

# Ultrasonic imaging of marbling at feedlot entry as a predictor of carcass quality grade

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*Department of Health Management, Atlantic Veterinary College, University of Prince Edward Island, 550 University Avenue, Charlottetown, Prince Edward Island, Canada C1A 4P3 (e-mail: gkeefe@upei.ca).  
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Keefe, G. P., Dohoo, I. R., Valcour, J. E. and Milton, R. L. 2004. **Ultrasonic imaging of marbling at feedlot entry as a predictor of carcass quality grade.** *Can. J. Anim. Sci.* **84**: 165–170. This study evaluated the ability of ultrasonic examination at entry into the feedlot to predict carcass traits. Feeder calves (487) from eight Prince Edward Island feedlots were examined with an Aloka 500 ultrasound and Critical Vision<sup>®</sup> image analysis software to determine carcass attributes (backfat, ribeye area and intramuscular fat) at feedlot entry. These measures, along with potential confounders, were evaluated for their ability to predict carcass grade. Three statistical procedures (multinomial logistic regression, constrained multinomial logistic regression and a proportional odds logistic regression) were used to evaluate the data. After evaluation, final analyses were performed using the constrained multinomial logistic regression (adjacent category) procedure. All three ultrasound determined carcass attributes were significantly associated with slaughter grade. The odds of being one grade category higher (e.g., AAA) versus the adjacent category (e.g., AA) were 1.74, 1.37 and 0.98 per percentage point intramuscular fat, mm of backfat or cm<sup>2</sup> of ribeye area, respectively. Heifers were 2.1 times more likely to be in the next higher grade category than steers. Feedlot of origin, days on feed and carcass weight were also significant predictors of final grade.

**Key words:** Cattle, beef; carcass traits; ultrasound; marbling; carcass grade

Keefe, G. P., Dohoo, I. R., Valcour, J. E. et Milton, R. L. 2004. **Examen aux ultrasons du persillé en début d'embouche comme indice de prévision de la qualité de la carcasse.** *Can. J. Anim. Sci.* **84**: 165–170. On a déterminé dans quelle mesure l'examen des bovins aux ultrasons à leur entrée au parc d'engraissement pourrait servir à prévoir les paramètres de la carcasse. Des bouvillons d'engrais (487) de huit élevages de l'Île-du-Prince-Édouard ont été examinés avec une sonde Aloka 500 et le logiciel d'analyse des images Critical Vision<sup>MC</sup> en vue d'établir les attributs de la carcasse (épaisseur du gras dorsal, superficie du faux-filet et gras intramusculaire) à l'arrivée au parc d'engraissement. On a évalué ces paramètres et les variables confusionnelles potentielles pour savoir s'ils pourraient servir à prévoir la catégorie de la carcasse. Les données ont été évaluées par trois méthodes statistiques (régression logistique multinominale, régression logistique multinominale contrainte et régression logistique relative proportionnelle). Après évaluation, on a procédé à une analyse finale par régression logistique multinominale contrainte (catégorie adjacente). Les trois attributs mesurés aux ultrasons présentent une corrélation significative avec la catégorie. La probabilité d'obtenir un classement supérieur (AAA) au lieu de la catégorie adjacente (AA) s'élève à 1,74, à 1,37 et à 0,98, respectivement, par point de pourcentage pour le gras intramusculaire, par mm pour l'épaisseur du gras dorsal et par cm<sup>2</sup> pour la surface du faux-filet. Les génisses sont deux fois plus susceptibles que les bouvillons de se retrouver dans la catégorie supérieure. Le parc d'engrais d'origine, le nombre de jours d'embouche et le poids de la carcasse sont des indicateurs prévisionnels importants de la catégorie.

**Mots clés:** Bovins de boucherie, paramètres de la carcasse, ultrasons, persillé, catégorie de la carcasse

The beef industry attempts to increase profitability by focusing on the production of beef products with desirable characteristics in the marketplace, which has led to a growing interest in tailoring beef carcass traits to consumer demand. Genetic improvement has been the traditional pathway to achieve altered carcass composition. However, long generation intervals and sire proofing times compared to competitive products make market responsiveness difficult.

Live animal ultrasound measurements of backfat and loin eye area, taken in close proximity to slaughter, have been used to predict carcass traits. The correlation between live animal results and carcass results [0.90 for rib fat and 0.87 for longissimus muscle area (LMA)] is so high it has led researchers to

state that a very experienced technician can measure LMA only marginally less accurately than it can be measured on the carcass (Robinson et al. 1992). More recently, Hassen et al. (2001), using a variety of models and ultrasound equipment concluded that ultrasound could also be used to accurately predict the percentage of intramuscular fat.

Much of the research in live animal ultrasound for carcass trait assessment has focused on genetic selection, particularly of the paternal line. Carcass traits appear to be moderately heritable. In one study, heritabilities of traits of interest were 0.48, 0.40 and 0.42 for backfat thickness, ribeye area

**Abbreviations:** LMA, longissimus muscle area

and marbling percentage, respectively (Wilson 1992). In a second study, heritabilities were 21% for LMA and 30% for ribeye fat (Robinson et al. 1993). In a large study involving nearly 5000 Hereford steers, marbling was moderately heritable (0.35) and negatively correlated with total postweaning average daily gain (0.54) (Arnold 1991). A review of the literature on the utility of ultrasound examination (Robinson et al. 1993) stated that, in general, the results indicate that carcass traits have genetic variability, are moderately heritable and that genetic progress can be made by selection using ultrasound technology.

Before seedstock industries will use a tool, such as ultrasound, it must be cost effective and there must be an economic incentive to select for improvement (Wilson 1992). This economic incentive will have to come to the cow calf producers from the feedlot operators. In order to discern potential premium payments for high carcass quality weaned cattle, an objective quality assessment tool must be available. Additionally, beyond encouragement of greater genetic progress among seedstock producers, ultrasound at feedlot entry may allow for sorting feedlot entrants for particular premium markets. The objective of this study was to evaluate the ability of an ultrasonic examination at entry into the feedlot to predict carcass traits at slaughter.

## MATERIALS AND METHODS

This research was conducted with the approval of the University of Prince Edward Island animal care committee using the guidelines set forth by the Canadian Council on Animal Care.

Eight Prince Edward Island feedlot operators who shipped to a slaughterhouse that provided animal-specific carcass assessment participated in the study. Calves destined for these feedlots were sourced at a variety of cow calf and salesbarn locations. Calves entered the trial whenever they entered the feedlot and were followed up to slaughter. Depending on handling facilities, calves were either scanned at the seller's farm (cow calf) or at the feedlot itself. At the time of trial entry, calves were identified with a unique eartag. In Table 1, study entry and exit variables, categorized by the unit of measure employed, are summarized. Frame scoring was performed using the Official United States Standards for Grades of Feeder Cattle (Boyles et al. 1992). Weights at the time of ultrasound (entry) were recorded in lb rather than kg because this is the scale that the software required. Carcasses were graded at slaughter as Canada AAA (AAA), Canada AA (AA) or Canada A (A) according to the grading system of the Canadian Food Inspection Agency (Canadian Beef Grading Agency 2003).

Duplicate ultrasonic images, in the longissimus muscle region between ribs 12 and 13, were created by an Animal Ultrasound Practitioners certified technician (Barham 1999) and stored as digital image files using an ALOKA 500 ultrasound unit with a 3.5 MHz 17 cm linear ultrasound probe, model UST-5049-3.5 (Aloka, Wallingford, CT). Using the Critical Vision<sup>®</sup> version 3.5 analysis software (Critical Vision Inc., Atlanta, GA), measures of backfat depth and area of the loineye were determined. Additionally, the image analysis capabilities of the software were exploited to

**Table 1. Variables used in the evaluation of the ability of an ultrasound examination at the time of entry into a feedlot to predict carcass grade at slaughter**

Variable	Type	Description/categories/units
Heifer	Dichotomous	Heifer (compared to steer)
Feedlot	Categorical	Feedlot number
Source type	Categorical	Site of ultrasound (feedlot, cow-calf owner-feeder)
Calf status	Dichotomous	Weaned, backgrounded
Carcass grade <sup>z</sup>	Ordinal	CANADA A, AA, AAA (outcome variable)
Frame score <sup>y</sup>	Ordinal	Large, medium, small
Hip height	Continuous	cm
Breed or cross	Categorical	Predominant breed
Implant	Categorical	Use and type of implant
Date weighed	Date	
Date entered feedlot	Date	
Date slaughtered	Date	
Days on feed	Continuous	
Weight at entry	Continuous	kg
Ribeye	Continuous	Ribeye area calculated from ultrasound (cm <sup>2</sup> )
Backfat	Continuous	Backfat thickness calculated from ultrasound (mm)
Intramuscular fat	Continuous	Marbling calculated from ultrasound (%)
Slaughter plant	Ordinal	
Carcass weight	Continuous	kg
Live weight	Continuous	kg
Yield percentage	Continuous	%

<sup>z</sup>Grading system of the Canadian Food Inspection Agency (Canadian Beef Grading Agency 2003).

<sup>y</sup>United States Standards for Grades of Feeder Cattle (Boyles et al. 1992).

estimate the percentage intramuscular fat (marbling) in the ribeye at the site.

Data were stored as collected in a Quattro Pro version 8 (Corel Corporation, Ottawa, ON) spreadsheet. Statistical procedures were conducted using Stata version 7 (Stata Corporation, College Station, TX). For analysis, the two measurements for each of the ultrasound variables were averaged. Intramuscular fat values less than 1.85% were set to a value of 1.85% to reflect the lower detection threshold level of the ultrasound equipment. Interactions between weight and the ultrasound variables (average backfat, average ribeye and average intramuscular fat), between farm and average intramuscular fat and between average intramuscular fat and days on feed were examined by forcing interaction terms into the models (described below).

Breeds were grouped together by dominant breed or crossbreed type. For example, Angus and Angus crossbreds were grouped together. This resulted in six different breed categories.

Data were analyzed using three models for multinomial data to determine the most appropriate. These included multinomial logistic regression, constrained multinomial logistic regression (adjacent category model) and a proportional odds (ordinal) logistic regression. Multinomial logistic regression makes no assumption about the ordering of the grades and estimates two full sets of coefficients for the factors being investigated [one set for each grade that is compared to the baseline (referent) grade, which was AAA].

Constrained multinomial regression assumes the outcome categories (grades) are ordered and the effects of factors in the model represent their effect on moving from one category to an adjacent category. Consequently, it produces a single set of coefficients for the factors being considered. Constraints were set so that grade levels were considered equidistant. That is, going from AAA down to A was considered twice as large a jump as AAA down to AA. Again, the grade of AAA was used as the reference group. In a proportional odds model, the coefficients for the factors being investigated reflect the effect of the factor on the (log) odds of the animal being below the grade in question compared to at or above the grade. As with the constrained multinomial model, it produces a single set of coefficients for the factors.

Each model was built by starting with a full model (containing all potential predictors) and removing those predictors that were neither statistically significant ( $P > 0.1$ ) nor confounders (removal had a large effect on other coefficient estimates). Although the models are not nested (i.e. one model containing a subset of the variables in a larger model), the adequacy of the models was roughly assessed using log likelihoods and likelihood ratio tests (Dohoo et al. 2003). These were used to compare the constrained (adjacent category) and proportional odds models to the most complex model, the multinomial logistic regression model.

The relationship between intramuscular fat and the probability of achieving each carcass grade was further evaluated by fitting a constrained multinomial logistic model containing only intramuscular fat as a predictor. From this model, predicted probabilities of each grade level were computed and graphed against the percentage of intramuscular fat.

## RESULTS

In total, 1240 animals were scanned. Due to marketing conditions at the time of slaughter, 691 of these cattle were shipped out of the region where animal-specific carcass assessment was not available. Consequently, 549 of the ultrasonically examined animals had corresponding carcass grade scores of A, AA or AAA. A full data set of all input and outcome parameters (Table 1) was available for 487 animals. Forty-six of the 487 animals graded A, whereas 277 and 164 graded AA and AAA, respectively.

Thirteen of the 21 variables included in Table 1 were not significant ( $P > 0.1$ ) in unconditional associations with the outcome or were highly correlated with other variables and were therefore dropped to avoid multicollinearity in the model. Table 2 provides summary statistics for continuous variables included in the logistic models. Backfat depth, ribeye area and percent intramuscular fat averaged 3.08 mm, 57.03 cm<sup>2</sup> and 4.11%, respectively, at the time of ultrasound. Days on feed averaged 215 d but varied widely from 15 to 614 d. Some animals were recently weaned, while others may have been back-grounded for a period before entering into the feedlot.

Log likelihood values (Dohoo et al. 2003) of -347.21, -360.55 and -361.00 were obtained for the multinomial logistic regression, the constrained (adjacent category) multinomial logistic regression and proportional odds models, respectively. Pseudo  $R^2$  values were 0.217, 0.187 and 0.186 for the multinomial logistic regression, the con-

strained (adjacent category) multinomial logistic regression and proportional odds models, respectively. The same sets of predictors were significant in each of the three models that were fitted. Of the two models that produce a single set of coefficients for the factors being investigated (constrained multinomial and proportional odds), the constrained model had the smaller log likelihood, that is, it fit the data better. As a result, the proportional odds model was not considered further. While the likelihood ratio test comparing the constrained models to the multinomial logistic regression was significant ( $P = 0.014$ ), the estimates of the effects of the variables were very similar in the two models. The constrained multinomial (adjacent category) model has far fewer variables estimated and hence is much easier to interpret. As a result, this model was selected for presentation (Table 3).

Three hundred and fourteen (64.5%) of the 487 animals with complete data were steers and 173 (35.5%) were heifers. Overall, 46 (9.4%), 277 (56.9%), and 164 (33.7%) carcasses graded A, AA and AAA, respectively. The feedlot that the animal came from was significantly associated with the final grade. When compared to the reference farm (Feedlot 1), feeders from Feedlot 2 were more likely to make AAA and feeders from Feedlot 4 were less likely to make AAA. All other farms were similar to the reference farm.

Being a steer increased the odds of an animal being in an adjacent lower category by 2.1 times. That is, the heifers were 2.1 times more likely than steers to grade AAA over AA and a further 2.1 times more likely to be AA than A. Heifers were approximately 4.4 times (2.1<sup>2</sup>) more likely to be AAA over A than steers. Within the constrained model, all other associations follow this same pattern.

For carcass weight, for every kg increase in weight, the odds of an animal being in an adjacent lower grade category decreases by 0.987 times. Consequently, a feeder that had a carcass weight of 350 kg compared to one that was 300 kg would be approximately half ( $0.987^{50} = 0.52$ ) as likely to be one category lower (AA versus AAA) and approximately one quarter (0.27) as likely to be an A versus an AAA. Alternatively, this could be expressed as the heavier animal (350 kg) being approximately twice as likely to be AAA as AA or four times as likely to be AAA as A.

Marbling score was measured as a percentage of fat in the scanned muscle. Backfat was measured in mm and ribeye area in cm<sup>2</sup>. For these variables, for every unit increase in percent intramuscular fat, backfat depth and ribeye area, the odds of a carcass being in an adjacent lower grade category changes by 0.57, 0.73 and 1.02 times, respectively. Alternatively, the odds of being graded one category higher were 1.74, 1.37 and 0.98 per percentage point intramuscular fat, mm of backfat or cm<sup>2</sup> of ribeye area, respectively.

For each increase in backfat depth by 1 mm at scanning animals were 0.73 times less likely to be an AA versus AAA and 0.73 times less likely to be an A versus an AA. For every increase of 1 cm<sup>2</sup> inch in ribeye area an animal would be 1.02 times more likely to be an AA versus an AAA and 1.02 times more likely to be an A than an AA.

For the days-on-feed variable: for every unit increase in days on feed the odds of a carcass being in a lower grade category

**Table 2. Summary statistics for continuous variables used in models for prediction of carcass grade in 487 Prince Edward Island feeder cattle**

Variable	Mean	Standard deviation	Minimum	Maximum
Carcass weight (kg)	330.58	43.91	209.09	474.55
Backfat (mm)	3.08	1.22	0.90	8.76
Ribeye (cm <sup>2</sup> )	57.03	11.94	29.81	111.23
Intramuscular fat (%)	4.12	0.98	1.85	8.36
Days on feed	213.41	83.64	15	614

compared to the next higher category decreased by 0.996 times. A feeder that was on feed for 100 d more than a comparison animal from the time of ultrasound measurement to slaughter would be 1.49 times less likely to be in a lower category (AA versus AAA or A versus AA) or conversely 1.49 times more likely to be in the next higher grade category.

The predictive ability of the model to determine various grade cutoffs was examined. Forty-six animals graded A. From these data, 33 of these animals had intramuscular fat score  $\geq 3$  but none had an intramuscular fat score  $\geq 5$ . The positive predictive value for AA or AAA, at the 3 and 5 cutoff was 93% (410/443) and 100% (93/93), respectively. These represent the probability that an animal with a percent intramuscular fat value  $\geq 3$  and  $\geq 5$  will grade higher than A. Additionally, 287 of 323 A or AA grade animals had  $\geq 3$  intramuscular fat score but only 47 of 323 had an intramuscular fat score  $\geq 5$ . The positive predictive values for AAA at the 3 and 5 cutoff were 35% (156/443) and 49% (46/93), respectively. These represent the probabilities that an animal grading  $\geq 3$  and  $\geq 5$  will grade AAA.

A second constrained multinomial logistic regression model was fitted using only intramuscular fat as a predictor. The relationship between intramuscular fat percentage and grade score can best be seen graphically (Fig. 1). The predicted probabilities of attaining a particular grade based on the ultrasound reading at entry into the feedlot are illustrated in the graph. The graph only goes up to 6% intramuscular fat since data were quite sparse above this level. Using this graph, the probability that a calf will grade A, AA or AAA based only on its intramuscular fat reading can be seen. For example, from the graph for an intramuscular fat score of three, the probability of being an A is predicted at approximately 14%, an AA is approximately 63% and an AAA is approximately 23%. Conversely, with an initial intramuscular fat reading of six, the expected proportion of A is approximately 3% and AA and AAA are 40 and 57%, respectively.

## DISCUSSION

This study examined the ability of ultrasound at feedlot entry to predict carcass quality grade at slaughter at the individual animal level. Previous Canadian work has concluded that ultrasound assisted sorting of cattle at feedlot entry improved weight gain and carcass traits, which enhanced profitability (Basarab et al. 1999).

The loss to follow up in this study (56%) was higher than anticipated for a variety of reasons. The project was complicated by a dispute between cattle feeders and the main slaughter plant midway through the project. During that time many producers chose to send their cattle into the live

**Table 3. Final constrained multinomial logistic regression model for carcass grade at slaughter of 487 Prince Edward Island feeder cattle (log likelihood = -360.55, Pseudo R<sup>2</sup> = 0.1867)**

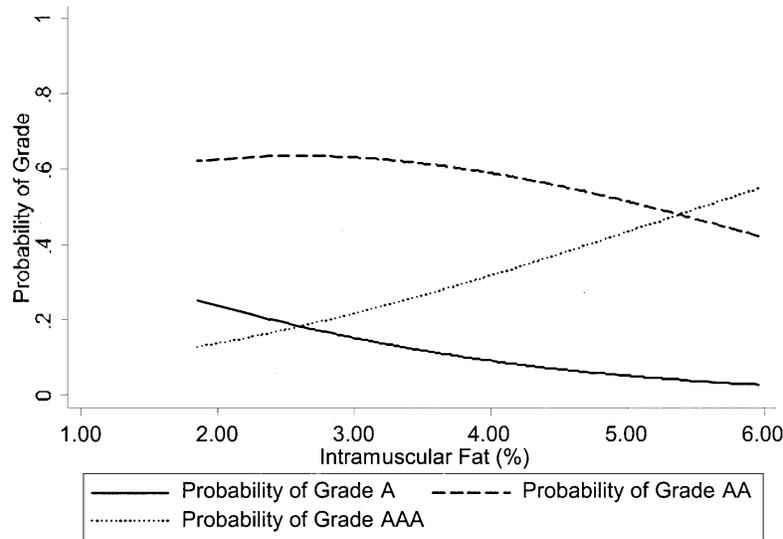
	Odds Ratio	Standard error	P	95% Conf.	Interval
Heifer	2.1031	0.4472	0.001	1.3517	3.2719
Carcass weight	0.9873	0.0034	0.000	0.9806	0.9940
Backfat depth	0.7283	0.0747	0.002	0.5956	0.8905
Ribeye area	1.0218	0.0119	0.065	0.9987	1.0454
Intramuscular fat	0.5744	0.0622	0.000	0.4646	0.7102
Days on feed	0.9962	0.0016	0.019	.9930	0.9994
Farm = 2	0.3008	0.1202	0.003	0.1374	0.6585
Farm = 3	1.6513	0.5590	0.138	0.8506	3.2061
Farm = 4	4.3207	1.8199	0.001	1.8925	9.8646
Farm = 5	1.4019	0.5277	0.369	0.6704	2.9318
Farm = 6	0.6240	0.3771	0.435	0.1909	2.0400
Farm = 7	0.7709	0.3000	0.504	0.3595	1.6531
Farm = 8	1.6446	0.9900	0.409	0.5054	5.3515

Ontario market. All these animals were lost to follow up. An analysis of available parameters (gender, intramuscular fat, ribeye, backfat, and weight on entry into the feedlot) for the censored animals did not indicate any substantial differences between the two groups.

Statistical evaluation of these data provided an interesting challenge. Three procedures, multinomial logistic regression, constrained multinomial logistic regression and ordinal logistic regression, were explored to see which best modeled the data. Log likelihood and pseudo R<sup>2</sup> measures indicated that all models were approximately equivalent in their predictive capacities. As a result, constrained multinomial logistic regression was used because it provided a more intuitive fit to the data. Each coefficient in this model represents the effect of the factor on the odds of being in one category compared to the adjacent category (i.e. AAA and AA or AA and A). With this model the distance between adjacent categories is assumed to be equivalent.

A grading of AAA was used as the reference group so that the odds ratio for a factor reflected the increased or decreased odds of being one grade lower (e.g., AA versus AAA). For example, an odds ratio of 2 for a factor would mean that, when that factor was present, the animal was more likely (twice as likely) to be an AA than an AAA, compared to an animal in which the factor was absent. Grade AAA was chosen as the baseline (referent) group instead of grade A because the latter was relatively rare and the effects of factors may have been estimated imprecisely using A as a referent group.

Thirteen parameters collected at the time of enrollment and four at the time of slaughter were used as predictors in



**Fig. 1.** Predicted probabilities of attaining Canada A, Canada AA or Canada AAA based on the ultrasound reading at entry into the feedlot for 487 Prince Edward Island Feeder cattle.

the model. Breed, frame score and hip height were not predictive of carcass grade, nor was implant use. Previous research has indicated an association between the use of some implants and lowered grade score (Foutz et al. 1997). In this study, only 144 of the 487 animals used in the final analysis were implanted. As a result, there may not have been sufficient power to evaluate this parameter. Weight at entry into the feedlot, liveweight at slaughter, yield percentage and slaughter plant were not statistically significantly associated with carcass grade, once the other factors had been incorporated into the model.

Gender of the animal and feedlot of origin were associated with grade. Heifers were likely to grade higher than steers. Days on feed was also associated with grade at slaughter. Animals that spent longer in the feedlot before going to market were likely to grade higher.

In addition to these animal characteristics, the three characteristics determined by ultrasound at the time of entry into the feedlot, ribeye area, backfat depth and intramuscular fat level were all associated with carcass grade. Carcasses from cattle with smaller ribeye and greater fat cover at entry into the feeding period were likely to be awarded higher grades at slaughter.

The main parameter of interest was predicted intramuscular fat level. This variable had a substantial association with grade score. For each increase percentage in intramuscular fat score the odds of being in the next higher adjacent grade category were 1.74. While at most marbling percentages any of the three carcass grades was possible (Fig. 1), the increasing probability of the highest grade (AAA) with increased intramuscular fat percentage is clearly evident.

### CONCLUSIONS

Before seed stock and feedlot industries will use a tool, such as ultrasound, it must be shown to be effective at predicting

variables of interest. The purpose of this project was to examine the ability of an ultrasound examination, early in the feeding period (or at entry to the feedlot), to predict carcass grade at slaughter. The technology was successful in providing predictors of carcass grade at the time of entry into the feedlot. Of particular interest, each increase of one percentage point in predicted intramuscular fat, the odds of being one grade category higher (A versus AA or AA versus AAA) almost doubled (odds ratio 1.74).

Ultrasound is widely used in genetic evaluation programs, particularly for bulls. The use in this area is likely to continue to expand, particularly into live carcass assessment of heifers for retention as brood cows. The scientific basis for use of ultrasound in feedlots to select animals for certain markets has been documented through this project. Future use of the technology for selecting feeder cattle for certain grade markets will now depend on the ability of producers to receive price premiums for a selected product. Marketing will play a key role if producers are to harness this new knowledge to improve their profitability.

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