Is Tenderness Nutritionally Controlled?

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Introduction

The premise that preslaughter nutrition influences meat tenderness is not of contemporary origin. Early animal production scientists (Armsby, 1917; Bull, 1916; Henry and Morrison, 1916) shared the belief that animals fed intensively on high-energy fattening rations produced meat cuts with superior tenderness. This belief, which has been perpetuated through several decades, gained extensive acceptance; however, subsequent investigation of the relationship between preslaughter feeding and meat tenderness has produced equivocal results. The purpose of this review is to explicate existing evidence and answer the question posed for discussion—*Is tenderness nutritionally controlled?*

Early Theory

Early attempts to elucidate the mechanism by which tenderness was enhanced via preslaughter feeding followed a syllogistic approach. Intensively fed animals were observed to have more extensively marbled lean than animals slaughtered directly off of pasture. Furthermore, "fed" animals were observed to produce more tender cuts of meat. Therefore, it was assumed (using what appeared to be sound logic) that intensive feeding enhanced marbling and marbling, in turn, enhanced tenderness. The development of this rationale is quite evident in a quote from Bull (1916) who discussed the purpose of feeding and fattening animals prior to slaughter—"The main object in fattening is to improve the flavor, tenderness and quality of lean meat by the deposition of fat between the muscle fibers."

In deference to the deductive reasoning that led to the foregoing conclusion, it is important to recognize that early theories regarding the relationship between marbling and meat tenderness were based only on practical observation and were not supported with experimental evidence. Subsequent research has not supported the marbling-tenderness hypothesis. To date, research has established only a low to moderate relationship between marbling and meat tenderness (Blumer, 1963; Campion et al., 1975; Carpenter, 1974; Jeremiah et al., 1970; Parrish, 1974; Pearson, 1966; Tatum et al., 1980). Furthermore, results of several studies (Adams et al., 1977; Campion et al., 1975; Dolezal, 1980; Tatum et al., 1980) indicate that meat from animals fed similarly differs little in tenderness despite rather large differences in intramuscular fat content.

Perhaps the most conclusive evidence regarding the influence of marbling on the relationship between preslaughter nutritional regimen and meat tenderness was reported by Bowling et al. (1977). Their experiment compared forage-finished and grain-finished beef carcasses which were selected to have equivalent marbling and maturity scores. In that study, grain-finished beef was superior in tenderness to forage-finished beef despite the lack of variation in marbling. Certainly, these data demonstrate that improved tenderness associated with intensive preslaughter feeding has little dependence upon intramuscular fat deposition.

In light of the foregoing findings, one must question the veracity of the beliefs of early scientists implicating marbling as the major factor associated with differences in meat tenderness caused by differences in preslaughter nutrition. Also subject to question is the degree to which these concepts have been accepted and implemented in livestock and meat production/marketing systems, in spite of a dearth of supporting experimental data. In retrospect, perhaps meat scientists should have been more attentive to an observation offered by Cover et al. (1956) in a study conducted one quarter of a century ago to examine the marbling-tenderness relationship—"It is disconcerting that something which has appeared so obvious to so many for so long should be so extraordinarily difficult to prove in the laboratory."

Contemporary Rationale

The scope of our understanding of the factors that influence meat tenderness has increased tremendously during the past two decades. Key studies such as those by Locker (1960), Locker and Hagyard (1963), Marsh and Leet (1966) and Marsh et al. (1968) have provided the basis for greater understanding of the mechanism by which numerous antemortem and postmortem factors contribute to meat tenderness. For many years it was believed that the connective tissue component of muscle was the primary intrinsic determinant of tenderness; however, the previously cited studies have demonstrated that the tenderness of meat, particularly that from youthful animals, is largely dependent upon the contractile state of muscle during the onset of rigor mortis. Furthermore, it has become apparent that the contractile state and subsequent tenderness of postmortem muscle is dependent, to a large extent, upon the cooling rate of carcass tissue during the first few hours postmortem.

According to Marsh et al. (1968), the cooling rate of a muscle is determined not only by ambient temperature, humidity and air velocity, but also by the size of the cooling body and the thickness of tissue covering the muscle being considered. In a similar connection, Wenham et al. (1973) studied the

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Reciprocal Meat Conference Proceedings, Volume 34, 1981

temperature-tenderness relationship using mutton and lamb carcasses, and postulated that larger, heavier carcasses produce more tender meat cuts because they chill more slowly and, as a result, are less susceptible to cold-induced toughening. Furthermore, Marsh and Leet (1966) indicated that a slightly greater thickness of fat, the proximity of a bone or the protective shielding of a muscle from cold, moving air may provide sufficient insulation to alter the rate of cooling and decrease the extent of cold-induced myofibrillar shortening and toughening.

Using these studies as bases, Smith et al. (1976) investigated the relationship between fatness, rate of chilling and tenderness of lamb. Resulting data supported the hypothesis that increased weight and fatness improves tenderness via changes in postmortem chilling rate. From the results of that experiment the authors developed the rationale that the insulatory effect of increased quantities of fat reduces the rate of carcass temperature decline during postmortem chilling and improves tenderness by lessening the extent of cold-induced toughening and by enhancing the rate and extent of postmortem muscle autolysis.

With cognizance of existing information regarding the effect of chilling rate on meat tenderness, it is important to notice that intensive feeding of animals generally increases both weight and fatness of the carcasses they produce (Black et al., 1931; Bowling et al., 1977; Bowling et al., 1978; Burson et al., 1980; Kropf et al., 1975; Schroeder et al., 1980; Schupp et al., 1979; Schinn et al., 1976; Wanderstock and Miller, 1948). Bowling et al. (1977) investigated the effects of preslaughter nutritional regimen (forage *vs* grain) on beef carcass traits and cooked beef palatability. In that study, cattle finished on grain produced the heaviest, fattest, most massive carcasses and the most tender steaks. In addition, grain-finished beef sustained less myofibrillar shortening during postmortem chilling (28.4% *vs* 17.2% sarcomere shortening for forage-finished and grain-finished beef, respectively). The authors attributed these differences in myofibrillar shortening and toughening to differences in postmortem temperature decline, resulting from differences in carcass weight and fatness, and demonstrated reduced sarcomere shortening and improved tenderness among the leaner, lighter forage-finished carcasses by exposing one side of each carcass to a higher temperature (27°) during the first few hours postmortem. Subsequent research (Schroeder, 1978) has documented the existence of relationships among preslaughter feeding regimen, rate of postmortem temperature decline and meat tenderness.

Based on these data, it would appear that intensive preslaughter feeding exerts an indirect influence on meat tenderness via its effects on carcass weight, fatness and postmortem chilling rate. If that is the case, then meat produced by animals fed widely divergent preslaughter diets and slaughtered at a constant weight or at similar levels of fatness should be relatively uniform in tenderness.

Oltjen et al. (1971) evaluated palatability traits of beef from forage-fed *vs* grain-fed steers slaughtered at similar weights; forage-fed beef was superior in tenderness to grain-fed beef. In an experiment conducted at Colorado State University (unpublished data), steers fed forage, corn silage or grain were slaughtered at a constant weight, resulting in substantial differences in subcutaneous fat thickness and degree of marbling. However, differences in tenderness were not of sufficient magnitude for statistical significance. In a similar study, conducted by Young et al. (1978), steers were fed various diets (grain, corn silage or haylage-corn silage) and slaughtered at similar levels of subcutaneous fat. Differences in tenderness, although consistent enough for statistical significance, were deemed inconsequential from a practical standpoint. The authors concluded that, when animals are fed to similar levels of fatness, meat tenderness is comparable whether the preslaughter diet consists of grain or forage.

Based on existing evidence, it may be concluded with relative certainty that at least a part of the variation in meat tenderness, associated with differences in preslaughter feeding, can be attributed to the effect of feeding regimen on carcass weight and/or fatness, and the subsequent effects of these factors on carcass temperature during the first few hours postmortem. Subcutaneous fat thickness of 7.6 to 12.7 mm (Bowling et al., 1977; Bowling et al., 1978; Dolezal, 1980; Merkel and Pearson, 1975) and carcass weights in excess of 227 kg (Schupp et al., 1979) appear to provide maximal protection against rapid postmortem chilling and cold-induced toughening.

Recently, evidence has been reported which indicates that preslaughter feeding may directly influence various intrinsic properties of postmortem muscle. Aberle et al. (1981) demonstrated relationships between preslaughter feeding regimen, growth rate of cattle and tenderness of cooked beef and suggested that growth rate exerts a direct effect on connective tissue stability and endogenous proteolytic enzyme activity in postmortem muscle. According to Aberle et al. (1981) animals fed high energy diets prior to slaughter exhibit rapid rates of growth and, therefore, would be expected to experience rapid rates of protein degradation and synthesis. The rate of protein turnover is believed to be related to both collagen solubility and myofibril fragmentation of muscle tissue.

There is a limited amount of data to support a relationship between preslaughter feeding and the solubility of collagen in postmortem muscle. Wu et al. (1980) reported that beef from steers fed a high concentrate ration for 120 days prior to slaughter contained a higher percentage of soluble collagen than did beef from steers slaughtered directly off of pasture. Similar findings were reported by Aberle et al. (1981).

In a similar connection, it is of interest to note that intensive preslaughter feeding appears to counter the adverse effect of animal age on meat tenderness. Hawrysh et al. (1975) compared beef from cows (3.5 years of age) fed concentrates for 205 days to beef from grain-finished steers; maturity had no effect on tenderness. In another experiment, Clayton et al. (1981) investigated the effect of carcass maturity (youthful *vs* mature) and preslaughter feeding regimen (fed *vs* non-fed) on beef palatability. Results of the latter study showed a significant maturity by feeding regimen interaction. When cattle were finished on a high-energy diet, beef from youthful and mature animals was similar in tenderness. However, when maturity comparisons were restricted to beef from non-fed cattle, the detrimental effects of maturity on tenderness (as measured by Warner-Bratzler shear force) were evident.

Although there is some indication that preslaughter nutrition directly affects connective tissue and myofibrillar properties in postmortem muscle, a paucity of conclusive evi-

dence precludes elucidation of the basic mechanisms involved. Undoubtedly, accumulation of additional data will facilitate more detailed understanding of the exact mechanisms by which preslaughter feeding influences meat tenderness.

Conclusion

There is a substantial amount of evidence which suggests that preslaughter nutrition has a pronounced effect on meat tenderness. Although there is some indication that preslaughter nutrition directly influences various intrinsic properties of postmortem muscle, the bulk of existing data suggests that intensive feeding improves tenderness by increasing carcass weight and fatness and, thereby reducing the susceptibility of the carcass to rapid postmortem chilling and cold-induced toughening.

Considering currently depressed economic conditions, changes in consumer desires, escalating costs of production and finite supplies of energy, it is doubtful that we will continue to adhere to present production practices. It is unlikely that we will continue to manufacture expensive insulation—in the form of fat—to counter the rapid chill methods currently employed by the slaughter industry. It appears inevitable that we will shorten preslaughter finishing periods, produce leaner carcasses and rely on technology, rather than intensive preslaughter feeding, to ensure the production of tender cuts of meat.

References

Aberle, E. D., E. S. Reeves, M. D. Judge, R. E. Hunsley, T. W. Perry. 1981. Palatability and muscle characteristics of cattle with controlled weight gain: Time on a high energy diet. J. Ani. Sci. 52:757.

Adams, N. J., G. C. Smith and Z. L. Carpenter. 1977. Carcass and palatability characteristics of Hereford and cross-bred steers. J. Ani. Sci. 46:438.

Armsby, H. P. 1917. Nutrition of Farm Animals. The Macmillan Company, New York.

Black, W. H., K. F. Warner and C. V. Wilson. 1931. Beef production and quality as affected by grade of steer and feeding grain supplement on grass. USDA Tech. Bull. 217.

Blumer, T. N. 1963. Relationship of marbling to the palatability of beef. J. Ani. Sci. 22:771.

Bowling, R. A., J. K. Riggs, G. C. Smith, Z. L. Carpenter, R. L. Reddish, and O. D. Butler. 1978. Production, carcass and palatability characteristics of steers produced by different management systems. J. Ani. Sci. 46:333.

Bowling, R. A., G. C. Smith, Z. L. Carpenter, T. R. Dutson, and W. M. Oliver. 1977. Comparison of forage-finished and grain-finished beef carcasses. J. Ani. Sci 45:209.

Bull, S. 1916. The Principles of Feeding Farm Animals. The Macmillan Company, New York.

Burson, D. E., M. C. Hunt, D. M. Allen, C. L. Kastner, and D. H. Kropf. 1980. Diet energy density and time on feed effects on beef *longissimus* muscle palatability. J. Ani. Sci. 51:875.

Campion, D. R., J. D. Crouse and M. E. Dikeman. 1975. Predictive value of USDA beef quality grade factors for cooked meat palatability. J. Food Sci. 40:1225.

Carpenter, Z. L. 1974. Beef quality grade standards—need for modifications? Proc. Recip. Meat Conf. 27:122.

Clayton, R. P., J. D. Tatum and R. A. Bowling. 1981. Effects of carcass maturity and feeding regimen on palatability traits of beef. J. Ani. Sci. (submitted for publication).

Cover, Sylvia, O. D. Butler and T. C. Cartwright. 1956. The relationship of fatness in yearling steers to juiciness and tenderness of broiled and braised steaks. J. Ani. Sci. 15:464.

Dolezal, H. G. Jr. 1980. Beef palatability as influenced by live animal characteristics, time-on-feed and carcass traits. M.S. Thesis. Texas A&M University, College Station, Texas.

Hawrysh, Zenia J., R. T. Berg and A. D. Howes. 1975. Eating quality of mature, marbled beef. Can. Inst. Food Sci. Technol. J. 8:30.

Henry, W. A. and F. B. Morrison. 1916. Feeds and Feeding. Henry-Morrison Publ. Co., Madison.

Jeremiah, L. E., Z. L. Carpenter, G. C. Smith, and O. D. Butler. 1970. Beef quality. I. Marbling as an indicator of palatability. Texas Agri. Exp. Sta., Departmental Technical Report No. 22. Department of Animal Science, Texas A&M University, College Station.

Kropf, D. H., D. M. Allen and G. J. Thouvenelle. 1975. Short-fed, grass-fed and long-fed beef compared. Kansas Agr. Exp. Sta. Rep. 230.

Locker, R. H. 1960. Degree of muscular contraction as a factor in tenderness of beef. J. Food Sci. 25:304.

Locker, R. H. and C. J. Hagyard. 1963. A cold shortening effect in beef muscles. J. Sci. Food Agr. 14:787.

Marsh, B. B. and N. G. Leet. 1966. Studies in Meat Tenderness. 3. The effect of cold shortening on tenderness. J. Food Sci. 31:450.

Marsh, B. B., P. R. Woodhams and N. G. Leet. 1968. Studies in meat tenderness. 5. The effect on tenderness of carcass cooling and freezing before the completion of rigor mortis. J. Food Sci. 33:12.

Merkel, R. A. and A. M. Pearson. 1975. Slow chilling could produce tender beef from lean carcasses. Meat Industry 21(5):27.

Oltjen, R. R., T. S. Rumsey and P. A. Putnam. 1971. All-forage diets for finishing beef cattle. J. Ani. Sci. 32:327.

Parrish, F. C., Jr. 1974. Relationship of marbling to meat tenderness. Proc. Meat Ind. Res. Conf. p. 117.

Pearson, A. M. 1966. Desirability of beef—its characteristics and their measurement. J. Ani. Sci. 25:843.

Schroeder, J. W. 1978. Beef quality and composition: Feeding regimes and postmortem handling techniques. M.S. Thesis. Colorado State University, Fort Collins, Colorado.

Schroeder, J. W., D. A. Cramer, R. A. Bowling, and C. W. Cook. 1980. Palatability, shelflife and chemical differences between forage- and grain-finished beef. J. Ani. Sci. 50:852.

Schupp, A., T. Bidner, W. McKnight, D. Smith, J. Carpenter, Jr., and F. Wiegmann. 1979. Acceptance of beef finished on forages or with limited grain. Louisiana Agr. Exp. Sta. Bull. No. 714.

Schinn, J., C. Walsten, J. L. Clark, G. B. Thompson, H. B. Hedrick, W. C. Stringer, A. G. Matches, and J. V. Rhodes. 1976. Effect of pasture and length of grain feeding on characteristics of beef. J. Ani. Sci. 42:1367 (Abstr.).

Smith, G. C., T. R. Dutson, R. L. Hostetler, and Z. L. Carpenter. 1976. Fatness, rate of chilling and tenderness of lamb. J. Food Sci. 41:748.

Tatum, J. D., G. C. Smith, B. W. Berry, C. E. Murphey, F. L. Williams, and Z. L. Carpenter. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. J. Ani. Sci. 50:833.

Wanderstock, J. J. and J. I. Miller. 1948. Quality and palatability of beef as affected by method of feeding and carcass grade. Food Res. 13:291.

Wenham, L. M., S. J. Fairbairn, K. McLeod, W. A. Carse, A. M. Pearson, and R. H. Locker. 1973. Eating quality of mutton compared with lamb and its relationship to freezing practice. J. Ani. Sci. 36:1081.

Wu, J. J., D. M. Allen, M. C. Hunt, C. L. Kastner, and D. H. Kropf. 1980. Nutritional effects on beef palatability and collagen characteristics. J. Ani. Sci. 51 (suppl. 1):71.

Young, A. W. and R. G. Kauffman. 1978. Evaluation of beef from steers fed grain, corn silage or haylage-corn silage diets. J. Ani. Sci. 46:41.