Order Number 9402392

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The University of Nebraska - Lincoln, 1993

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ELECTROMAGNETIC SCANNING OF BEEF QUARTERS AND PRIMALS TO PREDICT LEAN CONTENT

by

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A DISSERTATION

Presented to the Faculty of
The Graduate College at the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

Major: Animal Science
Under the supervision of Professor Chris R. Calkins
Lincoln, Nebraska
August, 1993

DISSERTATION TITLE

Electromagnetic Scanning of Beef Quarters and Primals

to Predict Lean Content

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GRADUATE COLLEGE
UNIVERSITY OF NEBRASKA

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Adviser: Chris R. Calkins

To study the use of electromagnetic scanning (EMS) in predicting lean content in beef cuts, two major studies were undertaken utilizing beef quarters and primals. The first study utilized a heterogeneous population containing 100 beef carcasses (60 steers and 40 heifers), representing a range in external fat thickness (.1 to 2.9 cm) and live weight (414 to 742 kg). The second study used 120 steer carcasses representing a more homogeneous population with ranges in external fat thickness of .45 to 2.43 cm and hot carcass weight of 219 to 382 kg. In both studies, right streamlined forequarters (FQ) and hindquarters (HQ) were scanned. Primal rounds, loins, ribs and chucks were prepared from the right quarters, scanned and physically separated into lean, fat, and bone. In the first study, EMS of either the HQ or FQ of steers accounted for 84 to 95% of the variation in lean content (kg) of beef sides and quarters and 71 to 93% of primals. Electromagnetic scanning accounted for 61 to 75% of the variation in percentage lean in sides and quarters and 48 to 65% of primals. Similar results were obtained for heifer carcasses. Validation of the best prediction models appeared to be successful based on correlations with the actual kg or

percentage of lean of the HQ and FQ. The second study utilized two EMS units (MQ-25 and MQ-27) to predict lean content of a heterogenous population of beef quarters and primals over a two year period. Scanning quarters to predict quarters from year one accounted for 91% of the variation in lean content with residual standard deviations (RSD) of 1.08 and 1.30 kg for the HQ and FQ, respectively, and 78 to 81% of lean percentage. Scanning of primals rather than quarters resulted in higher CD for predicting primal lean weight and percentage. The RSD was less than 2.5% for all cuts when predicting percentage lean. Equal or better results were found for year two. These data indicate that electromagnetic scanning is an effective and accurate technology for determining lean content in beef quarters and primals from heterogenous or homogeneous populations. Predicting percentage lean accounts for less variation than when predicting lean weight but RSD are under 2.5%.

ACKNOWLEDGEMENTS

The author would like to thank the many people that have made this degree a possibility. My adviser, Dr. Chris R. Calkins, deserves a special thanks for his guidance, extreme patience and understanding during my degree stay. I will always respect him for his scientific and professional values. Thanks for having me back. Deep appreciation is extended to Elton Aberle, Roger Mandigo, Rick Rasby and Anne Parkhurst for serving on my committee and giving their advice, support and perspective during my degree.

I want to extend my unrelenting thanks to my parents, Jerry and Geri Gwartney and my Sister, Regina Gwartney for their encouragement as I received my degree.

No acknowledgment would be complete without recognizing the people behind the scenes. These include Mary Jensen and her efficient lab crew, Nellie Archer, Calvin Schrock and all the wonderful workers who diligently labored on the 'Bucky Beef' project, including many graduate students. A special thanks goes out to Scott J. Eilert who is not only a true friend but a super colleague. A final thanks to the Jones' family and their hospitality over the years. I'll never forget them.

This dissertation is dedicated to my Grandmother, Susie Janie Marie Gwartney, who taught me about life and respect in her subtle ways. Thanks for all your special love and wonderful poems over the years. God Bless You.

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INTRODUCTION

Many electronic techniques have been used in the past and present to quantify animal carcass composition. The desire to quantify carcass composition accurately and quickly has always been an important goal of the livestock and meat industry. Practical aspects of the application along with the reliability of the final results are critical. Therefore, it is important to address the issues of electronic measurement of carcass composition.

Electromagnetic scanning has been in use for almost 10 years. In its initial stages, the basic technology lacked computer capabilities and sensing equipment that is available on today's units. Further improvement resulted in equipment that was very functional and capable of accurately assessing human and carcass composition. This technology appears to have several advantages over other electronic technologies and shows great promise in the future.

Electromagnetic scanning technology has recently gained increasing interest. The technique works because lean tissue has a greater electrical conductivity than fat due to water and electrolyte content. Fat and bone act as insulators and have 20 times less conductivity than lean. When these tissues are placed in an electromagnetic field, energy from the field is absorbed, more so in lean and less in fat and bone. Depending on the composition of the tissues, differential

responses in energy absorption will occur and can be related to composition.

The effectiveness of electromagnetic scanning has been well documented in pork carcasses and a few commercial pork plants have installed units in their packing facilities. Few studies have been done utilizing beef carcasses and those that have involved limited numbers of carcasses. Many Australian beef packing and boning plants have installed electromagnetic scanning units and utilize them solely for evaluating beef trim composition.

As the livestock and meat industry moves towards a value-based marketing system, an effective technology to evaluate carcasses is desired. This includes the ability to be objective, accurate, non-invasive, reliable, non-biased and fast. Many previous technologies satisfy only one or a few of these criteria. Electromagnetic scanning has the advantage over many electronic measurements because it is not site specific and measures the entire cut that is placed in the electromagnetic field.

LITERATURE REVIEW FOR ELECTROMAGNETIC SCANNING

I. Electronic techniques for measuring carcass composition

A. Overview and introduction for measuring composition

Ultrasonic technology was probably one of the first electronic techniques to be used to assess carcass subcutaneous fat thickness in the 1950's. As the technology became more advanced and computers became more powerful, ultrasonics were utilized to measure not only fat thickness but also ribeye area. Numerous researchers have identified that ultrasonics can be used to predict carcass composition, however, problems may result due to operator error.

Reflectance probes have been developed in the past primarily for use in predicting pork carcass composition. This technique relies on light emitting and tissue reflecting technology and is a fast and efficient method for estimating pork carcass composition. Recent investigations using this technology suggest that it may not be as accurate as once thought and it results in biases in some situations.

Bioelectrical impedance is a technique that was originally used for predicting human composition. It has recently been used to assess pork and beef carcass composition. Insertion of electrode needles is needed for this technique and geometrical considerations are important.

Nuclear magnetic resonance imaging has recently been studied as a means of electronically measuring carcass composition. This technique is unsuitable for use in the meats industry because it is very expensive and results in x-rays. Future machines would have to be x-ray free and less costly to be of any practical use, but for laboratory analysis, it works well and is very accurate.

Velocity of sound is a technology that is somewhat similar to ultrasonics in that it uses sound waves to penetrate animal tissue. The speed at which this occurs is measured and related to carcass composition because different tissues such as fat and lean will impede sound waves at different levels. This technique only evaluates parts or sections of the carcass and may lead to biases due to breed or sex effects on tissue distribution.

B. Ultrasound

Ultrasound technology provides an objective, relatively inexpensive and non-invasive measure of many carcass and live animal traits. It is based on the measurement of reflected sound waves that have penetrated and returned from soft animal tissue. Unlike velocity of sound, where the speed of sound waves are detected after traveling through biological tissue, ultrasound waves travel into the body and are reflected from boundaries between different densities of tissue and detected (Houghton and Turlington, 1992). Ultrasound works much like

radar except that sound waves are used instead of high-frequency radio waves (Lake, 1991) with most sensors operating in a fixed range between 1 and 10 Mhz. Lower frequencies (3 Mhz) allow for better penetration of tissue but lower resolution, while higher frequencies (5 Mhz) give better resolution of tissues close to the body surface such as fat thickness (Cross, 1989).

Ultrasound has been in use for many years (Wild, 1950). Stouffer et al. (1961) introduced ultrasound in the U.S. for use in measuring live animal traits such as backfat thickness and ribeye area. As ultrasound has become more prominent in measuring carcass composition and live animal traits, the equipment gained improved sensing probes and computer technology. Ultrasound is used for measuring fat thickness and ribeye area of young bulls to obtain estimated Expected Progeny Differences (Duello et al., 1992; Houghton and Turlington, 1992).

Numerous studies have correlated ultrasound measurements with subcutaneous fat depth at various locations and ribeye area of beef carcasses. Stouffer and Cross (1985) reported correlations of .78 and .87 for ultrasonic live measures versus actual 12th rib fat depth of beef cattle and ribeye area, respectively. A study by Smith et al. (1988) gave similar correlations (r=.81 for 12th rib fat depth, r=.20 to .43 for ribeye area) when investigating live beef cattle and their carcasses. A correlation of .55 was reported by Strasia

et al. (1989) for 12th rib fat depth in beef. Ultrasound measurements can still be quite variable for standard measurements.

The accuracy of ultrasound is another important issue. Although most literature concerning ultrasound report the data as correlation coefficients, these values can be limiting and misleading as measures of accuracy. Large population variation will cause inflated r values and r values do not indicate bias (Houghton and Turlington, 1992). Regardless of the method used to report accuracies, there is considerable variation among species, technicians and the instrumentation itself when dealing with ultrasonic measurements. Ultrasound technicians obtain better results after additional experience (Brethour, 1992). Other possible explanations for this observed variation in r values could be related to dirt on the hide, hide thickness, degree of fat thickness at the 12th rib and the inability to place the sensor in the same anatomical location each time a reading is taken (Stouffer, 1988). A more important component of error could be attributed to the variability among operators in producing, capturing and interpretation of ultrasound images (McLaren et al., 1991).

Ultrasound for measuring carcass backfat in live animals can be an equivalent method to taking carcass data by serial slaughter if the data are obtained through careful insonification and echographic interpretation. Placement of the sensing probe on the carcass surface only results in small

areas of the carcass being measured. Distribution of carcass tissues is not uniform across species and sexes, therefore, bias and inaccurate information may result. With today's equipment, there are still potential problems with operator error either through improper placement of the sensor probe or misinterpretation of the ultrasonic images (Brethour, 1992).

C. Electronic Probes

Optical probes are used widely in the pork slaughter industry for objective evaluation of carcass composition. This technique is relatively inexpensive, objective, and easy to use. The use of optical probes results in fast, efficient measurement of carcass composition.

Probes such as the Destron Pork Grader (PG 100), Hennessy Grading Probe and Fat-O-Meat'er use a metal probe that is inserted into a carcass while emitting infrared light at 590 to 1000 nm, depending on the probe manufacturer (Jensen, 1991). The different reflective properties of fat and lean allow the probe to function and in most cases, a reference diode is built into the sensor to compensate for aging and temperature effects (Jensen, 1991).

This technology continues to be utilized in the meat industry. However, recent studies show that there is significant bias due to limited, single measures of the carcass. This technology will under estimate well-muscled pork carcasses and their compositional lean makeup (Gu et al.,

1992). Additionally, the probe needs to be inserted at the correct anatomical location, usually the 10th rib, and at slaughter line speeds, this becomes a problem without automation. As the industry moves to leaner hogs, this potential problem needs to be addressed.

D. Bioelectrical Impedance

Bioelectrical impedance is a technology that has recently been used as an objective measure of carcass and cut composition because it is inexpensive, easy to use, and objective. Thomasset (1962) first reported the use of bioelectrical impedance to assess human composition.

The hypothesis that bioelectrical impedance can be related to conductive tissue mass is based on the principle that the impedance of a geometrical system is related to conductor length and configuration, its cross-sectional area, and signal frequency (Lukaski et al., 1986). Bioelectrical impedance uses a constant, alternating, electrical current that is passed through a cut or carcass. As the current is incorporated via transmitter terminals, it is impeded at different rates, depending on the tissue and resistance and reactance are measured (Swantek et al., 1992). This technique does not allow any information about the location of fat depots, namely intermuscular fat (Kallweit, 1992).

Lean and fat tissue have different impeding properties, thus a measure of composition is feasible. Once through the

carcass, the current is received by detector terminals. Body resistance, reactance and distance between the detection terminals are the usual variables measured when using bioelectrical impedance.

A four-terminal unit used to evaluate beef carcasses gave a R^2 for predicting total fat and lean of .83 and .89, respectively, when several bioimpedance measurements were combined (Johns et al., 1992). A study by Marchello and Slanger (1992) with pork indicated that bioimpedance can successfully categorize Boston butts into four lean classes.

Lamb carcass lean content can be estimated using bioelectrical impedance. Jenkins et al. (1988) indicated that resistive impedance along with other carcass measures can reduce residual variation by 51% when predicting fat-free soft tissue from lamb carcasses of the same weight.

Bioelectrical impedance may have potential as a non-destructive method for determining body composition. At present, however, needle probes are still needed and results could be affected by operator error in placement. Additionally, this technology is affected by geometrical configuration and volume of the biological conductor.

E. Nuclear Magnetic Resonance Imaging

Nuclear magnetic resonance imaging (MRI) is one of the most advanced and accurate electronic methods for measuring carcass composition. The resonance of hydrogen nuclei in a

magnetic field after electromagnetic radiation are the basis for MRI (Kallweit and Baulain, 1991; Henning, 1992). Images are produced as a result and are interpreted by computer. Although MRI is highly accurate in predicting carcass lean content (R^2=.88 to .95), it is very expensive and is not suitable for the food industry because x-rays are produced (Kallweit and Baulain, 1991). The speed at which the unit measures composition is very slow compared to other technologies and could not be used at present line speeds

Results obtained from pork bellies indicate that MRI can predict percentage fat accurately with R^2 = .92 (Kallweit and Baulain, 1991). The composition of beef ribs at the 9-10-11 rib section can also be accurately predicted using MRI with R^2 = .98 for lean tissue and .93 for fat tissue (Baulain et al., 1990). This technology has some promise for measuring carcass composition in the future with the use of lower field strengths that don't require superconducting magnets. Also, 'fast scan' possibilities that allow subjects to be measured without having to be perfectly still for lengthy periods of time are promising. Other low cost, simpler machines are available, but resolution is not as good as the more sophisticated models (Kallweit and Baulain, 1991).

F. Velocity of sound

Velocity of sound (VOS) is a relatively new technique that is based on the speed at which sound waves pass through

biological tissue. It uses the principle that sound waves will travel through muscle (1580 m/s) and fat (1480 m/s) tissue at different rates (Ferguson, 1991; Fisher, 1992). Velocity of sound has the advantage of being quick and inexpensive but needs further investigation and development for measurements at commercial processing speeds.

Studies with VOS in carcasses indicate that prediction equations for percentage lean are as good as taking live measures (Wood et al., 1991). Miles et al (1990) indicated that velocity of sound could accurately predict composition in beef cattle and carcasses. A cooperative study done by investigators at CSIRO and New South Wales indicated that velocity of sound was superior to fat depth in predicting percentage muscle and fat (Ferguson et al., 1991). Most of the studies showing positive relationships between velocity of sound and carcass composition have been focused on the shoulder and loin areas of the carcass. The residual standard deviations from this technology have been below 2.5% when predicting percentage lean, indicating that it is an accurate technique.

A critical part of the velocity of sound technology is the site at which the measure is taken, and along with ultrasound, is considered site specific. In addition, the measurement of distance and propagation time are critical in order to derive velocity (Lake, 1988). Most studies have been done under laboratory conditions and industry studies are