Automated Grading of Beef and Pork Carcasses

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Introduction

Carcass grading and classification is a critical phase of establishing the market value of live animals and their carcasses. This need to categorize meat products originated, according to Kiehl and Rhodes (1960), when a growing market for meat appeared as industrialization progressed, first in England and later in the United States. This development of markets and the continued urbanization of society gave rise to the need for a uniform nomenclature to facilitate the trading of meat products.

According to Kline, Kimbrell and May (1981), the primary purpose of classification and grading is to provide a basis of reporting dressed meat markets uniformly and establishing values. It also provides a system, even if imperfect, in which consumer preferences are made known to livestock producers, thereby encouraging, through price incentives, the production of more desirable live animals.

According to McCoy (1972), the need for grading and classification in the U.S. led to the pioneering efforts of the Illinois Agricultural Experiment Station to develop and define uniform grades for the purpose of price reporting. The United States Department of Agriculture established an Office of Markets in 1913, which was the beginning of what is now the USDA Livestock, Grain and Seed Division, Agricultural Marketing Service. According to Dowell and Bjorka (1941), this office began work in the development of the official grades for live animals and meat in 1915. The first grades formulated in 1916 were the basis of reporting the dressed beef markets according to grades. This work was inaugurated in 1917 as a national service. The early standards were unpublished and unofficial, but were used until 1926. During this time, experience and usage dictated a number of revisions. It was from these beginnings that the Office of the U.S. Secretary of Agriculture first published the Official United States Standards for Grades of Carcass Beef on June 3, 1926 (USDA, 1980). The official standards for grades of lamb and mutton carcasses were published initially and made effective on February 16, 1931 (USDA, 1982). Tentative pork grading standards were issued in 1930 and revised in 1940. The official pork grades for barrows and gilts were first published and adopted September 12, 1952 (USDA, 1970).

Historically, the standards have been subjective but needed quantifiable criteria that, when used to categorize and grade livestock carcasses, would identify those traits that contribute to carcass value differences. These differences and the need for identification have led to volumes of research data in which attempts have been made to quantify and measure traits that contribute to these differences. These include the scoring and measurement of many different objective and subjective traits.

The objectivity of the grading standards has improved since their original implementation, but objective application continues to be limited primarily because: 1) grade standards are applied by humans, and 2) they must be applied rapidly in a commercial production situation. For these reasons, grade application remains more subjective in nature rather than being objectively done.

Development of Objective Criteria for Carcass Grading

During the early history of carcass grading and classification, limited efforts were made to adapt grading criteria to objectively-measured criteria. The first significant attempts were begun in the late 1940's and continued into the 1950's. In reviewing the literature, it becomes apparent that there are three objective measurements of carcass and/or live animals that are easily measured and are usually of significant importance in determining carcass values. These are: 1) fat thickness; 2) LD muscle area; and 3) weight.

Measurement of Fat Thickness

It has long been recognized and reported that thickness of external finish is related to proportions of lean and fat in the animal carcass in all species. Many studies have reported significant relationships between external carcass fatness and fat and/or retail yields (Callow (1947), Kropf and Graf (1959), Murphey et al. (1960), Cole et al. (1962), Ramsey et al. (1962), Hedrick et al. (1963) and Carpenter et al. (1965)). Hazel and Kline (1952) reported on a simple live animal probe technique that showed great promise in predicting the respective fatness vs. leanness of live hogs and/or carcasses. Since that time numerous other workers have measured carcass fatness at a variety of locations in attempting to find those measurements that give the most effective predictibility of carcass composition.

Measurement of Loin Eye Area

Because of the ease of obtaining repeatable measurements and its relationship to carcass leanness, longissimus

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muscle area has been used repeatedly as a measure of carcass composition. Schoonover and Stratton (1957) and Shrewsbury and Wideman (1961) reported on the use of cameras attached to metal focusing frames to permanently record and allow subsequent measurements of longissimus muscle area. These workers reported good accuracy and repeatability of measurements using this method.

Carcass Weight

Many research studies have documented the negative influence of carcass weight on retail yield (Cole et al. (1960), Breidenstein (1962), Cole et al. (1962), Brungardt and Bray (1963), Butterfield (1963), and Swiger (1964)). These workers reported that carcass weight had a negative influence on retail yield and was also usually the single most important measure in predicting weight of retail yield.

Instrument Adaptation for Objectivity

Due to significance and relative ease of measuring the three preceding traits in the live animal and/or carcass, most attempts in developing instruments have focused on using technology to quantify them.

Ultrasonics

Some of the earliest attempts to objectively quantify live animal and/or carcass fatness and/or leanness utilized ultrasonics. Hazel and Kline (1959), Stouffer et al. (1961), Hedrick et al. (1963) and McReynolds and Arthaud (1970) pointed out the usefulness of ultrasonics in objectively evaluating live animals and their resulting carcasses. Recent breakthroughs in instrument design and capabilities give additional promise in the refinement and improvement of this technique. Koch and Varnador (1976) used the electronic meat measuring equipment (EMME) to evaluate beef carcass composition. This technique, when used with untrimmed weight, was slightly superior to the use of the USDA yield grade factors in predicting carcass retail yields.

Other Instruments

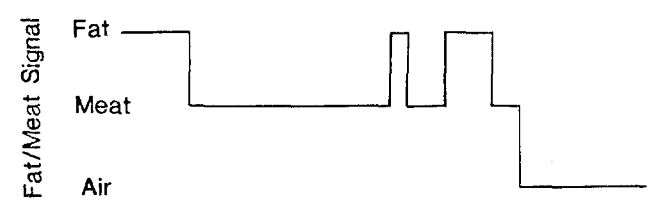
Efforts to develop a completely objective, economical carcass grading instrument are continuing. A common and necessary feature of all instrument systems is computer-compatability to facilitate rapid interpretation of data and achieve maximum objectivity. Recent attempts at automated grading have centered largely on probing devices that record the depth of fat and/or muscle tissue at standardized anatomical sites on the animal carcass. A partial listing of instruments developed recently includes:

1) Hennessy Grading Probe (HGP) – New Zealand
2) Danish Meat Fat Automatic Probe (MFA) – Denmark
3) Schlachtkoerper-Klassifizierungs-Geraet (SKG) – Federal Republic of Germany
4) Ulster Probe (UP) – Ireland
5) Video-Image-Analyzer (VIA) – United States (Kansas State University)

The Hennessy Grading Probe and the Danish Meat Fat Automatic Probe are the two that have been developed and commercially utilized to the greatest extent.

Figure 1.

HGP
GRADING PROBE – CARCASS PROFILE



Hennessy Grading Probe

The HGP is being commercially used in Sweden and is currently being investigated for use in Canada for grading pork carcasses. This grading probe is an optical probe that is inserted into the pork carcass body wall 5 to 10 cm off the midline, usually at the 10th and 11th ribs, the last rib, and/or at the third or fourth lumbar vertebra. The probe is first inserted completely through the body wall of the carcass and the fat and muscle readings are taken as the probe is withdrawn. A record of the fat and/or muscle depth measurements is available as shown in Figure 1. This instrument measures tissue depths based on light reflectance differences between fat and muscle and utilizes the visible light spectrum. Measurements resulting from the HGP include: 1) Subcutaneous fat thickness; 2) Muscle depth; 3) Marbling; 4) Carcass wall thickness; 5) Total depth probe; 6) Lean meat percentage; and 7) Carcass classification number. The HGP features are: range 0-140 mm; resolution 0.4 mm; accuracy $\pm$ 0.2 mm (2mm-140mm); speed-1 reading/second; power 12 volts DC; weight 1450 g; length $\times$ width 460 $\times$ 75 mm (Hennessy & Chong LTD, 1983).

Danish Meat Fat Automatic Probe

This is an automatic probe that originally measured carcass tissues based on the differences in electrical conductivity between lean and fat. This probe has been modified to measure tissues based on optical differences in reflectance, using the infra-red spectrum. It is used in the same manner as the HGP, and measures essentially the same factors. A study in which these probes have been compared for accuracy and precision has been published (Sack, 1983).

Video-Image Analysis

This system of evaluating carcasses operates by taking a picture of a carcass and/or a cross-sectional area of the carcass with a high-resolution, digitizing camera interfaced with a micro-processor that is programmed to interpret the picture according to the wishes of the operator. The system to be discussed here is the Video-Image Analysis instrument developed at Kansas State University. This instrument is composed of a video camera (General Electric TN 2500), video monitor (Sanyo model no. VM 4209), data-terminal (Lear Seigler ADM-3A) and computer (Intel ISB 86/12A). The operator positions the camera by means of a metal bracket at a known distance and angle relative to the cut surface. When the operator triggers the picture taking, the entire 12th rib cut surface is illuminated by fluorescent lights. The image is digitized and transmitted to the computer. The computer carries out the programmed procedures, this information is put into format and transmitted to the digital read-out where it is displayed. An image of the 12th rib surface as seen by the computer can also be displayed for operator reference. These steps can be carried out within 10 to 14 seconds using this prototype model. Data that are currently programmed to be computed and recorded from this sequence of operations on beef carcass 12th rib cut surfaces include: 1) Total 12th rib surface area (cm^2); 2) Fat area (cm^2) and percentage fat; 3) Lean area (cm^2) and percentage lean; 4) Particles of fat within the LD muscle (number); 5) Area summation of fat particles within the LD muscle (cm^2); 6) Fat thickness (cm); 7) Color lightness value of lean tissue.

Evaluating Instruments for Pork Carcass Grading

Comparisons of instruments have largely been confined to comparing their accuracy and precision in measuring fat and muscle in pork carcasses. Kempster et al. (1979) compared the Danish MFA, the Ulster Probe and the Optical Probe used in England. Kempster et al. (1981) evaluated the Hennessy Fat Depth Indicator and the Ulster Probe for utilization in grading and classifying pork carcasses. Jones et al. (1982) and Jones and Haworth (1983) evaluated the accuracy and precision of the Hennessy Fat Depth Indicator and an ultrasonic instrument to measure fat and predict the lean content of pork carcasses in Canada.

These studies showed that most of these probing devices were similar in accuracy of fat measurements and in predicting carcass lean percentages. The studies showed that durability and cost were probably of greater consideration when deciding which instrument to utilize in a commercial grading situation than were differences in accuracy. In general, the probing devices tend to over-predict backfat in trim carcasses and under-predict it in fatter ones. These workers generally concluded that multiple measures of fat depth at various carcass locations did not improve accuracy of lean prediction sufficiently enough to warrant the use of multiple probe sites in a commercial grading situation. In most cases, the probe sites most accurate for predicting carcass leanness were those located from the last rib to the second and third lumbar vertebra, 5 to 10 cm off the dorsal carcass midline. Table 1 shows some of the suggested probe sites used in regression equations for predicting pork carcass leanness using various instruments. Several countries, including Sweden, Denmark and England, are now using pork carcass grading systems with automated probes.

Instrument Measurement of Beef Carcass Traits

The Hennessy FDI has been utilized by Jones and Haworth (1982) and Kutsky et al. (1982) to measure beef carcass fatness. Jones and Haworth (1982), working on chilled beef sides, measured carcass fatness at ¼, ½ and ¾ the length of the LD muscle at the 11th thoracic vertebra. They reported that the ¼ position gave the most accurate and precise results; the ½ position the least accurate; and the ¾ position was less precise than the ¼ in fatter carcasses. They stated that, under abbattoir conditions, the FSI over-predicted carcass fatness, especially on fatter carcasses. Kutsky et al. (1982) used the FDI to measure beef carcass fatness on hot and chilled beef carcasses at multiple locations. Their data also suggest that the FDI accuracy decreases as carcass fatness increases.

Wassenberg (1983) measured chilled beef carcass 12th rib fat thickness, area (cm^2) and percentage 12th rib fat using the Video-Image Analysis (VIA) instrument. Table 2 shows the correlation coefficients between instrument measures of beef carcass fatness, actual fatness and percentage retail yield from the major boneless cuts. These studies indicate potential usefulness of both these instrument systems for measuring beef carcass fatness.

Wassenberg (1983) also used the VIA to predict area of 12th rib LD muscle. The VIA measures total area (cm^2) 12th rib muscle area which is highly correlated to area of 12th rib LD muscle, (.86). Twelfth rib LD muscle area was predicted using this measurement plus hot carcass weight and lean color lightness value. The simple correlation between predicted and actual 12th rib muscle area was .90. USDA yield grade was then calculated, using VIA-predicted 12th rib LD muscle area, VIA-measured 12th rib fat thickness, hot carcass weight and subjectively scored percentage kidney, pelvic and heart fat. Yield grade calculated using VIA measured traits was correlated to that calculated using actual measured traits at .91.

Conclusions

First and/or second generation grading instruments have shown to be relatively accurate in their ability to measure carcass traits, especially carcass fatness and in the case of the VIA, muscle area. Since a computer is a vital part of most instrument systems, many other potential ways of utilizing grading instruments are possible. Some of these might include computerized collection of carcass data, computerized identification of animals and their resulting carcasses, computerized sorting and railing of carcasses within slaughter plants and automated record keeping of individual animal carcass values.

As instrument grading develops, carcass grading standards must be redefined so that they reflect what the instrument is best capable of doing. This probably means that the present standards, which were written using traits identifiable by humans, will not be applicable using instrument systems.

The use of instruments to grade and classify carcasses is rapidly becoming a reality in several countries. Instrument technology, reliability and accuracy will improve as further developmental work is done. The next step beyond instrument development will be the combining of grading instruments with robotics to fully automate the grading procedure. How rapidly instrument grading systems are adopted will depend largely upon monetary input.

Humans will still have to be proficient in carcass grading and evaluation, due to the continual need for monitoring the instruments to detect malfunctions. However, the most critical manpower need for instrument grading will, in all probability, be meat-knowledgeable individuals trained as engineers and as computer programmers.

Table 1. Probe Locations Utilized in Regression Equations for Predicting Pork Carcass Leanness Using Various Probing Instruments.

Instrument	*Independent Variables*	R^2	RSD
Hennessy FDI[a]	Hot Weight + Last Rib Probe + Loin Probe	.40	2.08
Lean Meter[a]	Hot Weight + Last Rib Probe + Loin Probe	.27	2.22
Danish MFA[b]	Hot Weight + Last Rib Probe + Last Rib Muscle	-[c]	2.18
Ulster Probe[b]	Hot Weight + Last Rib Probe + Last Rib Muscle	-[c]	2.44
Optical Probe[b]	Hot Weight + Last Rib Probe + Last Rib Muscle	-[c]	2.15

[a] Jones and Haworth (1983)
[b] Kempster et al. (1979)
[c] R^2 not available

Table 2. Correlation Coefficients Between Instrument Measures of Beef Carcass Fatness, Actual Fatness and Percent Retail Yield of 4 Major Wholesale Cuts.

Instrument	*Fatness Measure*	*Actual Fat*	*Percent Boneless Retail Yield Major Cuts*[a]
FDI[a]	11th Thoracic	.69	−.37
	Ninth Thoracic	.56	−.36
	Fourth Sacral	.99	−.39
VIA[b]	12th Rib ¾ Measurement	.91	−.44
	Cm^2 12th Rib Fat Area	.65	−.47
	Percent 12th Rib Fat Area	.68	−.60

[a] Kutsky et al. (1982)
[b] Wassenberg (1983)
[c] Retail cuts trimmed to .95 cm. fat in FDI study, 1.27 cm. in VIA study.

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Discussion

R.G. Kauffman: Dell, I would like to ask you about the relevance of predicting predictors. I guess I am concerned about your endpoint, whatever instrument it might be. Are we talking about bone, fat and muscle and the latter of these being the most important of the three and that we want to predict the proportion of these components that represent the lean mass as compared to bone and fat.

It seems to me that too many of our instruments, including yours, are trying to predict a predictor rather than the product. Would you like to comment?

Allen: I'll say that that is exactly what I said, Bob. I am not a creative thinker. When we started with this, USDA had a task force to guide them on what to come up with as far as instrument grading is concerned. They are evidently as bad as I am. Because what they came up with to try to measure was fat thickness, loin eye size and marbling, and that is where I started. I think, as I indicated in my talk, that is where we make a mistake by trying to duplicate things that we have done routinely over the years from a person's standpoint. We have made it convenient for a person to grade carcasses. We have to forget that and go on to something else that is going to do a better job as far as getting to body composition which is really what we are talking about.

Kauffman: Are you suggesting what this system will be appropriate for? I guess that's what I didn't hear you say.

Allen: I think this system has some potential. Our engineers, as they have become more familiar with the area of meat and what we are trying to do, have discussed with me at great length a system they call "geometric density." I don't know what that is. They think this instrument has the ability to do that and they think it will have a very direct relation to carcass composition.

Kauffman: What do your engineers say about types of systems other than yours? Are there other types of systems that might be much more productive and effective?

Allen: Potentially. I am not sure I am the man to say what they are at this time. It very well may be that it will be a marriage of two or three of these systems. I do think that video image analysis potentially has a place. Not necessarily as we have used it here, but in the final instrument type. We may be using Jim Stouffer's ultrasonic machine on the hot carcass and come up with thickness of fat and muscle mass in these areas. I think we are also going to have to use video image analysis to incorporate that information into a computer rapidly enough to come up with a "carcass grade type thing." That is where we are headed. I don't think it is going to be this system only. This may be a good first step and it may not be. We are not going to go from A to Z just like that overnight. There is going to be a developmental process of instruments as we progress through whatever we start with to what the final version of that instrument may be. Does that answer your question?

L.J. Ernst: Dell, as we look more and more at export markets for various products, are we going to be forced into grading in order to get our product into some of these countries, which you mentioned above, by their system or is there going to be a dual standard?

Allen: I am not sure I am going to answer that the way you want it, Lyle. I don't know the way you want it. I don't think our export market is going to compete with the products necessarily produced in those countries and I am relating that more to beef than pork. I am pleading my ignorance in the pork area a little bit. We are not producing the same type of beef. I don't think we are going to be locked into an international set of standards on the beef that we export. They are coming to us for a particular type of product, I think, in the case of beef and we will be using our own set of standards. I am not sure that it will be the same as we have now.