The Role of Instrument Grading in a Beef Value-Based Marketing System

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ABSTRACT: A functional value-based marketing system must have a means of identifying the value of individual animals or carcasses. The U.S. beef industry has had a strong interest in instrument grading for the past 11 yr. With the major shift toward a value-based system of trading (carrass), the beef industry has defined its needs for an instrument to assess value. Ultrasound seems to be the technology with the greatest chance of success. This paper outlines the history of instrument grading and industry’s progress and plans in this area.

Key Words: Beef, Instruments, Grading, Ultrasound

Introduction

The beef industry’s goals are to become more competitive in the marketplace, to regain and enhance consumer demand and confidence and profitability. During the past 5 yr, the beef industry has made great progress toward accomplishing these goals (Cross et al., 1986; Savell et al., 1987, 1989, 1991). By transition from a commodity to a consumer-driven industry, consumer demands for a leaner product have been realized through a reduction of fat in the meat case by over 27% (Savell et al., 1991). The retailer response of reducing average fat trim from 13 mm to 4 mm was perhaps the most significant consumer response the beef industry has ever made.

Following these dramatic reductions in fat at the retail level, the entire beef industry prepared to respond to the anticipated retailer demand for a trimmer primal cut. Packers knew that they must reduce excess fat, either through buying trimmer cattle or through trimming before the boxed product was marketed. Some segments of the packing industry began to experiment with new animal/carrass specification programs, and others sought alternative methods of removing excess fat from the carrass. Feeders began the search for the types of cattle that could achieve the desired level of marbling without producing excess trimmable fat. Cow-calf producers began the search for the genetics necessary to respond to these expected economic signals.

During late 1987 through mid-1989, the entire beef industry waited for the expected economic signals to crystalize in the marketing system so that they could respond. To almost everyone’s surprise, nothing happened! These signals have yet to emerge in the marketplace. Retailers continue to trim to ≤ 4 mm fat, and to purchase primal cuts with 20 to 25 mm of external fat. Packers continue to use fat to enhance dressing percentage, and feeders continue to sell slaughter “on-the-average.” The industry realized that the marketing system was not functioning correctly and that until it became functional there could be no value-based marketing system, because a value-based marketing system is a system that sends clear and accurate economic signals from the consumer backward through the marketing chain.

With this realization, the Cattlemen’s Beef Board provided funds for the National Cattlemen’s Association and the Beef Industry Council to form a select Value-Based Marketing Task Force (Cattlemen’s Beef Board, 1990) to identify the major...
impediments to value-based marketing and offer suggestions for their resolution. The task force was appointed in the summer of 1989. Their recommendations were released in August 1990 (Cattlemen's Beef Board, 1990) and will have a significant impact on the future of instrument assessment of carcass value worldwide.

**Background**

The objective of this paper is to evaluate the U.S. beef industry's need for a functioning value-based marketing system and to evaluate the role of instrumental assessment of value in that system. The focus of this manuscript was influenced by the needs defined by the U.S. beef industry; therefore, all instrument systems were addressed. The authors used the priorities from the beef industry (Cattlemen's Beef Board, 1990) to justify the need for an objective (instrumental) system for the assessment of carcass value. This review will focus on the beef industry's efforts during the past decade and the direction they intend to pursue in this area.

**Discussion**

**Task Force Findings and Recommendations**

The goal of the task force was "to make beef more competitive, thereby increasing demand." To accomplish this goal, the task force's key objective was to "improve the efficiency of beef production by reducing trimmable fat by 20 percent and increasing lean by 6 percent, both by 1995, while maintaining taste qualities."

The challenge to the task force was to identify key impediments to value-based marketing and provide recommendations for their removal. Their deliberations always were predicated on the assumption that the industry is "consumer-driven." Thus, it was agreed that the signals must originate with the consumer and travel backward to the producer.

Strategies under consideration included the following:

1. The need to identify and quantify consumer targets, such as demand potential for Choice and Select beef by region.
2. The need to define fat trim specifications that meet the needs of retail/foodservice segments and determine the most efficient means of delivering the new product targets.
3. The need to develop information on quality/cutability relationships for use by packers, retailers, and purveyors in making value decisions related to yield, freight, and labor.
4. The need to encourage a shift from trading cattle "on the average," which may obscure the value placed on certain characteristics, toward trading on the merits of individual animals and carcasses. Further, it was recognized that improvements in price discovery and price reporting are needed before such trading will ever become more widely accepted.
5. The need to develop a system for instrument assessment of carcass value because the people raising cattle feel that the present subjective system does not give sufficient confidence to the producer.
6. The need to accelerate research aimed at clearly identifying the genetics of carcass merit, that is, the development of carcass EPD (expected progeny differences).
7. The need to develop models to predict the impact of changes in USDA quality and yield grade standards on the production of trimmable fat.
8. The need to pursue aggressively packaging technology that would enable a move to centralized production of consumer-ready products.

The task force concluded that the present system of grading beef would not be acceptable to most of the production segment because it is based on subjective evaluation of carcass traits. After preliminary recommendations on the need for an instrument system to assess value, the Grading & Labeling Committee of the National Cattlemen's Association began to prepare plans for the development of a "Request for Proposals" (RFP) to begin the research process in instrument grading. Before those recommendations are discussed, some history is in order.

**Historical Overview**

The beef industry's interest in objective grading is not new. For the past 11 yr, the National Cattlemen's Association has, as have other industry groups, stressed the need for such a system and has urged the USDA to provide funds to support its development.

In 1979, the FSQS (now AMS & FSIS) and NASA's Office of Technology jointly funded a study at the Jet Propulsion Lab to determine the feasibility of applying NASA technology to beef grading. NASA identified two technologies that could potentially accomplish the USDA's goals: ultrasound and video image analysis. In 1980, the FSQS asked the ARS to assume the task of developing an instrument to quality- and yield-grade beef carcasses. The FSQS provided funds to the ARS for these efforts. The ARS decided in 1980
that the best approach to accomplish the task was through the development of a Research and Development Contract to the academic and private sectors. An internal panel was established to develop end point criteria and physical standards to test the instrument (this was the impetus for the development of the present marbling photographs in cooperation with the National Live Stock & Meat Board). A technical committee was formed to develop the RFP. The RFP stated clearly the needs for the instrument (accuracy, precision, speed, durability, etc.), but did not specify any particular technology. The committee (as required by law) hosted all potential applicants in a group meeting to answer any questions concerning the "needs" of the instrument before the proposals were due. Eight firms submitted proposals suggesting technologies such as ultrasound and video image analysis. Kansas State University was awarded the contract because of a combination of cost and the fact that it had already developed the first-generation video imaging prototype.

From 1981 to 1983 the video image analysis (VIA) instrument was tested at the USDA's Meat Animal Research Center in cooperation with staff at Kansas State University. The VIA system was based on a camera/computer system that assessed the chilled, ribbed surface of the muscle and fat areas at the 12/13th interface. The system was designed to measure subcutaneous fat depth, the total number and area of marbling pieces, and lean color. The system had a potential of measuring 600 carcasses per hour on a moving chain system. The results of the tests were quite promising, especially in yield prediction (Cross et al., 1983). In 1984 the National Cattlemen's Association passed a resolution at their national convention urging further development of this grading instrument.

On February 7, 1984, the USDA invited 12 industry representatives (beef, pork, and lamb) to Washington, DC, to discuss the status of instrument grading. The industry representatives were unanimous in expressing the need for an objective system of grading. The group felt that the instrument should be able to function on unribbed, unchilled carcasses. This was a major deviation from previous efforts on chilled, ribbed carcasses. On June 13, 1984, the USDA hosted a second meeting with industry representatives in Beltsville, MD to discuss and identify state-of-the-art technology that could be used to assess value objectively. Five types of instrumentation were discussed: 1) nuclear magnetic resonance (NMR), 2) near infrared reflectance, 3) real-time ultrasound, 4) video imaging, and 5) CAT-Scan. The group effectively eliminated video imaging from future consideration by the USDA because of the requirement for unribbed, unchilled carcasses. Expensive methods such as NMR and CAT-Scan were eliminated, and infrared reflectance was eliminated because the research had not progressed far enough to make a good assessment and because it could not determine marbling (as perceived by this group). The group felt that, because of recent advances in ultrasound for use in the medical community, this approach offered the best chance of success.

In 1984 and 1985, staff from the National Live Stock & Meat Board, the American Meat Institute, National Cattlemen's Association, Texas A&M University, and Cornell University met to discuss the next step in regard to ultrasound. It was decided that research needed to be conducted to make certain that ultrasound had the potential to measure traits that predict yield (fat thickness and longissimus muscle area) and marbling. Staff at Texas A&M University agreed to concentrate on the yield traits, and workers at Cornell concentrated on marbling (a small amount of funds was provided to Cornell University to support the efforts of its staff; Stouffer et al., 1989). Results on fat thickness and longissimus muscle area were very promising, and results on marbling were intermediate. These preliminary results did indicate strong potential for ultrasound.

From 1986 to 1990 the use of real-time ultrasound in developing potential carcass EPD increased in popularity. Several universities began to use "off-the-shelf," portable, real-time ultrasound units to measure longissimus muscle area and fat thickness in young bulls. Standards for certification of ultrasound operators were developed by the Beef Improvement Federation. The first certification test was held at Texas A&M University in January 1989. Little research was being conducted to modify "off-the-shelf" ultrasound technology to meet the needs of an objective grading system.

Several significant events in the history of objective grading occurred in 1989. The Australian Meat and Live-Stock Corporation and the Australian Meat and Live-Stock Research and Development Corporation hosted a symposium in Sydney on the "Automated Measurement of Beef." Papers were presented from eight countries on systems to objectively measure carcass value. This group represented the "state-of-the-art" of activities worldwide in this area. Ultrasound was the technology identified with the greatest potential for beef (Stouffer, 1989; Sollish, 1979; Bailey et al., 1986; Berlow et al., 1988; Chen et al., 1989; Cross et al., 1989; Park and Whittaker, 1990). Also in 1989, NCA's Grading and Labeling Committee again listed the need for objective grading as a high priority, and NCA/BIC (Cattlemen's Beef Board) formed the Value-Based Marketing Task Force. The charge to this task force was to identify the impediments to a value-based marketing system.
and to suggest research/technology transfer needed to remove those impediments. Texas A&M University in 1989 entered into a cooperative project with the University of New England (Australia) to test the ability of real-time ultrasound to measure EPD on 700 beef herds in Australia. Staff from Texas A&M University trained the Australian ultrasound operators and assisted in the establishment of operator certification standards similar to the BIF standards in the United States.

In 1989 and 1990 the Australian Meat and Livestock Research and Development Corporation began planning for major efforts in the area of objective assessment of carcass value. It has tentative plans to spend in excess of $3,600,000 (U.S.) during the next 3 yr. The Australian beef industry plans to evaluate more than one technology, but most of its efforts will be in the ultrasound area. Its goals are very similar to those of U.S. workers: to measure the value-determining traits on the slaughter floor before the hide is removed.

In 1990 the NCA Grading and Labelling Committee formed an Instrument Grading Subcommittee to develop an RFP for instrument grading (NCA, 1990), and in June of that year the NCA solicited proposals for instrument grading.

**Industry Approach to Instrument Grading**

The NCA Instrument Grading Subcommittee (NCA, 1990) considered and agreed on the following points when developing their RFP for instrument grading:

1. Given the history of instrument grading research worldwide, it seems that ultrasound (real-time, B-, or A-mode) is the technology with the greatest chance of success in accomplishing the goals set forth by the Value-Based Marketing Task Force.

2. Grading or carcass assessment systems of the future should be designed so that the system does not prohibit the adoption of existing or new processing technologies by the packer. Thus, they recommended that the method of preference for measuring value-determining traits be on the slaughter rail (perhaps before the hide is removed).

3. The most important value end points or traits related to carcass merit or value are percentage or kilograms of lean (standardized to a certain fat content), marbling, lean color, and skeletal maturity. The NCA realized that the more traits that are identified for measurement by the instrument, the greater the expense and the greater the risk of failure. Given the difficulty of measuring lean color in a "hide-on," prerigor carcass and given the economic importance of percentage of lean and marbling, the NCA recommended that lean color not be considered as part of the requirements in the design of the instrument. The NCA felt that research should be initiated to determine whether lean color can eventually be measured in prerigor muscle but felt that the development of this instrument should not be delayed. The NCA felt that lean color can still be determined in the chiller until such research is completed.

4. The NCA realized that the determination of percentage or kilograms of lean will be via prediction equations as in the present USDA yield grade standards. They also realized that the independent variables (predictors) in the new equations may or may not likely change, but the intercept and the coefficients in the best equations almost certainly will.

The NCA felt that the final version of the instrument should meet the following requirements:

1. The instrument must be able to predict percentage or kilograms of lean, marbling (or percentage of chemical fat) and skeletal maturity with a high degree of accuracy.

2. The instrument must have a high level of precision (repeatability) on individual independent variables.

3. The instrument must be totally automated. The interpretation of the image or output should not require a human subjective evaluation; thus, it must be interfaced with the computer.

4. The instrument must be capable of evaluating all carcass traits and computing the dependent variables (percentage or kilograms of lean, marbling, and skeletal maturity) at projected industry production rates.

5. The instrument must be able to withstand extremes in temperature (0 to 40°C) and humidity (up to 100%) without losing accuracy and precision.

6. The instrument must be tamper-proof to prevent errors in assessment.

7. The precise recalibration of the instrument must be accomplished quickly and easily.

The NCA felt that the project should proceed in phases that contain several go/no-go decision points. These phases are described briefly below.

**Phase 1. Development of the First-Generation Laboratory Instrument for the Measurement of Carcass Traits.** The successful completion of this phase will produce an instrument that can approach the precision requirements described above. Accuracy will be tested for marbling and skeletal maturity and the measurement of the independent vari-
ables used to predict percentage or kilograms of lean. The accuracy of that prediction will be evaluated in subsequent phases. In addition, this first-generation instrument will have demonstrated the ability of the technology required to remove the human evaluation of the image from the system. The first-generation instrument will not be evaluated for speed, durability, or robotics. This phase will evaluate all potentially useful ultrasound techniques, including real-time imaging and pulse-echo transmission.

More specifically, this phase would include the development of basic data in the laboratory under strictly controlled conditions to characterize the acoustical properties of carcasses with various levels of carcass traits using A-mode ultrasound. A-mode is a non-imaging, pulse-echo technique that operates in a single line from a point transducer. These properties include longitudinal-wave velocity, shear-wave velocity, and attenuation. This data collection would take place under strictly controlled conditions. The laboratory data would be verified on prerigor carcasses. Temperature gradients, hide and fat covering, poor reflecting surfaces, and other complexities would exist that are not present in the laboratory, and signal processing software would have to be designed to compensate for these realities. Evaluation of the A-mode system should be conducted in parallel to the image processing work on the real-time ultrasound so that a decision can be made about which way to proceed. The two should be evaluated based on accuracy of predicting marbling and other predictions. If A-mode is acceptable, getting an acoustical contact on the robotic system would be much easier than it would be using real-time. Also during Phase 1, image processing software for the automated evaluation of carcass traits in real-time ultrasound images would be developed, including image enhancement software to increase the quality of the image, feature extraction software to identify parameters highly correlated to carcass traits, and prediction equations to correlate features with actual carcass measurements (Haumschild and Carlson, 1983; Berlow et al., 1989). In addition, interpretation software to automate accurately the determination of carcass traits would be developed. This will require artificial-intelligence-based technologies such as neural networks because of the complexity of locating the muscle boundaries in poor-quality images. Finally, software for automatic determination of subcutaneous fat thickness would be designed (a decision should be made whether to measure at an exact point or compute an average thickness over the whole surface).

If it seems likely that the development of the first-generation instrument will be a success, a decision will have to be made to begin Part II of Phase 1. In this part of Phase 1, it will be necessary to conduct research that will identify the most appropriate anatomical locations for the measurement of the predictors (independent variables) and the degree of latitude (missing the anatomical location) that can be designed into the next instrument without losing accuracy or precision. This is a critical stage for the engineering of the second-generation instrument (e.g., if the probe can miss the anatomical site by 50 mm, rather than 13 mm, without sacrificing accuracy or precision, considerable design and engineering expense can be saved).

**Phase 2. Development of the Second-Generation Instrument.** Phase 2 would involve the refining of the first-generation instrument and testing for accuracy and precision after the decision had been made on real-time or A-mode. The second-generation instrument would begin to have some of the durability traits needed in the final instrument. This phase would involve testing the second-generation instrument for accuracy and precision on a carefully selected sample of beef carcasses. Accuracy would be determined by actually fabricating the carcass to its predetermined lean end point and by evaluating skeletal maturity and marbling (and percentage of intramuscular fat). Making preliminary evaluations of the second-generation instrument for durability, making final decisions as to anatomical sites for the independent variables, making design recommendations for the third-generation instrument, and beginning the development of robotic systems would also be included in Phase 2.

**Phase 3. Development of the Third-Generation Instrument Interfaced with Its Robotic System.** This phase will produce the third-generation instrument that will be interfaced with its robotic system. This phase will be conducted in cooperation with the meat packing industry to best design the system for their slaughter floor operations. The third-generation instrument will be expected to meet the accuracy and precision requirements, the durability requirements, and the robotic requirements described for the final instrument. In addition, the official development of the USDA prediction equations will be initiated in this phase. Specifically, during Phase 3 a visual imaging system for the automatic primary location of the probe based on morphological characteristics of the carcass will be developed. More specifically, research in this phase will determine morphological landmarks on the carcass that are visually detectable and that can be used consistently to locate the longissimus muscle and vertebral ultrasonic sites on most of the types of cattle/carcasses produced by the fed beef industry. A durable, precise, and robust instrument based on the results of Phase 2 will be developed during this
phase, as will a robotic and effector capable of preparing the ultrasonic site on the hide and applying the transducer. During Phase 3 a robotic manipulator will be selected and control software will be developed. An evaluation of the work space and the tasks to be performed by the manipulator in order to finalize the construction of a robot with the appropriate characteristics will be undertaken. A control software program to perform tasks such as cleansing, shaving, and probe placement integrating sensor input from the visual imaging system, proximity sensor, and force feedback will be developed, as will an interface between sensing systems and the computer using standard protocols. A work cell to be installed in a research abattoir or packing plant will also be designed.

**Phase 4. Testing of the Final-Generation Instrument.** The outcome of this phase will be the final-generation instrument, which will be subjected to the full range of tests to test for accuracy, precision, durability, speed, and so on. This phase will include a specific design for a durable, maintainable, industrial system that will be suitable for extended pilot tests.

**Implications**

The need for a functioning value-based marketing system has become the driving force behind the increased emphasis on instrument grading. Average trading of animals is a major impediment to value-based marketing. The meat industry has realized that it must shift to a carcass-trading system based on the value of each carcass; thus, the need for an objective system of assessment has become a worldwide priority.

**Literature Cited**


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