on preliminary data and results. When comparing more than two groups, Stockburger (1998) recommends using an Analysis of Variance (ANOVA) test. ANOVA is used to compare data and results between genotypes. Results between models (with and without genotype) are compared using a pair-wise t-test.

Notation and Variables

The following notation is used throughout the remainder of this paper.

i	subscript indicating animal identification	$i \in \{1, \dots, 180\}$
j	subscript indicating measurement date	$j \in \{\text{Nov. 25, May 3, marketing date}\}$
k	subscript indicating marketing date	$k \in \{140, \dots, 240\}$
$BF_{i,j}$	12th rib fat for the i^{th} calf on the j^{th} date	
$REA_{i,j}$	ribeye area for the i^{th} calf on the j^{th} date	
$W_{i,j}$	weight for the i^{th} calf on the j^{th} date	
$HCW_{i,k}$	hot carcass weight for the i^{th} calf on the k^{th} marketing date	
$MS_{i,k}$	marbling score for the i^{th} calf on the k^{th} marketing date	
$KPH_{i,k}$	percent kidney, pelvic, and heart fat for the i^{th} calf on the k^{th} marketing date	
DOF_i	days-on-feed for the i^{th} calf	

Several variables are used to estimate the final carcass characteristics of finished cattle. Data were collected at various times throughout the finishing process (time-period

after weaning when cattle are fed high energy rations to increase fat deposition).

Measurements were taken for 12th rib fat (BF), ribeye area (REA), weight (W), marbling score (MS), hot carcass weight (HCW), and percent kidney, pelvic, and heart fat (KPH).

BF measures the fat thickness three-fourths the length of the ribeye from the chine bone (Hale et al. 2003). The amount of BF an animal has is a good indicator of the level of fat content in the entire carcass. Ultrasonic measurements for BF were taken twice during the finishing process, and a final BF measurement was taken on the marketing date. 12th rib fat has a negative affect on yield grade (YG) and ultimately, price.

REA is the size of the ribeye in square inches measured at the cut surface between the 12th and 13th ribs. A larger REA indicates cattle have more than average muscling. Ultrasonic measurements for REA were taken twice during the finishing process, and a final REA was taken on the marketing date. REA has a positive affect on YG causing price to rise as REA increases.

MS measures the amount of intramuscular fat an animal contains in the longissimus Dorsi on the cut surface between the 12th and 13th ribs (Brester 2002). MS is the primary determinant of quality grade (QG) in young cattle. Cattle with higher MSs receive higher quality grades.

Model

Producers are assumed to maximize expected profit for each animal i , or

$$(1) \quad \max_{DOF_i} \pi_i(DOF_i) = [P_B + P_{YG}(YG(REA_i(DOF_i), HCW_i(DOF_i), BF_i(DOF_i), KPH_i(DOF_i))) + P_{QG}(MS(DOF_i))] \times HCW_i(DOF_i) - IC_i - C(DOF_i)$$

where π_i = profit for the i^{th} calf, P_B = base price, P_{YG} = yield grade adjustment, P_{QG} = quality grade adjustment, C = daily cost during finishing phase. The following equation is the first order conditions for profit:

$$(2) \quad \frac{\Delta \pi_i}{\Delta DOF_i} = \frac{\Delta P_{YG}}{\Delta YG_i} \left(\frac{\Delta YG_i}{\Delta REA_i} \frac{\Delta REA_i}{\Delta DOF_i} + \frac{\Delta YG_i}{\Delta HCW_i} \frac{\Delta HCW_i}{\Delta DOF_i} + \frac{\Delta YG_i}{\Delta BF_i} \frac{\Delta BF_i}{\Delta DOF_i} + \frac{\Delta YG_i}{\Delta KPH_i} \frac{\Delta KPH_i}{\Delta DOF_i} \right) \times HCW_i + \frac{\Delta P_{QG}}{\Delta MS_i} \left(\frac{\Delta MS_i}{\Delta DOF_i} \right) \times HCW_i + \left[P_B + P_{YG}(\cdot) + P_{QG}(\cdot) \right] \times \frac{\Delta HCW_i}{\Delta DOF_i} - \frac{\Delta C(\cdot)}{\Delta DOF_i} = 0.$$

A feedlot operator can impact carcass traits, and ultimately profit, by varying days-on-feed. A change in DOF will impact price in three ways. First, a change in DOF will cause a change in YG. As DOF increase, REA will increase, having a small positive affect YG. However, an increase in DOF will cause HCW, BF, and KPH to increase, having a negative affect on YG. Additionally, a change in DOF will affect QG. As DOF increase, MS will increase, causing QG to improve. A trade-off is made between improved QG and poorer YG. Finally, a change in DOF will affect HCW. Increasing DOF will increase HCW, positively affecting carcass value.

In addition to affecting value, a change in DOF will affect costs. There are three daily cost during the finishing phase: feed, yardage, and interest. Feed and yardage increase at approximately the same rate while interest costs will increase at an increasing rate with DOF.

Premiums and discounts for yield and quality grade are based upon carcass characteristics, which in turn are functions of days-on-feed. Yield grade, which determines P_{YG} , is given as:

$$(3) \quad YG_{i,k} = 2.5 + 2.5 * BF_{i,k} + 0.2 * KPH_{i,k} + 0.0038 * HCW_{i,k} - 0.32 * REA_{i,k}$$

(Wagner and Osbourne 1997). Yield grade premiums and discounts are reported in Table 1.

Quality grade is measured by marbling score. Quality grade premiums and discounts are reported in Table 2. The cost of finishing a feedlot calf, $C(dof_i)$, includes feed, yardage, and opportunity costs of capital.

Table 1. Yield grade premiums/discounts per hundred weight of carcass*

Grade	Price Level		
	Low	Medium	High
1	\$3.18	\$4.77	\$7.20
2	\$1.58	\$2.38	\$2.75
3	\$0.00	\$0.00	\$0.00
4	(\$14.04)	(\$17.55)	(\$20.00)
5	(\$18.32)	(\$22.90)	(\$25.00)

*Source: derived from USDA:AMS.

Table 2. Quality grade premiums/discounts per hundred weight of carcass*

Grade	Price Level		
	Low	Medium	High
Prime	\$12.20	\$18.30	\$24.52
High Choice**	\$0.68	\$1.02	\$2.21
Choice	\$0.00	\$0.00	\$0.00
Select	(\$6.45)	(\$8.07)	(\$9.69)
Standard	(\$13.89)	(\$20.84)	(\$30.00)

*Source: derived from USDA:AMS.

**High Choice = cattle receiving a quality grade in the upper two-thirds choice.

Econometric Estimations

A system of simultaneous equations were developed for carcass traits that changed with DOF. Using a Hausman test, consistency was rejected, indicating endogeneity was present. Consequently, a two-stage least squares procedure was used (Wannacott 1979). In the two-stage least squares procedure, jointly dependent variables are estimated using the

instrument variables during the first stage. During the second stage, a least-squares regression of endogenous variable is done using calculated values obtained in the first stage, and the observed values of other predetermined variables. In this model, endogenous variables are final BF, REA, HCW, and MS. Exogenous variables include all ultrasound measurements and weights taken prior to the marketing dates. KPH is also treated as exogenous, as no live-animal data are available. To account for the effect of the leptin gene, dummy variables are used to represent CT and TT genotypes. Days-on-feed (DOF) is also included as an exogenous variable. When feedlot operators market cattle at different times based on genetic potential and other factors, the variable they can determine is DOF. Additional DOF will add weight and increase QG and YG. Feedlot operators must determine if additional weight and QG premiums offset YG discounts as well as marginal costs associated with feeding a calf for an additional day.

All exogenous variables along with T gene dummy variables were used in the first-stage estimation. Second-stage coefficients were estimated with the following system of equations:

$$\begin{aligned}
 \hat{BF}_{i,k} &= c(1) \times \text{Log}(BF_{i,2}) + c(2) \times \hat{REA}_{i,3} + c(3) \times KPH_{i,k} + c(4) \times \text{Log}(MS_{i,k}) \\
 &+ c(5) \times \text{Log}(DOF_{i,k}) \\
 \hat{REA}_{i,k} &= c(6) \times REA_{i,1} + c(7) \times \hat{BF}_{i,k} + c(8) \times \text{Log}(DOF_{i,k}) + c(9) \times REA_{i,2}^2 \\
 \hat{HCW}_{i,k} &= c(10) \times (W_{i,2} - W_{i,1}) / 160 \times DOF_{i,k} + c(11) \times W_{i,1} + c(12) \times REA_{i,2}
 \end{aligned}
 \tag{4}$$

Cattle in the study were marketed over a three week-period. Because of the short time frame, adequate variability did not exist in the MS. Consequently, data from Bruns et al. was used to estimate a MS growth curve as:

$$\hat{MS}_{i,k} = e^{5.87+0.0029 \times dof}
 \tag{5}$$

Using each calf's observed MS at marketing and the MS estimation (2), MS is projected to any given DOF as:

$$(6) \quad \hat{MS}_{i,DOF} = MS_{i,k} + e^{5.87} \times (e^{0.0029 \times DOF_i} - e^{0.0029 \times k})$$

Little variation was observed in KPH among the four marketing dates.

Consequently, KHP was assumed constant for each calf during simulation.

Simulation and Optimization

A simulation model was developed using the econometric estimation in (4) and (6). In the simulation, DOF was ranged from 161 days to 240 days, a relatively wide window. For each date in this interval, carcass characteristics were forecasted using equations (4) and (6). From these forecasts, yield and quality grades and associated premiums and discounts were determined. Then, profits for each animal on each day in the interval were forecasted. Next, a grid search optimization was used to find the DOF for each calf that maximized profit.

The simulation model and grid search were employed twice. First, the econometric model that includes genotypic information was used. Second, the model without genetic information was used. The profit-maximizing DOF from the simulation were then compared using a pair-wise t-test.

To evaluate the value of genotypic information, maximum profit must be determined both with and without this information. The difference between maximum profits is the value of the genotypic information. The steps in computing this difference are as follows. First, profit-maximizing days-on-feed are determined both with and without genotypic information, as mathematically described below. Second, profits for both DOF are computed in the model with full, i.e., genotypic, information. The results are expected

profits for each animal both when genotypic information is considered and when it is not considered. Finally, the differences in expected profits for each animal is computed. A t-test is then used to statistically test the hypothesis that the average difference in expected profits is equal to zero.

To more accurately model the feedlot marketing decision, a second optimization model was employed. Finished cattle are typically marketed in “potloads,” approximately 45 head, to reduce trucking costs. The second optimization was formulated as a mixed integer programming model. The objective function was to maximize the sum of potload profits with constraints imposing 45 head potloads and four marketing dates. The model determined the four highest profit marketing dates and the 45 head to be marketed on each date.

Mathematically, the objective function and constraints are expressed as:

$$(7) \quad \underset{a_{i,k}, b_k}{\text{Maximize}} \sum_{i,k} a_{i,k} \times \pi_{i,k}$$

subject to:

$$(8) \quad \begin{aligned} \sum_k a_{i,k} &= 1 \forall i \\ \sum_k b_k &= 4 \\ \sum_i a_{i,k} &= 45 \times b_k \forall k \end{aligned}$$

where $a_{i,k}$ is a binary variable equal to zero if calf i is not marketed on date k and one otherwise; b_k is a binary variable equal to zero if k is not a potload marketing date and one otherwise.

Profit-maximizing potload marketing dates are determined with and without the leptin genotypic information. The resulting optimal individual marketing dates and profits are then compared using a pair-wise t-test.

Data Collection

Data were collected on November 25, 2003, May 3, 2004, and on four marketing dates: May 20, May 26, June 3, and June 10. The first data collection date was November 25. This is when the cattle first arrived in the feedlot and were put on feed. The second data collection date was May 3. Data was collected on this date to aid in predicting an optimal marketing window. Live weights were taken twice during the feeding process for two reasons. First, the weight of an animal will have an effect on several of its final carcass traits. Second, the value of a finished animal is highly correlated with weight. Higher weights yield higher values.

While BF, REA and weights were taken throughout the finishing process, three additional traits were measured only at slaughter. HCW measures the weight of the carcass after the hide, head, viscera and extremities have been removed. HCW is used as a base to establish value. MS indicates the amount of marbling present in the ribeye on the cut surface between the 12th and 13th ribs. MS is the primary determinant of quality grade (QG). Cattle with a higher MS, and consequently a higher QG are worth more than cattle with lower MS. KPH measures how much kidney, pelvic, and heart fat a carcass contains as a percentage of HCW. KPH has a negative affect on YG.

Live Animal Characteristics

On the November collection date, blood samples were taken via venopuncture, animals were weighed, and ultrasonic measurements of 12th rib fat thickness and ribeye area were taken.

Blood samples were submitted to Igenity Testing Laboratories (Merial, Saskatoon, Saskatchewan, Canada) for leptin genotyping.

On the May collection date, weights were taken, and ultrasonic measurements of 12th rib fat thickness and ribeye area were taken. Ultrasonic measurements and weights from November and May are reported in Table 3.

Table 3. Live weights and ultrasonic measurements for 12th rib fat and ribeye area

	Ultrasound Measurements					
	Weights		12th rib fat		Ribeye Area	
	Nov. 25 (St dev)	May 3 (St dev)	Nov. 25 (St dev)	May 3 (St dev)	Nov. 25 (St dev)	May 3 (St dev)
All	611.0 (55.6)	1198.0 (83.7)	0.08 (0.06)	0.35 (0.13)	8.05 (0.97)	12.59 (1.26)
CC*	613.9 (46.8)	1202.9 (64.2)	0.07 ^{B**} (0.04)	0.33 (0.11)	8.11 (0.99)	12.77 (1.27)
CT	610.1 (59.0)	1200.6 (86.1)	0.07 ^B (0.06)	0.34 (0.12)	8.01 (0.97)	12.67 (1.34)
TT	611.7 (53.4)	1190.8 (86.4)	0.10 ^B (0.06)	0.38 (0.13)	8.11 (0.98)	12.38 (1.09)

* CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat'.

** ^B denotes statistical significance at 5%.

An ANOVA test indicated a significant difference in 12th rib fat. As was hypothesized, the TT (fat) genotype cattle had the highest initial BF measurement. The CC (lean) genotype steers had the lowest initial BF, with the CT (heterozygous) calves falling in between. No significant differences were observed for REA or weight.

Carcass Characteristics

On the four marketing dates, 43, 38, 39, and 60 cattle were slaughtered, respectively. Approximately 24 hours after slaughter, 12th rib fat and ribeye area measurements were taken, hot carcass weights were recorded, and KPH and marbling score were evaluated by Dr. Paul Berg (Animal and Range Sciences Department, North Dakota State University).

Of the initial 190 steers, 180 usable observations were obtained (10 had lost ear tags). The three genotypes of CC, CT, and TT had 21, 100, and 59 observations, respectively. The calves were slaughtered over four consecutive weeks (May 20, May 26, June 3, and June 10) at Tyson Fresh Meats™ in Dakota City, NE. Measurements for HCW, BF, KPH, and REA were taken at that time. Final carcass characteristics by are reported in Tables 4, 5, 6, 7, 8, and 9.

Table 4. Post-slaughter 12th rib fat measurements by genotype and marketing date

	May 20		May 26		June 3		June 10		Average	
	BF ₃ * (St dev)	n	BF ₃ (St dev)	n	BF ₃ (St dev)	n	BF ₃ (St dev)	n	BF ₃ (St dev)	n
All	0.55 (0.22)	43	0.51 (0.18)	38	0.55 (0.18)	39	0.43 (0.16)	60	0.50 (0.19)	180
CC**	0.37 (0.15)	5	0.51 (0.11)	6	0.53 (0.14)	6	0.42 (0.20)	4	0.47 ^{C***} (0.15)	21
CT	0.56 (0.26)	22	0.47 (0.22)	17	0.55 (0.20)	19	0.46 (0.15)	42	0.48 ^C (0.21)	100
TT	0.59 (0.14)	16	0.55 (0.14)	15	0.55 (0.18)	14	0.46 (0.18)	14	0.54 ^C (0.16)	59

* BF₃ = final 12th rib fat measurement, n = number of observations.

** CC = homozygous c or ‘lean’; CT = heterozygous; TT = homozygous t or ‘fat’.

*** ^C denotes statistical significant at 10%.

As was hypothesized, statistical differences were observed for 12th rib fat. The TT cattle had the highest average 12th rib fat measurement. On the various marketing dates, the TT cattle generally had the highest 12th rib fat, the CC had the lowest 12th rib fat, and the CT were in between. On June 3, the CT cattle did have a higher average 12th rib fat than the TT.

Statistically significant differences were also present in the REA data. CC cattle had a larger average REA than CT or TT. This is likely because of the inverse relationship

between fat deposition and muscle size. With the exception of the June 3 data collection, the CC cattle had the largest REA, followed by CT and then TT.

Table 5. Post-slaughter ribeye area measurements by genotype and marketing date

	May 20		May 26		June 3		June 10		Average	
	REA ₃ * (St dev)	n	REA ₃ (St dev)	n	REA ₃ (St dev)	n	REA ₃ (St dev)	n	REA ₃ (St dev)	n
All	12.60 (1.16)	43	12.74 (1.34)	38	12.17 (1.48)	39	13.05 (1.37)	60	12.68 (1.37)	180
CC**	13.02 (1.19)	5	13.73 (1.52)	6	11.95 (1.96)	6	13.73 (1.14)	4	13.05 ^{B***} (1.62)	21
CT	12.60 (1.13)	22	12.71 (1.39)	17	12.28 (1.43)	19	13.19 (1.45)	42	12.81 ^B (1.40)	100
TT	12.49 (1.25)	16	12.38 (1.07)	15	12.11 (1.45)	14	12.36 (0.94)	14	12.34 ^B (1.17)	59

* REA₃ = final ribeye area measurement, n = number of observations.

** CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat'.

*** ^B denotes statistical significance at 5%.

Table 6. Hot carcass weight by genotype and marketing date

	May 20		May 26		June 3		June 10		Average	
	HCW* (St dev)	n	HCW (St dev)	n	HCW (St dev)	n	HCW (St dev)	n	HCW (St dev)	n
All	795.6 (47.2)	43	812.3 (48.1)	38	786.2 (53.5)	39	771.3 (53.5)	60	789.0 (52.7)	180
CC**	795.9 (24.4)	5	821.7 (41.9)	6	779.0 (25.1)	6	785.0 (45.1)	4	796.3 (36.6)	21
CT	794.4 (51.4)	22	803.9 (54.5)	17	793.3 (70.5)	19	782.8 (55.3)	42	790.9 (57.2)	100
TT	797.2 (48.6)	16	818.0 (43.9)	15	779.5 (33.1)	14	732.8 (28.2)	14	783.0 (49.8)	59

* HCW = Hot carcass weight, n = number of observations.

** CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat'.

While no statistically significant differences were observed in HCW, some practical differences were present. The CC cattle did have a higher observed average HCW. HCWs for the first three marketing dates were very similar, however, the TT cattle had a lower

average HCW on the June 10 marketing date, causing the observed average HCW for TT cattle to be the lowest.

Table 7. Percent kidney, pelvic, and heart fat by genotype and marketing date

	May 20		May 26		June 3		June 10		Average	
	KPH* (St dev)	n	KPH (St dev)	n	KPH (St dev)	n	KPH (St dev)	n	KPH (St dev)	n
All	2.52 (0.52)	43	2.24 (0.50)	38	2.12 (0.47)	39	2.00 (0.53)	60	2.20 (0.54)	180
CC**	2.10 (0.65)	5	2.08 (0.49)	6	2.08 (0.38)	6	2.25 (0.29)	4	2.12 (0.45)	21
CT	2.57 (0.60)	22	2.35 (0.49)	17	2.03 (0.49)	19	1.98 (0.53)	42	2.18 (0.58)	100
TT	2.59 (0.27)	16	2.17 (0.52)	15	2.25 (0.47)	14	2.00 (0.59)	14	2.26 (0.51)	59

* KPH = percent kidney, pelvic, and heart fat, n = number of observations.

** CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat'.

No statistically significant differences were observed for KPH. While no trends developed over the four marketing dates, the averages support the hypothesis of increased fat deposition for TT cattle. The TT cattle had the highest observed average KPH, followed by CT and then CC.

Marbling score data contained no statistically significant differences. Averages continued to support the hypothesis of higher amounts of carcass fat for TT animals. TT cattle had MS of 11 and 23 points higher than CT and CC, respectively, although marbling scores varied considerable throughout the four marketing dates.

Table 8. Marbling score by genotype and marketing date

	May 20		May 26		June 3		June 10		Average	
	MS* (St dev)	n	MS (St dev)	n	MS (St dev)	n	MS (St dev)	n	MS (St dev)	n
All	446*** (64)	43	495 (98)	38	453 (101)	39	428 (98)	60	452 (94)	180
CC**	410 (87)	5	483 (126)	6	433 (91)	6	410 (60)	4	438 (95)	21
CT	455 (61)	22	483 (87)	17	442 (74)	19	436 (105)	42	449 (89)	100
TT	444 (62)	16	513 (103)	15	476 (135)	14	408 (82)	14	461 (103)	59

* MS = marbling score, n = number of observations.

** CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat'.

***200-299 = standard QG; 300-399 = select QG; 400-499 = low choice QG; 500-699 = high choice QG; ≥ 700 = prime QG.

Table 9. Final yield grade by genotype and marketing date

	May 20		May 26		June 3		June 10		Average	
	MS* (St dev)	n	MS (St dev)	n	MS (St dev)	n	MS (St dev)	n	MS (St dev)	n
All	2.84 (0.87)	43	2.74 (0.80)	38	2.90 (0.88)	39	2.23 (0.72)	60	2.27 (0.85)	180
CC**	2.20 (0.84)	5	2.33 (0.52)	6	3.00 (1.10)	6	2.25 (0.50)	4	2.48 (0.81)	21
CT	2.86 (0.89)	22	2.65 (0.86)	17	2.95 (0.91)	19	2.17 (0.70)	42	2.55 (0.88)	100
TT	3.00 (0.82)	16	3.00 (0.76)	15	2.79 (0.80)	14	2.43 (0.85)	14	2.81 (0.82)	59

* MS = marbling score, n = number of observations.

** CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat'.

Final yield grades (FYG) also supported the hypothesis of increased fat deposition for TT cattle, although no statistically significant differences were present. The TT cattle had the highest FYG on three of the four marketing dates. Conversely, the CC cattle had the lowest FYG on three of the four marketing dates, and consequently, the lowest average FYG.

Revenues

In addition to data collected on live cattle and their carcass characteristics, data for calculating revenues and expenses was assembled. A grid pricing system was employed to calculate revenue for the cattle.

Marketing schemes have become much more complex in recent years. When marketing finished cattle, producers are faced with a multitude of options. One option is to simply sell the live animal by the pound. This is typically how cattle were sold years ago. One marketing technique that reflects this previous live animal method is selling cattle based solely on carcass weight. Cattle are slaughtered, and producers are paid based only on the weight of the carcass. A more popular method of marketing finished cattle is using a value grid. A grid starts with a base price per cwt (hundred weight), and adjustments are then made based on quality grade, yield grade, and carcass weight. This grid based marketing system allows premiums for cattle having more desirable carcass traits.

The pricing model used to market the cattle for this project was a grid based marketing system. Consequently, optimal DOF occurs at or near quality/yield grade thresholds. Due to the volatility in the beef cattle market, low, medium, and high values of \$70/cwt, \$80/cwt, and \$90/cwt were used. These correspond with hot carcass weight prices of \$112/cwt, \$128/cwt, and \$144/cwt, respectively.

Expenses

In addition to determining the value of the animal, a cost of keeping that animal for an extra day was determined in order to perform profit analysis. There were three main costs associated with keeping an animal an extra day; feed, yardage, and interest. Feed costs simply refer to the cost of feed an animal will consume in a day. Feed costs were

calculated using actual invoices from the Zuehlke Feedlot in Britton, SD. Feed costs were \$1.36 per head per day. Yardage costs consist of the fixed and marginal cost of maintaining feedlot property, facilities, and machinery. Feedlot operators charge yardage on a per head per day basis to recover investment costs over the useful life of the operation. A feedlot manual from Iowa State University suggests a daily yardage cost of \$0.29 per head. Interest on investment was accounted for on the initial cost of the calf and the feed and yardage costs that accrued throughout the finishing process. Initial cost of calves was calculated using data from the North Dakota Ag Statistics Service. An interest rate of 5.5 percent was used under all price conditions.

RESULTS

Econometric Estimations

Results from the models that either utilized or ignored genetic information varied only slightly. This is because this model measured only the effect of the leptin gene. Biologically, no single gene will have a very large impact on a multitude of traits. A given gene will affect traits only slightly. Econometrically, estimated coefficients varied only slightly because of how the effect of the leptin gene was measured. T gene dummy variables were insignificant for the second-stage estimates, and thus, were only utilized as instruments during the first-stage estimations. Two-stage least squares estimated coefficients for the complete model are reported in Tables 10 and 11.

Significant estimated coefficients from both models were quite similar. Each unit of BF a calf had on May 3rd added just under one unit of BF at marketing. Ribeye area had an inverse relationship with BF. Heavier muscled cattle tend to deposit less fat. An additional inch of REA at slaughter decreased BF by 0.033 inches. Conversely, BF increased by 0.054 inches for every percent KPH. This is likely because KPH is another measure of carcass fat content. Marbling score was inversely related with BF. While both are measures of carcass fat content, animals with lower marbling scores had more BF per unit of marbling. With respect to DOF, BF increased at a decreasing rate.

Significant variables for the REA estimation were the two previous ribeye measurements, DOF, and the final BF measurement. Each unit of ribeye on November 25th added 0.25 square inches to their final measurement. Similarly, the May 3rd REA increased the final REA at an increasing rate, while additional DOF added to final REA at a decreasing rate. An inch of final BF decreased REA by 2.67 square inches.

Table 10. Two-stage least squares estimated coefficients for the complete model

	With Genotypic Information			Without Genotypic Information		
	Equation			Equation		
	BF ₃	REA ₃	HCW	BF ₃	REA ₃	HCW
	(St Error)	(St Error)	(St Error)	(St Error)	(St Error)	(St Error)
ADG*DOF	-	-	0.7040 ^A	-	-	0.7140 ^A
	-	-	(0.0881)	-	-	(0.0880)
ADG*DOF ²	-	-	-0.0009 ^B	-	-	-0.0010 ^B
	-	-	(0.0004)	-	-	(0.0004)
BF ₁	0.6717	0.7042	5.4033	0.7206	0.4655	4.5334
	(0.7267)	(1.7625)	(53.0621)	(0.7193)	(1.7560)	(53.1760)
BF ₁ ²	-0.5324	-	-	-0.6700	-	-
	(2.7539)	-	-	(2.7258)	-	-
BF ₃	-	-2.5561 ^A	13.9823	-	-2.5629 ^A	11.5408
	-	(0.6243)	(19.6536)	-	(0.6233)	(19.8878)
HCW	0.0003	-0.0008	-	0.0003	-0.0008	-
	(0.0003)	(0.0016)	-	(0.0003)	(0.0016)	-
KPH	0.0466 ^B	-	-	0.0467 ^B	-	-
	(0.0218)	-	-	(0.0217)	-	-
LOG(BF ₂)	0.3144 ^A	-	-	0.3119 ^A	-	-
	(0.0432)	-	-	(0.0427)	-	-
LOG(DOF)	0.5474 ^A	2.9294 ^A	-	0.5439 ^A	2.9118 ^A	-
	(0.1955)	(0.8375)	-	(0.1947)	(0.8281)	-
LOG(MS)	-0.3005 ^C	-	-	-0.2982 ^C	-	-
	(0.1586)	-	-	(0.1587)	-	-
REA ₁	-0.0053	1.0893	4.3305	-0.0044	1.1071	4.7634
	(0.0158)	(0.9211)	(3.0325)	(0.0157)	(0.9104)	(3.0418)
REA ₁ ²	-	-0.0506	-	-	-0.0518	-
	-	(0.0555)	-	-	(0.0555)	-
REA ₂	-	-1.5387 ^B	6.5395 ^B	-	-1.5706 ^B	6.8949 ^B
	-	(0.7159)	(2.8858)	-	(0.7106)	(2.9478)
REA ₂ ²	-	0.0832 ^A	-	-	0.0847 ^A	-
	-	(0.0283)	-	-	(0.0281)	-
REA ₃	-0.0441 ^B	-	-1.3040	-0.0450 ^B	-	-2.0598
	(0.0209)	-	(3.8388)	(0.0205)	-	(3.9396)
T1	-0.0115	-0.1925	-6.7603	-	-	-
	(0.0332)	(0.2194)	(5.6260)	-	-	-
T2	0.0026	-0.3018	-5.1435	-	-	-
	(0.0361)	(0.2349)	(5.9752)	-	-	-
W ₁	-	-	0.5309 ^A	-	-	0.5265 ^A
	-	-	(0.0368)	-	-	(0.0369)
Instruments	W ₁ , BF ₁ , REA ₁ , W ₂ , BF ₂ , REA ₂ , KPH, DOF, T1, T2, W ₁ ² , BF ₁ ² , REA ₁ ² , W ₂ ² , BF ₂ ² , REA ₂ ² , KPH ² , DOF ²			W ₁ , BF ₁ , REA ₁ , W ₂ , BF ₂ , REA ₂ , KPH, DOF, W ₁ ² , BF ₁ ² , REA ₁ ² , W ₂ ² , BF ₂ ² , REA ₂ ² , KPH ² , DOF ²		

* ^A denotes significance at 1%, ^B denotes significance at 5%, ^C denotes significance at 10%.

**BF_i = 12th rib fat on ith date; REA_i = ribeye area on ith date; W_i = weight on ith date; KPH = percent kidney, pelvic, and heart fat; Marb = marbling score; DOF = days-on-feed; HCW = hot carcass weight; ADG = average daily gain; T1 = dummy variable for CT genotype; T2 = dummy variable for TT genotype.

Table 11. Two-stage least squares estimated coefficients for significant variables

	With Genotypic Information			Without Genotypic Information		
	Equation			Equation		
	BF ₃ (St Error)	REA ₃ (St Error)	HCW (St Error)	BF ₃ (St Error)	REA ₃ (St Error)	HCW (St Error)
ADG*DOF	-	-	0.6904 ^A	-	-	0.6904 ^A
	-	-	0.0767	-	-	0.0767
ADG*DOF ²	-	-	-0.0010 ^A	-	-	-0.0010 ^A
	-	-	0.0004	-	-	0.0004
BF ₃	-	-2.6764 ^A	-	-	-2.6656 ^A	-
	-	0.4370	-	-	0.4370	-
KPH	0.0538 ^A	-	-	0.0537 ^A	-	-
	0.0204	-	-	0.0204	-	-
LOG(BF ₂)	0.3686 ^A	-	-	0.3689 ^A	-	-
	0.0318	-	-	0.0318	-	-
LOG(DOF)	0.4821 ^A	1.6046 ^A	-	0.4803 ^A	1.6037 ^A	-
	0.1499	0.1142	-	0.1501	0.1142	-
LOG(MS)	-0.2154 ^C	-	-	-0.2144 ^C	-	-
	0.1115	-	-	0.1117	-	-
REA ₁	-	0.2545 ^A	-	-	0.2542 ^A	-
	-	0.0837	-	-	0.0837	-
REA ₂	-	-	7.1052 ^A	-	-	7.1052 ^A
	-	-	1.3624	-	-	1.3624
REA ₂ ²	-	0.0223 ^A	-	-	0.0223 ^A	-
	-	0.0026	-	-	0.0026	-
REA ₃	-0.0333 ^A	-	-	-0.0330 ^B	-	-
	0.0129	-	-	0.0129	-	-
W ₁	-	-	0.5701 ^A	-	-	0.5701 ^A
	-	-	0.0284	-	-	0.0284
Instruments	W ₁ , BF ₁ , REA ₁ , W ₂ , BF ₂ , REA ₂ , KPH, DOF, T1, T2, W ₁ ² , BF ₁ ² , REA ₁ ² , W ₂ ² , BF ₂ ² , REA ₂ ² , KPH ² , DOF ²			W ₁ , BF ₁ , REA ₁ , W ₂ , BF ₂ , REA ₂ , KPH, DOF, W ₁ ² , BF ₁ ² , REA ₁ ² , W ₂ ² , BF ₂ ² , REA ₂ ² , KPH ² , DOF ²		

* ^A denotes significance at 1%, ^B denotes significance at 5%, ^C denotes significance at 10%.

**BF_i = 12th rib fat on ith date; REA_i = ribeye area on ith date; W_i = weight on ith date; KPH = percent kidney, pelvic, and heart fat; Marb = marbling score; DOF = days-on-feed; HCW = hot carcass weight; ADG = average daily gain; T1 = dummy variable for CT genotype; T2 = dummy variable for TT genotype.

Variables of significance for the HCW estimate were initial weight, the May 3rd REA, and an interaction term between the trial ADG and DOF. Each pound of weight on November 25th added 0.57 pounds to HCW. Cattle with larger REA measurements were

observed to have higher dressing percentages. Consequently, each unit of REA on May 3rd added 7.11 pounds of HCW. As DOF increased, HCW increased at a decreasing rate.

Projected Carcass Characteristics

Under a low price (\$112/cwt), cattle were marketed at an average live weight of approximately 1210 pounds. At this weight, the majority of cattle received premiums for being YG1 or YG2 and still managed to achieve a choice grade. On average, the CC cattle had the heaviest carcasses, lowest BF, and largest REAs, allowing them to have and lower YGs. At a low price, the TT cattle were optimally marketed with the lightest carcasses, smallest REAs, and the most BF. The TT cattle also had the highest marbling score, so they were more apt to attain choice QG. Differences in 12th rib fat were statistically significant at the 10 percent level. Projected carcass traits for cattle marketed under low price conditions with leptin genotypic information are reported in Table 12.

Table 12. Projected carcass characteristics under low price

	n*	HCW Pounds (St Dev)	BF Inches (St Dev)	REA Inches ² (St Dev)	Marb. (St Dev)	YG (St Dev)
All	180	756.6 (57.6)	0.43 (0.14)	12.63 (1.04)	413 (88.)	2.35 (0.67)
CC*	21	760.9 (47.1)	0.41 ^{C***} (0.13)	12.82 (1.05)	402 (81)	2.24 (0.54)
CT	100	756.6 (59.2)	0.42 ^C (0.14)	12.70 (1.13)	406 (81)	2.29 (0.69)
TT	59	755.0 (58.8)	0.47 ^C (0.14)	12.45 (0.87)	429 (101)	2.49 (0.68)

*n = number of observations; HCW = hot carcass weight; BF = 12th rib fat; REA = ribeye area; Marb. = marbling score; YG = yield grade.

**CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat.'

***^C denotes statistical significant at 10%.

At a medium price (\$128/cwt), animals were optimally marketed with carcass traits similar to characteristics in a low price situation. Cattle had slightly heavier carcasses, more BF, larger REAs, higher marbling scores, and higher calculated yield grades. This was because higher prices created incentives to feed cattle longer. Increased HCW, larger REA, and higher MS all have a positive affect on profit. DOF increased by an average of eight days. Cattle marketed at a medium price with leptin genotypic information were projected to have carcass traits reported in Table 13.

Table 13. Projected carcass characteristics under medium price

	n*	HCW Pounds (St Dev)	BF Inches (St Dev)	REA Inches ² (St Dev)	Marb. (St Dev)	YG (St Dev)
All	180	767.7 (59.5)	0.45 (0.15)	12.65 (1.04)	426 (92)	2.43 (0.68)
CC**	21	773.0 (45.3)	0.43 (0.15)	12.84 (1.05)	416 (87)	2.29 (0.56)
CT	100	770.3 (62.6)	0.44 (0.14)	12.72 (1.13)	423 (83)	2.38 (0.68)
TT	59	761.3 (59.0)	0.48 (0.15)	12.46 (0.86)	437 (109)	2.56 (0.70)

*n = number of observations; HCW = hot carcass weight; BF = 12th rib fat; REA = ribeye area; Marb. = marbling score; YG = yield grade.

**CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat.'

The trend remained constant as prices increased from medium to high (\$144/cwt) with higher prices providing incentives to feed cattle longer. Carcass traits were higher in all categories. While fewer cattle were projected to earn premiums for YG1 and YG2, fewer cattle received the discount for QG Select, and a few cattle reached the premium for upper two-thirds choice. Projected carcass traits under a high price with leptin genotypic information are reported in Table 14.

Table 14. Projected carcass characteristics under high price

	n*	HCW Pounds (St Dev)	BF Inches (St Dev)	REA Inches ² (St Dev)	Marb. (St Dev)	YG (St Dev)
All	180	777.2 (59.4)	0.47 (0.15)	12.66 (1.04)	438 (93)	2.48 (0.68)
CC**	21	781.8 (43.4)	0.45 (0.15)	12.86 (1.04)	427 (90)	2.33 (0.58)
CT	100	780.5 (63.3)	0.46 (0.15)	12.74 (1.12)	435 (82)	2.44 (0.69)
TT	59	769.9 (57.4)	0.50 (0.15)	12.48 (0.85)	447 (112)	2.61 (0.70)

*n = number of observations; HCW = hot carcass weight; BF = 12th rib fat; REA = ribeye area; Marb. = marbling score; YG = yield grade.

**CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat.'

While projected carcass traits varied based on prices, all characteristics followed the same basic trend. The TT cattle consistently had the lightest carcasses, the most BF, the smallest REA, and the highest calculated YG. Conversely, the CC cattle had the heaviest carcasses with the largest REA and lowest BF. So, CC carcasses received YG premiums. The CT cattle routinely fell between the CC and TT cattle. Without exception, TT cattle had the highest average marbling scores, while CC and CT cattle produced carcasses with lower marbling scores. The TT cattle did, however, exhibit higher variability in marbling scores.

Days-on-feed

Under a low price, calves were projected to optimally be sold at 185 days, on average. There was no statistical difference among genotypes. However, as prices increased, cattle were fed longer. Optimal DOF by price level and genotype are reported in Table 15.

Table 15. Average profit-maximizing days-on-feed for individual calves and the entire group

	Low price		Medium price		High price	
	Individual	Potload	Individual	Potload	Individual	Potload
	(St dev)	(St dev)	(St dev)	(St dev)	(St dev)	(St dev)
All	185 (24)	195 (30)	193 (23)	201 (26)	200 (21)	207 (26)
CC*	185 (23)	197 (32)	194 (21)	202 (25)	200 (20)	209 (24)
CT	183 (24)	192 (29)	193 (24)	200 (26)	200 (21)	207 (25)
TT	188 (25)	198 (31)	192 (24)	201 (27)	198 (22)	207 (28)

*CC = homozygous c or ‘lean’; CT = heterozygous; TT = homozygous t or ‘fat.’

Table 15 also compares the profit-maximizing DOF for marketing cattle in potloads. No statistically significant differences were observed.

When marketing cattle in 45 head groups, optimal days-on-feed varied considerably among models. Interestingly, individual cattle were not consistently marketed on a specific marketing date (i.e., 1, 2, 3, or 4). Optimal DOF for marketing potloads of cattle are reported in Table 16.

Table 16. Average profit-maximizing days-on-feed for 45 head groups

Marketing Date	Low price		Medium price		High price	
	Leptin genotype		Leptin genotype		Leptin genotype	
	Known	Unknown	Known	Unknown	Known	Unknown
1	161	161	171	171	173	174
2	176	176	185	182	194	201
3	201	201	207	201	222	224
4	240	240	240	240	240	240

Economic Analysis

Optimal DOF ignoring the knowledge of leptin genotype was evaluated in the model that included genetic information. Profit was calculated for those days and compared

to profit from the optimal DOF when genetic information was considered. A statistical comparison yielded no significant differences. T-test results are shown in Table 17.

Table 17. T-test comparisons of per head profits when marketed on individual optimal days-on-feed*

	Low price		Medium price		High price	
	Leptin genotype		Leptin genotype		Leptin genotype	
	Known	Unknown	Known	Known	Unknown	Known
Mean	23.69	23.69	87.03	87.03	151.85	151.01
Variance	6254.6	6254.6	6913.7	6913.7	7723.2	7929.7
t-statistic	0.0000		0.0000		-0.0902	

*Two-tailed t-test assuming unequal variance.

The profit results when marketing potloads of cattle were also statistically insignificant. While optimal marketing dates varied slightly, the profit associated with those dates varied even less. When marketing cattle by the potload, the value of the knowledge of the leptin gene was between \$0.00 and \$0.33 per head. Genetic information was most valuable when marketing at a high price. However, no statistical differences were observed regardless of price level. Potload marketing t-test results are reported in Table 18.

Table 18. T-test comparisons of per head profits when marketed in 45 head groups*

	Low price		Medium price		High price	
	Leptin genotype		Leptin genotype		Leptin genotype	
	Known	Unknown	Known	Known	Unknown	Known
Mean	17.71	17.71	82.18	82.07	147.82	147.49
Variance	6481.8	6481.8	7069.6	7144.2	7778.3	7784.5
t statistic	0.0000		-0.0126		-0.0359	

*Two-tailed t-test assuming unequal variance.

When cattle were marketed on an individual basis, genetic information provided little value to the producer. While a two-tailed t-test assuming unequal variances yielded no significant statistical differences, there was a consistent pattern that developed amongst

genotypes. The CC cattle were the most profitable under all price conditions. Not only were the TT cattle the least profitable, they consistently produced the largest variance as well. Profit results for individual marketing are reported in Table 19.

Table 19. Average profit by genotype when marketed individually

	Low price			Medium price			High price		
	CC*	CT	TT	CC	CT	TT	CC	CT	TT
Mean	33.41	23.80	20.04	97.26	87.45	82.68	155.24	152.84	146.41
(St dev)	(72.6)	(75.4)	(88.0)	(74.2)	(79.5)	(92.7)	(88.4)	(84.3)	(98.1)
n**	21	100	59	21	100	59	21	100	59

*CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat.'

**n = number of observations.

Profit results when cattle were marketed in 45-head groups were consistent, although slightly lower, with results from individual marketing. While a two-tailed t-test assuming unequal variances showed no significant differences, the results are of practical interest. The CC cattle produced carcasses with profits between \$10.99 and \$19.41 higher than the TT cattle. This is while the variance of TT cattle profits were between 26 and 48 percent higher than that of the CC cattle. Results are reported in Table 20.

Table 20. Average profit by genotype for 45-head groups

	Low price			Medium price			High price		
	CC*	CT	TT	CC	CT	TT	CC	CT	TT
Mean	25.05	18.86	13.16	90.42	82.77	78.26	159.80	149.17	141.28
(St dev)	(77.0)	(76.0)	(89.7)	(78.3)	(80.1)	(93.3)	(76.5)	(84.7)	(98.2)
n**	21	100	59	21	100	59	21	100	59

*CC = homozygous c or 'lean'; CT = heterozygous; TT = homozygous t or 'fat.'

**n = number of observations.

While no statistical significance was observed, several interesting and notable patterns developed during the economic analysis of the leptin gene in feedlot cattle. CC

cattle routinely had the highest profit. Conversely, the TT cattle consistently had the lowest profit with the highest variance. While the use of genetic information did yield a positive economic benefit, the costs (e.g. labor and resources to obtain DNA for genotypic analysis) involved with obtaining genetic information outweighed the benefits associated with the knowledge of the leptin gene.

CONCLUSIONS AND IMPLICATIONS

The purpose of this study was to determine the value of the knowledge of leptin genetics in finished cattle. At present, there is insufficient evidence to conclude that leptin genetics can aid producers in more profitably marketing finished cattle. The results, however, do suggest that there is a relationship between leptin genetics, profit-maximizing days-on-feed, and profitability. Only 180 observations, of which only 21 were homozygous lean (CC) cattle were available. More observations may have produced more definitive results. Additionally, cattle used in this study were, on average, of high genetic marbling potential. Results may have been different in cattle of mixed or lesser quality.

While there were few statistical differences in projected carcass characteristics, homozygous fat cattle do have a higher degree of fat content in all traits pertaining to fat deposition. This has several implications. While CC cattle appear to have more value at slaughter, study results indicate that the TT cattle may be ‘easier fleshing’ (apt to carry more external body fat). Cattle with greater fleshing ability are much preferred from a maternal standpoint. The amount of external fat is the primary determinant of a cows body condition score (BCS). On average, females with a higher BCS will produce heavier calves, have a shorter calving interval, and more longevity (Herd and Sprott 1985).

Classifying the TT cattle as maternal and the CC cattle as terminal could create a new breeding strategy for producers. Seedstock producers could breed specifically for CC bulls to mate with large herds of TT cows. Having parents of known genotype, homozygous C or homozygous T, would ultimately lead to more CT cattle.

Additional implications from this study include feeding strategies for finished cattle. Currently, larger-framed cattle are fed high concentrate diets to allow them to

deposit fat more rapidly. Conversely, smaller-framed cattle are fed more roughage initially to allow them to grow and reach heavier carcass weights. Leptin genotypic information could potentially be used to sort cattle at placement. Homozygous fat (TT) cattle could be fed a higher roughage diet to allow them to reach heavier weights while the homozygous lean (CC) cattle could be pushed earlier with a high concentrate diet to allow rapid fat deposition to occur earlier in the finishing phase.

The use of hormonal implants is very common in the beef industry. Since TT cattle produce a more serum leptin, an implant of leptin antibody could potentially allow them to deposit less fat early in their growth cycle, allowing them to reach heavier weights and still avoid YG4 discounts. While genotyping all cattle entering a feedlot may be inadvisable, leptin implants could potentially be developed for all cattle. This could potentially equip feedlot operators with a ‘tool’ to better manage fat deposition.

Previous research indicated that the leptin gene was associated with marbling and, more generally, fat deposition. Results from this study confirm those results. However, this polymorphism appears to have little economic significance. With only 21 CC observations, discriminatory power may have been insufficient. Further investigation using more observations may be necessary.

REFERENCES

- Barendse, W., R. Bunch, M. Thomas, S. Armitage, S. Baud, and N. Donaldson. "The TG5 DNA marker test for marbling capacity in Australian feedlot cattle." *Australian Journal of Experimental Agriculture*. 44(2004): 669-674.
- Beef Feedlot Systems Manual. *Iowa State University Extension Service, Ames, IA: Iowa State University* January 2001.
- Berg, E.P., E.L. McFadin, K.R. Maddock, R.N. Goodwin, T.J. Baas, and D.H. Keisler. "Serum concentrations of leptin in six genetic lines of swine and relationship with growth and carcass characteristics." *Journal of Animal Science* 81(2003): 167-171.
- Bierman, C.D., and D.M. Marshall. "Associations of leptin gene marker with carcass traits in cattle. (Breeding and Genetics)." *Journal of Animal Science* 79(2001):S40.
- Bierman, C.D., D.M. Marshall, E. Campbell, and N.H. Granholm. "Associations of a Leptin Gene Polymorphism with Beef Carcass Traits." *South Dakota State University Beef Report, Brookings, SD: South Dakota State University Agricultural Experiment Station* 2003-2004.
- Bindon, B.M. "Genetic and non-genetic opportunities for manipulation of marbling." *Australian Journal of Experimental Agriculture* 44(2004):687-696.
- Brester, G.W. "Meeting Consumer Demands with Genetics and Market Coordination: The Case of the Leachman Cattle Company." *Review of Agricultural Economics* 24(2002):251-265.
- Bruns, K.W., R.H. Pritchard and D.L. Boggs. "The relationships among body weight, body composition and intramuscular fat content in steers." *Journal of Animal Science* 82(2004):1315-1322.
- Buchanan, F.C., C.J. Fitzsimmons, A.G. Van Kessel, T.D. Thue, D.C. Winkelman-Sim, and S.M. Schmutz. "Association of a Missense Mutation in the Bovine Leptin Gene with Carcass Fat Content and Leptin mRNA Levels." *Genetics Selection Evolution* 34(2002):105-116.
- Chvosta, J., R.R. Rucker, and M.J. Watts. "Transaction Costs and Cattle Marketing: The Information Content of Seller-provided Presale Data at Bull Auctions." *American Journal of Agricultural Economics* 83(2001):286-301.
- Dhuyvetter, K.C., T.C. Schroeder, D.D. Simms, R.P. Bolze Jr., and J. Geske. "Determinants of Purebred Beef Bull Price Differentials." *Journal of Agriculture and Resource Economics* 21(1996):396-410.

- Fitzsimmons, C.J., S.M. Schmutz I, R.D. Bergen, and J.J. McKinnon. 1998. "Effects of the obese gene in cattle on carcass fat characteristics." *Plant and Animal Genome VI Conference* January 18-22, 1998, Town and Country Hotel, San Diego, Calif.
- Geary, T.W., E.L. McFadin, M.D. MacNeil, E.E. Grings, R.E. Short, R.N. Funston, and D.H. Keisler. "Leptin as a predictor of carcass composition in beef cattle." *Journal of Animal Science* 81(2002):1-8.
- Hale, D.S., K. Goodson, and J.W. Savell. "Beef Quality and Yield Grades" Texas A & M University. 2003.
- Hennessy, D.A., J.A. Midanowski, and B.A. Babcock. "Genetic Information in Agricultural Productivity and Product Development." *American Journal of Agricultural Economics* 86(2004):73-87.
- Herd, D.B., and L.R. Sprott. "Body Condition, Nutrition and Reproduction of Beef Cows." *Texas Agricultural Extension Service, College Station, Texas: The Texas A&M University System*. 1985.
- Houseknecht, K.L., C.A. Baile, R.L. Matteri, and M.E. Spurlock. "The Biology of Leptin: A Review." *Journal of Animal Science* 76(1998):1405-1420.
- Johnston, D.J. "Selecting for marbling and its relationship with other important economic traits. What impact does it have?" In *Marbling Symposium 2001 Coffs Harbour, Aust*, pp.88-93.
- Kemp, Bob. "Utilization of the cytosine to thymine missense mutation in the bovine leptin gene." RAK Genetic Consulting Ltd. 2003.
- Ladd, G.W., and C. Gibson. "Microeconomics of Technical change: What's a Better Animal Worth?" *American Journal of Agricultural Economics* 60(1978):236-240.
- Ladd, G.W., and M.B. Martin. "Prices and Demands for Input Characteristics." *American Journal of Agricultural Economics* 58(1976):21-30.
- Lagonigro, R., P. Wiener, F. Pilla, J.A. Woolliams, and J.L. Martin. "A New Mutation in the Coding Region of the Bovine Leptin Gene Associated with Feed Intake." *Animal Genetics* 34(2003):371-374.
- Oprzadek, J., K. Flisikowske, L. Zwierzchowski, and E. Dymnicki. "Polymorphisms at loci of leptin (LEP), Pit1 and STAT5A and their association with growth, feed conversion and carcass quality in Black-and-White bulls." *Animal Science Papers and Reports* 21(2003):135-145.

- Rodriguez, V.M., P. Catalina, M.P. Portillo, M.T. Macarulla, and A. Palou. "Dietary fat source regulates ob gene expression in white adipose tissue of rats under hyperphagic feeding." *British Journal of Nutrition* 87(2002):427-434.
- Sansinanea, A.S., S.I. Cerone, I. Zonco, C. Garca, and N. Auza. "Serum leptin levels in cattle with different nutritional conditions." *Nutrition Research* 21(2001):1045-1052.
- Shackelford, S.D., M. Koohmaraie, L.V. Cundiff, K.E. Gregory, G.A. Rohrer and J.W. Savell. "Heritabilities and phenotypic and genetic correlations for bovine postrigor calpastatin activity, intramuscular fat content, Warner-Bratzler shear force, retail product yield, and growth rate." *Journal of Animal Science* 72(1994):857-863.
- Stockburger, D.W. *Introductory Statistics: Concepts, Models, and Applications* Atomic Dog Publishing, Cincinnati, Ohio. 1998.
- Tessanne, K., H.C. Hines, and M.E. Davis. "Relationships of Polymorphisms in the Bovine Leptin Gene with Differences in Beef Carcass Traits." *Research and Reviews: Beef and Sheep, Special Circular 170-99, Columbus, OH: The Ohio State University* April 16, 2003.
- Thue, T.D., B.G. Goldade, A.V. Kessel, S.M. Schmutz, B. Laarveld, and F.F. Buchanan. "Quantification of mRNA from adipose in beef cattle selected on genotype at the obese gene." *Plant and Animal Genome IX Conference* January 13-17, 2001. Town and Country Hotel, San Diego, California.
- US Department of Agriculture, Market News Service. www.ams.usda.gov/mnreports. June 18, 2004.
- US Department of Agriculture, North Dakota Agricultural Statistics Service. *North Dakota Agricultural Statistics* 1999 and 2004.
- Wagner, W.R., and P.I. Osbourne. "Quality and Yield Grades in Beef Cattle." *West Virginia University Extension Service, Morgantown, West Virginia: West Virginia University* December 1997.
- Wegner, J., P. Huff, C.P. Xie, F. Schneider, F. Teuscher, P.S. Mir, Z. Mir, E.C. Kazala, R.J. Weselake, and K. Ender. "Relationship of plasma leptin concentration to intramuscular fat content in beef from crossbred Wagyu cattle." *Canadian Journal of Animal Science* 81(2001):451-457.
- Wonnacott, R.J., and T.H. Wannacott. *Econometrics*. Second Edition. John Wiley and Sons, New York, New York. 1979: 292-294.

Yamada, T., S-I. Kawakami, and N. Nakanishi. "The relationship between plasma concentrations and the distribution of body fat in crossbred steers." *Animal Science Journal* 74(2003):95-100.

Zuehlke, Gary. Zuelhke Feedlot, Britton, SD. Personnel Communication. 2004.

APPENDIX A. GAMS CODE

*computes the value of leptin genotyping
*copyright North Dakota State University
*created by Eric A. DeVuyst and Jared Bullinger
*April 2005

option limrow=0;
option limcol=0;

SETS

grades /Prime,HighChoice,Choice,Select,Standard,g1*g5/
qgrade(grades) /Prime,HighChoice,Choice,Select,Standard/
ygrade(grades) /g1*g5/
char /hcw,rea3,bf3,imf,dof,dof_2,W1,REA1,BF1,W2,W3,REA2,BF2,KPH,W1_2,
 REA1_2,BF1_2,W2_2,W3_2,BF2_2,REA2_2,KPH_2,C,T1,T2,highvalue,
 medvalue,lowvalue,lg_bf2,lg_imf,lg_w3,hcw_2,lg_dof,lg_w1,lg_bf3,
 adg, adg_2/
finalchar(char) /hcw,rea3,bf3,imf/
stg1char(char) /dof,W1,REA1,BF1,W2,W3,REA2,BF2,KPH,W1_2,
 REA1_2,BF1_2,W2_2,W3_2,BF2_2,REA2_2,KPH_2,C,T1,T2/
price /low, medium, high/
tag /1*14,16*63,65,67*114,116*129,131*134,136*151,153*169,171*174,
 176*181,183*190/
rep_t /rt1,rt2/
kdate /k161*k240/
;

\$ondelim

TABLE tstage1(char,finalchar) 2nd stage estimate coefficients for char eqns
\$include "f:\Final GAMS Model\stg2char_t.csv"
Table not_stage1(char,finalchar) 2nd stage estimate coefficients for char eqns
\$include "f:\Final GAMS Model\stg2char_not.csv"
TABLE grid (grades,price)
\$include "f:\Final GAMS Model\grade.csv"
TABLE data1(tag,char)
\$include "f:\Final GAMS Model\tag_data.csv"
TABLE optpot(tag,price) optimal kill dates from T less model for potloads
\$include "f:\Final GAMS Model\notoptpot.csv"
TABLE totpot(tag,price) optimal kill dates from T model for potloads
\$include "f:\Final GAMS Model\t_optpot.csv"
TABLE optdays(tag,price) optimal kill date from T less Model
\$include "f:\Final GAMS Model\optDOFnot.csv"
\$offdelim
;
data1(tag,'c') = 0;

```

data1(tag,'bf1_2') = SQR(data1(tag,'bf1'));
data1(tag,'bf2_2') = SQR(data1(tag,'bf2'));
data1(tag,'w1_2') = SQR(data1(tag,'w1'));
data1(tag,'w2_2') = SQR(data1(tag,'w2'));
data1(tag,'w3_2') = SQR(data1(tag,'w3'));
data1(tag,'real_2') = SQR(data1(tag,'real'));
data1(tag,'rea2_2') = SQR(data1(tag,'rea2'));
data1(tag,'kph_2') = SQR(data1(tag,'kph'));
data1(tag,'lg_bf2')=LOG(data1(tag,'bf2'));
data1(tag,'lg_w3')=LOG(data1(tag,'w3'));
data1(tag,'lg_w1')=LOG(data1(tag,'w1'));
data1(tag,'lg_imf')=LOG(data1(tag,'imf'));
data1(tag,'adg') = (data1(tag,'w3')-data1(tag,'w1'))/160;

```

PARAMETERS

```

yardage daily yardage cost
feed daily feed cost
int_rate interest rate on operating
age(tag) optimal marketing age by tag number
profit objective
projchar(tag,finalchar) projected carcass characteristics
fyg(tag)
revenue(tag,kdate,price)
profit(tag,kdate,price)
priceq(tag,kdate)
prycey(tag,kdate)
priceb(price) /low 112, medium 128, high 144/
projimf(tag,kdate)
cprice(tag,price) calf prices in dollars per cwt live weight
slide(tag) price slide in dollars per cwt live weight under 750 pound
;
cprice(tag,'low') = 78.87;
cprice(tag,'medium') = 88.87;
cprice(tag,'high') = 98.87;
slide(tag) = (750-data1(tag,'w1'))*0.08;
cprice(tag,price) = cprice(tag,price)+slide(tag);

```

```

LOOP(tag,
IF ((data1(tag,'dof') EQ 1),
data1(tag,'dof') = 176;
);
IF ((data1(tag,'dof') EQ 2),
data1(tag,'dof') = 182;
);
IF ((data1(tag,'dof') EQ 3),
data1(tag,'dof') = 190;

```

```

);
IF ((data1(tag,'dof') EQ 4),
    data1(tag,'dof') = 196;
);
);
LOOP((kdate,tag),
    age(tag) = 161 + ORD(kdate)-1;
    projchar(tag,'imf') = data1(tag,'imf') + EXP(5.870174776)*
        (EXP(0.002909732*age(tag))
        -EXP(0.002909732*data1(tag,'dof')));
    projchar(tag,'hcw') = tstage1('w1','hcw')*data1(tag,'w1')
        +tstage1('adg','hcw')*age(tag)*data1(tag,'adg')
        +tstage1('adg_2','hcw')*POWER(age(tag),2)
        *data1(tag,'adg')
        +tstage1('rea2','hcw')*data1(tag,'rea2');
    projchar(tag,'bf3') = (tstage1('lg_bf2','bf3')*data1(tag,'lg_bf2')
        +tstage1('kph','bf3')*data1(tag,'kph')
        +tstage1('lg_imf','bf3')*data1(tag,'lg_imf')
        +tstage1('lg_dof','bf3')*LOG(age(tag))
        +tstage1('rea3','bf3')*
        (tstage1('rea1','rea3')*data1(tag,'rea1')
        +tstage1('lg_dof','rea3')*LOG(age(tag))
        +tstage1('rea2_2','rea3')*data1(tag,'rea2_2')))
        /(1-tstage1('rea3','bf3')*tstage1('bf3','rea3'));
    IF((projchar(tag,'bf3') LT 0),
        projchar(tag,'bf3') = 0.01;
    );
    projchar(tag,'rea3')= (tstage1('rea1','rea3')*data1(tag,'rea1')
        +tstage1('rea2_2','rea3')*data1(tag,'rea2_2')
        +tstage1('lg_dof','rea3')*LOG(age(tag))
        +tstage1('bf3','rea3')*
        (tstage1('lg_bf2','bf3')*data1(tag,'lg_bf2')
        +tstage1('lg_dof','bf3')*LOG(age(tag))
        +tstage1('kph','bf3')*data1(tag,'kph')
        +tstage1('lg_imf','bf3')*data1(tag,'lg_imf')))
        /(1-tstage1('rea3','bf3')*tstage1('bf3','rea3'));
    fyg(tag) = TRUNC(2.5+2.5*projchar(tag,'bf3')+0.2*data1(tag,'kph')
        +0.0038*projchar(tag,'hcw')-0.32*projchar(tag,'rea3'));
    IF ((fyg(tag) LT 1),
        fyg(tag) = 1;
    );
    IF ((fyg(tag) GT 5),
        fyg(tag) = 5;
    );
    LOOP(price,
        LOOP(grades,

```

```

IF((fyg(tag) EQ (ORD(grades)-5)),
  pricey(tag,kdate) = grid(grades,price);
);
priceq(tag,kdate) = grid('prime',price)
);
IF((projchar(tag,'imf') LT 700),
  priceq(tag,kdate) = grid('highchoice',price)
  IF((projchar(tag,'imf') LT 500),
    priceq(tag,kdate) = grid('choice',price)
    IF((projchar(tag,'imf') LT 400),
      priceq(tag,kdate) = grid('select',price)
      IF((projchar(tag,'imf') LT 300),
        priceq(tag,kdate) = grid('standard',price)
      );
    );
  );
);
);
);
);
projimf(tag,kdate) = projchar(tag,'imf');
revenue(tag,kdate,price) = (priceb(price)+pricey(tag,kdate)+priceq(tag,kdate))
  /100*projchar(tag,'hcw');
profit(tag,kdate,price) = revenue(tag,kdate,price)-1.36*age(tag)-0.29*age(tag)
  -1.65*age(tag)**2/2*0.055/365
  -cprice(tag,price)/100*data1(tag,'w1')
  *(1+age(tag)/365*0.055)
;
);
PARAMETERS
maxprof(tag,price) max profit for each tag
optkdate(tag,price) optimal kill date for each tag
;
maxprof(tag,price) = SMAX(kdate,profit(tag,kdate,price));

LOOP((tag,kdate,price)$ (profit(tag,kdate,price) EQ maxprof(tag,price)),
  optkdate(tag,price) = 160 + ORD(kdate);
);

LOOP(price,
  * age(tag) = optdays(tag,price);
  age(tag) = optkdate(tag,price);
  projchar(tag,'imf') = data1(tag,'imf') + EXP(5.870174776)*
    (EXP(0.002909732*age(tag))
      -EXP(0.002909732*data1(tag,'dof')));
  projchar(tag,'hcw') = tstage1('w1','hcw')*data1(tag,'w1')
    +tstage1('adg','hcw')*age(tag)*data1(tag,'adg')
    +tstage1('adg_2','hcw')*POWER(age(tag),2)

```

```

        *data1(tag,'adg')
        +tstage1('rea2','hgw')*data1(tag,'rea2');
projchar(tag,'bf3') = (tstage1('lg_bf2','bf3')*data1(tag,'lg_bf2')
        +tstage1('kph','bf3')*data1(tag,'kph')
        +tstage1('lg_imf','bf3')*data1(tag,'lg_imf')
        +tstage1('lg_dof','bf3')*LOG(age(tag))
        +tstage1('rea3','bf3')*
        (tstage1('real','rea3')*data1(tag,'real')
        +tstage1('lg_dof','rea3')*LOG(age(tag))
        +tstage1('rea2_2','rea3')*data1(tag,'rea2_2'))
        /(1-tstage1('rea3','bf3')*tstage1('bf3','rea3'));
LOOP(tag$(projchar(tag,'bf3') LT 0),
projchar(tag,'bf3') = 0.01;
);
projchar(tag,'rea3')= (tstage1('rea1','rea3')*data1(tag,'real')
        +tstage1('rea2_2','rea3')*data1(tag,'rea2_2')
        +tstage1('lg_dof','rea3')*LOG(age(tag))
        +tstage1('bf3','rea3')*
        (tstage1('lg_bf2','bf3')*data1(tag,'lg_bf2')
        +tstage1('lg_dof','bf3')*LOG(age(tag))
        +tstage1('kph','bf3')*data1(tag,'kph')
        +tstage1('lg_imf','bf3')*data1(tag,'lg_imf'))
        /(1-tstage1('rea3','bf3')*tstage1('bf3','rea3'));
fyg(tag) = TRUNC(2.5+2.5*projchar(tag,'bf3')+0.2*data1(tag,'kph')
        +0.0038*projchar(tag,'hgw')-0.32*projchar(tag,'rea3'));
*DISPLAY projchar;
);

PARAMETER
SUMPROF(price) max total profit
tlessprof(price) profit when t less optimal kill dates are used
;

sumprof(price) = SUM(tag,maxprof(tag,price));

DISPLAY sumprof, optkdate, maxprof;

LOOP(price,
age(tag) = optdays(tag,price);
tlessprof(price) = SUM(tag,
        SUM(kdate$(age(tag) EQ ORD(kdate)+160),
        profit(tag,kdate,price)));
);

DISPLAY tlessprof;

```

PARAMETER

net(tag,kdate);

BINARY VARIABLES

a(tag,kdate)

b(kdate)

;

VARIABLE

totprof

;

EQUATIONS

once(tag) can only market each animal once

pot(kdate) must market 45 head per kill date

dates can only market on 4 dates

obj profit

;

once(tag).. SUM(kdate,a(tag,kdate)) =E= 1;

pot(kdate).. SUM(tag,a(tag,kdate)) =E= 45*b(kdate);

dates.. SUM(kdate,b(kdate)) =E= 4;

obj.. SUM((tag,kdate),a(tag,kdate)*net(tag,kdate)) =E= totprof;

MODEL potload /once,pot,dates,obj/;

net(tag,kdate) = profit(tag,kdate,'high');

potload.iterlim = 1500000;

potload.reslim = 12000;

b.l(kdate) = 0;

b.l('k163')=1;

b.l('k181')=1;

b.l('k230')=1;

b.l('k235')=1;

a.l(tag,kdate)=0;

LOOP((tag,kdate)\$ (ORD(kdate)+1 EQ optpot(tag,'high')),

a.l(tag,kdate) = 1;

);

OPTION MIP=cplex;

OPTION OPTCR = 0.01;

OPTION SOLPRINT=OFF;

potload.RESLIM=10000000;

potload.ITERLIM=10000000;

SOLVE potload MAXIMIZING totprof USING MIP;

DISPLAY a.l,b.l, totprof.l;

net(tag,kdate) = profit(tag,kdate,'medium');

OPTION MIP=cplex;

```

LOOP((tag,kdate)$ (ORD(kdate)+1 EQ optpot(tag,'medium')),
  a.fx(tag,kdate) = 1;
);
SOLVE potload MAXIMIZING totprof USING MIP;
DISPLAY a.l,b.l, totprof.l;
net(tag,kdate) = profit(tag,kdate,'low');
OPTION MIP=cplex;
LOOP((tag,kdate)$ (ORD(kdate)+1 EQ optpot(tag,'low')),
  a.l(tag,kdate) = 1;
);
SOLVE potload MAXIMIZING totprof USING MIP;
DISPLAY a.l,b.l, totprof.l;

LOOP(price,
  maxprof(tag,price) = SUM(kdate,as(tag,kdate,price)*profit(tag,kdate,price));
);

PARAMETER
  notprof(price);
  notprof(price) = SUM(tag,maxprof(tag,price));
DISPLAY notprof, maxprof;

```