VIDEO IMAGE ANALYSIS USED TO PREDICT CARCASS PRIMAL LEAN AND FAT YIELDS, USDA YIELD GRADE FACTORS AND USDA YIELD GRADES

by

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Introduction

Historically there has been a need for selecting factors which indicate the quality and yield attributes of meat. The Official United States Standards for Grades of Carcass Beef, Title 7, (1980) were developed to differentiate meat into categories to facilitate marketing. Revisions of the standards have been made periodically since their inception and these changes usually bring disagreement from one or more segments of the beef industry.

Presently beef carcasses are evaluated for yield grade by a USDA official meat grader using the following factors: 1) hot carcass weight, 2) ribeye area, 3) adjusted fat thickness and 4) percent kidney, heart and pelvic fat.

Ribeye area can be measured; however, under usual grading conditions due to the rapidity required in applying the grades, ribeyes are subjectively estimated rather than objectively measured. Hot carcass weight is obtained from plant records and is used in the yield grade equation as it relates to ribeye size. Fat thickness can be measured at the 12th rib cut surface and then is subjectively adjusted by the grader's opinion of the carcass overall fatness. In actual practice, even this measurement is seldom objectively measured and instead is subjectively evaluated. Kidney, heart and pelvic fat is a subjective determination of the percent internal fat in the carcass.

Since there is much pressure from the packer on the grader to upgrade meat, error results from the use of subjective evaluation. The Comptroller General Report to Congress of the United States (1978) and the Office of The Inspector General, Cross et al. (1980) have both reviewed beef grading practices and their reviews have shown as much as 21% overall error in application of quality and yield grades and an 11.6% error rate in yield grades alone. Both reviews have indicated that an effort to reduce errors must be made to make beef carcass grading more reliable and useful to industry and consumers.

Considerable research has been done on finding attributes of the beef carcass which will more accurately predict its ultimate yield in either pounds or percent. However, little advancement has occurred in recent years.

With the advancement of technology in the past decade, interest has been created in instrument evaluation of beef carcasses utilizing ultrasound, meat fat probing, optical probes, electronics, and/or video cameras to objectively predict beef carcass yields.

This study was designed to test and evaluate the Video Image Analyzer, an instrument that objectively evaluates the beef carcass at the 12th rib cut-surface and to test its predictions of carcass yield to the USDA prediction equation presently used.

CHAPTER 1

REVIEW OF LITERATURE

Development of Beef Grading Standards

A better understanding of the present beef grading system and its problems can be attained when placed in the perspective of their historical development.

Kiehl and Rhodes (1960) reported that a growing market for meat appeared as industrialization progressed first in England and later in the United States. With the growth of markets, commerce and the urbanization of society there became a need for the development of grade standards. A language evolved to facilitate trade in the Colonial period. Farnum (1938) documented that Colonial regulations emphasized quantity standards but also provided for a minimum set of quality standards. Organized markets did not seem to be important prior to 1700.

Sheets (1934) concluded that quality or grade standards developed slowly. Prior to the twentieth century, only the crudest scale of classification of quality differences in meats was recognized.

Kiehl and Rhodes (1960) reported that as meat was traded in foreign markets, and as livestock was traded in other than local markets, considerable attention was focused on the inadequacies of price reporting by individual markets where quality terminology was not uniform. This led to pioneering efforts attempting to develop uniform grades for purposes of price reporting. McCoy (1972) verified that the Agricultural Experiment Station of Illinois was a leader in this area. Between 1901 and 1908, a series of investigations were made into the actual conditions of the markets and means were sought for a remedy to the situation. The United States Department of Agriculture established an Office of Markets in 1913. This is presently the Livestock, Grain and Seed Division, Agricultural Marketing Service, USDA. This office began work in the development of the official grades for live animals and meat in 1915 (Dowell and Bjorka, 1941).

Federal price reporting was initially based on uniform terminology developed at the University of Illinois. Shortly thereafter federal price reporting was based on official grade terms originated by the Federal Government (Kiehl and Rhodes, 1960). The first efforts of marketing of meat products were in obtaining price information pertaining to the meat trade so the livestock market conditions could be interpreted (Harding, 1948).

The first grades formulated in 1916 provided the basis of uniformly reporting the dressed beef markets according to grades. This work was inaugurated as a national service early in 1917. These standards were unpublished and unofficial but were used until 1926. In the meantime, a number of revisions were made as experience and usage dictated. The revised grade descriptions were promulgated by the Secretary of Agriculture, June 3, 1926, as the Official United States Standards for the Grades of Carcass Beef (USDA Title 7, 1980).

Kiehl and Rhodes (1960) stated there was conflict between various area producers and breeders who were concerned about their products' marketability due to the 1926 standards. In short each group viewed grading as a device for their product differentation and promotion. Each had their own opinion on what the standards should represent in each grade.

Vertical competition between the producer of cattle and the meat packer and retailer is conducive to political conflict (Palamountain, 1955).

McCoy (1972) concluded that the derivation of an acceptable and adequate set of grade standards requires an enormous effort. Even when a consensus can be obtained, problems arise in selecting indicators by which the attributes can be measured in live animals and meat. This is especially difficult where only subjective measures are used. Continuous change requires continuous review of the grade standards. Revisions or amendments must be made as the occasion demands.

USDA Title 7 (1980) documents that the use of federal grades has been on a voluntary basis from the beginning except during World War II and the Korean Conflict when it was mandatory in all federally inspected plants.

Amendments or revisions have been made in the Official United States Standards for Grades of Carcass Beef (1980) in the following years:

1939-provided a single standard for the grading and labeling of steer, heifer and cow beef; changed certain grade terms of steer, heifer, and cow beef from "Medium", "Common", and "Low Cutter" to "Commercial", "Utility", and "Canner", respectively.

1941-made similar changes in the grade terms for bull and stag beef as the amendment in 1939; established grade terminology for all beef: Prime, Choice, Good, Commercial, Utility, Cutter and Canner.

1949-eliminated all references to color of fat.

1950-combined Prime and Choice grades and designated them as Prime; renamed Good grade as Choice; divided the Commercial grade into two grades by designating the beef produced from young animals included in the top half of the grade as Good, and retained the Commercial grade designation for the remainder of the beef in that grade.

1956-divided the Commercial grade into two grades strictly on the basis of maturity, young animals designated Standard while Commercial was retained as the grade for beef from mature animals.

1965-adopted cutability standards; clarified the manner of evaluating conformation; placed less emphasis on changes in maturity in the Prime, Choice, Good, and Standard grades; eliminated consideration of the two degrees of marbling in excess of that described as abundant.

1973-provided separate quality grades for beef from "Bullock" (young bulls); eliminated "Stag" and redesignated "Bullock" or "Bull" dependent on evidences of maturity.

1975-eliminated the consideration of maturity in determining quality grade in all bullock beef and all steer, heifer, and cow beef included in the youngest maturity group; increased the minimum marbling requirements by 1/2 degree for the very youngest beef in the Good grade; eliminated conformation as a factor for determining quality grade; required that all carcasses which were quality graded must also be yield graded.

1980-clarified conditions necessary for removal of yield grade designations from officially graded beef; added specific language to make carcasses, which have had the characteristics of the ribeye or the thickness of fat over the ribeye altered, ineligible for grading and made these practices a fraudulent and deceptive practice; allowed grading only in carcass form and only in establishments where the animal was slaughtered or initially chilled; established a 10-minute minimum period between ribbing and presentation for grading.

Prediction of Carcass Composition

9-10-11 Rib. Researchers recognized a need for obtaining a rapid and reliable method to estimate carcass composition. Hankins and Howe (1946) found the separable fat content and chemical composition of the 9-10-11th rib was highly related to the separable fat and chemical composition of the dressed carcass. Correlation coefficients between the percent of separable lean, fat and bone of the 9-10-11th rib to the percent of separable dressed carcass lean, fat and bone were .90 $\pm$ .01, .93 $\pm$ .01 and .80 $\pm$ .03, respectively. Regression equations were developed using the composition of the three-rib section to determine carcass composition.

Numerous studies have been conducted after the Hankins and Howe study to determine prediction equations utilizing 9-10-11th rib separation data to estimate carcass composition. Crown and Damon (1960) determined the correlation coefficients for percentages of separable lean, fat and bone of the 9-10-11th rib cuts were .825, .965 and .85 when correlated with the separable lean, fat and bone of the 12th rib cut. These highly significant correlations reveal the close relationship of the two cuts.

Hedrick et al. (1963) related the separable components of the 9-10-11th rib to yields of individual trimmed and wholesale cuts.

Busch et al. (1968) stated that predicting edible portion of a beef carcass could accurately be accomplished from rib separation data.

Henderson et al. (1966) disagreed with previous work and concluded that neither separable lean nor retail yield from the wholesale rib was an accurate predictor of carcass muscling. A more recent study by Crouse and Dikeman (1976) showed a .79 correlation between percentage retail product from the rib and percent retail product from the carcass.

Predicting Percent Yield. Murphey et al. (1960) using subjective evaluations of exterior and kidney, heart and pelvic fat found a simple correlation of .92 between estimated and actual yield of bone-in retail cuts. The most useful estimating equation was determined to be as follows: Percent of boneless retail cuts from round, loin, rib and chuck=51.34 - 5.784 (fat thickness over rib eye, inches) - .0093 (carcass weight, lb) - .462 (kidney fat, percent of carcass) + .74 (area of rib eye, sq. in.). It was reported that by adjusting the average fatness over the rib eye to account for deposition of fat over the carcass, improvement could be made in predicting yield.

Palmer et al. (1961) when utilizing Murphey's equation noted a simple correlation of .76 between on-the-rail percent estimates and actual percentage yields.

Abraham et al. (1980), working with 280 beef carcasses, showed that when using the same four factors as in the USDA equation (Murphey's equation), over 80% of the variation in the yields was accounted for in multiple reqression equations. The study showed that on the average the carcasses had 3.41% higher yield than predicted by the USDA equation. A regression equation developed from this study was only slightly more highly correlated with cutability than was the equation from which the USDA yield grades were derived.

Predicting Carcass Composition Using Body Measurements. Pierce (1957) determined circumference of the round to be positively associated with percent yields of all wholesale cuts except hindquarter, flank and plate. He concluded that subjective evaluation of conformation was superior to any of the other objective measurements studied such as length of loin, length of body, depth of body, thickness of shoulder, or depth of fat.

Butler (1957) reported that longer bodied carcasses yielded a higher percentage of hindquarter and round.

Cole, Orme and Kincaid (1960) used area of longissimus muscle area, carcass weight, separable lean of particular beef cuts, and various linear carcass measurements to determine their usefulness for prediction of total carcass leanness. The area of loin eye was associated with only 18% of the variation of separable carcass lean, and five to thirty percent of the variation in the separable lean of the more valuable cuts of beef. Likewise, the relationships of the various linear carcass measurements with either loin eye area or carcass separable lean were quite low. Carcass width and circumference measurements were more highly related to loin eye area, while the various linear measurements descriptive of carcass length were closely related to total lean. Bone weight of the entire carcass was highly related to total separable carcass lean (r=.75). Separable lean of a particular cut of beef was found to be more descriptive of carcass leanness or muscling than either the longissimus muscle area or the various carcass measurements. Correlation coefficients between total separable carcass lean and the lean of various wholesale cuts were .95 with round, .93 with chuck, .81 with foreshank, .80 with sirloin, and .75 with shortloin. The high relationship of the lean content in these and other beef cuts (especially the round), to the total lean of the carcass is indicative of their usefulness to predict total carcass muscling in a particular beef carcass.

Orme et al. (1960) indicated the validity of using the weight of certain entire muscles to estimate the degree of muscling in a particular beef carcass. Partial correlation coefficients between weight of total carcass lean and weight of certain muscles or muscle groups were: biceps femoris, .97; sirloin tip muscle group, .82; longissimus muscle, .79; and inside round group, .72.

Cole et al. (1962) determined that increases in carcass length tended to be accompanied by decreases in longissimus muscle area but increases in pounds of lean.

Brungardt and Bray (1963) found the percent trimmed round made the largest contribution to the multiple correlation coefficient in prediction retail yield. Two measurements, percent trimmed round and a single 12th rib fat measurement, accounted for 81% of the variation in percent retail cut yield.

Birkett et al. (1965) showed a multiple correlation of .82 between percent closely trimmed wholesale cuts and a combination of carcass weight, forearm, round circumference, and loin and rump length.

Abraham et al. (1968) stated width of round contributed significantly to equations predicting yield of boneless steak and roast meat. Length of body and conformation were not significantly related to yield of boneless steak and roast meat. Berry et al. (1973) suggested selection for longer bodied cattle will have little effect on the ultimate retail yield of beef.

Predicting Pounds of Yield. Cole et al. (1962) determined carcass weight was more closely related to pounds of separable lean than was any other characteristic. With carcass weight held constant, fat thickness was more highly associated than ribeye size with variation in pounds of separable lean. An equation using fat thickness and carcass weight was associated with over 70% of the variation in separable lean. Predicted values obtained in this study were comparable in accuracy to those obtained by Hankins and Howe (1946).

Fitzhugh et al. (1965) found carcass weight accounted for more variation in roast and steak meat than any combination of other variables. An equation using kidney fat and carcass weight accounted for 90% of the variation in the weight of the boneless steak and roast meat. Equations containing a measure of fat thickness and carcass weight accounted for over 83% of the variation in the weight of the boneless steak and roast meat. They determined the major cause of high correlation between the longissimus muscle area and steak and roast meat was their common correlation with carcass weight.

Carcass Weight As a Predictor. Carcass weight has been found to increase the predictive ability to estimate percent boneless retail cuts and also has been reported to account for over 50% of the variation in pounds of separable lean.

Brungardt and Bray (1963) stated that because measurements of carcass muscle were negatively correlated with side weight, total carcass weight is suggested as a poor indicator of percent edible portion of muscle. Swiger et al. (1964) reported a correlation coefficient between carcass weight and percent retail yield to be -.48. Abraham et al. (1968) stated carcass weight was highly correlated with percent of boneless steak and roast meat (r=-.50).

Allen et al. (1968) found carcass weight had a significant effect upon percent retail cuts and fat trim, but not on percent separable muscle, fat and bone. Carcass weight showed low negative relationships to percentages of muscle. Therefore, researchers agree that as weight increases, percent muscle decreases and percent fat increases.

Swiger et al. (1964) reported the simple correlation between live weight and pounds retail product was .94. Body composition (fat thickness at 12th rib) adds little information to the amount of retail product when carcass weight is known.

Abraham et al. (1968) determined by simple and partial correlations, carcass weight accounted for most of the variation in weight of boneless steak and roast meat. This confirms reports by Kropf and Graf (1959), Cole et al. (1962) and Fitzhugh et al. (1965).

Allen et al. (1968) found carcass weight had a significant effect upon weight of separable fat, muscle, and bone and yields of retail cuts and fat trim. Epley et al. (1970) noted hot carcass weight was the single most valuable predictor of total and primal weight of retail cuts, while fat thickness was the least valuable. Powell and Huffman (1973) stated hot carcass weight was significantly correlated with edible carcass composition but accounted for approximately 30% of the variation in edible carcass composition. Crouse et al. (1975) indicated by simple correlations that carcass weight was a good predictor of cutability within a breed group but a poor indicator over all breed groups.

Longissimus Muscle Area. The longissimus muscle area is a frequently used measurement in predicting either percent or pounds of retail yield.

Hedrick et al. (1965) found longissimus muscle area more highly associated with weight than with percent retail cuts. Brungardt and Bray (1963) showed when using 12th rib fat thickness measurement, carcass weight, longissimus muscle area and kidney, heart and pelvic fat that the longissimus muscle area had a significant influence which agrees with Abraham et al. (1968). The longissimus muscle contributed the least of the four variables in estimating retail yield and later these same conclusions were made by Crouse et al. (1975).

Goll et al. (1961) stated there is no evidence from his study that rib eye area is closely related to items representing overall carcass value.

Fat Thickness. Gottsch et al. (1961), Brungardt and Bray (1963), Hedrick et al. (1969) and Henderson et al. (1966) agree that fat is negatively associated with yield of wholesale and retail cuts. Pierce (1957) and Butler (1957) concluded that finish influences the yields of wholesale cuts more than conformation does. Epley et al. (1970), Powell and Huffman (1973), Crouse et al. (1975) and Abraham et al. (1968) determined that fat thickness is the single most valuable predictor of percent retail cuts.

Ramsey et al. (1962) stated one fat thickness measurement was slightly more closely related to separable lean than were yield grades. Their data indicate that fat has a more definite influence on percent separable lean than does rib eye area because when rib eye area was omitted from the yield grade calculations, the resulting yield grades were more highly related to separable lean and fat than when rib eye was included.

Abraham et al. (1968) found average of three fat thickness resulted in higher coefficients of multiple determination than a single fat thickness measurement. Allen et al. (1968) showed the average 12th rib fat thickness measurement to significantly affect weight and percent of separable components, retail cuts and fat trim.

Crouse and Dikeman (1974) reported correlations of adjusted fat thickness with percentages of moisture, fat and protein to be -.87, .86 and -.85, respectively.

Brackelsberg and Willham (1968) determined by simple correlations that live measurement of fat thickness was as accurate for predicting total carcass fat trim as was the conventional 12th rib carcass fat thickness measurement.

Marbling. Crouse and Dikeman (1974) determined marbling scores and adjusted fat thickness to be important in predicting carcass chemical composition. Correlations of marbling scores with carcass percentages of moisture, fat and protein were -.53, .54. -.55, respectively.

Kauffman et al. (1975) reported a combination of adjusted fat thickness, longissimus muscle area and marbling score accounted for 73% $\pm$ 2.2 of the variation in percent fat free muscle $\pm$ 2.2 percent. This combination surpassed the effectiveness of the USDA cutability equation and did not require an estimate of percent kidney, heart and pelvic fat. The new combination of factors also eliminates the use of carcass weight which is negatively related to composition and has implied a superiority of lighter weight carcasses.

Crouse and Dikeman (1976) developed a multiple regression equation including adjusted fat thickness, longissimus muscle area, estimated kidney, heart and pelvic fat, hot carcass weight and marbling score which accounted for 79.2% of the variation in percentage of retail product with a standard error of $\pm$ 2.05.

Abraham et al. (1980) disagreed with Kauffman et al. (1975) and Crouse and Dikeman (1976) reporting that marbling did not improve the explained proportion of yield .

Comparisons of Prediction Equations. Thackston et al. (1967) reported that, based on simple and multiple correlation coefficients, the Wisconsin method was more highly correlated to retail yield than was the USDA cutability formula.

Powell and Huffman (1968) indicated by chemical analysis the Hankins and Howe equation was the most accurate predictor of actual carcass composition, but least practical, followed by USDA yield grade equation, Olkahoma method, carcass specific gravity, and then the Tennessee, Wisconsin, and Illinois method. The correlation coefficients were highly significant between all the equations and carcass composition.

Cross et al. (1973) stated the USDA equation most accurately predicted actual percentages of boneless retail cuts when compared to seven other reported equations. The Tennessee Simplified Equation No. Four provided the least reliable prediction.

Accuracy of Grade Application

Beef grading is highly subjective and grades assigned to carcasses have a significant financial impact on all industry segments. This economic impact leads to constant pressure on graders and may affect their grading.

The General Accounting Office (GAO) of the United States wanted to determine how well USDA graders did their job under the conditions in which they work. In the Comptroller General's report to Congress titled "Department of Agriculture's Beef Grading: Accuracy and Uniformity Need to be Improved" (1978), the GAO found that grading was not accurate or consistent from one section of the country to another or even between plants in the same section of the country. They made the following recommendations to the USDA: 1) increase research efforts to develop instruments to accurately measure beef carcass characteristics, 2) establish grading accuracy standards, 3) improve management of the program and 4) resolve questions about the adequacy and usefulness of the current beef grade standards. GAO visited 29 slaughter plants in 12 states where its beef grading expert reviewed a total of 2215 carcasses. Of these, 474 (21%) were misgraded. Agricultural field supervisory personnel generally agreed with the expert's findings. The majority of errors (62%) involved overgrading which benefited the packers. Although USDA personnel disagreed with some GAO observations, overall it agreed with the report and generally endorsed the recommendations. However, there were several key areas in the GAO report with which Food Safety and Quality Service (FSQS) and the Science and Education (SEA) did not concur as documented in a report from SEA to the Office of the Inspector General (OIG) entitled " An Evaluation of the Accuracy and Uniformity of the USDA Beef Quality and Yield Grading System" (1980).

These differences in interpretation and approach could have had significant effects on the results of the GAO findings. These differences had a direct bearing on the justification of the OIG study and are a follows: 1) FSQS, SEA and the Planning Committee felt that a minimum of three individuals instead of one "expert grader" should have been used to conduct a study of such importance and that each of the three individuals should be tested to establish his ability to consistently grade carcasses having a wide range of grade factors. 2) The grading error rate as reported by the GAO was computed by counting the total number of carcasses that were misgraded, thus it was the percentage of carcasses that were misgraded for either yield and/or quality grade. FSQS felt that this method of computation of error was not appropriate; rather, error should have been reported individually for quality grade or yield grade since combining the two errors into one error rate unduly inflated the value. The GAO study failed to take into account the bias and variability of the USDA grader in determining grade and the variability of the person checking the grader. USDA felt that, in any such study, in order to accurately estimate "percentage error", the bias and variability of the grader being evaluated and the bias and variability of the reviewer(s) should be established and used in the computation. 3) The GAO study did not have a specific, predetermined method of plant selection and did not provide for unbiased selection of carcasses within each plant. USDA academic statisticians felt that plants in all meat grading mainstations should have been sampled in order to accurately evaluate the uniformity of grading.

The OIG study in which a three member Grading Panel evaluated 5582 beef carcasses from 56 plants and 11 mainstations found: the National percentage error of quality grades was 7.3, for yield grades was 11.6, and the percentage error among mainstations was not statistically different for quality or yield grades. Due to the magnitude of the quality grading error (7.3) in relation to the National Grading Panel error (5.5), there is little reason to believe that much improvement in the accuracy of quality grading can be achieved under the present system of grading. In contrast, the National Yield Grading Error (11.6) was considerably larger than the National Grading Panel (7.0) and would indicate that efforts to reduce the errors in yield grading might be productive. In seven of the 11 mainstations, the percentage error in quality grading was significantly in favor of the plant. Yield grading errors were significantly in favor of the plant in three of the 11 mainstations.

The OIG study recommended that 1) the Meat Quality Division, FSQS should continue to support USDA's efforts to develop tools (marbling photographs and instruments) to assist graders in evaluating certain grade factors; 2) the Meat Quality Division, FSQS should concentrate its efforts on reducing yield grading errors on a national basis. This would involve requiring graders to measure and more carefully evaluate carcasses whose yield grade is recognized as being close to the upper or lower limit of a yield grade. It may involve a re-evaluation of the factors in the present yield grade standards with the possibility that certain factors (such as carcass weight and percentage of kidney, pelvic and heart fat) might no longer be used for yield grading; 3) FSQS should conduct or support studies conducted under controlled conditions to evaluate the effect of environmental conditions (grading speed, light intensity, time after ribbing, chill, proper ribbing, and trimming of external fat) on grading error; and 4) FSQS should formulate minimum job performance standards for GS-7 and GS-9 graders.

Instrument Evaluation of Carcasses

To evaluate beef carcasses objectively, Schoonover and Stratton (1957) presented a photographic grid technique to be used to measure surface area of carcass cuts, especially area of rib eye. Quality factors were retained when using color film and preliminary data indicated that proportion of lean as determined by the photographic grid measurement had a direct relationship with body composition as determined by specific gravity. Deans et al. (1959) using lambs, Corbin et al. (1959) and Shrewsbury and Wideman (1961) agreed with Schoonover and Stratton (1957) that photographic techniques are usable, efficient and uncomplicated in evaluating loin eyes.

Price et al. (1958) found that with hogs, fatness can accurately be measured with the Sperry Reflectoscope ultrasonic equipment, as shown by a close relationship with live probe, carcass probe, backfat thickness on the intact carcass and backfat thickness measured on a cross-section of the rough loin at the site of the ultrasonic reading. Similarly, results with swine have indicated ultrasonics can be used to measure the depth of lean. Work with beef cattle has indicated some promise for measuring fat thickness, although the relationship has been lower for cattle then for swine. Ultrasonic studies on beef cattle by Stauffer et al. (1961), McReynolds and Arthaud (1970) and Hedrick et al. (1962) gave evidence of the usefulness of high frequency sound for objective carcass evaluation.

Sixty-six beef carcasses and 19 forequarters were evaluated by electronic meat measuring equipment (EMME) reported Koch and Varnadore (1976). Operation of the EMME depends on the ability of lean tissues to conduct electricity approximately 20 times better than fat tissues. Measurement involves the induction of an electrical field within the sample by means of a solenoid surrounding the active zone. Koch and Varnadore (1976) stated that the EMME number accounted for more variation than the combination of fat thickness, percent kidney and longissimus muscle area when used simultaneously with untrimmed weight, but the difference in determination was less than one percent.

Kempster et al. (1979) reported that in recent years, probing instruments have been developed in Denmark and Ulster which allow the measurement of fat depths to be recorded automatically for pig carcasses. One instrument is the Danish Meat Fat Automatic Probe (MFA) which is based on the difference in electrical conductivity between lean and fat. Pedersen and Busk (1979) explained 73% of the variation in percentage lean in the carcass using MFA. The MFA can also be used to measure longissimus muscle depth because it detects the change in conductivity in moving from lean to air at the bottom of the muscle. Bacon factories in Denmark are equipped with a combination of MFA systems which are used to predict carcass lean content from weight and a combination of fat and muscle depth measurements. Another instrument, the Ulster probe (UP), is based on color difference between lean and fat and is used in all Ulster bacon factories. The optical probe or intrascope (OP) is a third instrument which determines the lean content of a pig carcass. The OP measures the fat depths over the longissimus muscle at the last rib. It is recognized that the optical probe may not be ideal for all circumstances because the operator has to identify the fat and muscle boundary visually and there is some subjectivity associated with its operation.

Kutsky et al. (1982) researched the Fat Depth Indicator (FDI). They probed the 400 beef carcasses before and after chilling, at a point approximating the location at which the thickness of fat is measured in the determination of USDA yield grade. These studies indicate that while the FDI might be useful in segregating carcasses into fatness groups to achieve greater efficiency in chilling and fabrication, it likely would make little improvement in the accuracy of yield grading or in the selection of high or low cutability carcasses within the same yield grade. Jones and Haworth (1983) concluded that the FDI was superior to other measuring techniques and that a single measurement of fat thickness at the midback or loin would suffice for the prediction of retail yield or lean percentage, respectively, in commercial pig carcass evaluation.

Using a prototype electron scanning planimeter (ESP), Malmfors (1981) found that ESP evaluation of either the cut surface of the loin or the ham combined with carcass measurements accounted for 78-88% of the variation in percentage lean in the carcass. Also, the ESP could feasibly evaluate 20 carcasses in 45 minutes while it takes 45 minutes to evaluate one carcass by using Swedens' customary pig progeny test procedure. The ESP could also be used in 1) determining the leanness of processed and cured meat products, 2) measuring pig meat quality and 3) evaluating cut surfaces in color photographs. The ESP is based on the image of the cut surface and is focused by means of optical lenses onto a photosensitive screen, called the mosaic of the vidicon. The mosaic is a coating of millions of light-sensitive globules insulated from one another on a sheet of mica which is strengthened by a metallic coating. The globules form a multitude of tiny capacitors which emit electrons and become charged according to the intensity of the light striking it. When the electrical image is scanned by an electron beam the globule-capacitors discharge a voltage proportional to the intensity of the light striking it.

Lin (1978) determined that by using algorithms and a microcomputer, loin eye area and fat thickness could readily be computed. With the input of other factors, the yield grade of a beef carcass could be obtained. Comparing his system and human judgment he concluded this system is as good as human judgment for isolated cuts of beef, and better than human judgement on line production.

Lenhert (1980) describes the VIA developed at Kansas State University, Manhattan, Kansas, as a system consisting of a camera, (General Electric TN 2500), video monitor (Sanyo model no. VM 4209), data-terminal (Lear Seigler ADM-3A), and computer (Intel ISBC 86/12A). In operation, the camera is positioned by the operator at a known distance and angle relative to the cut surface by means of a metal bracket. When the operator triggers the grading operation, the entire 12th rib cut-surface is illuminated by fluorescent lights. Its image is digitized and transmitted to the computer. The computer carries out a sequence of operations to locate and measure gross fat and muscle areas; to enhance, count, and determine the distribution of intramuscular and intermuscular fat pieces; and to convert these data to areas, percentages or predictions if required. This information is then put into a format and transmitted to the digital readout where it is displayed. An image of the meat as seen by the camera is also shown on the video monitor display for further reference. These steps can all be carried out well within the time (approximately 10-14 seconds) alloted to the evaluation of each carcass.

The Video Image Analyzer (VIA) developed by Gilliland (1982) was tested on the 9-10-11th rib section from 44 bullock and steer carcasses by Cross et al. (1983). Cross found the prediction equations developed from instrument traits had a higher predictive ability than those developed from non-instrument (carcass) traits. The best instrument equation for predicting kg of lean contained the variables total lean area (cm^2); rib weight (kg); total fat area (percent); and fat thickness (cm) and had a coefficient of determination (C.D.)

of 93.6%. In comparison, the best non-instrument prediction equation had a C.D. of 84.2% and contained the variables hot carcass weight (kg); actual fat thickness (cm); and rib eye area (cm^2). The equation develop from the VIA to predict percent primal lean cut-out has a C.D. of 88.1% using the variables total lean area, cm^2; and hot carcass weight, kg. The best non-instrument equation had a C.D. of 83.6% using the variables actual fat thickness, cm; ribeye area, cm^2; and USDA marbling score. This study shows a high potential of the VIA as a yield grading device.

Literature Citations

Abraham, H.C., C.E. Murphey, H.R. Cross, G.C. Smith, and W.J. Franks, Jr. 1980. Factors affecting beef carcass cutability: An evaluation of the USDA yield grades for beef. J. Anim. Sci. 50:841.

Abraham, H.C., Z.L. Carpenter, G.T. King, and O.D. Butler. 1968. Relationships of carcass weight, conformation and carcass measurements and their use in predicting beef carcass cutability. J. Anim. Sci. 27:604.

Allen, D.M., R.A. Merkel, W.T. Magee and R.H. Nelson. 1968. Variation in some beef carcass compositional characteristics within and between selected weight and fat thickness ranges. J. Anim. Sci. 27:1239.

Berry, B.W., G.C. Smith, and Z.L. Carpenter. 1973. Beef carcass length and yields of boneless retail cuts. J. Anim. Sci. 37:1132.

Birkett, R.J., D.L. Good, and D.L. Mackintosh. 1965. Relationship of various linear measurements and percent yield of trimmed cuts of beef carcasses. J. Anim. Sci. 24:16.

Brackelsberg, P.O. and R.L. Willham. 1968. Relationships among some common live and carcass measurements and beef carcass composition. J. Anim. Sci. 27:53.

Brungardt, V.H. and R.W. Bray. 1963. Estimate of retail yield of the four major cuts in the beef carcass. J. Anim. Sci. 22:177.

Brungardt, V.H. and R.W. Bray. 1963. Variation between sides in the beef carcass for certain wholesale and retail yields and linear carcass measurements. J. Anim. Sci. 22:746.

Busch, D.A., C.A. Dinkel, D.E. Schafer, H.J. Tuma and B.C. Breidenstein. 1968. Predicting edible portion of beef carcasses from rib separation data. J. Anim. Sci. 27:351.

Butler, O.D. 1957. The relation of conformation to carcass traits. J. Anim. Sci. 16:227.

Cole, J.W., C.B. Ramsey and R.H. Epley. 1962. Simplified method for predicting pounds of lean in beef carcasses. J. Anim. Sci. 21:355.

Cole, J.W., L.E. Orme and C.M. Kincaid. 1960. Relationship of loin eye area, separable lean of various beef cuts and carcass measurements to total carcass lean in beef. J. Anim. Sci. 19:89.

Comptroller General Report to Congress of the United States, CED-78-141, July 21, 1978. Department of Agriculture's Beef Grading: Accuracy and uniformity need to be improved.

Corbin, J.E., J.L. Williamson, H.B. Geurin and H.L. Wilcke. 1959. Photographic method of measuring loin eye area. J. Anim. Sci. 18:1485.

Cross, H.R., L.W. Douglass, E.D. Linderman, C.E. Murphey, J.W. Savell, G.C. Smith and D.M. Stiffler. 1980. An evaluation of the accuracy and uniformity if the USDA beef quality and yield grading system. Final Report to Office of Inspector General, USDA.

Cross, H.R., D.A. Gilliland, P.R. Durland and S.C. Seideman. 1983. Beef carcass evaluation by use of a video image analysis system. J. Anim. Sci. (submitted).

Crouse, J.D. aand M.E. Dikeman. 1974. Methods of estimating beef carcass chemical composition. J. Anim. Sci. 38:1190.

Crouse, J.D., M.E. Dikeman, R.M. Koch and C.E. Murphey. 1975. Evaluation of traits in the USDA yield grade equation for predicting beef carcass cutability in breed groups differing in growth and fattening characteristics. J. Anim. Sci. 41:548.

Crouse, J.D. and M.E. Dikeman. 1976. Determinates of retail product of carcass beef. J. Anim. Sci. 42:584.

Crown, R.M. and R.A. Damon, Jr. 1960. The value of the 12th rib cut for measuring beef carcass yields and meat quality. J. Anim. Sci. 19:109.

Deans, R.J., L.J. Bratzler and D.C. Price. 1959. The photometric measurement of carcass cross sectional areas directly from projected polaroid transparencies. J. Anim. Sci. 18:1485.

Dowell, A. and K. Bjorka. 1941. Livestock Marketing. McGraw Hill, New York.

Epley, R.J., H.B. Hedrick, W.C. Stringer and D.P. Hucheson. 1970. Prediction of weight and percent retail cuts of beef using five carcass measurements. J. Anim. Sci. 30:872.

Farnum, H.W. 1938. Chapters in the History of Social Legislation in the United States to 1860. Washington: Carnegie Institution of Washington.

Fitzhugh, H.A. Jr., G.T. King, F.A. Orts, Z.L. Carpenter and O.D. Butler. 1965. Methods of predicting the weight of boneless roast and steak meat from easily obtained carcass measurements. J. Anim. Sci. 24:168.

Gilliland, D.A. 1982. Software operations manual of a computerized beef grading instrument. Masters Report. Kansas State Univ., Manhattan, Kansas.

Goll, D.E., L.N. Hazel and E.A. Kline. 1961. Relationship between some beef carcass measurements and yield of wholesale cuts. J. Anim. Sci. 20:264.

Gottsch, A.H., R.A. Merkel and D.L. Mackintosh. 1961. Relationship of muscle, fat, bone and some physical measurements of beef carcass cutability. J. Anim. Sci. 20:917 (Abstr.).

Hankins, O.G. and P.E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. USDA Tech. Bul. 926.

Harding, T.S. 1948. Some landmarks in the history of the Department of Agriculture. Agricultural History Series No. 2. USDA.

Hedrick, H.B., J.C. Miller, G.B. Thompson and R.R. Freitag. 1965. Factors affecting longissimus dorsi area and fat thickness of beef and relation between these measurements and retail yield. J. Anim. Sci. 24:333.

Hedrick, H.B., W.C. Stringer and G.F. Krause. 1969. Retail yield comparison of average Good and average Choice conformation beef carcasses. J. Anim. Sci. 28:187.

Hedrick, H.B., W.E. Meyer, M.A. Alexander, J.F. Lasley, J.E. Comfort,A.J. Dyer and H.D, Naumann. 1963. Indices of meatiness in beef. Mo. Agr. Exp. Sta. Res. Bul. No. 820.

Henderson, D.W., D.E. Goll and E.A. Kline. 1966. Relationships of muscling and finish measurements from three different groups of beef carcasses with carcass yield. J. Anim. Sci. 25:323.

Jones, S.D.M. and C.R. Haworth. 1983. Instrument prediction of the lean content of pork carcasses using ultrasound or light reflectance. J. Anim. Sci. 56:418.

Kauffman, R.G., M.E. VanEss, R.A. Long and D.M Schaefer. 1975. Marbling: Its use in predicting beef carcass composition. J. Anim. Sci. 40:235.

Kempster, A.J., D.W. Jones and A. Cuthbertson. 1979. A comparison of the Danish MFA, Ulster and optical probes for use in pig carcass classification and grading. Meat Sciences 3, 109-120.

Kiehl, E.R. and V.H. Rhodes. Historical development of beef quality and grading standards. 1960. Mo. Agr. Exp. Sta. Res. Bul. 728. Univ. of Missouri, Columbia.

Koch, R.M. and W.L.Varnadore. (1976). Use of electronic meat measuring equipment to measure cutout yield of beef carcasses. J. Anim. Sci. 43:108.

Kropf, D.H. and R.L. Graf. 1959. The effects of carcass grade, weight and classification upon boneless beef yield. J. Anim. Sci. 18:95.

Kutsky, J.A., C.E. Murhey, G.C. Smith, J.W. Savell, D.M. Stiffler and R.N. Terrell. 1982. Use of the Hennessy and Chong fat depth indicator for predicting fatness of beef carcasses. J. Anim. Sci. 55:565.

Lenhert, D.H. 1980. Proposal for the delivery of a prototype instrument for measuring marbling. Submitted to USDA by Dept. of Elec. Eng., Kansas State Univ., Manhattan, Kansas.

Lin, Sha-Shu Pishen. 1978. Automated pattern recognition of beef. Masters Thesis. Kansas State Univ. Manhattan, Kansas.

Malmfors, G. 1981. Pig carcass evaluation by use of an electronic scanning planimeter, ESP. Sveriges Lantbruksuniversitet, Uppsala, Sweden.

McCoy, J.H. 1972. Livestock and Meat Marketing. The AVI Publishing Co., Inc., Westport, Connecticut.

McReynolds, W.E. and V.H. Arthaud. 1970. Ultrasonic application for estimating fat thickness of beef cattle. J. Anim. Sci. 30:186.

Murphey, C.E., D.K. Hallett, W.E. Tyler and J.C. Pierce, Jr. 1960. Estimating yields of retail cuts from beef carcasses. J. Anim. Sci. 19:1240 (Abstr.).

Orme, L.E., J.W. Cole, C.M. Kincaid and R.J. Cooper. 1960. Predicting total carcass lean in mature beef from weights of certain entire muscles. J. Anim. Sci. 19:726.

Palamountain, J.C. 1955. The Politics of Distribution. Harvard Univ. Press, Cambridge.

Palmer, A.Z., J.W. Carpenter, R.L. Reddish, C.E. Murphey and D.K. Hallett. 1961. Estimated and actual yields of boneless retail cuts from Brahman crossbred cattle and carcasses. J. Anim. Sci. 20:919 (Abstr.).

Pedersen, O.K. and Busk, H. 1979. Development of automatic equipment for grading pig carcasses in Denmark. The National Institute of Animal Science, Copenhagen.

Pierce, J.C. 1957. The influence of conformation, finish and carcass weight on the percentage yield of wholesale and retail cuts of beef. Proc. Recip. Meat Conf. 10:119.

Powell, W.E. and D.L. Huffman. 1968. An evaluation of quantitative eatimates of beef carcass composition. J. Anim. Sci. 27:1554.

Powell, W.E. and D.L. Huffman. 1973. Predicting chemical compositon of beef carcasses from easily obtainable carcass variables. J. Anim. Sci. 36:1069.

Price, J.F., H.B. Pfost, A.M. Pearson and C.W. Hall. 1958. Some observations on the use of ultrasonic measurements for determining fatness and leaness on live animals. J. Anim. Sci. 17:1156.

Ramsey, C.B., J.W. Cole and C.S. Hobbs. 1962. Relation of beef carcass grades, proposed yield grades and fat thickness to separable lean, fat and bone. J. Anim. Sci. 21:193.

Schoonover, C.O. and P.O. Stratton. 1957. A photographic grid used to measure rib eye areas. Wyoming Ag. Exp. Sta., Laramie, Wyoming.

Sheets, E.W. 1934. Meat Research in the United States. Scientific Monthly.

Shrewsbury, C.L. and D. Wideman. 1961. A new photographic technique for determination of fat and lean areas in meat carcass cuts. J. Anim. Sci. 20:274.

Stauffer, J.R., M.V. Wallentine, G.H. Wellington and A. Diekmann. 1961. Development and application of ultrasonic methods for measuring fat thickness and rib-eye area in cattle and hogs. J. Anim. Sci. 20:759.

Swiger, L.A., K.E. Gregory, L.J. Sumption and B.C. Breidenstein. 1964. The importance of measuring cut-out in cattle. J. Anim. Sci. 23:854 (Abstr.).

Thackston, G.R., J.W. Cole, C.B. Ramsey and C.S. Hobbs. 1967. Comparisons of three beef quantity prediction equations. J. Anim. Sci. 26:212 (Abst.).

USDA. 1980. Official United States Standards for Grades of Carcass Beef. USDA. AMS. Title 7.

CHAPTER 2

VIDEO IMAGE ANALYSIS USED TO FORMULATE PREDICTION EQUATIONS FOR TOTAL POUNDS AND PERCENT PRIMAL LEAN AND FAT YIELD OF BEEF CARCASSES

Summary

The primal lean cut-out from the right side of 115 steer carcasses was utilized to evaluate the Video Image Analyzer's (VIA) ability to predict carcass composition and, also, to compare VIA prediction accuracy to the accuracy of a committee of three experts trained in grading beef carcasses.The VIA accuracy in predicting total kg and percent primal lean was slightly higher when compared to the accuracy of the committee scored factor's prediction capabilities. Equations for predicting percent and kg of total primal fat was slightly lower for the VIA in comparison to the committee factors. We found the VIA is as reliable as the present method used by the USDA to evaluate the percentage beef carcass yield of primal lean. This method of evaluating carcasses could minimize grade application error by the grader and would be less subject to errors in human judgement. It also shows potential for use as a predictor of total production weight yields (kg) which could facilitate forward sales of boxed beef product.

(Key Words: Beef, Grading, Instrument, Yield, Objective Measure, Standards, Meat)

Introduction

Historically a need has existed for selecting factors which indicate the quality and yield attributes of meat. Presently, beef carcasses are evaluated for yield grade by a trained USDA meat grader. The factors used are not always objectively measured. With much pressure from the packer on the grader to upgrade meat and errors arise from the use of subjective evaluation (Cross et al. 1980). Considerable research has been done to find beef carcass attributes which will more accurately predict its ultimate yield in either kg or percent (Hankins and Howe, 1946; Cole et al., 1962; Murphey et al., 1960; Cole, Orme and Kincaid, 1960; Brungardt and Bray, 1963; Abraham et al., 1968; Cross et al., 1973). The U.S. Department of Agriculture is interested in developing a more objective grading system and Video image analysis has potential in instrument grading (Cross et al. 1983). The Video Image Analyzer (VIA) developed at Kansas State University was tested by Cross et al. (1983) on the 9-10-11th rib section of 44 carcasses and they showed it had considerable potential as a yield grading device, justifying further research. This study was designed with the following objectives; 1) to test and evaluate the Video Image Analyzer, 2) to develop regression equations for predicting percentages and kg of boneless closely trimmed primal lean and fat using the VIA and 3) to test these equations against new regression equations using committee scored USDA yield grade factors presently used in the USDA equation for predicting percentage and kg of beef carcass yield from the primal round, loin, rib and chuck.

Experimental Procedure

Source of Animals. One hundred-fifteen Choice steer carcasses were selected at the EXCEL meat packing plant in Dodge City, Kansas. Selection was based on 12th rib fat thickness and carcass weight to fit possible combinations of four fat thickness groups and three weight groups (Table 1) in proportions of the total beef carcass population as identified by Abraham (1976).

Committee Scored USDA Factors. Twenty-four hours post slaughter, the carcasses were graded by a trained USDA meat grader. After initial grading,the carcasses were selected for this study. A committee of three trained experts on grading beef carcasses individually evaluated the right side of each carcass for all USDA yield and quality grade factors. Final committee scored USDA yield and quality grades were calculated using average evaluations of the three member grading committee.

Video Image Analyzer (VIA). The right side of each carcass was evaluated using the Video Image Analyzer as described by Lin (1978), Lenhert (1980), Gilliland (1982) and Cross et al. (1983). The average of three VIA readings taken from the entire 12th rib cut surface on each carcass was used for each VIA measured trait. The VIA measured 1.) total area (cm^2), 2.) fat area (cm^2 and percent), 3.) lean area (cm^2 and percent), 4.) particles of fat within the longissimus muscle (number), 5.) area summation of fat particles within the longissimus muscle (cm^2), 6.) fat thickness (cm) and 7.) color reflectance value of the lean tissue.

Cutting Procedures. Carcass sides were transported to the EXCEL meat fabrication plant at Wichita, Kansas, where the right side of each carcass was weighed and then cut into wholesale cuts according to Wellington (1953) and Orts (1962) except for separation of the rib from the short plate and separation of the flank from the short loin. These separations were made by measuring from the protruding edge of the thoracic vertebrae various distances laterally according to carcass weight ranges as shown in table 2. Only the right side was fabricated as Butler et al. (1956), Breidenstein et al. (1964) and Hedrick et al. (1965) reported that left and right sides of carcasses have bilateral symmetry.

All primal cuts (round, loin, rib and square-cut chuck), were weighed prior to, and after, trimming of external fat and were cut into boneless closely trimmed lean with external and exposed seam fat not exceeding 1.27 cm. Lean trim was visually standardized at 80% lean, and 20% fat as nearly as possible.

Each primal cut was trimmed as described in the USDA Institutional Meat Purchase Specifications for Fresh Beef (1975). The primal round was separated into the top (inside) round (IMPS 168); bottom (outside) round (IMPS 170); knuckle (IMPS167); lean trim; fat trim; and bone. The primal loin was separated into the boneless strip loin (IMPS 180); full tenderloin (IMPS 189) (except fat did not exceed 1.27 cm fat thickness); top sirloin butt (IMPS 184); flap (IMPS 185A); ball tip (IMPS 185B); triangle (IMPS 185C); lean trim; fat trim; and bone. The primal rib was separated into the rib eye roll (IMPS 112); lean trim; fat trim; and bone. The primal chuck was separated into the shoulder clod (IMPS 114); chuck roll (IMPS 116A); chuck tender (IMPS 116B); lean trim; fat trim; and bone.

Total lean, fat and bone from these primal cuts were utilized in this study and will be referred to as either percent or kg primal lean, fat or bone (primal cut-out).

Statistical Analysis. Simple correlations were calculated within the three weight ranges among all VIA, committee scored USDA factors and primal cut-out variables and showed similar results in each weight group. Therefore, simple correlation coefficients were calculated on the combined data from all weight ranges among the variables of interest. Data were statistically treated by analysis of variance and regression analysis.

The criteria used to select the prediction equation included the C_p statistic described by Mallow (1973) and MacNeil (1983) and the error mean square of the regression models fitted by the stepwise procedure. The expected value of the C_p statistic is the number of regression deqrees of freedom (P) in the model, when the regression model is one that produces unbiased estimates of the dependent variable. Thus, the C_p statistic was used to select a subset of candidate regression models for which C_p was near P, then the prediction model was selected from the subset by choosing the one with the smallest error mean square. This procedure should result in the selection of prediction equations that produce minimum variance, unbiased estimates.

All VIA measured traits were used as independent variables to develop equations to predict kg and percent of total primal lean and fat. Also, committee scored USDA yield grade factors were used as independent variables to develop equations which predict kg and percent primal lean and fat. All equations for VIA and committee scored USDA yield grade factors were developed using all 115 carcasses.

Results

Table 3 shows means and standard deviations of Video Image Analyzer (VIA) traits, committee scored USDA factors and primal cut-out variables for all 115 steer carcasses.

Simple correlation coefficients of VIA traits and committee scored USDA factors with total primal cut-out (percent and kg) are shown in table 4.

VIA traits, total area (cm^2) (r=.63) and lean area (cm^2) (r=.58) were significantly correlated with primal lean cut-out (kg). Lean area percent showed a positive correlation with percent primal lean cut-out (r=.60); and had negative correlations of -.59 and -.58 when correlated with primal fat cut-out (percent and kg, respectively)

VIA measured fat area expressed as in cm^2 and as a percentage had correlations with primal lean (percent) of -.47 and -.60, respectively; and when correlated with percent primal fat cut-out had coefficients of .48 and .59. VIA measured fat area (cm^2) was also, highly correlated with primal fat cut-out (kg) (r=.65) and VIA measured fat area (percent) was correlated at .58 with primal fat cut-out (kg).

VIA measured fat thickness was positively correlated with primal fat cut-out percent (r=.67) and kg (r=.60).

Hot carcass weight, when correlated with primal cut-out: lean (kg), bone (kg) and fat (kg) showed coefficients of .95, .77 and .57, respectively. This is expected because total carcass weight is directly related to individual carcass components as reported by Cole et al. (1962), Swiger et al. (1964), Abraham et al. (1968), Allen et al. (1968) and Powell and Huffman (1973). Committee scored preliminary yield grade (PYG) and adjusted preliminary yield grade (APYG) were correlated with percent primal fat cut-out at .68 and .80; and with primal fat cut-out (kg) at .56 and .65, respectively.

Longissimus muscle area (cm^2) evaluated as a measured committee scored factor was positively correlated with primal lean cut-out expressed as percent (r=.33) and kg (r=.65). These correlations are similar to their counter-part VIA measured trait of lean area (cm^2) when correlated with primal lean cut-out expressed as percent (r=.48) and kg (r=.58).

Table 5 indicates simple correlation coefficients of VIA traits with committee scored factors. VIA total area (cm^2) was highly correlated (r=.68) with committee measured longissimus muscle area (LEA). A coefficient of greater magnitude (r=.86) was obtained when correlating lean area (cm^2) with the committee measured LEA.

Lean area (percent) was negatively correlated with committee scored PYG (r=.68) and APYG (r=.70), and fat area (percent) was positively correlated at a similar magnitude with the committee scored PYG and APYG. Fat area (cm^2) was positively correlated with committee scored PYG and APYG (r=.65 and .63). VIA fat thickness (cm) had significant correlations of .91 and .85 with committee scored PYG and APYG.

Variables measured by the VIA were highly correlated with one another (Table 6). Fat area (cm^2) was positively correlated with fat area (percent) (r=.89), negatively correlated with lean area (percent) (r=-.89), and fat thickness (cm) (r=-.65). Lean area (cm^2) was negatively correlated with fat area (percent) (r=-.53) and positively correlated (r=.53) with lean area (percent). Fat area (percent) and lean area (percent) were correlated with fat thickness (cm) at .68 and -.68, respectively. Area summation of fat particles was positively correlated with number of fat particles (r=.81) and both area summation and number of fat particles were positively correlated with color (r=.47 and .56).

Table 7 shows regression equations developed from VIA traits and committee scored USDA factors using stepwise procedures for predicting kg and percent total primal lean and fat cut-out from the 115 steer carcasses. Independent variables utilized were the conventional USDA carcass factors and the VIA measured traits.

In predicting primal lean in kg using VIA traits, a predictive accuracy of 95.63% was obtained using side weight (kg), lean area (cm^2), fat area (percent), and color. Using the conventional USDA yield grade carcass factors, measured and/or scored by the grading committee, resulted in an accuracy of 94.29% in predicting kg of total primal lean cut-out.

The best instrument equation (VIA) for predicting percent primal lean cut-out had and accuracy of 46.36% and included side weight (kg), fat area (percent), lean area (percent), and color. The predictive accuracy was 46.35% when utilizing the committee scored carcass factors hot carcass weight (kg), longissimus muscle area (cm^2), adjusted preliminary yield grade, and kidney, heart and pelvic fat (percent). As would be expected, the R^2 decreased when the dependent variable total primal lean cut-out was calculated on a percentage basis rather than a weight basis.

Table 8 shows the best prediction equations for estimating kg and percent total primal fat trim using the VIA traits and committee scored USDA factors. The best equation for predicting kg of fat from the carcasses using the VIA had an accuracy of 68.26% with side weight (kg), fat area (cm^2), fat area (percent), fat particles (number), and fat thickness (cm) in the equation. When estimating the kg of fat from the carcass, using committee scored carcass factors, the predictive accuracy was 75.88%. The equation included hot carcass weight (kg), adjusted preliminary yield grade, and kidney, heart and pelvic fat (percent).

In estimating the percent fat the best predictive equation utilizing VIA measured traits had an accuracy of 51.81% containing the independent variables lean area (cm^2), fat area (percent), and fat thickness (cm). The best non-instrument equation contained two variables, preliminary yield grade and adjusted preliminary yield grade; with a predictive accuracy of 65.04%.

Discussion

The prediction equations developed from the instrument traits compared to the equations developed from non-instrument traits had equal or slightly higher predictive capabilities in estimating total kg and percent primal lean. However, when predicting total kg and percent fat trim, the instrument equations had a slightly lower predictive ability. This may be due to the VIA inability to determine an adjusted fat thickness measurement. Murphey et al. (1960), Palmer et al. (1961), Ramsey et al. ((1962), Powell and Huffman (1973) and Crouse and Dikeman (1974) found fat thickness to be highly associated with body composition.

The ability of the VIA to predict both percent and kg of primal lean was slightly more accurate than the committee scored USDA factors. This shows that it has useful potential in the future for objectively grading beef carcasses. Since the non-instrument evaluations of the carcasses were determined by a committee of three expert grading officials the carcass traits were measured and evaluated under more ideal and controlled conditions than in normal grading conditions where one individual grader makes the determination of grade and considerable application error occurs (Cross et al., 1980). This application error could be minimized using the VIA since its measurements would be less subject to errors in human judgement.

Equations developed for predicting kg of primal lean from the instrument traits and the USDA carcass traits had R^2's of 95.63% and 94.29%, respectively. These results indicate a very simple method for predicting weight of edible portion of carcasses and are in agreement with Cole et al. (1962) and Fitzhugh et al. (1965). The VIA should have practical value to industry, especially to the packer who fabricates carcasses from his kill. Since the VIA can quickly and accurately predict potential primal cut-out weights, the packer would know at the time of VIA grading what his production yields would be. This may be of considerable value to facilitate forward sales of boxed beef product.

The equation developed from the instrument traits to predict kg of primal lean (kg) had an R^2 of 95.63% in comparison to 93.60% which Cross et al. (1983) found when predicting kg of lean from the 9-10-11th rib section. The prediction of kg is slightly higher when utilizing the entire carcass weight rather than rib weight because of the significant role weight plays in the equation. The equation developed from the VIA to predict percent primal lean had an R^2 of 46.36%; and committee scored USDA factors had an R^2 of 46.35%. These findings are proportionally related to those findings of Cross et al. (1983) where the R^2 from the VIA was 88.10% and the non-instrument R^2 was 83.60% for predicting rib lean yields. The difference in predictive accuracy may be attributed to predicting the 9-10-11th rib lean compared to total carcass primal lean.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

TABLE 1

DISTRIBUTION OF CARCASSES SELECTED BY WEIGHT RANGE AND FAT THICKNESS

Weight range, kg	272-317	318-362	363-408	
Number	44 hd	50 hd	21 hd	
Percentage	38.3%	43.5%	18.3%	
Fat thickness, cm				Totals by fat thickness
<.76	2 4.6%	2 4.0%	2 9.5%	6 5.2%
.77-1.27	15 34.1%	10 20.0%	3 14.3%	28 24.4%
1.28-1.78	20 45.5%	21 42.0%	8 38.1%	49 42.6%
1.79-2.54	7 15.9%	17 34.0%	8 38.1%	32 27.8%

TABLE 2

DISTANCE FROM 6TH, 12TH AND 13TH THORACIC VERTEBRAE
FOR PLATE AND FLANK REMOVAL

Carcass wt, kg	272-317	318-362	263-408
Distance, cm	24.1	25.4	26.7

TABLE 3

MEANS AND STANDARD DEVIATIONS OF VIA TRAITS, COMMITTEE SCORED USDA FACTORS AND PRIMAL CUT-OUT VARIABLES

Variables	Mean	Standard Deviation
VIA at the 12th rib surface		
Total area, cm^2	21.28	2.02
Fat area, cm^2	7.94	1.59
Lean area, cm^2	.37	.05
Fat area, %	13.34	1.41
Lean area, %	.63	.05
Fat particles, no.	36.39	14.20
Fat particles, area summation	.17	.07
Fat thickness, cm	1.37	.43
Color	24.93	2.99
Committee scored USDA factors		
Hot carcass wt, kg	329.14	31.57
Adj. prel. yield grade	3.63	.37
Prel. yield grade	3.47	.41
Actual fat tck., cm	1.50	.43
Longissimus muscle area, cm^2	11.85	1.25
Kidney, heart & pelvic fat, %	2.36	.56
Marbling (a)	352.33	60.45
Lean maturity (b)	48.48	15.40
USDA yield grade	48.63	15.40
Primal cut-out		
Percent fat	9.53	1.30
Kg fat	15.30	2.55
Percent bone	12.11	.84
Kg bone	19.43	2.15
Percent total lean	53.26	8.30
Kg total lean	85.52	8.30

(a) Marbling: 100=Traces; 300=Small.
(b) Lean maturity: 0=A0; 100=B0.

TABLE 4

SIMPLE CORRELATION COEFFICIENTS OF
VIA TRAITS AND COMMITTEE SCORED USDA FACTORS WITH
PRIMAL CUT-OUT

	Primal cut-out					
	Lean %	Lean kg	Bone %	Bone kg	Fat %	Fat kg
VIA traits at the 12th rib surface						
Total area, cm^2	-.03	.63	-.48	.26	.11	.47
Lean area, cm^2	.48	.58	-.09	.34	-.38	-.06
Lean area, %	.60	.03	.41	.14	-.59	-.58
Fat area, cm^2	-.47	.28	-.53	.02	.48	.65
Fat area, %	-.60	-.03	-.40	-.14	.59	.58
Fat particles, no.	-.19	.35	-.12	.29	-.02	.21
Fat particles, area summation	-.01	.34	-.09	.26	-.07	.14
Fat thickness, cm	-.44	-.07	-.46	-.25	.67	.60
Color	-.28	.07	-.04	.11	.15	.21
Committee scored USDA factors						
Lean maturity	.08	.19	-.14	-.06	-.04	.07
Hot carcass weight, kg	-.11	.95	-.16	.77	.01	.57
Preliminary YG	-.43	-.13	-.55	-.36	.68	.56
Adj. preliminary YG	-.47	-.16	-.54	-.36	.80	.65
Longissimus muscle area, cm^2	.33	.65	-.22	.36	-.25	.12
Marbling	-.12	.00	-.19	-.08	.07	.08
Kidney, heart & pelvic fat, %	-.44	-.24	-.26	-.26	.16	.07

TABLE 5

SIMPLE CORRELATION COEFFICIENTS OF
VIA TRAITS WITH COMMITTEE SCORED USDA FACTORS

	Committee scored USDA factors						
	Lean maturity	Hot carcass wt, kg	Prel. yield grade	Adj. prel. grade	Longissimus muscle area, cm^2	Marbling	Kidney, heart & pelvic fat, %
VIA traits at 12th rib surface							
Total area, cm^2	.22	.65	.32	.24	.68	.10	-.06
Lean area, cm^2	.10	.44	-.28	-.35	.86	-.13	-.30
Lean area, %	-.14	-.16	-.68	-.70	.31	-.26	-.28
Fat area, cm^2	.20	.43	.65	.63	.10	.24	.19
Fat area, %	.13	.16	.68	.71	-.32	.27	.29
Fat part., no.	-.17	.40	.03	-.04	.20	.19	.05
Fat part., area sum.	-.24	.36	.02	-.04	.32	.14	.02
Fat thickness, cm	.12	.07	.91	.85	-.19	.11	.15
Color	-.53	.16	.11	.08	.02	-.02	.03

TABLE 6

SIMPLE CORRELATION COEFFICIENTS
AMONG VIA TRAITS

	Total area cm^2	Fat area cm^2	Lean area cm^2	Fat area %	Lean area %	Fat part. no.	Fat part. sum.	Fat tck. cm	Color
Total area, cm^2	1.0	.72	.62	.32	-.33	.32	.27	.32	.09
Fat area, cm^2		1.0	-.10	.89	-.89	.32	.19	.65	.24
Lean area, cm^2			1.0	-.53	.53	.09	.17	-.27	-.14
Fat area, %				1.0	-.10	.21	.07	.68	.25
Lean area, %					1.0	-.22	-.07	-.68	-.26
Fat part., no.						1.0	.81	.05	.47
Fat part., area summation							1.0	.02	.56
Fat thickness, cm								1.0	.11
Color									1.0

TABLE 7

PREDICTION EQUATIONS FOR ESTIMATING KG AND PERCENT PRIMAL LEAN

USING VIA TRAITS

	Kg	Percent
Intercept	14.3931	56.8341
Side wt, kg	.4979	-.0096
Lean area, cm^2	1.3350	
Fat area, %	-36.9020	-10.0417
Lean area, %		.3802
Color	-.2488	-.0603
R^2 x 100	95.63	46.36
C_p	7.08	5.53
Standard error	3.88	1.10

USING COMMITTEE SCORED USDA FACTORS

	Kg	Percent
Intercept	31.9023	60.5072
Hot carcass wt, kg	.2328	-.0075
Adj. prel. yield grade	-6.0441	-1.3168
Longissimus muscle area, cm^2	1.3826	.4263
Kidney, heart & pelvic fat, %	-2.8754	-.8700
R^2 x 100	94.29	46.35
C_p	3.59	3.23
Standard error	4.43	1.45

TABLE 8

PREDICTION EQUATIONS FOR ESTIMATING KG AND PERCENT PRIMAL FAT TRIM

USING VIA TRAITS

	Kg	Percent
Intercept	-19.2866	7.4504
Side wt, kg	.1009	
Fat area, cm^2	-.7887	
Lean area, cm^2		-.1338
Fat area, %	45.9421	4.5511
Fat particles, no.	-.0356	
Fat thickness, cm	14.3650	4.0174
R^2 x 100	68.26	51.81
C_p	4.97	5.10
Standard error	3.26	.92

USING COMMITTEE SCORED USDA FACTORS

	Kg	Percent
Intercept	36.3151	-.7572
Hot carc. wt, kg	-3.2531	
Prel. yield grade		-1.1141
Adj. prel. yield grade	13.1493	3.9007
Kidney, heart & pelvic fat, %	.0464	
R^2 x 100	75.88	65.04
C_p	3.10	.75
Standard error	2.81	.78

Literature Cited

Abraham, H.C. 1976. Grade consist of fed beef. USDA, Economic Research Service, Livestock Meat Situation, 211:34-35.

Abraham, H.C., Z.L. Carpenter, G.T. King, and O.D. Butler. 1968. Relationships of carcass weight, conformation and carcass measurements and their use in predicting beef carcass cutability. J. Anim. Sci. 27:604.

Allen, D.M., R.A. Merkel, W.T. Magee and R.H. Nelson. 1968. Variation in some beef carcass compositonal characteristics within and between selected weight and fat thickness ranges. J. Anim. Sci. 27:1132.

Brungardt, V.H. and R.W. Bray. 1963. Estimate of retail yield of four major cuts in the beef carcass. J. Anim. Sci. 22:177.

Butler, O.D. 1957. The relation of conformation to carcass traits. J. Anim. Sci. 16:227.

Breidenstein, B.C., R.G. Kauffman, T. La Plant and H.W. Norton. 1964. Bilateral symmetry of the pork carcass. J. Anim. Sci. 23:1054.

Cole, J.W., C.B. Ramsey and R.H. Epley. 1962. Simplified method for predicting pounds of lean in beef carcasses. J. Anim. Sci. 21:355.

Cole, J.W., L.E. Orme and C.M. Kincaid. 1960. Relationship of loin eye area, separable lean of various beef cuts and carcass measurements to total carcass lean on beef. J. Anim. Sci. 19:89.

Cross, H.R., Z.L. Carpenter and G.C. Smith. 1973. Equations for estimating boneless retail cut yields from beef carcasses. J. Anim. Sci. 37:1267.

Cross, H.R., L.W. Douglass, E.D. Linderman, C.E. Murphey, J.W. Savell, G.C. Smith and D.M. Stiffler. 1980. An evaluation of the accuracy and uniformity of the USDA beef quality and yield grading system. Final Report to Office of Inspector General, USDA.

Cross, H.R., D.A. Gilliland, P.R. Durland and S.C. Seideman. 1983. Beef carcass evaluation by use of a video image analysis system. J. Anim. Sci. 57:908.

Crouse, J.D., M.E. Dikeman, R.M. Koch and C.E. Murphey. 1975. Evaluation of traits in the USDA yield grade equation for predicting beef carcass cutability in breed groups differing in growth and fattening characteristics. J. Anim. Sci. 41:548.

Fitzhugh, H.A. Jr., G.T. King, F.A. Orts, Z.L. Carpenter and O.D. Butler. 1965. Methods of predicting the weight of boneless roast and steak meat from easily obtained carcass measurements. J. Anim. Sci. 24:168.

Gilliland, D.A. 1982. Software operations manual of a computerized beef grading instrument. Masters Report. Kansas State Univ., Manhattan, Kansas.

Hankins, O.G. and P.E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. USDA Tech. Bul. 926.

Hedrick, H.B., J.C. Miller, G.B. Thompson and R.R. Freitag. 1965. Factors affecting longissimus dorsi area and fat thickness of beef and relation between these measurements and retail yield. J. Anim. Sci. 24:333.

Lenhert, D.H. 1980. Proposal for the delivery of a prototype instrument for measuring marbling. Submitted to USDA by Dept. of Elec. Eng., Kansas State Univ., Manhattan, Kansas.

Lin, Sha-Shu Pishen. 1978. Automated pattern recognition of beef. Masters Thesis. Kansas State Univ. Manhattan, Kansas.

MacNeil, M.D. 1983. Choice of a prediction equation and the use of the selected equation in subsequent experimentation. J. Anim. Sci. (submitted).

Mallow, C.L. 1973. Some comments on C_p. Technometrics 15: 661.

Murphey, C.E., D.K. Hallett, W.E. Tyler and J.C. Pierce, Jr. 1960. Estimating yields of retail cuts from beef carcasses. J. Anim. Sci. 19:1240 (Abstr.).

Orts, F.A. 1962. Beef carcass measurements and cutting procedures. Proc. 15th Ann. Recip. Meat Conf., National Livestock and Meat Board, Chicago, Illinois.

Palmer, A.Z., J.W. Carpenter, R.L. Reddish, C.E. Murphey and D.K. Hallett. 1961. Estimated and actual yieldseless retail cuts from Brahman crossbred cattle and carcasses. J. Anim. Sci. 20:919 (Abstr.).

Powell, W.E. and D.L. Huffman. 1973. Predicting chemical composition of beef carcasses from easily obtainable carcass variables. J. Anim. Sci. 36:1069.

Ramsey, C.B., J.W. Cole and C.S. Hobbs. 1962. Relation of beef carcass grades, proposed yield grades and fat thickness to separable lean, fat and bone. J. Anim. Sci. 21:193.

Swiger, L.A., K.E. Gregory, L.J. Sumption and B.C. Breidenstein. 1964. The importance of measuring cut-out in cattle. J. Anim. Sci. 23:854 (Abstr.)

USDA, Institutional Meat Purchase Specifications for Beef. 1975. Agri. Marketing Service, Meat Grading Branch, Washington, D.C.

Wellington, G.H. 1953. Recommended procedure for cutting beef. Proc. Recip. Meat Conf. 6:73.

CHAPTER 3

VIDEO IMAGE ANALYSIS
USED TO PREDICT USDA YIELD GRADE FACTORS, USDA YIELD GRADES AND USED TO PREDICT PERCENT PRIMAL LEAN COMPARED TO USDA PREDICTED PERCENT PRIMAL LEAN

Summary

Primal cut yields were determined from the right side of 115 steer carcasses which were then randomly assigned to one of two groups of 69 and 46 carcasses. Regression equations based on the 69 carcasses were used to predict percent primal lean using Video Image Analyzer (VIA) traits, measured 12th rib longissimus muscle area (LEA), and committee scored preliminary yield grade (PYG) and adjusted preliminary yield grade (APYG). The 46 carcasses provided an impartial data set on which correlation coefficients of various predicted primal lean percents with actual percent primal lean were obtained. Regression equations were developed using VIA traits to predict measured LEA, and committee scored PYG and APYG. These equations had R^2 values of 81.81%, 84.71% and 77.64%, respectively. Simple correlations of measured LEA and committee scored PYG and APYG with those determined by VIA were significant ($p<.01$) at .90, .92 and .88, respectively. Accuracy of predicted percent primal lean using the following equations: 1) USDA equation, (Murphey, 1960), 2) VIA equation (developed from 69 carcasses), and 3) five equations utilizing combinations of VIA predicted factors and committee scored USDA factors in the USDA equation (Murphey, 1960) was tested by calculating correlations with actual percent primal lean. Predictive accuracy was improved by using combinations of VIA predicted factors and committee scored factors. Yield Grade determined by the VIA was highly correlated with USDA Yield Grade determined by a grading committee (.91). Utilizing the VIA to predict factors such as longissimus muscle area and preliminary yield grade instead of subjectively scoring grading factors should increase yield grading accuracy.

(Key Words: Beef, Grading, Instrument, Yield, Objective measure, Standards, Meat)

Introduction

Considerable research has been done on determining what beef carcass factors will most accurately predict percent lean (Cole, Orme and Kincaid, 1960; Brungardt and Bray, 1963; Abraham et al., 1968). Epley et al. (1970), Powell and Huffman (1973), Crouse et al. (1975) and Abraham et al. (1968) determined fat thickness to be the single most important predictor of percent retail cuts. Abraham et al. (1968) agreed with Brungardt and Bray (1963) that the longissimus muscle area had significant influence in contributing to predicted percent retail cuts. Murphey et al. (1960) found improvement in the USDA regression equation for predicting percent lean from the round, loin, rib and chuck by subjectively adjusting carcass fat thickness thus adjusting preliminary yield grade. Cross et al. (1973) stated the USDA equation most accurately predicted actual percentage of boneless retail cuts when compared to seven other reported equations.

In beef slaughter plants that utilize USDA grading, beef carcasses are evaluated for yield grade by a USDA meat grader. In a modern large volume beef slaughter plant, grading is usually done on a high speed chain. Due to the speed and volume required, objective factors used to determine yield grade are usually subjectively applied. This, in addition to the pressure put on the grader to upgrade carcasses, results in human grading error (Cross et al., 1980).

Chapter 1 indicates the Video Image Analyzer (VIA) as a reliable predictor of percent primal lean compared to the factors used in determining USDA Yield Grade. This study was designed with the following objectives: 1) to develop prediction equations for predicting 12th rib longissimus muscle area, and committee scored preliminary yield grade and adjusted preliminary yield grade from VIA measured traits, 2) to determine the relationship between committee scored factors and the VIA predicted USDA factors, 3) to obtain correlation coefficients of predicted percent primal lean with actual percent primal lean using the USDA Yield Grade prediction equation, a prediction equation using only VIA measured traits and five other prediction equations that combine VIA predicted USDA yield grade factors and those scored by a committee and, 4) determine VIA accuracy in predicting USDA Yield Grade.

Regression equations were determined from 69 carcasses to predict percent primal lean using VIA traits, measured longissimus muscle area, and committee scored preliminary yield grade and adjusted preliminary yield grade. Forty-six carcasses were utilized as an impartial set of data to test if various predicted primal lean percents were correlated with actual percent primal lean.

Experimental Procedure

Source of Animals. One hundred-fifteen Choice steer carcasses were selected at the EXCEL meat packing plant in Dodge City, Kansas. Selection was based on 12th rib fat thickness and carcass weight to fit possible combinations of four fat thickness groups and three weight groups (Table 1) in proportions of the total beef carcass population as identified by Abraham (1976).

Committee Scored USDA Factors. Twenty-four hours post slaughter, carcasses were graded by a trained USDA meat grader. After initial grading, carcasses were selected for this study. A committee of three trained experts on beef carcass grading individually evaluated the right side of each carcass for all USDA yield and quality grade factors. Final USDA yield and quality grades were calculated using average evaluations of the three member grading committee.

Video Image Analyzer (VIA). The right side of each carcass was evaluated using the Video Image Analyzer as described by Lin (1978), Lenhert (1980), Gilliland (1982) and Cross et al. (1983). The average of three VIA readings taken from the entire 12th rib cut surface was used for each VIA measured trait. The VIA measured 1.) total area (cm^2), 2.) fat area (cm^2 and percent), 3.) lean area (cm^2 and percent); 4.) particles of fat within the longissimus muscle (number), 5.) area summation of fat particles within the longissimus muscle (cm^2), 6.) fat thickness (cm) and 7.) color reflectance value of the muscle.

Cutting Procedures. Carcass sides were transported to the EXCEL fabrication plant at Wichita, Kansas, where the right side of each carcass was weighed and then cut into wholesale cuts according to Wellington (1953) and Orts (1962) except for separation of the rib from the short plate and separation of the flank from the short loin. These separations were made by measuring from the protruding edge of the thoracic vertebrae various distances laterally according to carcass weight ranges as shown in table 2. Only the right side was fabricated as Butler et al. (1956), Breidenstein et al. (1964) and Hedrick et al. (1965) reported that left and right sides of carcasses have bilateral symmetry.

All primal cuts (round, loin, rib and square-cut chuck), were weighed prior to, and after, trimming of external fat and were cut into boneless closely trimmed lean with external and exposed seam fat not exceeding 1.27 cm. Lean trim was visually standardized at 80% lean, and 20% fat as nearly as possible.

Each primal cut was trimmed as described in the USDA Institutional Meat Purchase Specifications for Fresh Beef (1975). The primal round was separated into the top (inside) round (IMPS 168); bottom (outside) round (IMPS 170); knuckle (IMPS 167); lean trim; fat trim; and bone. The primal loin was separated into the boneless strip loin (IMPS 180); full tenderloin (IMPS 189) (except fat did not exceed 1.27 cm fat thickness); top sirloin butt (IMPS 184); flap (IMPS 185A); ball tip (IMPS 185B); triangle (IMPS 185C); lean trim; fat trim; and bone. The primal rib was separated into the rib eye roll (IMPS 112); lean trim; fat trim; and bone. The primal chuck was separated into the shoulder clod (IMPS 114); chuck roll (IMPS 116A); chuck tender (IMPS 116B); lean trim; fat trim; and bone.

Total lean, fat and bone from these primal cuts were utilized in this study and will be referred to as either percent or kg primal lean, fat or bone (primal cut-out).

Statistical Analysis. Utilizing 115 carcasses, regression equations were developed from VIA traits to predict the USDA factors longissimus muscle area (LEA), preliminary yield grade (PYG) and adjusted preliminary yield grade (APYG). Measured LEA, committee scored PYG and APYG were correlated with VIA predicted LEA, VIA predicted PYG and VIA predicted APYG. Committee scored Yield Grade was correlated with VIA determined Yield Grade. The 115 carcasses were then randomly assigned into two groups. The first group consisted of 69 carcasses and the second group of 46. On 69 carcasses, stepwise regression procedures were used to develop the best regression equation based on VIA traits to predict percent primal lean.

The criteria used to select the prediction equation included the C_p statistic described by Mallow (1973) and MacNeil (1983) and the error mean square of the regression models fitted by the stepwise procedure. The expected value of the C_p statistic is the number of regression deqrees of freedom (P) in the model, when the regression model is one that produces unbiased estimates of the dependent variable. Thus, the C_p statistic was used to select a subset of candidate regression models for which C_p was near P, then the prediction model was selected from the subset by choosing the one with the smallest error mean square. This procedure should result in the selection of prediction equations that produce minimum variance, unbiased estimates.

Using the data of 46 carcasses, the VIA equation's prediction of percent primal lean, the official USDA equation's prediction of percent primal lean and five regression equations combining VIA predicted USDA factors with the complimentary committee scored USDA factors entered into the official USDA regression equation for predicting percent boneless retail cuts from the round, loin, rib, and chuck were tested by calculating their correlation coefficients to the actual percent primal lean.

Results and Discussion

Regression equations were developed from VIA traits to predict preliminary yield grade (PYG), and adjusted preliminary yield grade (APYG) as scored by the committee and measured longissimus muscle area (LEA) (table 3).

The equation developed from 115 carcasses to predict preliminary yield grade using VIA traits had a predictive accuracy of 84.71%. VIA traits used were fat area (cm^2), fat thickness (cm) and side weight (kg). VIA traits were also used to predict adjusted preliminary yield grade and had a predictive accuracy of 77.64%. Traits used in this equation were fat thickness (cm), fat pieces (number) and fat area (percent). A predictive accuracy of 81.81% resulted from the regression equation developed from VIA traits to predict 12th rib longissimus muscle area and used side weight (kg) and the VIA measured traits of fat thickness (cm), total surface area (cm^2), lean area (cm^2), fat particles (area summation) and fat particles (number).

Table 4 shows simple correlations of committee scored USDA factors LEA, PYG and APYG with the same factors as predicted using the VIA regression equations shown in table 3. Correlations were first determined on all 115 carcasses. Then to further test the ability of the VIA to predict LEA, PYG and APYG, similar prediction equations were developed from 69 carcasses and used to predict these factors on the remaining 46. The correlations of predicted factors with committee scored USDA factors using 46 carcasses are, also, shown in table 4. Correlation coefficients in all cases showed a high positive relationship and substantiate the effectiveness of the VIA in predicting LEA, PYG and APYG. This accuracy and consistency further suggests the potential value of the VIA used as a tool to improve the accuracy of the human grader in evaluating USDA yield grade factors.

The equation utilized by USDA to predict percent boneless retail cuts from the round, loin, rib and chuck was developed by Murphey et al. (1960); and is 51.34 -5.784 (fat thickness, inches) -.0093 (hot carcass wt lb) -.462 (kidney, heart and pelvic fat, percent) +.740 (longissimus muscle area, square inches). Using 69 carcasses from this study, the best regression equation for predicting percent primal lean using VIA traits had an accuracy of 52.93% is shown in table 5 and used side weight (kg), lean area (cm^2) and lean area (percent).

For the remaining 46 carcasses, these two equations were compared with the actual percent primal lean by correlation coefficients. The correlations were .588 and .582 for the USDA and the VIA equations, respectively (Table 7).

Five other prediction yields were obtained for predicting percent primal lean on the 46 carcasses. In these equations, the VIA was used to predict LEA, PYG and APYG and these factors were used in combination with committee scored USDA factors in the USDA equation developed by Murphey et al. (1960). Table 6 shows means and standard deviations of the percent lean cut-out for the prediction equations utilizing 46 carcasses. Correlation coefficients of the predicted percent primal lean with actual percent primal lean are presented in table 7.

Correlation coefficients of predicted percent primal lean with actual percent primal lean is improved in all equations where one or more VIA predicted USDA factors are substituted into the Murphey et al. (1960) equation used by the USDA. The equation using VIA predicted LEA and PYG combined with committee scored percent kidney, heart and pelvic fat and hot carcass weight and the equation using VIA predicted LEA and APYG combined with committee scored percent kidney, heart and pelvic fat and hot carcass weight showed the highest correlations of predicted with actual percent primal lean (.649 and .647).

Yield Grade of a beef carcass is currently determined on the basis of the following equation = 2.5 + (2.50 x adjusted fat thickness, in.) + (.20 x percent kidney, heart and pelvic fat) + (.0038 x hot carcass weight, lbs) - (.32 x area longissimus muscle, sq in.) as described in Official United States Standards for Grades of Carcass Beef (1980). VIA predicted Yield Grade was estimated by using this equation and substituting VIA predicted LEA and PYG into the equation in place of committee scored factors. Table 8 shows means and standard deviations of VIA predicted Yield Grade and the committee scored USDA Yield Grade when utilizing 115 carcasses. VIA predicted Yield Grade and committee scored USDA Yield Grade were correlated at .91. This correlation indicates the VIA is able to predict USDA Yield Grade with considerable accuracy and suggests the feasibility of using the VIA to yield grade carcasses in lieu of human graders, or as a tool to assist human graders.

The VIA can be used for accurately predicting LEA and PYG. When these predicted values are combined with hot carcass weight and committee scored percent kidney, heart and pelvic fat, it results in greater accuracy in predicting primal lean. Using the VIA to predict these two yield grade factors would remove much of the subjectivity, and associated error, from the present yield grading system and should improve industry, public and USDA grader confidence in the accuracy and repeatability of yield grading.

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TABLE 2

DISTANCE FROM 6TH, 12TH AND 13TH THORACIC VERTEBRAE
FOR PLATE AND FLANK REMOVAL

Carcass wt, kg	272-317	318-362	263-408
Distance, cm	24.1	25.4	26.7

TABLE 3

REGRESSION EQUATIONS USING VIA TRAITS TO PREDICT MEASURED LONGISSIMUS MUSCLE AREA, COMMITTEE SCORED PRELIMINARY YIELD GRADE AND ADJUSTED PRELIMINARY YIELD GRADE

	Longissimus muscle area (LEA)	Prel. yield grade (PYG)	Adj. prel. yield grade (APYG)
115 carcasses			
VIA traits			
Intercept	.2159	2.5462	2.2070
Fat area, cm^2		.0576	
Fat thickness, cm	-.9760	1.9351	1.5084
Side wt, kg	.0044	-.0016	
Total area, cm^2	.1710		
Lean area, cm^2	.5072		
Fat particles, area summation	4.9515		
Fat particles, no.	-.0169		-.0036
Fat area, %			1.9877
R^2 x 100	81.81	84.71	77.64
C_p	7.1	3.2	1.4
Standard error	.55	.17	.18
69 carcasses			
Intercept	-1.1929	2.4622	2.2578
Fat area, cm^2		.0692	
Fat thickness, cm		1.7889	1.5282
Side wt, kg	.0061	-.0014	
Lean area, cm^2	.7067		
Fat area, %			1.4208
Color	.0569		
R^2 x 100	79.89	81.14	71.22
C_p	9.8	5.9	4.1
Standard error	.54	.19	.21

TABLE 4

SIMPLE CORRELATION COEFFICIENTS OF VIA PREDICTED USDA FACTORS WITH MEASURED LONGISSIMUS MUSCLE AREA, COMMITTEE SCORED PRELIMINARY YIELD GRADE AND ADJUSTED PRELIMINARY YIELD GRADE

VIA predicted factors	Committee scored factors	Carcasses	
		115 (a)	46 (b)
Longissimus muscle area	Longissimus muscle area	.90	.89
Preliminary yield grade (PYG)	Preliminary yield grade	.92	.95
Adjusted PYG (APYG)	Adjusted PYG	.88	.92

a) equation based on 115 carcasses and predicted on 115
b) equation based on 69 carcasses and predicted on 46

$p < .01$

TABLE 5

VIA REGRESSION EQUATION FOR PREDICTING PERCENT PRIMAL LEAN BASED ON 69 CARCASSES

Intercept	44.2684
Side wt, kg.	-.0112
Lean area, cm^2	.4877
Lean area, %	10.1424
R2 x 100	52.93
C_p	4.7
Standard error	1.03

TABLE 6

MEANS AND STANDARD DEVIATIONS COMPARING PREDICTED PERCENT PRIMAL LEAN TO ACTUAL PERCENT PRIMAL LEAN TESTED ON 46 CARCASSES

	Mean	Standard deviation
Actual percent primal lean	53.15	1.48
Predicted percent primal lean using		
Official USDA equation	48.27	1.40
VIA (developed using 69 carcasses)	52.90	1.02
VIA predicted LEA combined with hot carcass wt, committee KPH and APYG	48.07	1.32
VIA predicted PYG combined with hot carcass wt, committee KPH and LEA	48.99	1.40
VIA predicted APYG combined with hot carcass wt, committee KPH and LEA	48.31	1.34
VIA predicted LEA and PYG combined with hot carcass wt and committee KPH	48.79	1.31
VIA predicted LEA and APYG combined with hot carcass wt and committee KPH	48.12	1.25

LEA=Longissimus muscle area
APYG=Adjusted preliminary yield grade
PYG=Preliminary yield grade
KPH=Kidney, heart and pelvic fat

TABLE 7

SIMPLE CORRELATIONS COEFFICIENTS OF VIA PREDICTED LEAN, USDA PREDICTED LEAN AND PREDICTED LEAN FROM COMBINATIONS OF VIA PREDICTED USDA FACTORS AND COMMITTEE SCORED USDA FACTORS WITH ACTUAL PERCENT PRIMAL LEAN TESTED ON 46 CARCASSES

Equations	Actual percent primal lean
Official USDA equation predicted lean percent	.588
VIA predicted lean percent (developed using 69 carcasses)	.582
VIA predicted LEA combined with hot carcass wt, committee KPH and APYG	.612
VIA predicted PYG combined with hot carcass wt, committee KPH and LEA	.623
VIA predicted APYG combined with hot carcass wt, committee KPH and LEA	.616
VIA predicted LEA and PYG combined with hot carcass wt and committee KPH	.649
VIA predicted LEA and APYG combined with hot carcass wt and committee KPH	.647

LEA=Longissimus muscle area
APYG=Adjusted preliminary yield grade
PYG=Preliminary yield grade
KPH=Kidney, heart and pelvic fat

$p < .01$

TABLE 8

MEANS AND STANDARD DEVIATIONS OF
VIA YIELD GRADE AND COMMITTEE SCORED USDA YIELD GRADE

	Mean	Standard Deviation
VIA	3.38	.575
Committee scored USDA YG	3.59	.587

Literature Cited

Abraham, H.C. 1976. Grade consist of fed beef. USDA, Economic Research Service, Livestock Meat Situation, 211:34-35.

Abraham, H.C., Z.L. Carpenter, G.T. King, and O.D. Butler. 1968. Relationships of carcass weight, conformation and carcass measurements and their use in predicting beef carcass cutability. J. Anim. Sci. 27:604.

Brungardt, V.H. and R.W. Bray. 1963. Estimate of retail yield of four major cuts in the beef carcass. J. Anim. Sci. 22:177.

Breidenstein, B.C., R.G. Kauffman, T. La Plant and H.W. Norton. 1964. Bilateral symmetry of the pork carcass. J. Anim. Sci. 23:1054.

Cole, J.W., L.E. Orme and C.M. Kincaid. 1960. Relationship of loin eye area, separable lean of various beef cuts and carcass measurements to total carcass lean on beef. J. Anim. Sci. 19:89.

Cross, H.R., Z.L. Carpenter and G.C. Smith. 1973. Equations for estimating boneless retail cut yields from beef carcasses. J. Anim. Sci. 37:1267.

Cross, H.R., L.W. Douglass, E.D. Linderman, C.E. Murphey, J.W. Savell, G.C. Smith and D.M. Stiffler. 1980. An evaluation of the accuracy and uniformity of the USDA beef quality and yield grading system. Final Report to Office of Inspector General, USDA.

Cross, H.R., D.A. Gilliland, P.R. Durland and S.C. Seideman. 1983. Beef carcass evaluation by use of a video image analysis system. J. Anim. Sci. 57:908.

Crouse, J.D., M.E. Dikeman, R.M. Koch and C.E. Murphey. 1975. Evaluation of traits in the USDA yield grade equation for predicting beef carcass cutability in breed groups differing in growth and fattening characteristics. J. Anim. Sci. 41:548.

Epley, R.J., H.B. Hedrick, W.C. Stringer and D.P. Hutcheson. 1970. Prediction of weight and percent retail cuts of beef using five carcass measurements. J. Anim. Sci. 30:872.

Gilliland, D.A. 1982. Software operations manual of a computerized beef grading instrument. Masters Report. Kansas State Univ., Manhattan, Kansas.

Hedrick, H.B., J.C. Miller, G.B. Thompson and R.R. Freitag. 1965. Factors affecting longissimus dorsi area and fat thickness of beef and relation between these measurements and retail yield. J. Anim. Sci. 24:333.

Lenhert, D.H. 1980. Proposal for the delivery of a prototype instrument for measuring marbling. Submitted to USDA by Dept. of Elec. Eng., Kansas State Univ., Manhattan, Kansas.

Lin, Sha-Shu Pishen. 1978. Automated pattern recognition of beef. Masters Thesis. Kansas State Univ., Manhattan, Kansas.

MacNeil, M.D. 1983. Choice of a prediction equation and the use of the selected equation in subsequent experimentation. J. Anim. Sci. (submitted).

Mallow, C.L. 1973. Some comments on C_p. Technometrics 15: 661.

Murphey, C.E., D.K. Hallett, W.E. Tyler and J.C. Pierce, Jr. 1960. Estimating yields of retail cuts from beef carcasses. J. Anim. Sci. 19:1240 (Abstr.).

Orts, F.A. 1962. Beef carcass measurements and cutting procedures. Proc. 15th Ann. Recip. Meat Conf., National Livestock and Meat Board, Chicago, Illinois.

Powell, W.E. and D.L. Huffman. 1973. Predicting chemical composition of beef carcasses from easily obtainable carcass variables. J. Anim. Sci. 36:1069.

USDA, Institutional meat Purchase Specifications for Beef. 1975. Agri. Marketing Service, Meat Grading Branch, Washington, D.C.

USDA. 1980. Official United States Standards for Grades of Carcass Beef. USDA. AMS. Title 7.

Wellington, G.H. 1953. Recommended procedure for cutting beef. Proc. Recip. Meat Conf. 6:73.

VIDEO IMAGE ANALYSIS USED TO PREDICT CARCASS PRIMAL LEAN AND FAT YIELDS, USDA YIELD GRADE FACTORS AND USDA YIELD GRADES

by

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B. S. Kansas State University, 1974

AN ABSTRACT OF A MASTER'S THESIS

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MASTERS OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY

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One hundred-fifteen Choice steer carcasses were selected based on 12th rib fat thickness and carcass weight range in proportions identified in the total beef carcass population according to Abraham (1976). Carcasses were selected by weight range and 12th rib fatness. The right side of each carcass was evaluated by the VIA (Video Image Analyzer) and a three member grading committee. These same sides were fabricated and all primals were cut into boneless closely trimmed cuts with external and exposed seam fat not exceeding 1.27 cm. Independent variables were segregated for the VIA, USDA carcass factors, and primal cut-out yield data. Simple correlation coefficients were calculated using all the weight ranges and relationships among the parameters were determined. Data were statistically treated by analysis of regression and variance. Stepwise regression procedures were used.

The equation developed from the VIA to predict total primal cut-out yield (percent) had an R^2 of 46.36% and included side weight (kg); fat area (percent); lean area (percent); and color compared to an R^2 of 46.35% using USDA yield grade traits.In predicting total primal cut-out lean yield in kg the VIA had a predictive accuracy of 95.63% and the predictive accuracy of the USDA yield grade traits scored by the committee was 94.29%. The VIA predicted 12th rib longissimus muscle area, preliminary yield grade, and adjusted preliminary yield grade with accuracies of 81.81, 84.71 and 77.64, respectively. Regression equations for combinations of committee scored USDA factors and VIA predicted USDA factors were calculated on 46 carcasses. Using VIA predicted preliminary yield grade and VIA predicted longissimus muscle area in conjunction with hot carcass weight and committee scored USDA kidney, heart and pelvic fat (percent) correlated with actual percent primal lean cut-out was .649. VIA predicted longissimus muscle area combined with hot carcass weight and committee scored USDA kidney, heart and pelvic fat (percent) and committee scored USDA adjusted preliminary yield grade correlated with actual percent primal lean cut-out was .612. These two correlations are higher than the predicted percent lean from either the official USDA equation (r=.588) or the VIA equation based on 69 carcasses (r=.582) when compared to the actual percent primal lean cut-out. These findings support a practical use of this instrument in grading in the industry as it can remove considerable subjectivity from present USDA grader evaluations.