MEAT CARCASS GRADING IN THE FUTURE[1]

M. A. PRICE

Department of Animal Science, University of Alberta, Edmonton, Alta. T6G 2H1.
Received 21 Sept. 1981, accepted 19 Oct. 1981.

PRICE, M. A. 1982. Meat carcass grading in the future. Can. J. Anim. Sci. **62**: 3–13.

A fully functional grading or classification system must allow trading in carcasses and meat to be conducted without the buyer needing to inspect the product personally. To achieve this, the system must accurately indicate the quantity of meat, the intrinsic quality of the meat, and any aspects of appearance which would influence retail acceptability. An objective system is proposed which could be applied to carcasses of all genera and would allow all the necessary information for confident remote trading. The grading information would indicate the actual weight of lean meat in the carcass together with the important indicators of appropriate retail outlet (size, age, fat thickness and absence of defects). Other information on the label would indicate postslaughter treatments likely to influence the palatability of the meat.

Pour être vraiment fonctionnel, un système de classement ou de classification doit permettre la mise au commerce de carcasses et de viande sans qu'il soit nécessaire à l'acheteur d'inspecter la marchandise. Pour cela, le système doit spécifier exactement la quantité de viande offerte et ses qualités intrinsèques ainsi que toute particularité susceptible d'influer sur son acceptabilité au niveau du détail. L'auteur propose un système objectif applicable aux carcasses de toutes les espèces de bétail et fournissant toute l'information voulue pour les transactions à distance. L'information relative au classement spécifie le poids réel du maigre dans la carcasse ainsi que certains indices importants pour le marché du détail (taille, âge, épaisseur du gras de couverture, absence de défauts). L'étiquette indiquerait en outre les traitements post abattage susceptibles d'influer sur la valeur gustative de la viande.

Key words: Carcass, grading, meat quality

Grading is the separating of a commodity into lots, each lot having a relatively high degree of uniformity in certain characteristics associated with market preferences and value (McCoy 1979). The function of grading is to facilitate trade in that commodity. Grading manufactured products is a simple matter of descriptive labelling; all products bearing a particular label being identical (Wood screw; Threadfast; Flat head; Robertson socket; Zinc chromate plated steel; 6 × 1''). However, with primary products such as meat carcasses, the grader faces an infinite variety of descriptions. His job then must be to group the carcasses in a way which will reflect market preferences and direct the carcass into the appropriate sectors of the meat industry (supermarket trade, restaurants, institutions, further processing, etc.). The problem, however, is further complicated by the fact that the carcass will be traded several times between producer and con-

[1]Presented at the Canadian Society of Animal Science Symposium entitled The Future of Meat as a Sustainable Food System, 11 Aug. 1981, St. Catharines, Ontario.

0008-3984/82/6201-0003 $2.00

sumer and the same characteristics are not equally important at each transaction.

It is essential to the system that the traits which are evaluated during grading reflect the interest of the people who want to trade in the product, and that the evaluation itself is totally consistent and repeatable.

An ideal carcass-grading system would result in an identical grade on a given carcass regardless of who graded it or where or when it was graded. The grade description should then become part of a label which would include such information as genus and carcass weight. An adequate label would allow the carcass to be traded in a fully competitive manner with no further information, and without the buyer needing to examine the carcass personally.

THE CURRENT SITUATION

It would not be useful or possible to review all of the formal and informal systems of carcass grading and classifying that exist in the world's meat markets. However, these systems share a number of aims and use a variety of methods to achieve them; these are worthy of review.

Yield Grading

A carcass consists mainly of (a) bones, tendons and ligaments, which can be considered inedible; (b) muscle, which is the major edible portion; and (c) fat, which complements muscle during cooking and eating. The ideal carcass, therefore, contains a minimum of bone, a maximum of muscle and an optimum amount of fat (Berg and Butterfield 1976). This does not necessarily coincide with the ideal composition of a live animal. Most carcass appraisal systems include an estimation of the proportion (cutability or yield) of saleable meat in the carcass (i.e. muscle plus the desired amount of fat). Traditionally, this has been achieved by assessing conformation (muscle thickness) and finish (the amount of fat on the carcass).

Many methods have been employed to estimate these two; the least desirable (though probably not the least accurate (Kempster et al. 1976) being visual appraisal. Visual appraisal is undesirable in a grading system simply because, being subjective, it cannot be proved by measurement. This will inevitably lead to occasional disagreements with the grader which may, in time, erode buyers' and sellers' confidence in both the grader and the system.

The most commonly used objective method of estimating fatness consists of measuring the fat depth at some defined point on the carcass. When the carcass is routinely cut, fat is normally measured directly on the cut surface (e.g. over the longissimus muscle at the quartering position in beef; along the chine in pork carcasses in countries where they are split longitudinally). When the carcass is not cut, fat depth can be measured by probes of various kinds, but inaccurate location of the probing site is a possible source of error. The best site for fat depth measurement has been the subject of considerable research (Fredeen and Bowman 1968; Kempster et al. 1976; Fahey et al. 1977; Evans and Kempster 1979; Thompson and Atkins 1980). The problem has not been resolved.

A more innovative approach to carcass fatness estimation is the use of specific gravity or density measurements (Jones et al. 1978), though the incorporation of these methods into packing plant procedures for grading purposes has not been attempted, and is unlikely to be practical. Direct measurement of total carcass fatness by a non-destructive technique would be preferable to any method involving prediction of fatness from other measurements. No such direct method of measuring the quantity of fat in a carcass is currently known.

Objective estimates of conformation are usually limited to measuring muscle cross-sectional areas and occasionally the use of photographic standards (e.g. Agricul-

tural Research Council 1965). The former are poorly related to cutability and the latter suffer from the difficulty of differentiating muscularity from fatness. Yeates (1965) proposed the use of the carcass weight to length ratio ('fleshing index') as a measure of carcass thickness. The assumption was that if fat could be estimated and discounted the remaining thickness would be an index of muscling. The system made no allowance for variations in the muscle:bone ratio. A system known as Electronic Meat Measuring Equipment (EMME) attempts to make a direct measurement of the total muscle content of a package of meat. It has not yet been adapted to carcass grading.

In practice, the most variable carcass tissue is fat, so that, with present technology, its estimation is considerably more important than estimating the other tissues. Only if accurate and practical methods are devised to estimate fatness will it be advantageous to estimate the muscle:bone ratio. Kempster and Harrington (1980) have indicated that 'fat corrected' conformation is of value in commercial carcass classification. Of course, if muscle could be estimated directly, the estimation of fat and bone would be unnecessary.

The use of any simple measurement to predict the total amount of some tissue in the carcass will inevitably lack robustness. Most predictors are accurate within a defined breed, sex and weight range and will become less accurate outside the particular range for which they were established. For this reason the use of predictors must, in the long run, be replaced by methods which can directly measure the content of each tissue in the carcass. It will then be possible to use a single system of yield grading for carcasses of all genera. Approaches like density for fatness and EMME for muscle are steps in the direction of pangeneric grading. Acceptable commercial methods of tissue measurement will need to be extremely rapid (preferably instantaneous) and inexpensive to operate.

Although it has been common in the past to seek carcasses with greater proportions of muscle in the expensive cuts it is now accepted that, at least within species, the distribution of muscle around the carcass is relatively constant (Berg and Butterfield 1976). Grading systems should, therefore, concern themselves only with establishing the amount of muscle in the carcass, not where it is. Bone also appears to be predictably distributed within a carcass (Jones et al. 1978; Richmond et al. 1979). The factors affecting distribution of fat, however, are not clearly understood even within a breed (Johnson et al. 1972; Berg et al. 1979; Kempster and Evans 1979; Jones et al. 1980a,b,c; Jones et al. 1981).

Quality Grading

Quality grading is designed to categorize the appearance and eating quality of the product. Although appearance is not an accurate guide to eating quality (Woodhams and Trower 1965; Price 1971) an abnormal appearance will reduce the likelihood of sale, particularly in a supermarket situation. It cannot, therefore, be dismissed as unimportant. One important determinant of appearance is preslaughter stress which can increase the incidence of pale, soft, exudative and dry, firm, dark meat. The characteristic texture and appearance associated with these conditions are often not fully developed at the time of grading; improved, objective techniques are therefore needed to identify the occurrence of these conditions, particularly in borderline cases.

Although some determinants of eating quality (genus, anatomical location, physiological age) are intrinsic to a particular piece of meat, much of the variation in eating quality is caused by extrinsic, postslaughter factors (suspension technique, ageing time and conditions, storage, preparation and cooking). It is not surprising, therefore, that poor relationships are generally found between characteristics which

can be identified by the grader and final eating quality. Indeed, with continued advancement in meat technology the usefulness of meat quality grading based on intrinsic factors becomes questionable.

The following quality indicators are commonly considered by graders in the various systems in operation today.

PHYSIOLOGICAL AGE. The age of the animal from which the carcass was derived affects the eating quality of the meat (Jeremiah 1978). In general, tenderness decreases (Pearson 1966) and flavor intensifies (Park and Thomas 1973) as the animal matures. These relationships are, however, by no means precise. Since chronological age is not reliably available to the grader, physiological age must be used. It is not known whether physiological age is any more or less reliable for this purpose than chronological age.

Physiological age can be assessed from the dental record (especially in sheep, cattle and horses), the degree of ossification of certain cartilages, the appearance of certain bones or from combinations of the three. The first method is more precise than the other two and is therefore considered preferable in carcass grading systems (Graham and Price 1980; Price and Graham 1980). It is commonly used for this purpose in Europe, Africa and Australia.

COLOR. Color of muscle and fat per se, within very wide ranges, has little influence on the palatability of meat (Pearson 1966; Breidenstein et al. 1968). Nevertheless, it is an important quality criterion because consumers have a perception of a normal range of color in the meat they buy. They will resist colors or shades outside this range, particularly in fresh meat.

Where color is assessed for grading purposes it is usually done subjectively, with the intention of identifying off-colors. The criteria vary depending upon the type of carcass being appraised, e.g. an acceptable color for pork may be unacceptable for veal (too red) and for beef (too pale). Objective methods of measuring color exist, ranging from sophisticated color-meters to color standards in the form of tiles or high-quality photographs. When muscle is cut, the color of the cut surface gradually changes from the purplish-red color of myoglobin to the brighter red color of oxymyoglobin. Care must, therefore, be taken to ensure that the meat has had ample time to 'brighten' before its color is assessed by a grader. The rate of this change may be affected by genus (Lawrie 1974).

TEXTURE. Texture of muscle is normally taken to mean the size of the fasiculae (muscle bundles) or grain of the meat (Lawrie 1974). There is little direct relationship between this and eating quality. However, coarse texture (large-sized bundles) can indicate an older animal, which would normally be tougher (Jeremiah 1978). In animals of similar age, however, coarser texture may simply indicate larger muscle fibers which would suggest greater tenderness (Yeates 1965; Lawrie 1974). Texture of muscle is, therefore, at best, an unreliable guide to eating quality.

Texture of fat refers to its external appearance, especially in beef carcasses. A smooth, waxy sheen is preferred to a rough, pebbly surface. In North America the practice of 'shrouding' carcasses ensures a smooth fat surface and may also help to whiten the fat by removing surface blood (Yeates 1965). There is no evidence that the surface appearance of the fat is related to palatability.

FIRMNESS. Consumers discriminate against meat with soft fat. Carbon chain length, the degree of saturation and carcass temperature all affect the hardness of carcass fats (McDonald et al. 1969). The chemistry of depot fat in ruminants is not greatly affected by diet, or other environmental factors, but it can be in monogastric animals. Soft or oily fats appear to be more susceptible to spoilage, such as oxidative rancidity, than hard fats, (Yeates 1965). The hardness of carcass fat also

has an important influence on the perceived firmness of muscle. Following the resolution of rigor mortis, the presence and physical condition of the depot fats — subcutaneous, intermuscular and intramuscular — are the main determinants of muscle firmness since they form a framework from which the relatively pliable lean portion derives its support.

Another factor affecting the firmness of lean is the change in pH during postmortem glycolysis. Abnormally high ultimate pH often results in particularly firm (though dark and dry) muscle, while low pH can lead to soft and exudative muscle. Both these conditions have been studied extensively (Hedrick 1965; Buchter 1975; Price and Tennessen 1981). There is marked consumer resistance to meat showing any of these characteristics.

MARBLING. Marbling is the presence of visible fat within the muscle. As little as 5% of ether extract in the fresh sample can be observed as 'slight' marbling, 10–15% is considered 'abundant' (Breidenstein et al. 1968; Parrish et al. 1973). Its presence can be related to juiciness and flavour, though the correlations are small; it is almost unrelated to meat tenderness in all genera (Blumer 1963; Crouse et al. 1978; Jeremiah 1978). However, marbling is closely correlated to overall fatness, and since fatter carcasses have slower chilling rates this may help to reduce the cold shortening phenomenon, which is thought to contribute to toughness (Marsh 1977). This may explain the common notion that marbling is a guide to tenderness. Although it is generally felt that some minimum level of fatness (perhaps coinciding approximately with the level at which marbling becomes visible) is necessary to maintain palatability, experimental evidence for this appears to be lacking (Wood et al. 1981). Marbling alone is, therefore, unlikely to be a useful indicator of eating quality, and appears to contribute no more information than could be obtained from an overall measure of carcass fatness. The complete absence of marbling is, however, considered a defect in terms of appearance and should be noted by the grader if it occurs.

Postmortem Factors Affecting Meat Quality

The factors discussed in **Quality Grading**, with the exception of preslaughter stress and physiological age, account for only a small proportion of the total variation in meat palatability. A far greater proportion of this variation is accounted for by the treatments applied to the carcass between slaughter and eating. The conversion of muscle to meat is a complex biochemical process manifested by the phenomenon of rigor mortis. This conversion process, and the quality of the resultant meat, can be affected by the biochemical conditions of the muscle at slaughter, the tension placed on the muscle during rigor and the speed of the conversion. These influences have been reviewed by Jeremiah (1978).

Following the resolution of rigor mortis, biochemical changes continue to occur in the meat leading to a time-related improvement in tenderness known as ageing or conditioning. The rate of improvement is strongly influenced by the temperature of the carcass during ageing; e.g. meat held for 2 days at 38°C or 1 day at 43°C has been found to be more tender than similar meat held for 14 days at 2°C (Lawrie 1974).

A number of postslaughter innovations to improve tenderness have been described. Most depend upon either stimulating the rate of postmortem glycolysis or mechanically restricting the interdigitation of actin and myosin filaments (see reviews by Marsh 1975, 1977; Dutson et al. 1977; Parrish 1977; Stouffer 1977). In addition to these techniques, and others, which are applied to the whole carcass during the storage period, a number of tenderizing procedures can be applied to individual cuts of meat during preparation

prior to cooking. These include the use of tenderizing enzymes and mechanical tenderizers such as needle and blade insertion, pounding and, in the extreme, chopping and grinding. Flavor enhancers and a number of other processes can also be used to alter radically the eating quality of a particular cut of meat.

Cooking procedures themselves will further affect the eating quality (Leander et al. 1977). The application of moist heat enhances the hydrolysis of the connective tissue collagen to gelatin, improving tenderness. Conversely, any form of heat tends to toughen the muscle fibers by denaturing muscle proteins. The rate and duration of cooking as well as the final temperature will, therefore, affect the ultimate eating quality of the meat. Finally, the way in which the meat is served (e.g. thick or thin sliced) the food served with it and the environment in which it is served will all influence palatability.

TOWARDS A PERFECT SYSTEM

It seems clear from the foregoing discussion that, with the exception of physiological age, parameters which can be assessed by the grader are of minor importance as determinants of ultimate eating quality, though some appearance factors which he can identify may be of great importance in determining the most appropriate market for the meat. Of overwhelming importance to eating quality will be the postslaughter treatment of the carcass and the preparation, cooking and serving of the meat. To facilitate trade, therefore, information is required on all these aspects. The information which is both measurable and useful should be recorded at the time of grading and the date of slaughter and subsequent treatment of the carcass should become a matter of labelling regulations.

The basic criteria for both yield and quality grading are not genus dependent. It should, therefore, be possible to devise a single grading system applicable to carcasses of all genera. Naturally, the actual grade criteria could vary from genus to genus. Accurate carcass grading on the basis of the following traits would be sufficient to allow full trading on the basis of description only.

Genus

Although the genus is an important part of the carcass description, it is probably unnecessary to further subdivide this (i.e. into beef and veal, mutton and lamb etc.) since the other criteria in the classification (age, size) will do so automatically.

Carcass Muscle Content

In the ultimate carcass-grading system, carcass muscle content should be quantified. This measure would then completely replace current yield grading systems. The method adopted should be rapid (several hundreds of carcasses per hour), objective, and involve direct measurement of the amount of muscle, not predictions of it. No such technology exists at present. Trade among producers, packers and the meat industry should then be conducted on the basis of muscle weight alone, the price per unit of muscle being modified by the other grading criteria in accordance with supply and demand.

In addition to absolute quantity, the meat industry has traditionally prized muscle thickness (conformation), claiming, without scientific support, that lightly muscled carcasses are of inferior quality, not merely in terms of cutability, but also in terms of palatability. In recent years, with increased emphasis on heavy muscling and light fat covering, carcasses from 'double muscled' animals, of all species, are also becoming more common. These, too, meet some resistance in the market place. Although there is little scientific evidence to justify it, it would be possible to build a measure of 'conformation' (carcass muscle:bone ratio) into the grading system to accomodate this notion. In its most highly developed form this would involve scan-

Table 1. Examples of carcass size criteria

Class	Beef	Pork	Sheep
I	<100 kg	<15 kg	<15 kg
II	100–225	15–50	15–35
III	226–325	51–90	36–50
IV	236–425	91–150	50–100
V	>425 kg	>150 kg	>100 kg

ning the carcass to find total bone content similarly to finding total muscle content. From the ratio of these two, and in consultation with the meat industry, an acceptable range of muscle: bone ratio within each genus and size group would be established. Carcasses falling outside this range would be designated lightly or heavily muscled. Carcasses within the acceptable range would pass without comment.

Carcass Size

The carcass weight should continue to be recorded as at present, and be used to place the carcass in a size class. Each genus should have defined weight ranges for each of about five size classes (see Table 1). The carcass weight would have no function other than placing the carcass in its size class, and hence would not be a part of the specifying label.

Physiological Age

Physiological age should be determined by genus-specific fully objective methods, preferably placing as much emphasis on dentition as possible (Price and Graham 1980). The youngest age class (corresponding to suckling pig and white veal) would be designated Class I and would have to be determined largely on skeletal characters (soft, red bones) since all animals in this class would have their milk teeth. About five age classes would probably be sufficient to group carcasses, within each genus, fairly accurately in terms of intrinsic meat quality (see Table 2).

Carcass Fatness

With carcass muscle content known, it would be unnecessary to measure carcass fatness for the purpose of calculating cutability. However, for telephone trading purposes it is probable that buyers would still need an indication of fatness, particularly subcutaneous fat, since it is necessary to trim overfat carcasses (at a cost), and some cuts are considered unattractive by consumers unless they have a certain minimum fat cover. About five fat thickness classes would probably be sufficient in each genus (see Table 3).

Sex

For trading purposes six sex classes are normally recognized: young females, old females, young neutered males, old neutered males, young males and old males. Old neutered males are generally not differentiated from old females. The definitions of 'young' and 'old' vary with place and genus. With the exception of swine, the young neutered male is considered 'standard' and the price paid for other sex/age types are normally discounted. The basis for discounting young females is

Table 2. Examples of physiological age criteria

Class	Beef	Pork	Sheep
I	Soft red bones	Soft red bones	Soft red bones
II	0 incisors	0 incisors	0 incisors
III	1–4 incisors	?	1–2 incisors
IV	5–8 incisors	?	3–4 incisors
V	Epiphyses fused	?	5–8 incisors

Table 3. Examples of carcass fatness criteria

Class	Beef	Pork	Sheep
I	<1 mm	<5 mm	<1 mm
II	1–5	6–15	1–5
III	6–10	16–30	6–10
IV	11–20	31–50	11–15
V	>20 mm	>50 mm	>15 mm

their lower cutability and smaller size at the same fatness. Since both of these factors would be accounted for elsewhere in a perfect grading system, it would be unnecessary in such a system for the grader to identy young females per se.

The basis for discounting young males (including cryptorchids) is historic prejudice based on a supposed poorer meat quality, insufficient fatness, darker coloured meat and coarse texture. It has been amply demonstrated by research (Rhodes 1969; Field 1971; Price 1971; Hawrysh et al. 1980) that differences in palatability between meat from young males and from young castrates are small enough to be negligible. The other objections to young male carcasses (fatness, color and texture) would be accounted for in other parts of a perfect system. It would therefore, be unnecessary for the grader to identify young male carcasses per se.

Carcasses from older males are currently distinguished from those of older non-males because it is felt that they may have differences in texture and flavor making their meat suitable only for certain manufactured meat products such as sausages. Although the validity of this claim is not clear, in the absence of evidence to the contrary the grading system should continue to identify carcasses from mature males in order to direct them to their best niche in the meat system. These carcasses should simply be identified by an appropriate specifying symbol.

Specifying Symbols

The combination of physiological age and postgrading treatment of the carcass and meat will largely determine eating quality. However, a number of factors, which come under the general description of appearance, currently affect the marketability of carcasses and meat. These factors (color, texture, firmness) should only be recorded when they fall outside the range of normal acceptability. Smith (1980) referred to this type of grading as dichotomous. Thus, although there is a range of fat color which is acceptable, the position within this range that a particular carcass occupies need not be recorded. If the description falls outside this range, however, that fact should be specified by an appropriate symbol. The factors and cut-off points should be modified from time to time, to accomodate changes in taste and to progressively eliminate unfounded prejudice.

Summarizing the foregoing discussion leads to the conclusion that the future of meat carcass grading lies in developing an objectively based classification system. The first thing to be identified by the classifier being the genus followed by:

carcass size class, based on weight and genus;

the weight of lean meat in the carcass;

carcass fatness class, based on fat thickness and genus;

physiological age class based on skeletal and dental characteristics; and

a set of symbols specifying any abnormalities which might influence the most appropriate market channel for the carcass or meat.

Further information about the meat including recommended handling and cooking methods, should be the subject of labelling regulations, ensuring accurate statements of the anatomical location of the cut, the date of slaughter and all post-

slaughter treatments applied to the carcass. In practice, standard postslaughter treatments would be defined from time to time, and the label would only need to indicate deviations from this standard. The labelling information would be of the greatest benefit to consumers, ensuring repeatability of eating quality, while the grading information would be of the greatest benefit to people in the marketing chain from the producer to the retailer.

THE RESEARCH NEEDS

Before implementing the classification and labelling system outlined in the previous section a number of gaps in our present knowledge need to be closed.

Carcass Tissue Content

Innovative research is required to identify and test non-destructive methods of cheaply, quickly, safely and accurately measuring the quantity of each of the three tissues, bone, muscle and fat in a carcass. Simple measurements of carcass parameters, and their translation through prediction equations to give tissue content, are unlikely to prove sufficiently robust to serve the long-term interests of the meat industry. The ultimate method should be equally accurate on carcasses of any size or species and should work on the principle of simply detecting and measuring the amount of each tissue in the carcass. Because such techniques would also be useful in live animals and have profound implications to both veterinary and human medicine, a massive research effort to this end would be fully justified. It is possible that techniques already in use in the basic sciences could be adapted to this function. Concurrent research on all three tissues is justified, though ultimately the accurate measurement of one or two may be sufficient for yield-grading purposes.

Physiological Age and Eating Quality

It is widely accepted that meat from older animals can be distinguished from that of younger animals of the same species. Research is needed to identify, in each species, the relationships between physiological age and meat quality, and to define the factors which control them. On the basis of this research, objective definitions of age classes which can reasonably be expected to differ in intrinsic meat quality can be defined for each species.

Appearance and Eating Quality

Research should continue to be conducted to investigate the relationships between aspects of appearance such as marbling, color and texture, and the palatability of the meat in the carcass. On the basis of this research the grading system can be progressively modified to increase or decrease the emphasis on appearance factors. The search for accurate, objective methods for the grader to assess eating quality from appearance should continue, though present knowledge gives little hope of success. Only factors which can be measured should be considered.

Sexual Status and Eating Quality

With improved technology, particularly in terms of yield grading, the only reason for recording sexual status of a carcass would be if it affected eating quality. The relationships between sex and eating quality should therefore continue to be investigated especially in older animals.

Carcass Fat Distribution

Within each genus, the amounts of bone and muscle in the carcass are sufficient to indicate their distribution. The factors affecting the distribution of fat are not so clearly known or understood. Continued research is required to identify the factors which influence the distribution of carcass fat both within and between depots in all species.

Carcass grading affects people at all stages in the marketing chain. A great deal of meat marketing is shrouded in mystique and folklore, often giving credence to fac-

tors which are irrelevant. Grading systems need not be slaves to mysticism, but the system described in this paper could allow the survival of any aspect of carcass description if sufficient people in the system wanted it, provided it could be measured, or unerringly identified.

AGRICULTURAL RESEARCH COUNCIL. 1965. Recommended procedures for use in the measurement of beef cattle and carcasses. ARC, London.

BERG, R. T. and BUTTERFIELD, R. M. 1976. New concepts of cattle growth. University of Sydney Press, Sydney, Australia.

BERG, R. T., JONES, S. D. M., PRICE, M. A., FUKUHARA, R., BUTTERFIELD, R. M. and HARDIN, R. T. 1979. Patterns of carcass fat deposition in heifers, steers and bulls. Can. J. Anim. Sci. **59**: 359-366.

BLUMER, T. N. 1963. Relationship of marbling to the palatability of beef. J. Anim. Sci. **22**: 771-778.

BREIDENSTEIN, B. B., COOPER, C. C., CASSENS, R. G., EVANS, G. and BRAY, R. W. 1968. Influence of marbling and maturity on the palatability of beef muscle. I. Chemical and organoleptic considerations. J. Anim. Sci. **27**: 1532-1541.

BUCHTER, L. 1975. Slaughter of meat animals. Pages 133-148 *in* D. J. A. Cole and R. A. Lawrie, eds. Meat. AVI Publishing Co. Inc., Westport, Conn.

CROUSE, J. D., SMITH, G. M. and MANDIGO, R. W. 1978. Relationship of selected beef carcass traits with meat palatability. J. Food Sci. **43**: 152-157.

DUTSON, T. R., YATES, L. D., SMITH, G. C., CARPENTER, Z. L. and HOSTETLER, R. L. 1977. Rigor onset before chilling. Proc. Rec. Meats Conf. **30**: 79-86.

EVANS, D. G. and KEMPSTER, A. J. 1979. A comparison of different predictors of the lean content of pig carcasses. 2. Predictors for use in population studies and experiments. Anim. Prod. **28**: 97-108.

FAHEY, T. J., SCHAEFER, D. M., KAUFFMAN, R. G., EPLEY, R. J., GOULD, P. F., ROMANS, J. R., SMITH, G. C. and TOPEL, D. G. 1977. A comparison of practical methods to estimate pork carcass composition. J. Anim. Sci. **44**: 8-17.

FIELD, R. A. 1971. Effect of castration on meat quality and quantity. J. Anim. Sci. **32**: 849-858.

FREDEEN, H. T. and BOWMAN, G. H. 1968. Backfat thickness and carcass weight as predictors of the yield of hams and loins of pig carcasses. Can. J. Anim. Sci. **48**: 117-129.

GRAHAM, W. C. and PRICE, M. A. 1980. The relationship between age and dentition in cattle. 59th Annu. Feeders' Day Rep., Department of Animal Science, University of Alberta, Edmonton, Alta. pp. 46-48.

HAWRYSH, Z. J., PRICE, M. A. and BERG, R. T. 1980. The influence of roughage level in the finishing diet on the eating quality of beef from bulls and steers slaughtered at two liveweights. Can. Inst. Food Sci. Technol. J. **13**: 71-79.

HEDRICK, H. B. 1965. Influence of ante-mortem stress on meat palatability. J. Anim. Sci. **24**: 255-263.

JEREMIAH, L. E. 1978. A review of factors affecting meat quality. Agriculture Canada, Research Station, Lacombe, Alberta Technical Bull. 1.

JOHNSON, E. R., BUTTERFIELD, R. M. and PRYOR, W. J. 1972. Studies of fat distribution in the bovine carcass. I. The partition of fatty tissues between depots. Aust. J. Agric. Res. **23**: 381-388.

JONES, S. D. M., PRICE, M. A. and BERG, R. T. 1978. A review of carcass density, its measurement and relationship with bovine carcass fatness. J. Anim. Sci. **46**: 1151-1158.

JONES, S. D. M., PRICE, M. A. and BERG, R. T. 1978. Effects of breed and sex on the relative growth and distribution of bone in cattle. Can. J. Anim. Sci. **58**: 157-165.

JONES, S. D. M., RICHMOND, R. J., PRICE, M. A. and BERG, R. T. 1980a. Effects of breed and sex on the patterns of fat deposition and distribution in swine. Can. J. Anim. Sci. **60**: 223-230.

JONES, S. D. M., PRICE, M. A. and BERG, R. T. 1980b. Fattening patterns in cattle. 1. Fat partition among the depots. Can. J. Anim. Sci. **60**: 843-850.

JONES, S. D. M., PRICE, M. A. and BERG, R. T. 1980c. Fattening patterns in cattle. 2. Fat distribution among the wholesale cuts. Can. J. Anim. Sci. **60**: 851-856.

JONES, S. D. M., PRICE, M. A. and BERG, R. T. 1981. Accumulation of lipid in rib cuts from bull and heifer carcasses of two breeds. Can. J. Anim. Sci. **61**: 23-26.

KEMPSTER, A. J., AVIS, P. R. D., CUTHBERTSON, A. and HARRINGTON, G. 1976. Prediction of the lean content of lamb carcasses of different breed types. J. Agric. Sci. (Camb.) **86**: 23-34.

KEMPSTER, A. J. and EVANS, D. G. 1979. The effects of genotype, sex and feeding regimen on pig carcass development. 2. Tissue weight distribution and fat partition between depots. J. Agric. Sci. (Camb.). **93**: 349–358.

KEMPSTER, A. J. and HARRINGTON, G. 1980. The value of 'fat-corrected' conformation as an indicator of beef carcass composition within and between breeds. Livest. Prod. Sci. **7**: 361-372.

LAWRIE, R. A. 1974. Meat science. 2nd ed. Pergamon Press, Oxford.

LEANDER, R. C., HEDRICK, H. B., BROWN, M. F. and WHITE, J. A. 1977. Effect of heating on the ultrastructure of bovine muscle. Proc. Rec. Meats Conf. **30**: 99-111.

MARSH, B. B. 1975. Tenderness. Pages 339-357 *in* D. J. A. Cole and R. A. Lawrie, eds. Meat. AVI. Publishing Co. Inc., Westport, Conn.

MARSH, B. B. 1977. The basis of tenderness in muscle foods. J. Food Sci. **42**: 295-297.

McCOY, J. H. 1979. Livestock and meat marketing. 2nd ed. AVI. Publishing Co. Inc., Westport, Conn.

McDONALD, P., EDWARDS, R. A. and GREENHALGH, J. F. D. 1969. Animal nutrition. Oliver and Boyd, Edinburgh.

PARRISH, F. C., Jr. 1977. Skeletal muscle tissue disruption. Proc. Rec. Meats Conf. **30**: 87-98.

PARRISH, F. C., Jr., OLSON, D. G., MINER, B. E., YOUNG, R. G. and SNELL, R. L. 1973. Relationship of tenderness measurements made by the armour tenderometer to certain objective, subjective and organoleptic properties of bovine muscle. J. Food Sci. **38**: 1214-1218.

PARK, R. J. and THOMAS, P. L. 1973. Factors affecting sheep meat flavour. Wool Tech. Sheep Breed. **20**: 69-72.

PEARSON, A. M. 1966. Desirability of beef — its characteristics and their measurement. J. Anim. Sci. **25**: 843-854.

PRICE, M. A. 1971. Infertile bulls versus steers. IV. Meat quality. J. Agric. Sci. (Camb.) **77**: 325-329.

PRICE, M. A. and GRAHAM, W. C. 1980. Dental development and age in cattle. Can. J. Anim. Sci. (Abstr.) **60**: 1067.

PRICE, M. A. and TENNESSEN, T. 1981. Preslaughter management and dark-cutting in the carcasses of young bulls. Can. J. Anim. Sci. **61**: 205-208.

RHODES, D. N. 1969. The quality of meat from male and non-male animals. Pages 189-198 *in* D. N. Rhodes, ed. Meat production from entire male animals. J. & A. Churchill Ltd., London.

RICHMOND, R. J., JONES, S. D. M., PRICE, M. A. and BERG, R. T. 1979. Effects of breed and sex on the relative growth and distribution of bone in pigs. Can. J. Anim. Sci. **59**: 471-479.

SMITH, G. C. 1980. Grades for the future: what, why and how? Proc. Rec. Meats Conf. **33**: 89-99.

STOUFFER, J. R. 1977. Post mortem factors affecting tenderness — muscle restraint. Proc. Rec. Meats Conf. **30**: 75-78.

THOMPSON, J. M. and ATKINS, K. D. 1980. Use of carcase measurements to predict percentage carcase composition in crossbred lambs. Aust. J. Exp. Agric. Anim. Husb. **20**: 144-150.

WOOD, J. D., MOTTRAM, D. S. and BROWN, A. J. 1981. A note on the eating quality of pork from lean pigs. Anim. Prod. **32**: 117-120.

WOODHAMS, P. R. and TROWER, S. J. 1965. Palatability characteristics of rib steaks from Aberdeen Angus steers and bulls. N.Z. J. Agric. Res. **8**: 921.

YEATES, N. T. M. 1965. Modern aspects of animal production. Butterworths, London.