NON-NUTRITIONAL MEANS OF MANIPULATING MEAT QUALITY ON THE FARM

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Summary

Non-nutritional factors that can be used for manipulating meat quality at the farm level, are discussed. These include hygiene and disease control, age and weight of animal, genetic factors, sex, and physiological factors. Information is available indicating items farmers can control to alter carcass composition with particular reference to fat content. The factors considered, with the possible exception of cattle age, do not appear to exert a major influence on palatability relative to the known importance of post-mortem carcass treatment. The conclusion was reached that the most important factors discouraging the use of available techniques of manipulating meat quality on the farm are the lack of a simple and clear definition of the quality/qualities of carcasses/meat desired plus an economic incentive to produce such quality.

I. INTRODUCTION

Meat quality depends on several factors including bacterial and other surface and internal contamination; composition of the carcass - the fat, muscle and bone content and their ratio - when related to consumer requirements on any particular market; and the palatability of muscle and fat. The definition of quality changes from time to time as market requirements change.

To produce high quality meat on the farm, accurate market information is required on quality specifications for any particular market. Generally, farmers do not receive such information and in many if not most cases it has not been satisfactorily documented at any stage in the marketing chain. Thus it is difficult to decide in which direction to manipulate quality when the required quality has not been defined. Unless the marketing system provides the farmer with some financial incentive to produce meat of some desired quality, a discussion such as this one is entirely academic.

The contamination aspect of quality will receive brief mention in this paper. More attention will be given to carcass compositional aspects of quality assuming that the main market requirement is for minimal bone, maximal amounts of muscle and some acceptable level of fat which may vary widely between markets. The saleable product from beef carcasses is muscle with an acceptable level of fat, a combination often termed edible meat (Preston and Willis 1970). The on-farm contribution to palatability other than that from nutrition will be covered and the major factor known to influence palatability, namely post-mortem carcass treatment, is reviewed by another author. Comments are mainly limited to sheep and cattle. A selective rather than a complete review has been attempted.

II. HYGIENE AND DISEASE CONTROL

Using present methods of removing the skin, head, feet and viscera from the dressed carcass at a meat works, clean meat cannot be produced from dirty stock (Watt 1968). Little research is reported on developing better methods. Regulations in many countries require that before slaughter stock be clean and withdrawn from feed for a period. Protracted withdrawal may result in carcass losses from a variety of types of animal (Kirton 1973). Methods are required which will enable the production of clean carcasses when fuller animals are slaughtered so that the problem of clean carcass production falls outside the realm of farm management practices. Disease control programmes such as those for tuberculosis and

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brucellosis in cattle, and management to reduce salmonella, pleurisy and other infections and parasites such as cysticercosis may become increasingly important farm management practices in future.

III. AGE AND WEIGHT

Age and weight at slaughter are both factors a farmer can control according to market demands. Weight influences size of cuts and age affects tenderness, at least in cattle.

Carcass composition is closely related to carcass weight in several species (Barton and Kirton 1958) and similarly, joint composition is more closely related to empty body weight than to age or nutritional history (Tulloh 1963). Allometric growth coefficients relating body/carcass weight to muscle weight are less than 1 for bone, around 1 for muscle and greater than 1 for fat (Tulloh 1963; Fourie, Kirton and Jury 1970). Thus fat becomes an increasing proportion of heavier carcasses and the proportion of muscle and bone decreases with increasing carcass weight. Information reviewed by Preston and Willis (1970) showed that the percentage edible meat in cattle declines with increasing body/carcass weight in a given animal or breed while the percentage excess fat and the edible-meat-to-bone ratio increase.

Therefore, the quality of any carcass declines in terms of composition once the body/carcass weight has passed the size at which that animal has reached the maximum acceptable fat level for the particular market. However, whenever more fat is present, the desired amount can be achieved by trimming off excess fat. The final decision as to the weight at which an animal is no longer acceptable depends on the economics of the whole operation including the trimming of excess fat and in which it is sold. In mince, sausages and luncheon meats, excess fat can be sold at meat prices. Processors may also be prepared to accept increasing quantities of fat trim to achieve larger cuts for some specific high priced markets.

Age is of great importance where farmers have to fit animal requirements to seasonal feed supplies and wish, for management reasons not primarily related to meat quality, to avoid retaining them over periods of feed shortage. Age is frequently specified in grading and classification schemes with younger animals normally receiving higher prices per unit weight mainly because of anticipated greater tenderness. Knowledge of age and weight also indicates slow growing animals that tend to be less efficient feed converters. Selection for growth rate is one of the tools permitting a farmer to achieve animals of a desired weight and composition in shorter times. However, apart from that of Field et al. (1963) there is little evidence to date to suggest that, within a sheep breed, growth rate affects carcass composition or other aspects of quality (Botkin et al. 1971). Brumby, Walker and Gallagher (1962) and Cundiff et al. (1969, 1971) suggest that selection for growth rate in cattle would reduce carcass fat if slaughter weight were maintained unchanged.

In general, the evidence reviewed by Preston and Willis (1970) indicates that the tenderness of beef animals decreases with age. For sheep, research covering young and older lambs and yearlings provides no consistent evidence that tenderness decreases with age (Batcher et al. 1962; Weller, Galgan and Jacobson 1962; Paul, Torten and Spurluck 1964; Carpenter and King 1965; Woodhams, Kirton and Jury 1966; Smith et al. 1970a, b; Kirton 1970; Jeremiah, Smith and Carpenter 1971). More recently, Wenham et al. (1973) showed that provided carcasses are correctly treated after slaughter to avoid adverse effects of rapid chilling or early freezing on pre-rigor carcasses, there is little difference in tenderness of roasted meat from lambs, hoggets (yearling sheep) or ewes up to 9 years old with all being highly satisfactory. Less confidence is attached to the findings of Kirton (1970) and Kirton and Paterson (1972) who used smaller numbers of yearling and older sheep, had less carefully controlled pre-rigor conditions and used frying rather than
roasting as the method of cooking. They reported that the meat of older sheep was less tender than that of yearling sheep.

IV. GENETIC FACTORS

Obvious on-farm factors which allow manipulation of carcass and meat quality are choice of breed and breeding policy.

(a) Cattle

(i) Breed

The influence of cattle breed on carcass composition, edible meat yield, colour of lean, colour of fat and palatability has been reviewed by Preston and Willis (1970). In general the review indicates that traditional British breed beef animals (Hereford, Angus, Shorthorn) are fatter than the dairy breeds, particularly the Friesian, and also than animals of Brahman breeding. Cattle of Charolais breeding tend to be leanest particularly when breeds are compared at the same carcass weight. Few important breed differences have been shown except for the Charolais and its crosses which have a higher proportion of edible meat in the carcass (see also Everitt, Evans and Franks 1969) and the Brahman and its crosses may be slightly less palatable than other breeds. Hodgson (1970), Everitt (1970, 1972) and Hooven et al. (1970) have commented on the suitability of animals of dairy origin relative to traditional beef animals and found few differences due solely to origin of animals in carcass quality.

The Jersey provides a good example of the difficulty in getting a satisfactory definition of meat quality. Although this breed is commonly accepted as an inferior meat animal, in a limited number of trials the Jersey has been recorded as equal or superior to other breeds in the comparison in terms of palatability (Berg, Mendel and Church 1963; Cole et al. 1964; Hooven et al. 1970; Everitt 1972). Morgan and Everitt (1969) and Preston and Willis (1970) have indicated that with some exceptions the yellow Jersey fat is considered undesirable. As the yellow colour is due to carotene, a precursor of vitamin A, if properly handled the fat colour should be a marketing advantage instead of an inferior characteristic.

(ii) Genetic improvement

The review of Preston and Willis (1970) and recent results of Cundiff et al. (1969, 1971) and Mason, Vial and Thompson (1972) suggest that measures of fatness apart from perhaps marbling are moderately to highly heritable in beef cattle. As fatness, and in particular fat thickness over the "eye-muscle" (longissimus dorsi) gives an excellent indication of fat and meat in the carcass, selection for or against fatness should change carcass composition in the desired direction. Similarly, percent edible meat, percent lean and percent bone are moderately to highly heritable. Tenderness as measured by shear force appears highlyheritable whereas taste panel scores have low to zero heritability.

However, it seems unlikely to date that beef quality has been changed by selection, apart from in the direction of increased fatness, through emphasis on conformation especially in the British breeds. This is so because fat thickness and lean content are very difficult to estimate by eye in the live animal. Selection based on fat thickness measured ultrasonically (McReynolds and Arthaud 1970) may be the best method currently available on live cattle, the alternative being actual carcass measurements on a sample of progeny. Further research is required on other alternative methods of measuring fat thickness such as thermister probes (Brackelsberg, William and Walters 1967) and blood cholesterol as an index of fat (Sink et al. 1973).
(b) Sheep

(i) Breed

Research establishing breed and cross differences in carcass composition and measures of quality is relatively recent in sheep. Comparisons have been reported by Carpenter et al. (1964), Ray and Mandigo (1966), Seebeck (1966), Kirton, Hight and Duggan (1967), Cornell Researchers (1968), Cassard, Bailey and McNeal (1969), Fourie, Kirton and Jury (1970), Palmy et al. (1972), and Dickerson et al. (1972). Composition was not considered in all experiments on animals of similar body/carcass weight. These, plus unpublished Ruakura experiments, show that the Southdown and its crosses tend to be the fattest of the breeds studied at any carcass weight; a factor accounting for this breed's reputation for early maturity and also its blocky conformation (Kirton and Pickering 1967).

In this regard, the Southdown is the sheep breed equivalent to the British cattle breeds. At the leaner end of the scale are the Suffolk, Romney and Hampshire. Many more experiments are required before breed differences in carcass composition and their ranking order are clearly established.

The carcasses of finewool sheep (Rambouillet x Delaine, and Rambouillet x Reservation) have been reported as less tender than those from medium and coarse wool breeds (King and Bland 1960; Carpenter et al. 1964; Ray and Mandigo 1966), a finding requiring demonstration over other finewool breeds and crosses before it can be accepted as a general rule.

(ii) Genetic improvements

Heritability estimates for various carcass traits in sheep have been given by Pimmo (1967), Bowman, Marshall and Broadbent (1968), Smith, Kemp and Cundiff (1968), Smith et al. (1969), Botkin et al. (1969), Shelton and Carpenter (1970), Bradford and Spurlock (1972), Ray, Bell and Holland (1972), and Bowman and Hendy (1972). With the exception of the estimates of Smith et al. (1968), in general the heritability of joint weights (in some cases proportions), measurements of fatness, and eye-muscle area are moderate to high. This indicates that appropriate selection should result in improvements in carcass composition in any desired direction. Live animal methods such as the 7th rib probe (Bradford and Spurlock 1972, see for earlier references; Lax et al. 1973) do not appear to be useful methods for measuring fatness. Methods of measuring fatness in the live animal are needed to allow performance testing for this quality attribute; the alternative of progeny testing requires carcass-measuring facilities and may result in slower progress than performance testing.

Although King and Bland (1960), Broadbent and Bowman (1964), Woodhams, Kirton and Jury (1966) and Purchas et al. (1969) have found no differences in palatability between the progeny of different sires, Purchas et al. (1969) believe such differences exist and Shelton and Carpenter (1970) have reported a tenderness heritability of 21%, indicating the possibility of improvement through selection. Anon. (1972) reported that mean tenderness shear values did not differ between the progeny of 14 sires, but measurements of adhesion between muscle fibres did.

(c) Pigs

(i) Genetic improvement

The literature on genetic improvement in swine was reviewed by Freden (1958). As well as showing that heritabilities of carcass quality factors such as length, backfat thickness and muscle colour are moderate to high, experiments have demonstrated that selection based on these characteristics is effective. Selection for decreased backfat thickness measured by live probe (Gray et al. 1965) or for and against backfat thickness measured by metal rule and leatmometer (Hetzer and Harvey 1967) in three breeds have achieved realised heritabilities of 0.4-0.5 for this characteristic. Mean backfat thickness differed between high and low Duroc lines (Hetzer and Harvey 1967) by 2.6 cm after 10 generations of selection.
It was interesting to note that selection against fatness tended to improve the growth rates of Durocs but to slow it for Yorkshires (Hetzer and Miller 1972). Selection for carcass length based on measurement of sib carcasses achieved a realised heritability of 0.5 after 5 generations of selection (Duckworth and Holmes 1968). Muscle colour which can be an important defect in pigs has a heritability of 0.3-0.4 in the Danish Landrace (Jonsson, Jensen and Pedersen 1972) with values of 0.4-0.5 reported for the Landrace and 0.2-0.3 for the Large White in the U.K. (Pease and Smith 1965).

Of very great importance is the report by Fredeen (1958) and Jonsson (1963) that major improvements have taken place in backfat thickness and carcass length in Danish pigs on a nationwide basis. Some of this improvement is ascribed to successful selection. These results demonstrate the possibilities with other farm animals such as sheep and cattle.

(d) Changing muscle distribution

Butterfield (1963) showed a lack of breed difference in muscle distribution in cattle as diverse as the Angus, Hereford, 4/8 Brahman and unimproved Shorthorn indicating that selection in the "improved" breeds had not improved this distribution. Similarly, Fourie (1965) showed very little difference in muscle distribution between the blocky Southdown and leggy New Zealand Romney sheep. On the basis of such results it has been suggested that muscle distribution is functionally determined and is almost impossible to change. An alternative possibility is that breeders have been unable to recognise differences in muscle distribution using eye assessment of conformation as their selection criterion. If distribution could be recognised in the live animal then it would remain to be tested whether changes might be made through breeding. Two recent mouse experiments involving 7 (McLellan and Frahm 1973) and 17 (Stephenson, pers. comm.) generations of selection have provided evidence suggestive that changes in muscle distribution might be achieved. In addition Seebeck (1973) has reported the presence of breed and sire differences in muscle distribution in cattle and there is evidence that animals selected for draft purposes such as the Charolais have a superior distribution (Preston and Willis 1970). Such a possibility should not therefore be completely discounted. However, the desirability of altering muscle distribution is again another question. Advances in meat technology may make it possible to convert all of the carcass into high quality cuts in which case distribution is no longer of such great importance.

v. SEX

As farmers cannot yet control sex ratios, possible sex differences in meat quality are not as important as the decision whether or not to castrate male animals. Spaying females is not considered because this is not a practical procedure, is seldom practiced or widely advocated and does not produce advantages in meat quality (Everitt and Jury 1966).

The effects of castration of male sheep, cattle and pigs have been widely researched and frequently reviewed (Robertson 1966; Rhodes 1969; Preston and Willis 1970; Field 1971). In general, entire male animals grow faster, gain more efficiently, produce leaner carcasses and may be slightly tougher at older ages than similar aged castrates. No male off-flavour or odour has been demonstrated for beef and mutton although a distinctive odour can be detected from the hot cooked meat of many older male pigs.

Older rams were not investigated until recently. Kirton and Paterson (1972) showed that fried loin samples from older rams were markedly tougher than from yearling rams or yearling and older ewes. Bradford and Spurlock (1964) reported that yearling ram loins were tougher than those of wethers in one of two experiments. Wenham et al. (1973) found no difference in tenderness between the roasts from older rams and ewes. Although Batcher, Beant and Kunze (1969),
Anon. (1970a) and Wenham et al. (1973) have detected very slight differences in flavour or cooking odour between rams and wethers or ewes, neither these authors nor Rhodes (1969, p. 189) and Kirton and Paterson (1972) have reported any "taint" that might be considered objectionable by consumers.

VI; PHYSIOLOGICAL

Preston and Willis (1970), Purchas and Pearson (1970), and Hafs, Purchas and Pearson (1971) have reviewed the use of hormones for promoting growth and increasing meat production and Machlin (1972) has covered hormonal influences on fat deposition in the pig. The use of the synthetic sex hormones (diethylstilbestrol, hexoestrol) has been the most successful practical use of growth promoting substances in the meat industry (Preston and Willis 1970; Preston 1972), and in general results in leaner meat production. The use of diethylstilbestrol in implants and animal feedstuffs was banned in the U.S.A. in 1973 because of its detection at a level of parts per billion in the offal of treated animals. Alternative growth-promoting substances such as zeranol (Brown 1970; Sharp and Dyer 1971; Borger et al. 1973), which is a steroid-imitating chemical derived from the metabolites of a microorganism found on mouldy corn, are becoming available.

VII. DISCUSSION

Farmers cannot be expected to manipulate meat quality on the farm until those responsible for marketing can clearly define the cleanliness, composition and palatability components required by the main markets and the farmer is rewarded for his ability to meet these specifications. His main contribution is likely to be through ability to produce carcasses of a desired age, size and fat cover. Market specifications of the above type are generally not available for any of the main world markets. Until these are obtained and translated to the farmer through a carcass grading/classification system, little progress in improving quality on the farm can be expected. In this regard, research into grading/classification systems is needed to clearly specify the composition of the classified carcasses and to relate the specifications to market requirements.

Reports describing current systems and suggesting innovations (Doty and Pierce 1961; Charles 1964; Kemp and Barton 1966, 1969; Adam 1970; Barton 1970; Everitt and Evans 1970; Kirton and Jury 1970) and techniques of assessment (e.g. Cuthbertson, Harrington and Smith 1972) will hopefully lead to improved grading systems following the pattern of that recently introduced in Canada for beef (Anderson 1972). Such systems should allow for factors that consumer and market research (e.g. Naumann et al. 1961; Anon. 1970b; Carpenter, Lesser and Prescott 1972) show to be of importance.

Hygiene problems may be overcome by research into slaughtering methods. Effort in this direction is warranted. Disease research is particularly important on problems likely to involve regulatory prohibitions on imports in international trade. Much information on the influence of age and weight on carcass composition is available. The major problem at present is the extension of these results in a form which allows them to be related to the grading or classification system on an economic basis.

Although a picture of the comparative merits of different breeds is emerging, more research is required to clarify many of the details. Synthesising breeds of farm animal combining the advantages of several breeds (e.g., the Colbred sheep), has only recently been undertaken at a scientific level. Whether this approach is warranted to improve meat quality remains to be established. Part of the problem to date may have been the lack of definition of carcass/meat quality.

In contrast to the situation for pigs, there is little evidence to suggest that improvements in carcass/meat quality have occurred in cattle and sheep
through selection in any country on a national basis. Problems have included lack of definition of goals and measurement of the desired characteristics in live sheep and cattle to enable selection. Because of the difficulties and costs involved, the problems are too great for solution by individual breeders and must be handled through large-scale recording and breeding schemes as has been done so successfully in many dairy and pig industries throughout the world. Further research and much extension and organisation is needed to get the schemes that have been or are being initiated to operate effectively.

Despite the mass of evidence indicating the many advantages of entire male animals over castrates, farmers are still reluctant to run males because of marked trade prejudices against their carcasses in Anglo-Saxon countries except for manufacturing purposes.' In addition, there are some management problems of maintaining control over breeding policies where surplus male animals are run on properties with receptive females. Behavioural problems with bulls may be a problem (Rhodes 1969, comment p-179). Methods of partial castration and induced cryptorchidism, where effective, presumably eliminate problems of controlled breeding.

Research on growth promoting substances, although of considerable interest, may remain of questionable application until a rational rather than emotional system of standards governing their use is developed, preferably on an international basis.

Finally, unless scientists with applied results make some effort to get these into the hands of decision makers and the appropriate extension channels, as well as publishing them in research journals, the time lag between the completion of the experiment and the application of the results at farm and industry level to improve meat quality will remain as great as at present.

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IX. REFERENCES