# GENETICS OF MEAT QUALITY IN CATTLE

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## SUMMARY

Meat quality was defined to include only visual and eating quality traits of beef. Visual quality traits included in the discussion were intramuscular fat content (marbling), lean colour, fat colour, and muscle texture. Eating quality traits considered were tenderness, juiciness and flavour. Marbling score varies significantly among breeds and was moderately to highly heritable. Lean colour differences were partly associated with differences in percentages of muscle fiber types. Heritability of lean colour was moderate. Muscle texture breed differences and within breed variation reported in the literature were significant but to small to be of practical importance. *Bos indicus* breeds were least tender and more variable in tenderness scores. Double-muscled breeds tended to be most tender. Heritability estimates for tenderness were quite variable but tend towards being less than 0.3. Tenderness score is a complex trait that is largely influenced by non-genetic factors. Estimates of genetic effects on flavour and juiciness were inconsistent but indicated potential breed differences. Interest in genetic improvement of meat quality traits has increased in the last few years because of consumer demands for a tender, lean, consistent and high quality product. However, little research has been conducted on the economic value of meat quality traits from a selection point of view and many of the genetic and phenotypic parameters among meat quality, carcass composition and production are either unestimated or poorly estimated. Potential negative consequences of selection for meat quality traits need to be carefully considered before being included in breed improvement programs. Further characterization of breeds for meat quality and other important traits as well as monitoring of meat quality traits in current breed improvement programs is recommended.

## INTRODUCTION

Meat quality and the genetic aspects associated with it continue to be of interest to scientists and industry alike. Evidence for this statement can be found by examining recent literature and conference programs. In general the research focus has become more "basic" in nature as scientists attempt to understand the biochemical and molecular basis of observed differences in meat quality both among and within breeds. However the beef industry is struggling with the need to meet changing consumer demands and perceptions, regarding beef quality. This paper will build on two recent publications by Renand (1988) and Dikeman (1990) and therefore will not present numerous references on breed differences and genetic parameters for meat quality in cattle. The objectives of this paper are to (1) review pertinent literature from approximately the last 5 years, and (2) discuss the need for genetic improvement of meat quality in cattle.

## DISCUSSION

As discussed by many authors, the defintion of meat quality can be quite different depending on one's perspective. For the purposes of this paper, the defintion proposed by Dikeman (1990) will be used. This definition of meat quality includes four major areas; visual quality, eating quality, nutritional quality and safety. Each major area is also sub-divided into intrinsic traits and extrinsic factors. The discussion will focus primarily on the intrinsic traits of visual quality and eating quality. Specific visual quality traits that will be discussed include intramuscular fat (marbling), lean colour, fat colour, and muscle texture. Eating quality traits of interest are tenderness, juiciness and flavour.

**Review of Recent Literature**

Visual quality traits, with the exception of marbling, have not received much emphasis in research examining genetic variation. It is generally accepted that genetic variation among breeds for marbling is large. Renand (1988) in a study involving literature results computed a 15% range in intramuscular lipid content in a wide variety of *Bos taurus* breeds. Cundiff (1987) reported a difference of 5.1 genetic standard deviations between means for the most highly marbled (Jersey) and least marbled (Chianina) breeds from a series of studies by Koch et al. (1976, 1979 and 1982b) that included both *Bos indicus* and *Bos taurus* breeds. Crouse et al. (1989) reported a decrease in marbling score as the percentage of *Bos Indicus* inheritance increased. More recently Lunt et al. (1993) reported that American Wagyu steers had significantly more marbling than Angus steers at the same carcass maturity score. Substantial variation within breeds has also been reported for marbling. Cundiff (1987) estimated that variation within breed was essentially equal to variation among breeds for marbling score and reported an average literature heritability estimate of 0.38. Koch et al. (1982a) reported a large range in heritability values of 0.17 to 0.73, that averaged 0.42. Van Vleck et al. (1992) estimated a marbling score heritability of 0.45 from a small data set representing a large range in breed types. Renand (1988) computed a mean heritability estimate of 0.26 for intramuscular lipid content from three reported studies. It seems that the heritability of marbling score will settle around 0.40 but further investigations are needed to examine the variation in actual intramuscular lipid content.

Genetic differences among and within breeds for lean colour have been reported. Lean colour is inversely related to muscular development potential and the percent of white muscle fibers (Monin, 1991). Muscle myoglobin content was lower and light reflectance higher for Limousin, Charolais, Romangola and Blonde d'Aquitane compared to Simmental, White Cattle, Hereford and Chianina crossbreds (Liboriussen et al., 1977). Homozygous double-muscled cattle were reported to have significantly lighter colour scores than heterozygous double-muscled cattle (Bouton et al., 1982). Tatum et al. (1990) reported that Piedmontese bulls had a significantly larger percentage of white muscle fibers compared to Gelbvieh and Red Angus bulls. Similar results were reported for homozygous double-muscled versus heterozygous double-muscled or normal cattle (Ashmore et al., 1972 and West, 1974). Shackelford et al. (1994) and Crouse et al. (1989) reported significant differences in lean colour score for a wide range of breeds but the range in colour score was only 1.03 units on a seven point scale and 0.54 units on an eight point scale, respectively. Lean colour score heritability of 0.12 was reported by Shackelford et al. (1994). Dikeman (1990) reported a range in heritabilities of 0.24 to 0.80 for muscle myoglobin concentration and Renand (1988) computed a mean heritability of 0.26 for colour measured as reflectance value. More recently, Renand et al. (1992) reported preliminary results from an experiment involving divergent selection of Charolais bulls for an index of final weight and residual feed efficiency following a postweaning growth test. The only meat quality trait that approached a significant difference was heme iron content, indicating a possible reduction in meat colour intensity for progeny of high indexing bulls. Lean colour score differences between breed seem to be at least partially related to differences in percentage of muscle fiber types. Reported heritability values indicate that additive genetic variation exists for lean colour.

Fat colour differences have been reported between dairy and beef breeds even when fed similar diets and compared at similar ages (Dikeman, 1990 and Walker et al., 1990). Lunt et al. (1993) reported no significant differences in fat colour, luster or quality between Angus and American Wagyu breeds. Oikawa and Kyan (1986), as referenced by Dikeman (1990) reported a heritability of 0.16 for fat colour. Fat colour is greatly affected by non-genetic factors such as age and diet and is not a very important trait on a genetic basis (Dikeman, 1990).

Muscle texture as described by Dikeman (1990) is a complex trait affected by marbling content, connective tissue content, muscle fiber and bundle size and muscle fiber type. Significant breed differences in lean firmness and texture scores were reported by Shackelford et al. (1994) and in lean firmness score by Crouse et al. (1989) for a wide variety of breeds including both *Bos indicus,* and *Bos taurus* breeds. Breed differences though significant were relatively small and probably of little economic importance. American Wagyu steers had firmer muscle of a finer, more desirable texture than Angus steers when scored on Japanese beef quality grade factors (Lunt et al., 1993). Lean texture and firmness score heritability estimates of 0.14 and 0.30, respectively were reported by Shackelford et al. (1994). The importance of lean texture and firmness on an across and within breed basis has not been investigated sufficiently to make any useful conclusions regarding genetic effects.

Eating quality traits (tenderness, juiciness and flavour) have received much more attention than visual quality traits. It is generally accepted that breed differences in tenderness are real and that double-muscled breeds appear to be the most tender followed by the rest of the *Bos taurus* breeds and finally the *Bos indicus* breeds (Dikeman, 1990). Crouse et al. (1989) demonstrated that sensory panel scores for tenderness decreased and shear values increased as the percentage of Brahman inheritance increased. As well, variation in tenderness within breed increased as the percentage of Brahman and Sahiwal inheritance increased. The marked difference in meat tenderness and shear force of *Bos indicus* breeds has led to several studies examining the biochemical basis for this difference. A general conclusion seems to be that a calcium dependant proteolytic enzyme system plays a role in determination of breed differences in tenderness (Johnson et al., 1990a; Johnson et al., 1990b; Wheeler et al., 1990 and Whipple et al., 1990). Shackelford et al. (1992) estimated the heritability of postrigor calpastatin activity to be 0.70 in a small data set representing diverse breed types. Tenderness score, as evaluated by sensory panels has a wide range in heritability estimates. Dikeman (1990) reported a range of 0.09 to 0.70 from a variety of sources. Renand (1988) computed heritabilities of 0.26 for tenderness score and 0.33 for shear force value from three and eight studies, respectively. Van Vleck et al. (1992) estimated heritabilities for tenderness score and shear force to be 0.10 and 0.09, respectively. Tenderness score is a composite trait made up of several contributing factors, some of which may be at least under partial gentic control. Further complications arise when factors associated with pre- and post-slaughter management of animals and carcasses enter the picture, for example tenderness is greatly affected by chilling regime in the abbatoir (Wood et al., 1990).

Evidence of genetic effects on flavour are varied and small compared to the effect of non-genetic factors (Dikeman, 1990). Koch et al. (1982b), Crouse et al. (1989) and Van Vleck et al. (1992) all reported essentially no significant differences of any economic importance among breeds for flavour intensity scored by sensory panel evaluation. Liboriussen et al. (1977) reported significant differences among breeds for semitendinosis muscle but not longissimus muscle. Tatum et al. (1990) found no difference between longissimus muscle flavour intensity for Red Angus and Piedmontese bulls but less intense flavour for Gelbvieh bulls. The difference in breed means was only 0.4 units on an 8 unit scale implying essentially no practical difference. Dikeman (1990) reported literature estimates of heritability for flavour intensity ranging from 0.26 to 0.43. Van Vleck et al. (1992) estimated a heritability of 0.03 for flavour score, which was not significantly different from zero. The evidence for genetic effects on flavour are presently inconsistent and inconclusive.

Juiciness score of meat is related to ultimate pH, water holding capacity and intramuscular fat content. Koch et al. (1982b) reported that Hereford-Angus and Pinzgauer steaks were ranked significantly higher than other breeds and Brahman and Sahiwal had the lowest juiciness scores. These authors also noted that actual differences in score values were quite small. Crouse et al. (1989) found no difference in juiciness among Hereford, Angus, Pinzgauer, Brahman and Sahiwal purebreds and crosses. Similar results were reported by Tatum et al. (1990) for Piedmontese, Gelbvieh and Red Angus bulls. Van Vleck et al. (1992) estimated a heritability value of 0.14 for juiciness and significant breed effects using similar data as Koch et al. (1982b) and Crouse et al. (1989). Renand (1988) computed mean heritabilities from reported studies for ultimate pH and water loss of 0.26 and 0.24, respectively. There is little evidence of significant genetic effects on juiciness score except for a small number of breed differences.

Estimates of genetic covariances among various meat quality traits and among meat quality traits with performance or carcass traits are scarce. Koch et al. (1982a) reported genetic correlations of marbling score with preweaning growth rate, postweaning growth rate and retail product weight of 0.32, 0.15 and -0.02, respectively. These authors also reported genetic correlations for shear force value with the same three traits of -0.05, 0.06 and -0.07, respectively. Mean genetic correlations, based on within breed analyses for shear force, tenderness score and intramuscular lipid content with growth rate were 0.34, -0.31 and -0.91, respectively and with carcass fatness were -0.13, 0.26 and 0.74, respectively (Renand, 1988). Lean colour, ultimate pH and water loss mean genetic correlations with growth rate and carcass fatness were 0.20, 0.10, 0.13 and -0.15, -0.23, -0.16, respectively (Renand, 1988). As noted by Renand (1988) caution must be used in interpreting these results because of inconsistencies with other reported values. For example, a slightly negative correlation between tenderness and growth rate was in contrast to other estimates based on across breed analyses. Van Vleck et al. (1992) reported strong positive genetic correlations ranging from 0.60 to 0.95 among flavour, juiciness, tenderness and marbling and favourable genetic correlations for shear force with flavour, juiciness, tenderness and marbling of -0.82, -0.95, -0.96 and -0.53, respectively. These estimates must be viewed with caution because the approximate standard errors ranged from 0.12 to 0.94. Genetic correlations for lean colour with lean texture and firmness were 0.60 and 0.19, respectively and between lean texture and firmness was .52 as reported by Shackelford et al. (1994). A favourable genetic correlation of 0.58 between calpastatin activity and shear force was reported by Shackelford et al. (1992). These authors also reported favourable but insignificant genetic correlations of -0.48 and -0.20 for calpastatin activity with average daily gain and retail product weight, respectively and for shear force with average daily gain (-0.44) and retail product weight (-0.08). In general, genetic correlations associated with meat quality traits must be viewed with caution because of large standard errors and inconsistent results.

**The Need for Genetic Improvement of Meat Quality**

Perhaps the most appropriate way to begin this section is by referencing a few statements from the organiser of the session on genetics of meat quality at the Fourth World Congress on Genetics Applied to Livestock Production. Lundstrom (1990) noted that it was still an open question whether the cost of selection for higher meat quality was justified and that the most important question for the future was what emphasis should be put on meat quality in selection. In the last four years, progress has been made on these two questions in the pork industry (Hovenier et al., 1993) but evidence of progress in the beef industry is marginal at best. Carcass quality or composition and growth traits still dominate genetic improvement research interests and most industry programs, respectively. The United States beef industry has conducted surveys that documented wide variation in beef composition and palatability traits at the retail level and that consumers consider retail cuts with external fat wasteful, low in taste, and unhealthy (Morgan et al., 1991; Savell et al., 1989 and Savell et al., 1991). Most recently a U.S. National Beef Quality Audit was performed with the purpose of determining whether beef had changed significantly during the 17 years since the last study and to serve as a benchmark as to where the beef industry was in reference to what was being produced (Lorenzen et al., 1993). The authors concluded this report by noting that there had been great opportunity for significantly increased lean production and reduction of total fat. However, over the last 17 years slaughter weights had increased with approximately the same degree of subcutaneous fat, less marbling and fewer high quality grade carcasses (Lorenzen et al., 1993). Clearly a problem exists with the quality of meat being offered to the consumer, at least in the United States and probably in many other countries as well. From an economic point of view, poor quality or variable quality meat has a significant negative impact on the beef industry. Consumer driven, consistent and quality products seem to be the order of the day. One question the industry and especially the genetic segment of the industry has to struggle with is what portion of the problem has an economically important genetic basis and what, if anything can or should be done genetically to improve the product. The obvious answer is everything should be done. But what is feasible, practical and economically justifiable remains a question. This brings the discussion right back to the opening sentences of this section and the remarks of Lundstrom (1990).

There is general agreement among almost all industry players that non-genetic effects play the major role in determining meat quality. However, if there is sufficient economic incentive for genetic improvement in meat quality then it should be included in the breeding goals of appropriate industry segments. Do we know how economically important meat quality traits are from an objective perspective. I believe not, at least a recent literature search did not reveal a substantial number of papers on the subject. A lack of clear direction on what traits are economically important has lead to a vast and inconsistent array of subjective and objective measures of meat quality traits. Large amounts of evidence have been presented at various times regarding breed differences in meat quality traits and measures. Unfortunately, many of the results are confusing and inconsistent except for a few traits (eg. tenderness of *Bos indicus* cattle). Characterization of the breeds for meat quality and other important traits needs to be completed. Monitoring change in meat quality traits as part of current breed improvement programs provides an excellent means for collection of important information. Genetic parameters, except for a small number of heritability estimates, are rather poorly estimated, if at all for meat quality traits. There is a paucity of estimates of genetic and phenotypic relationships among meat quality, carcass quality and production traits (Koots, pers. comm.) As noted by Renand (1988) inconsistent results regarding relationships among traits depending on whether the basis of comparison was across or within breed creates confusion in interpretation of existing results. Most recently, the perceived need for genetic improvement in tenderness through marbling has lead to an amazing focus on objectively measuring marbling and its incorporation in genetic improvement programs of many diverse breeds. Are we sure that current tenderness genetic levels and variation contribute to a problem with tenderness of the product? Even if the answer is yes, is marbling the criterion that should be used for measuring and evaluating genetic value for tenderness? Should all breeds or even a majority of breeds be trying to select for increased marbling and thereby tenderness? Cundiff (1987) estimated that it would take approximately eight generations (40 years) to change marbling levels from the current level observed in the Chianina to that observed in the Angus from selection for marbling alone. Surely single trait selection for marbling would not practiced by any breed because as further noted by Cundiff (1987) one correlated result would be the loss of most of the advantage the Chianina has over the Angus in cutability. Effective and efficient genetic improvement programs in the beef industry need to utilize breed differences, within breed variation, and specialized sire and dam lines (Smith, 1964) to produce genetic packages that match the diverse production environments and market requirements of the worldwide industries. It is time to pause and critically examine the need and methods for genetic improvement of meat quality traits in cattle.

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