Ultrasound applications in beef cattle carcass research and management

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ABSTRACT: Application of ultrasound as a research tool to study bovine carcass characteristics, including growth and development physiology, represents a technological breakthrough that has revolutionized our basic understanding of biology in cattle. However, practical applications of ultrasound to the beef industry hold tremendous potential to enhance overall management and improve beef production systems. Estimation of carcass characteristics in live animals, including backfat thickness, longissimus muscle area, percent intramuscular fat, rump fat, and gluteus medius depth, allow for sorting and selecting cattle for carcass merit. These practical applications of ultrasound hold great potential to return substantial net income on a per animal basis in the beef industry. Development of integrated management systems that combine ultrasound with new and existing technologies, such as linear measurement, video imaging, and thermal imaging, may further enhance practical applications.

Key Words: Cattle, Carcass Grading, Management, Ultrasound

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Introduction

The beef industry has experienced dramatic changes in the past decade. The advent of value-based marketing and increased emphasis on carcass quality and tenderness have brought about a paradigm shift in genetic selection of beef cattle. Collection of carcass data for use in genetic selection has historically been accomplished through progeny testing. This is a slow, tedious, and expensive process. It typically takes a minimum of 3 to 5 yr and $5,000 to "prove" a sire's genetics through progeny testing.

Reliable information and accurate standardized measurements are required to evaluate carcass composition, body condition score, and growth of beef cattle. Ultrasound provides a noninvasive method for estimating fat and muscle accretion and body composition on live cattle. It is a fast, reliable technology with a high degree of repeatability, and provides a nondestructive measure of carcass components in the live animal (Faulkner et al., 1990). By using ultrasound technology to collect carcass data on live animals, progeny testing can be completed in less than 2 yr at a cost of approximately $450 per sire.

Current research indicates that correlations between carcass and ultrasound traits are positive and moderate to high in magnitude. Moser et al. (1997) concluded that yearling ultrasound measurements of breeding cattle could be useful in predicting breeding values for carcass traits. Ultrasound measurements can also be very accurate predictors of carcass yield, and reasonable predictors of carcass quality (Perkins et al., 1997). Other studies found that ultrasonic measurements of carcass traits can be used to sort steers prior to the finishing phase and to predict optimal slaughter endpoints (Williams and Trenkle, 1997; Brethour, 2000; Field et al., 2000).

Estimation of carcass characteristics in live animals potentially allows for sorting and selecting cattle for carcass merit. Collectively, current and future applications of ultrasound hold tremendous potential to enhance management for improved carcass production efficiency in beef cattle. As ultrasound equipment becomes increasingly portable and less costly, it is only a matter of time until widespread implementation of this technology occurs in the beef industry.

Veterinary Ultrasound Equipment

Most ultrasound machines consist of a console unit that contains the electronics, controls, and a screen upon which the ultrasound image is visualized by the operator, and a transducer, which emits and receives high-frequency ultrasound waves. Linear-array transducers consist of a series of piezo electric crystals arranged in a row. These crystals emit high-frequency sound waves upon being energized. Linear-array transducers of 3.5-, 5.0-, and 7.5-MHz frequency ranges are

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most commonly used in cattle to perform ultrasound, and most veterinary ultrasound scanners are compatible with probes of different frequencies. Depth of tissue penetration of sound waves and image resolution is dependent upon and inversely related to the frequency of the transducer. Thus, a 3.5-MHz transducer results in greater tissue penetration and less image detail, whereas a 7.5-MHz transducer results in less tissue penetration and greater image detail. Body composition scanning typically requires the use of a 3.5-MHz transducer, such as that used in the collection of live-animal carcass ultrasound measures. In collecting images of this type, depth of tissue penetration is a key factor in obtaining interpretable images.

Ultrasound Estimation of Carcass Traits in Live Cattle

There are currently four primary carcass traits that are measured in the live animal via ultrasound technology. These traits include backfat thickness, longissimus muscle area, percentage intramuscular fat, and rump fat.

Backfat Thickness. Ultrasound measurements have been shown to represent thickness of subcutaneous fat in studies with slaughtered beef cattle (Faulkner et al., 1990; Otto et al., 1991). backfat represents the subcutaneous fat thickness between the 12th and 13th rib over the longissimus muscle. This is the most common measure of subcutaneous fat on a carcass and is directly related to carcass yield grade. Ultrasound measurement of backfat is a single-plane, linear measure. Because of this, it is the most accurate of the carcass ultrasound measurements. Correlation estimates between ultrasound and actual carcass backfat have been found to range from 0.76 to 0.93 (Perkins et al., 1992a,b; Perkins et al., 1997). Ultrasonic backfat determinations are fairly accurate, but may underestimate actual backfat in fatter cattle and overestimate backfat in leaner cattle (Brethour, 1992; Perkins et al., 1997; Charagu et al., 2000). However, ultrasound estimates of backfat have been within 2.54 mm of actual backfat in 70 (Perkins et al., 1992a), 72 (Perkins et al., 1992b), 62 (Waldner et al., 1992), and 56% (Hassen et al., 1995) of all animals scanned. Brethour (1992) found repeatability between consecutive ultrasound backfat measurements to be 0.975, with an average difference between ultrasound and carcass backfat of 1.19 mm. Genetic correlations between actual backfat and ultrasound backfat have been estimated at 0.57, with a heritability estimate for ultrasound backfat of 0.38 (Moser et al., 1997). Furthermore, ultrasonic measurement of subcutaneous fat is highly correlated with subjective body condition scores in Holstein cattle (Domecq et al., 1995). The use of ultrasound to standardize and objectively measure body condition scores in lactating dairy cows and in beef cattle may improve nutritional and reproductive management in dairy production systems.

Longissimus Muscle Area. Longissimus muscle area represents a cross-sectional area of the longissimus muscle at a point between the 12th and 13th rib. It is the most common estimator of total carcass muscle and is used in yield grade calculation. Ultrasonic longissimus muscle area determination is two-dimensional in nature (length, depth). Therefore, it is more difficult to get as accurate an estimate for longissimus muscle area than it is for backfat. Correlation estimates between ultrasonic longissimus muscle area and actual longissimus muscle area are more variable and range from 0.43 (Smith et al., 1992) to 0.85 (Waldner et al., 1992) to a high of 0.95 (Perkins et al., 1997). The average absolute difference between ultrasound estimates and actual carcass measures have been found to be 7.15 cm^2 or less (Perkins et al., 1992b). Genetic correlations between ultrasonic longissimus muscle area and actual longissimus muscle area and heritability for ultrasound longissimus muscle area have been estimated at 0.59 and 0.28, respectively (Moser et al., 1997).

Several other studies have shown similar correlations between ultrasound and carcass measurements for backfat (r = 0.81 to 0.86) and longissimus muscle area (r = 0.61 to 0.76) (Henderson-Perry et al., 1989; Stouffer et al., 1989; May et al., 2000; Realini et al., 2001).

Intramuscular Fat. Percentage of intramuscular fat is measured in the longitudinal image of the longissimus muscle directly over the 11th, 12th, and 13th rib. Percentage of intramuscular fat provides an estimate of the degree of marbling or intramuscular fat deposited in the longissimus dorsi muscle. The USDA marbling categories range from devoid to abundant. Devoid represents lean muscle tissue with less than 2% intramuscular fat, whereas abundant represents a fat percentage of greater than 10%. Recently, computer software has been developed to aid in the ultrasonic determination of marbling or percentage of intramuscular fat (Brethour, 1994;2000; Herring et al., 1998). Estimation of intramuscular fat percentage is accomplished with specialized software, which analyzes longitudinal images of the longissimus muscle. Marbling is determined by two phenomena: “backscatter” and “attenuation.” Backscatter results from the impinging of sound waves on tissue with small or irregular surfaces, such as marbling. Attenuation results from the weakening of the sound wave as it passes through tissue (Brethour, 1991). Brethour (1990) found that ultrasound speckle, the random graininess or mottling in ultrasound images resulting from impinging of sound waves on rough, irregular tissue surfaces, was an accurate way to estimate carcass marbling score and grade. Correlations between ultrasound intramuscular fat and actual marbling scores have ranged from 0.35 to 0.87 (Wilson, 1992; Izquierdo et al., 1994; Hassen et al., 1995; Perkins et al., 1997). Perkins et al. (1997) found correlations between ultrasound intramuscular fat and actual carcass quality grade to be 0.69. Brethour (2000) indicated correlations between serial ultrasound marbling scores to be as high as 0.85. Duckett and Klein (1997) found that carcass quality grade was accurately predicted from ultrasound intramuscular fat content for 75% of steers used in their project. In a study conducted with stocker steers, steers were scanned at the end of a stocker grazing period prior to shipment to the feedyard. Correlations between actual carcass quality grade and prefeeding period ultrasound intramuscular fat were estimated at 0.49 (Field et al., 2000).

Rump Fat and Gluteus Medius Depot. Rump fat and gluteus medius depth measurements are taken over the rump between the hooks and the pins. Rump fat is negatively correlated to percent retail product and is an additional indicator of total carcass fat. Therefore, the greater the rump fat, the lower the percent retail product. Rump fat measures may be most useful for predicting percent retail product in leaner cattle, which have less 12th-rib fat. Realini et al. (2001) found ultrasound to be an effective method of measuring 12th-rib backfat and longissimus muscle area. Their study indicated that these measurements could be combined with other live measurements, particularly rump fat and gluteus medius depth, to estimate retail yield. Johns et al. (1993) suggested that prediction accuracy of retail product yield could be improved through the measurement of gluteus medius depth utilizing the same image as the rump fat. Tait et al. (2000) indicated that inclusion of gluteus medius depth ultrasound estimates in the rump fat image in multiple regression equations could increase prediction accuracy for weight of retail product from the beef round. Other studies have also indicated that live-animal ultrasound measurements, such as rump fat and gluteus medius depth, are reasonably accurate predictors of retail yield and percentage lean of the beef carcass compared to actual carcass measurements (Bullock et al., 1991; Herring et al., 1994b; Williams et al., 1997).

Technician Accuracy and Repeatability

Technician training and experience is critical in proper ultrasound image collection and image interpretation, if accurate measures of live animal 12th-rib backfat and longissimus muscle area are to be obtained (Robinson et al., 1992; Herring et al., 1994a). Typically, ultrasound is more accurate at predicting backfat, a one-dimensional measurement, than at predicting longissimus muscle area (Houghton and Turlington, 1992; Perkins et al., 1992a). Herring et al. (1994a) stated that the two main sources of error in ultrasound data collection are image acquisition and image interpretation. Hassen et al. (1998) used data from two cattle feeding trials to estimate accuracy and repeatability of ultrasound measurements of backfat and longissimus muscle area. Two certified technicians collected and interpreted images from steers just prior to slaughter. Repeatability of ultrasound backfat was similar for both technicians (0.96 vs 0.97). However, one technician exhibited better repeatability at longissimus muscle area than the other technician (0.92 vs 0.79). The authors concluded that the degree of experience did not show a consistent difference in accuracy of the estimation of ultrasound backfat and longissimus muscle area, thus technicians could be readily trained to make accurate predictions of these traits.

System and Software Reliability

The ultrasound system used to capture and interpret images can have a significant impact on the accuracy and reliability of ultrasound-based carcass measurement estimates. Herring et al. (1994a) evaluated the effect of machine, technician, and interpreter on ultrasonic measures of backfat and longissimus muscle area. Technicians measured steers using an Aloka 210DX with a model 5034, 10.7-cm, 3.5-MHz transducer, and an Aloka 500V with a model 5044, 17.2-cm, 3.5 MHz-linear transducer (both distributed by Corometrics Medical Systems, Wallingford, CT), and interpreted images captured by both. The results show an interaction between machine and technician for both traits measured. Accurate longissimus muscle area estimation with ultrasound was found to be more difficult with machines requiring split-screen imaging compared with machines that allow for complete longissimus muscle area imaging on a single screen. However, technicians with a high degree of experience and skill can measure longissimus muscle area accurately with the split-screen machines, such as Aloka 210DX. Correlations between measurements ranged from 0.36 to 0.90 for longissimus muscle area and 0.69 to 0.90 for backfat. In a comparison of four ultrasound systems, Herring et al. (1998) looked at the effectiveness of software systems for the prediction of percentage intramuscular fat. The four systems included Animal Ultrasound Services, Inc. (Ithaca, NY); Cattle Performance Enhancement Co. (**CPEC**) (Kansas State University [**KSU**] technology) (Oakley, KS); Critical Vision, Inc., Atlanta, GA (**CVIS**); and Classic Ultrasound Equipment, Tequesta, FL. Their study showed the CPEC and CVIS systems to be the most precise at estimating percentage intramuscular fat in finished steers. Charagu et al. (2000) evaluated the Aloka SSD-1100 and Tokyo Keiki CS 3000 ultrasound machines for accuracy of backfat and longissimus muscle area prediction in steers, heifers, and bulls. Their study revealed sex differences between the machines for both backfat and longissimus muscle area. Regardless of sex of animal, both machines had similar accuracy in cattle with larger longissimus muscle area, but significantly differed in lighter muscled cattle. Hassen et al. (2001) evaluated the accuracy of two machines, the Aloka 500V and the Classic Scanner 200, at predicting intramuscular fat in beef steers prior to slaughter. They concluded that both machines could be used to accurately predict intramuscular fat in live cattle.

Practical Applications

Using ultrasound technology to sort and select cattle for carcass merit has the potential to return substantial net income on a per animal basis. Ultrasound technology is used in two basic categories: 1) sorting and selecting seedstock, and 2) sorting feedlot cattle at reimplant for optimal carcass quality and yield grade endpoints.

Live-animal carcass ultrasound is being employed extensively in the seedstock industry to select purebred replacement cattle with genetics for superior carcass merit. These cattle are usually scanned and data collected at 1 yr of age (320 to 440 d). It is important that the data be collected on contemporary groups and comparisons made only within similar management systems. The ability to select replacement seedstock for carcass trait characteristics at 1 yr of age, rather than waiting to obtain actual progeny carcass data, can significantly impact the rate of genetic progress. In fact, several breed associations are actively developing carcass EPD based on live-animal carcass ultrasound measurements, allowing producers to use these ultrasound-generated EPD to make important selection decisions.

Live-animal carcass ultrasound offers advantages to the feeding industry in terms of sorting feeder cattle at reimplant for optimal endpoint results. Prior research indicates substantial gains may be made from sorting feeder cattle prior to marketing. A decision support system within an ultrasound cattle-sorting system (KSU/CPEC) was developed and used to sort feeder cattle at reimplant for prediction of optimal endpoints (Brethour, 1989; 1994; 1995). The KSU/CPEC system uses carcass development models to make sorting decisions by projecting additional days on feed to obtain maximal profitability. It is a stochastic model that estimates the future likelihood for an animal's carcass to be placed in the cells of a typical three-dimensional (quality grade, yield grade, carcass weight) price grid. These probabilities are multiplied by corresponding premiums and discounts to determine an estimate of future carcass value. In the KSU/CPEC system, marginal feed cost is determined through feed performance assumptions. Using these assumptions, sorting offers returns of $11 to $25 per animal, depending on the number of groups into which cattle are sorted. The greater the number of sorts, the better the return, up to five sorts (Koontz et al., 2000). With industry average returns to cattle feeding ranging from $10 to $15 per animal, sorting can offer excellent economic benefits. Basarab et al. (1997) evaluated the use of video imaging and ultrasound in feeder steers to improve carcass uniformity. Ultrasound measures of backfat and longissimus muscle area were used along with animal weight, rump height, frame score, and muscle score (obtained through video imaging techniques) in the Musculo-Skeletal Imaging sorting system. A separate sorting system (Oltjen sorting system) combined the use of ultrasound with initial body weight, rump height, feeding inputs, and a computer model of cattle growth. All steers were fed and evaluated at three different Alberta, Canada feedlots. Results were variable between feedlots, but indicated a potential to use sorting systems combining ultrasound with other technologies to sort steers for increased uniformity and enhanced profitability. In a separate study, Basarab et al. (1999) evaluated the KSU sorting system in two Alberta, Canada, feedlots. This system combines initial body weight, ultrasound backfat and intramuscular fat, and computer-modeled economic data to project the number of days on feed that maximize profitability. This was compared with the conventional system of sorting cattle for harvest by weight and visual appraisal. The KSU-sorted steers gained faster, had a reduced incidence of dark cutters, increased carcass quality grade, and a reduction in over-fat carcasses. Overall profitability was increased by $15.22 per steer in one feedlot and by $27.67 per steer in the other feedlot. Field et al. (2000) indicated the potential to sort steers at the end of the stocker grazing period prior to shipment to the feedyard. A commercial system (ACCU-TRAC Electronic Cattle Management System, or ECM; Micro Beef Technologies, Amarillo, TX) that combines the use of ultrasound with video imaging and computer modeling to sort feeder cattle for optimal returns on a value-based grid pricing system is currently in place in several feedlots.

Future Applications

Presently in the beef industry, ultrasound technology is not used to evaluate seedstock cattle for carcass merit until 1 yr of age. The thinking behind this has been that cattle needed to achieve at least this level of physiological maturity before adequate evaluation could occur. However, if seedstock cattle could be reasonably evaluated at the time of weaning, substantial economic impact could result. Brethour (2000) measured 144 weaning-age (219 d) calves for determination of intramuscular fat and correlated that measurement with actual carcass marbling at harvest. Analysis indicated that the initial intramuscular fat estimates were 78 ± 4% accurate in classifying future quality grade and predicting whether an animal would grade USDA Choice. Since it typically requires an additional $150 per animal to develop a calf from weaning to yearling age, the ability to obtain accurate measurements at weaning could be economically beneficial. There are also no current methods in place to determine potential tenderness in the live animal. The National Cattlemen's Beef Association National Beef Tenderness Survey identified beef tenderness problems as one of the major contributors to customer dissatisfaction (NCBA, 1999). In addition, Huffman et al. (1996) found that consumer eating satisfaction is highly correlated to the degree of tenderness as assessed by Warner-Bratzler Shear force. The ability to determine potential tenderness of a carcass via live-animal carcass ultrasound could tremendously enhance genetic selection and ultimate uniformity of beef. Recently, a novel automated image interpretation software, Beef Image Analysis, was introduced that may allow for sorting of calves at weaning, determine rankings for potential tenderness, and remove much of the current subjectivity in image interpretation (developed by Designer Genes, Harrison, AR). This new software uses conventional cross-sectional and longitudinal images of the longissimus dorsi muscle to make potential tenderness determinations in individual animals. Preliminary data indicate significant positive correlations between ultrasound-determined tenderness estimates and actual Warner-Bratzler shear force estimates in steers sampled (unpublished data). The software must be validated for accuracy and repeatability, and if proven reliable, could lead to the production of a more uniform, consistent beef product and enhance consumer satisfaction.

The future of live-animal carcass ultrasound relies on the continued verification of software and algorithm updates. In addition, as machines are updated or new machines introduced, future studies will be needed for unbiased comparisons among systems. Research will focus on the utilization of carcass ultrasound to more accurately and economically select cattle that will meet or exceed beef industry and consumer expectations. New measurements will be developed that will allow for quantification of tenderness, ribeye shape, indications of stress, and more accurate estimation of percent retail product. Other potential uses include the application of ultrasound in determining designated implant strategies in feeder cattle. Models could be developed using ultrasound intramuscular fat estimates, expected days to harvest, cost of gain, implant impact on carcass quality grade, and impact on gain response due to implant.

Implications

Ultrasound technology has advanced rapidly in the last two decades and will become an increasingly important tool in all segments of the beef industry. As a research and management tool, ultrasound will increase understanding of the growth and development curves of the various beef breeds, including patterns of fat deposition. It will also enhance the ability to accurately select seedstock for improved carcass merit and to properly sort cattle in the feedlot for improved feeding efficiency and targeted marketing. Future applications of ultrasound could also aid in selection of replacement females requiring lower production inputs, and in the development and calculation of cow maintenance expected progeny differences.

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