

PERFORMANCE, CARCASS, CARTILAGE CALCIUM, SENSORY
AND COLLAGEN TRAITS OF LONGISSIMUS MUSCLES OF OPEN
AND 30-MONTH OLD HEIFERS THAT PRODUCED ONE CALF

by

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Dedication

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This thesis is dedicated to my loving wife, Briana Waggoner and my wonderful parents, Wayne & Joyce Waggoner. It was their love, encouragement and continued support that enabled me to complete this difficult step in life. Additionally, I would like to express my greatest appreciation to my sisters and families, Shari Woelk and Ruth Ann Martin, grandparents, Ray and Evelyn Francis, and my wife's family, Jean, Danielle, Steve and Dennis Elam for all of their support.

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GENERAL REVIEW OF LITERATURE

Chapter 1

Introduction. The more offspring a dam produces, the less efficient the production unit becomes because cull-cow meat is produced less efficiently the later the dam is slaughtered (Harte, 1975; Taylor et al., 1985). However, when a dam is slaughtered shortly after her first calf is weaned, there is a substantial increase in efficiency because the dam herself assumes the role of slaughter offspring and most of the conventional, maternal-overhead costs of producing a calf disappears by becoming part of productive growth (Harte, 1975; Taylor et al., 1985).

Feedlot Performance of Open, Pregnant and Calved Heifers. Bouton et al. (1982) reported that pregnant heifers had higher gains (.61 compared to .55 kg/d) than open heifers. These results agree with those reported by Bond et al. (1986; study 1 of a two-part study) that pregnant heifers gained faster ($p < .01$) than open heifers; whereas, feed intake was the same, both prepartum and postpartum. Additionally, weight gain on pasture for pregnant heifers averaged about 100 g per d higher than open heifers (Roux et al., 1987). However, open heifers had heavier slaughter and carcass weights ($p < .01$) because the nutrients were converted to carcass tissue gain, while in the pregnant heifers nutrients were utilized for fetal growth (Bond et al., 1986). Snapp (1947) reported that pregnant heifers did not have significantly higher gains than open heifers when fed the same diet. In agreement with this, Walker et al. (1985) found that when pregnant and open heifers were fed a finishing diet, dry-matter intake, average-daily gain, and feed-to-gain ratio were not significantly different. However, when final live weight was adjusted by

subtracting total uterus weight, the pregnant heifers gained less ($p < .05$) and were less ($p < .05$) efficient than open heifers (Walker et al., 1985).

Of primary interest to my research is the performance comparison of calved heifers and open heifers. Roux et al. (1987) reported that calved heifers were 4-wk older than open heifers at the same slaughter weight. Boucque et al. (1980) found that average daily gains for one group of once-calved heifers was significantly higher than that of maiden heifers; whereas, gains for another group of once-calved heifers was significantly lower than for the maiden heifers. Only these two studies are available in the literature on the comparison of calved and open heifers. Results indicate that performance of calved heifers is similar to that of open heifers.

Carcass Traits of Open, Pregnant and Calved Heifers. A number of researchers have concluded that pregnancy and/or having a calf reduces dressing percent (Brookes and O'Byrne, 1965; Walker et al., 1985, Bond et al., 1986; Roux et al., 1987). However, other researchers reported that pregnancy and calving did not significantly effect dressing percent (Snapp, 1947; Boucque et al., 1980).

Results on meat quality reported in several studies indicate that pregnancy and calving had no significant effect on lean color (Snapp, 1947; Brookes and O'Byrne, 1965; Doumont et al., 1987), or texture, firmness, or maturity (Bond et al., 1986). Additionally, the effects of pregnancy and calving had no significant effect on quality grade (Snapp, 1947; Walker et al., 1985), intramuscular fat (Bouton et al., 1982), and marbling (Bond et al., 1986; Study 1). Additionally, there was no significant difference in USDA carcass maturity between open or once-calved heifers. However, Bond et al. (1986) reported that once-calved

heifers had less ($p < .01$) fat over the longissimus muscle, smaller ($p < .01$) ribeyes, and lower ($p < .05$) yield grades. These findings on fatness and yield grades contradict results reported by Bouton et al. (1982) who found no difference in carcass fat cover, and those of Walker et al. (1985) who reported no difference in yield grades between pregnant and open heifers. Also, no differences in amount of kidney knob or udder fat were found between pregnant and open heifers (Brookes and O'Byrne, 1965).

Brookes and O'Byrne (1965) and Bond et al. (1986) concluded that it is possible to produce acceptable carcasses from once-calved heifers that have been fed a high concentrate diet after calving.

Effect of Length-of-Feeding on Meat Quality and Palatability. USDA beef quality grades are the most accepted and utilized standards the beef industry has to account for differences in cooked beef palatability. USDA quality grades are extremely authoritative, and many management and marketing decisions are based on them. The majority of cattle feeders feed specific diets and utilize certain management practices to produce one product - USDA Choice beef.

Time on feed itself may have some affect on meat quality and palatability.

With an increase in time-on-feed comes an increase in total carcass lipid (Marchello et al., 1976). Additionally, increased time-on-feed was associated with increased carcass maturity (Zinn et al., 1970a; Tatum et al., 1980). However, Zinn et al. (1970a) reported that it was not until after 180 d on feed that animal age exerted the greater influence on tenderness.

Matulis et al. (1987), using cull cows fed a high energy diet for 0, 28, 56, and 84 d, reported that marbling scores and quality grades improved significantly between 28 and 56 d. Carcasses from open and calved heifers were

higher in quality after 42-d of high concentrate feeding than carcasses from 7 and 21 d on feed (Bond et al., 1986). Tatum et al. (1980) found that increased time on feed was associated with an increased percentage of Choice carcasses.

Zinn et al. (1970b) and Dolezal et al. (1982b), fed cattle for 150 d to 270 d and 90 d to 200 d, respectively, and found that quality grades and marbling scores were highest ($p < .05$) for the longer times-on-feed. Zinn et al. (1970b) found that the deposition of intramuscular fat was not a continuous process, but it occurred at 60 to 90 d intervals.

No improvement in Warner-Bratzler shear (WBS) values were observed for longissimus dorsi (LD) muscles due to increased time-on-feed (Marchello et al., 1976). Tatum et al. (1980) found that WBS values generally decreased as degree of marbling increased, which resulted from a longer time-on-feed. However, there was not a linear relationship, nor was there always statistical significance in decreasing WBS force with increasing degree of marbling (Tatum et al., 1980). Matulis et al. (1987) also reported that WBS values of LD muscle decreased ($p < .05$) with increased time on feed. Similarly, animals fed 100 d or more had lower ($p < .05$) LD muscle WBS values than those animals fed for less than 90 d (Dolezal et al., 1982b). Similar results were reported by Gutowski et al. (1979) who found WBS values were lower ($p < .05$) for long-fed cattle (98 d) than for short-fed cattle (48 d). However, highest WBS values were at 240 and 270 d than at 150, 180 and 210 d on feed (Zinn et al., 1970a), indicating that extremely long feeding periods are detrimental to tenderness. Short feeding periods of 7, 21, and 42 d postpartum of once-calved heifers did not greatly influence palatability characteristics (Bond et al., 1986). While some studies have concluded that feeding an energy-rich diet prior to slaughter will improve palatability (Tatum et al., 1980; Dolezal et al., 1982b), diminutive advantages or

negative effects were obtained from extensive feeding periods (Zinn et al., 1970a). Tatum et al. (1980) and Dolezal et al. (1982b) concluded that the length of feeding required to obtain the desired flavor, juiciness, and tenderness of beef appears to be optimal at approximately 100 d for yearling cattle fed a normal finishing diet.

Effect of Preslaughter Growth Rate on Meat Palatability. The amount of fat in beef cuts has been drastically reduced in the past few years due to changes in consumer demand. Because of this, animals are being selected with less external fat. Partly responsible for variations in tenderness is the decrease in fat cover of beef carcasses (Bowling et al., 1977; Dolezal et al., 1982b).

Growth rate of cattle before slaughter has an important effect on tenderness (Aberle et al., 1981). These authors suggested that a relationship between growth rate and tenderness may be due to amounts, or to the activity, of endogenous proteolytic enzymes present at the time of slaughter. Therefore, the preslaughter growth rate could be a more important indicator of meat tenderness than the length of time that a high-energy diet is fed. This would be especially true if the high-energy diet has been fed for some minimum period of time to permit maximum activity of all enzyme systems which operate in rapidly growing muscle tissue.

Cattle fed high-energy diets grow faster, have higher quality grades, may have increased rates of protein turnover, more soluble collagen, or more myofibril fragmentation (Aberle et al., 1981; Wu et al., 1981; Hall and Hunt, 1982; Miller et al., 1983b). Fishell et al. (1985) reported that when steers were fed a high-, medium-, or low-energy diet to obtain an ADG of 1.42, .77, and .34 kg per d, respectively, that sensory-panel tenderness scores were highest ($p < .05$)

for the high ADG steers. However, there were no significant differences in LD muscle WBS force values for different rates of ADG, although the high ADG steers tended to have lower WBS values (Fishell et al., 1985). Several researchers have reported that increased growth rate before slaughter is accompanied by increased collagen synthesis and turnover (Wu et al., 1981; Miller et al., 1983b; Fishell et al., 1985). Bailey (1985) reported that as growth rate decreases, collagen cross-links stabilize and the more stabilized cross-links result in less tender meat. Therefore, it is not the amount of collagen present, but the quality of the collagen that contributes to meat texture (Bailey, 1985). However, Hall and Hunt (1982) reported that steers slaughtered while in the A-maturity age range, which had tolerated wide ranges in feeding regimen, had little affect on tenderness, amounts of total collagen, or collagen solubility. Accelerated production in which steers are fed a high-energy diet beginning after weaning and slaughtered at a Good-grade (now Select) endpoint, resulted in LD palatability at least equal to LD palatability of conventionally-produced steers (Dikeman et al., 1985).

Effect of Sex Condition on Meat Palatability. If sexing of bovine semen becomes possible, it could be more important to recognize differences in carcass traits between steers and heifers (Slanger et al., 1985). Nevertheless, it is extremely important to understand whether differences in meat palatability exist between different status females (open heifers, pregnant heifers, once-calved heifers).

Zinn et al. (1970a) indicated that heifers mature at an earlier age, reaching a peak in tenderness about 30 d earlier than steers. Steers reached any given quality-grade endpoint 30 to 60 d faster, due to higher average daily

gains, than heifers (Zinn et al., 1970b).

Zinn et al. (1970a) reported that tenderness differences between steers and heifers in WBS force values were generally small and not statistically significant. However, Murray et al. (1981) reported that steers and heifers differed in LD, but not semimembranosus muscle WBS force values. However, the muscles of calved heifers were always juicier ($p < .05$) than those from maiden heifers. Contradictory to this research, there was no significant difference in tenderness, juiciness or flavor between steaks of maiden and once-calved heifers (Joseph and Crawley, 1971; Bond et al., 1986). Additionally, other researchers found no significant differences in WBS forces (Bouton et al., 1982; Bond et al., 1986) or cooking losses (Bouton et al., 1982) between once-calved and maiden heifers.

Doumont et al. (1987) found that sensory- panel tenderness scores for the LD muscle were higher in calved heifers than maiden heifers, while the opposite was reported for the semitendinosus muscle, and no difference was found for the adductor muscle. Slanger et al. (1985) reported that uncooked muscles from heifers were more tender than those from steers, but heifers had less tender cooked muscles.

It appears that very little difference exists in palatability traits or WBS values between the status of females or between steers and heifers.

Effect of Subcutaneous Fat Thickness on Meat Palatability. Increased subcutaneous fat depth is one of the consequences of feeding a high-energy diet (Dolezal et al., 1982a). The beef industry needs to produce beef with less fat in order to meet the growing consumer demand for lean beef (Riley et al., 1983a). Bowling et al. (1977) reported that moderate levels of subcutaneous fat

reduce the rate of carcass temperature decline during postmortem chilling and improve beef tenderness by lessening the extent of cold-induced toughening and by enhancing the rate and extent of postmortem muscle autolysis. For these reasons, subcutaneous fat thickness may be one of the most important factors affecting palatability. Dikeman et al. (1979) found that WBS values were significantly higher for rib steaks exhibiting less than .63 cm of fat thickness than for rib steaks possessing at least .63 cm of subcutaneous fat cover. Good grade, non-electrically stimulated steers with at least 7.6 mm of subcutaneous fat did not differ significantly from USDA Good and Standard grade, non-electrically stimulated steers with less than 7.6 mm of fat cover for juiciness, muscle-fiber tenderness, connective-tissue amount, overall-tenderness scores, WBS force values, and cooking losses (Riley et al., 1983b). Additionally, electrically stimulated, young bull carcasses with at least 7.6 mm of fat did not differ ($p>.05$) from carcasses with less than 7.6 mm of fat for any palatability trait except connective-tissue amount. However, non-electrically stimulated bull carcasses with at least 7.6 mm of fat had higher ($p<.05$) muscle fiber tenderness, overall tenderness, and juiciness ratings, and lower ($p<.05$) WBS values than bulls with less than 7.6 mm of fat. However, there were no differences ($p>.05$) in connective-tissue amount and cooking loss for the non-electrically stimulated bull carcasses of differing fat thicknesses (Riley et al., 1983b). Similar results were reported by Riley et al. (1983a) in which electrically-stimulated bull carcasses stratified according to four fat thicknesses (less than 3.8 mm, 3.9 to 6.4 mm, 6.5 to 9.0 mm, and greater than 9.0 mm) did not differ in any palatability traits with the exception of connective-tissue amount, which was significantly higher in the 3.9 to 6.4 mm fat thickness group. However, non-electrically stimulated bulls from the 6.5 to 9.0 and

greater than 9.0 mm fat thickness groups had higher ($p < .05$) muscle fiber tenderness and overall tenderness ratings and lower ($p < .05$) WBS values than the other fat thickness groups. While there were no ($p > .05$) differences in connective-tissue amount among any of the fat thickness groups, the group with greater than 9.0 mm fat thickness did have higher ($p < .05$) juiciness ratings and lower ($p < .05$) cooking losses than any of the other groups, which did not differ significantly. Jennings et al. (1978) found that there were no significant differences in palatability traits or WBS force values between carcasses of less than 1.02 cm or greater than 1.52 cm of subcutaneous fat. Similar results were reported by Dikeman and Crouse (1975) that indicated carcass fat and longissimus intramuscular fat were unsatisfactory indicators of palatability and that increased carcass fat did not result in any measurable increase in palatability. Jennings et al. (1978) reported that it is possible that the .93 cm average value for fat thickness on carcasses selected to have less than 1.02 cm of fat thickness may have been sufficient to prevent cold-shortening induced toughness and juiciness problems under normal carcass chilling procedures.

Generally, research has shown that approximately 7.6 mm of subcutaneous fat is adequate to retard the severity of postmortem chilling and maintain acceptable product palatability. Subcutaneous fat in excess of 7.6 mm has little or no effect on meat palatability and WBS force values. Reports by Dolezal et al. (1982a) indicated that palatability of cooked beef increased as fat thickness increased from less than 2.5 mm up to 7.6 mm, but increases greater than 7.6 mm did not further improve palatability. Additionally, Tatum et al. (1982) reported that fat thickness levels of 7.6 to 10.2 mm provided relatively high assurance of desirable palatability of beef rib steaks. They further concluded that a minimum subcutaneous fat depth of 7.6 mm combined with a minimum of

a slight degree of marbling, facilitated a better stratification of carcasses according to their expected palatability than did marbling alone.

Hormonal Effects of Growth, Calcium Metabolism, and Calcification on Bone Maturation. Many growth-promoting compounds of both exogenous and endogenous origin affect the growth and development of livestock for red-meat production (Unruh, 1986). Skeletal growth and development are under complex hormonal control (Raisz and Kream, 1981).

Physiological age in beef carcasses is determined by subjective evaluation of ossification in the split sacral, lumbar and thoracic vertebrae, and by lean color, texture and rib bone shape (USDA, 1976). Grant et al. (1970) found that with increasing physiological maturity there was an increase in calcium in the thoracic buttons.

Several investigations of estrogens in relation to skeletal growth and composition have shown that repeated injections of estrogens over long periods of time appear to cause a condition of generalized "hyper-ossification" (Pfeiffer and Gardner, 1938; Day and Follis, 1941). Estrogen causes a decrease in normal destruction of long trabeculae just beneath the cartilage-shaft junction (Day and Follis, 1941; Wiedemann, 1976). This increases the density of the epiphyses and apparently accounts for the increase in concentration of ash in the whole bone. Additionally, skeletal changes were greater in females than in males when estrogen was injected (Day and Follis, 1941). However, the mechanism by which estrogen affects bone metabolism remains obscure (Raisz and Kream, 1981). There is no convincing evidence of direct effects of estrogens on bone cartilage synthesis or bone resorption (Caputo et al., 1976; Canalis and Raisz, 1978).

Calcium needs increase two to three fold from late gestation to early lactation in the cow (Collier et al., 1984). Yet, the fact that relatively few cows encounter parturient paresis (extreme calcium imbalance at term), is a tribute to the adequacy of the endocrine regulation systems.

Endocrine control of skeletal growth involves not only calcium-regulating hormones, but also several systemic hormones and other factors. Hormone receptors are the primary mechanism by which information from the endocrine system is linked to cellular metabolism. Estrogen plays a very important role in bone calcification and has been shown to increase ossification. However, many hormones have extremely important roles in mineral mobilization of calcium from feed or bones for lactation and reproduction.

Effect of Physiological Maturity on Meat Palatability. Carcass maturity is one of two subjective evaluations utilized by USDA graders to determine USDA quality grades of beef carcasses. Youthful carcasses have been reported to be more tender than the most mature carcasses (Simone et al., 1959; Tuma et al., 1962; Goll et al., 1965; Romans et al., 1965; Briedenstein et al., 1968; Prost et al., 1975b; Cross et al., 1984). However, other researchers have found that carcass maturity had no significant effect on palatability (Norris et al., 1971; Berry et al., 1974; Carrol et al., 1976; Reagan et al., 1976; Miller et al., 1983b).

Tuma et al. (1962) reported that the greatest difference in tenderness of rib steaks was between 18 and 42 mo of age. However, these researchers found no significant differences for juiciness and flavor due to age. Simone et al. (1959) reported that sensory-panel evaluations for tenderness, juiciness, and flavor traits in roast beef from 18- and 30-mo old steers resulted in a significant decrease in tenderness only for the 30-mo old steers. Romans et al.

(1965) concluded that after evaluating steaks from A, B, C and D maturity carcasses, that A and B maturity groups were significantly more tender than D-maturity steaks. However, these investigators found no significant difference between A, B, C and D maturity rib steaks for juiciness or WBS force. Additionally, B-maturity rib steaks were significantly more flavorful than D-maturity steaks. Breidenstein et al. (1968) observed that rib steaks from E maturity carcasses were less tender than those from A and B maturity carcasses. These researchers, however, found no significant differences in flavor and juiciness among the three maturity groups. Goll et al. (1965) studied rib steaks from A-, B- and F-maturity carcasses and found that steaks from A and B maturity carcasses were more tender than those from F-maturity carcasses. However, these researchers did not observe any significant differences in juiciness and flavor due to maturity. Miller et al. (1983b) reported that there were no significant differences between A or B and C or D maturity carcasses for tenderness, juiciness, connective tissue amount, flavor desirability or WBS values. Norris et al. (1971) reported that carcasses representing three physiological maturity levels, ranging from young A to old B maturity, had little effect on palatability of steaks. Additionally, Carrol et al. (1976) found that within A maturity, a third of a degree of difference in maturity had no consistent influence on palatability. Reagan et al. (1976) reported that cattle ranging in age from 305 to 9,828 d did not differ significantly in fat percentage, WBS value, or sensory panel juiciness, tenderness and amount of connective tissue.

Effect of Muscle Collagen Content on Meat Palatability. The palatability of meat primarily is categorized into tenderness, juiciness, and flavor

characteristics. Of all palatability factors considered, tenderness probably is the most important trait affecting consumer acceptability. Differences in connective tissue (collagen) amount (percentage of muscle weight), crosslinking and solubility can be important factors in the tenderness of meat. Wilson et al. (1954) found no differences in muscle collagen and elastin content between steers and cows, but muscles from both of these older groups contained less collagen and elastin than veal muscle. These researchers also reported that because veal is more tender than meat from mature animals, the amount of collagen and elastin in the LD muscle of cattle is not a critical factor in tenderness. Goll et al. (1963) found no significant difference in collagen content of fresh biceps-femoris muscle in cattle ranging in age from 40 d to 10 yr, 5 mo. However, mature collagen appears to contain more extensive or stronger crosslinkages than collagen from young animals, and that the release of soluble protein and soluble hydroxyproline indicated that collagen from the younger animals was solubilized much more rapidly than collagen from the older animals (Goll et al., 1964a). Prost et al. (1975a) found no consistent change in amount of connective tissue associated with increasing animal age. In agreement, Reagan et al. (1976) reported there was no difference ($p < .05$) in total collagen content between 10 to 27 yr and 305- to 1,033- d old cattle. However, total collagen content, measured as hydroxyproline, of the LD muscle was higher for C and D maturity carcasses than for A and B maturity carcasses, but maturity-class means for percentages of soluble collagen were not different between maturity groups (Miller et al., 1983b). Contradictory to these results, Hunsley et al. (1971) concluded that collagen content, measured as hydroxyproline, of 6- and 9- mo old groups of cattle was higher than for the 15- and 18-mo groups. Also, collagen content was not a critical measure of LD

muscle tenderness (Hunsley et al., 1971). Reagan et al. (1976) reported that cattle ranging in age from 10 to 27 yr had lower ($p < .05$) percentages of soluble collagen than samples from 305- to 1,033-d old cattle.

Hill (1966) reported that less collagen was solubilized in meat from older animals (7 to 15 yr) than from younger animals (8 to 9 wk) and this was related to decreased tenderness. Shimokomaki et al. (1972) found that there was a steady decrease in all reducible crosslinks up to about 5 yr; the rate slowed down after 5 yr until reducible crosslinks were virtually absent at 10 yr. These results were in agreement with those reported by Bailey et al. (1974) that there is an initial rapid rise in reducible crosslinks during the deposition of new collagen, but this is followed by a gradual decrease so that at maturity the reducible crosslinks are virtually absent. Greater resistance to degradation in biologically older bovine collagen is thought to be directly related to increased crosslink formation (Miller et al., 1983a). Carmichael and Laurie (1967) reported that the percentage of insoluble collagen swiftly increases to a plateau as animal age increases; however, total collagen in the LD muscle of 4-yr old bovine is markedly lower than that in animals 6 mo to 2 yr old. Additionally, there is an increase in the number and strength of bovine collagen crosslinks with increased chronological age (Carmichael and Laurie 1967; Bailey et al., 1974).

McClain (1976) reported that the types and extent of crosslinking in intramuscular collagen varies with animal age, postmortem aging, nutritional status and even muscle to muscle within the same animal. Thermal shrinkage temperature, which was taken as that temperature at which a sudden release of soluble hydroxyproline occurred, increased with advancing age from near 55 C for 40- to 49-d old calves to 70 C or above for 10 yr old cows. This indicates

that older animals have stronger or more extensive collagen cross-linkages (Goll et al., 1964b). Depending on the extent of this crosslinking, collagen fibers can still possess a significant degree of tensile strength even after heat denaturation, and, thus may be a factor in determining the quality attributes of meat (McClain, 1976).

Therefore, it is not only the total amount of collagen, but, the extent of crosslinking and the relative proportions of thermally labile and thermally stable crosslinks which should be considered when biochemical explanations of the contribution of collagen to the tenderness of meat are sought (Goll et al., 1964a; Hill, 1966; Carmichael and Laurie, 1967; McClain, 1976).

Effect of Marbling and USDA Quality Grade on Meat Palatability.

Characteristics of muscle, such as marbling, are included in the meat-grading standards of the U.S. Department of Agriculture as indicators of subsequent eating quality of cooked meat. Of the palatability traits of meat, tenderness has more influence on the overall acceptability of meat than flavor or juiciness according to Norris et al. (1971) and Campion et al. (1975). Campion et al. (1975) suggested that 2.9 % fat in the LD muscle was sufficient for acceptability of cooked meat. This percentage corresponds to the slight degree of marbling in the USDA grading standards.

Jost et al. (1983) reported that marbling alone accounted for only .4% of the tenderness variation of the LD muscle. Armbruster et al. (1983) reported that marbling scores ranging from slight to extremely abundant explained less than 1.2% of the variation on tenderness and little of the variation in other sensory attributes. Smith et al. (1984) concluded that differences in marbling (practically devoid to moderately abundant) explained about 33% of the variation

in overall palatability ratings of loin steaks from A, B, C, and A+B maturity carcasses. Campion et al. (1975) reported that components of quality grade accounted for no more than 10% of the variation in any of the taste panel measurements, with marbling score accounting for the greatest portion of that variation.

Tatum et al. (1982) reported that marbling had a low, but positive, relationship to all of the palatability traits of beef. More than 90% of the steaks with slight or higher degrees of marbling were desirable in overall tenderness, flavor, and overall palatability. Dikeman et al. (1979) found that taste panel tenderness scores, for steaks ranging in marbling from practically devoid to greater than moderate plus, were lowest ($p < .05$) for practically devoid and traces marbled steaks and highest ($p < .05$) for modest average and above marbled steaks. In addition, flavor scores generally were higher for steaks possessing small minus or higher marbling than steaks displaying slight plus or less marbling. Also, these researchers reported slightly abundant or more marbling produced juicier steaks than those ranging from slight minus to modest plus, which in turn were juicier than those possessing practically devoid and traces marbling. Breidenstein et al. (1968) reported that juiciness and flavor were significantly influenced by marbling level (slight, modest, slightly abundant, abundant). Jennings et al. (1978) concluded that steaks from carcasses with modest or above marbling had higher ($p < .05$) tenderness and juiciness ratings and lower ($p < .05$) WBS force values than steaks containing slight or below marbling. In agreement with this, Dikeman et al. (1979) reported that WBS values were highest ($p < .05$) for steaks practically devoid and traces marbling, and lowest ($p < .05$) for steaks from average modest or higher marbling scores. Additionally, Tuma et al. (1962) reported that WBS values were

lower ($p < .005$) for steaks from slightly abundant than for slight marbled steaks.

In contrast to these findings, many researchers have reported that marbling level does not effect taste-panel tenderness, juiciness or flavor scores (Tuma et al., 1962; Goll et al., 1965; Field et al., 1966; Breidenstein et al., 1968; Norris et al., 1971; Garcia-de-Siles et al., 1977). Furthermore, Breidenstein et al. (1968), Norris et al. (1971) and Jost et al. (1983) found no differences in WBS values due to marbling.

Marbling alone has been reported to account for little variation in meat tenderness. However, the interaction of marbling and maturity, which are combined for USDA quality grades, might have an effect on meat palatability. Skelley et al. (1976) reported that the acceptability of beef top-loin steaks showed very little dependance upon USDA quality grade. They showed that average Good is a dividing point since steaks from carcasses grading high Standard, low Good, or average Good were slightly inferior to steaks from carcasses grading high Good or higher. Simone et al. (1959) reported that taste panel tenderness, juiciness, and flavor scores were significantly higher for steaks from Choice grade than those from Good grade carcasses. Tatum et al. (1980) found that steaks from high Choice and average Choice carcasses were significantly more juicy, flavorful and more desirable in overall palatability than were steaks from low Good and high Standard carcasses. Similar results were reported by Dolezal et al. (1982b) who found that steaks from Standard carcasses received the lowest ($p < .05$) ratings for all of the palatability attributes except juiciness, while steaks from Choice carcasses received the highest ($p < .05$) ratings for juiciness, flavor desirability, overall palatability, and had the lowest ($p < .05$) WBS force values. Smith et al (1983) reported that taste panel flavor desirability of loin steaks decreased significantly between Prime, Choice, Good,

and Standard grades.

In another study by Dolezal et al. (1982a), few differences existed in palatability between rib steaks from carcasses of different USDA quality grades. Additionally, other sensory evaluation studies indicated that quality grade did not significantly influence tenderness (Prost et al., 1975b; Skelley et al., 1976).

Prost et al. (1975a) reported in design I, of a two-part experiment, that when carcasses were separated into low quality and high quality groups that the low quality group had a significantly higher content of connective tissue determined by the hydroxyproline method. However, in design II, the combined mean of all muscles studied revealed no significant influence of quality grade on the content of connective tissue. Similarly, Wilson et al (1954) and Dolezal et al. (1982b) found that quality grade did not effect the amount of collagen and elastin or organoleptically detectable connective tissue, respectively.

Because marbling is such an important part of the USDA quality grades of beef, much research has been conducted on the various degrees of marbling and their effects on tenderness attributes. Marbling alone accounts for a very low percentage of the variation in tenderness. However, increased degree of marbling or quality grades may result in increased sensory panel scores and decreased WBS values.

Hormonal Effect on Performance, Carcass, and Meat Palatability Traits of Heifers. The primary objective of implanting livestock with growth-promoting compounds is to enhance their production and growth (Unruh, 1986). Commercial estradiol is combined with progesterone or testosterone in most implants (Preston, 1975). Implants such as Synovex-H, generally increase rate of gain 8 to 12 % and improve feed conversion 4 to 10 % (Klosterman et al.,

1969; Ray et al., 1969; Embry, 1972; Preston, 1975; Goodman et al., 1982; LaTourell et al., 1983; Laudert et al., 1983; Laudert and Nelson, 1983).

Heifers implanted with Synovex-H had significantly higher final shrunk weights (Goodman et al., 1982) and produced heavier carcasses (Goodman et al., 1982; Laudert et al., 1983) than controls. Implanting generally decreases dressing percent, probably reflecting a decrease in the amount of carcass fat which can result in an improvement in carcass yield grade (Preston, 1975). However, other experiments show no influence of estrogens on USDA yield or quality grades (Goodman et al., 1982; Jones, 1982; Maltulis et al., 1987). Ribeye area and other measures of muscling generally show an increase in size or weight due to implanting (Preston, 1975).

No significant differences between Synovex-H implanted heifers and controls have been found for WBS values and palatability traits (Stout et al., 1981 and Maltulis et al., 1987), nor for cooking losses (Stout et al., 1981). However, Stout et al. (1981) reported that the control heifers tended to have more desirable tenderness ratings and lower WBS values.

Growth promoting compounds generally increase gain, improve feed conversion, increase muscle mass and decrease fatness. Additionally, implanting does not seem to affect WBS values or palatability traits.

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Chapter 2

PERFORMANCE, CARCASS, CARTILAGE CALCIUM, SENSORY AND COLLAGEN TRAITS OF LONGISSIMUS MUSCLES OF OPEN AND 30-MONTH OLD HEIFERS THAT PRODUCED ONE CALF.

Introduction. Feeding steers for slaughter has long been the main supply of beef for purveyor and retail-beef sales. However, during the last 40 yr, heifers in the U.S. slaughter mix have nearly doubled. The increase in heifer numbers probably is a result of increased reproduction rates and a decreased percentage of calf mortality, resulting in fewer heifers being retained for cowherd replacements. This change has resulted in a more efficient beef-production system.

John Brethour (1987, personal communication) initiated the Single-Calf-Heifer (SCH) system, which involves retaining surplus heifers, breeding them to produce one calf, and finishing the heifers in a feedlot beginning shortly after parturition. The SCH is very efficient because it combines reproduction and meat production into one system. This system dramatically increases the salvage value of the heifer after producing the calf and virtually eliminates maintenance costs generally associated with traditional cow-calf operations. The more offspring a dam produces, the less efficient the production unit becomes because cull-cow meat is produced less efficiently the later the dam is slaughtered (Harte, 1975; Taylor et. al., 1985).

The current USDA (1976) grading system sorts carcasses into groups based on quality- and yield-indicating traits. Maturity is an important quality-indicating trait, in which "A" and "B" maturity carcasses are from cattle up to 30 mo and 42 mo of age, respectively. When cattle have bone

and/or lean characteristics typical of cattle older than 42 mo, they are classified as C, D, or E maturity, and referred to as being "hard-boned." "Hard-boned" carcasses are not eligible for the same grades as A and B maturity carcasses and are discounted significantly in price because of it.

Preliminary performance comparisons of the traditional, cow-calf system was replaced with the SCH system, estimated returns to be 3.8 times higher with SCH (John Brethour, personal communication). Also, carcasses produced from the SCH system received USDA quality and yield grades similar to those of heifers of similar ages that had not had a calf.

Bond et al. (1986) reported that calved heifers had lower dressing percentages ($p < .01$), less fat over the longissimus muscle ($p < .01$), smaller longissimus muscle areas ($p < .01$) and lower USDA yield grade numbers ($p < .05$) than open heifers. However, these researchers reported that there were no significant differences in lean color, texture, and firmness; maturity traits; or marbling between the open and once-calved heifers. Yet, little is known about the effects of pregnancy, parturition, and lactation on physiological maturity, meat tenderness and other palatability traits. Therefore, the objectives of our research were to evaluate the effects of having one calf on carcass yield and quality traits, and tenderness of the longissimus dorsi muscle from cattle produced by the SCH system.

Materials and Methods

Heifer Performance. One hundred and thirteen 3/8 Simmental x 5/8 Hereford heifers, born in the spring of 1985, were pasture mated to Red Angus and White Park sires at 14 to 16 mo of age. Eight-seven of these heifers calved at about 2 yr of age and were designated as Single-Calf-Heifers (SCH) with 33 of these being implanted (I-SCH) with Synovex-H and 54 being nonimplanted (NI-SCH). Twenty-six of the 113 heifers which did not calve are identified as 2-yr-old open-heifers (2-OH) which served as controls. Additionally, 22, 1-yr-old open heifers (1-OH), born in the spring of 1986 from the same source, also were utilized to represent the standard heifer-production system.

The 1-OH and 2-OH groups were fed a high-grain diet for 137 and 112 d, respectively, before being slaughtered. Ultrasound was utilized along with visual appraisal to estimate when heifers reached about 0.90 cm fat thickness. Heifers that calved were grouped and started on the same high-grain diet about 1 mo after calving and were fed for 137 d before slaughter. The SCH assigned to the implanted treatment group were implanted when started on the high-grain diet. Calves were early weaned about 5 wk prior to slaughter so the heifers would dry up. The 1-OH averaged 16 1/2 mo, the 2-OH averaged 29 mo and the I-SCH and NI-SCH averaged 30 mo at slaughter.

Due to the normal range in calving dates, the SCH were sorted into two groups, started on feed about 1 mo apart and consequently slaughtered in two groups about 1 mo apart.

Carcass Evaluation. Cattle were transported approximately 220 miles to a

commercial packing plant where they were held for approximately 4 hr before slaughter. After slaughter, carcasses were chilled at 1 C for about 22 hr and evaluated for USDA (1976) yield and quality grades by an experienced, three-member panel. Skeletal and lean maturity scores were recorded as A maturity (0-99), B maturity (100-199) and C maturity (200-299). Additionally, the longissimus dorsi (LD) muscle between the 12th and 13th ribs was evaluated for lean color, firmness, and incidence of "heat ring" (dark coarse band) (Appendix I).

Longissimus Sensory Evaluation. Fifteen wholesale ribs were randomly selected from each treatment group. At 48 hr postmortem, the ribs were shipped to Kansas State University and vacuum aged for 7 d at 1 C. Three steaks, 2.54 cm thick were removed from the 10th, 11th and 12th rib-regions, vacuum packaged, frozen and stored at -10 C until evaluated. The most posterior steak was utilized for collagen analysis, the adjacent steak was utilized for sensory panel (SP) analysis and the most anterior steak was designated for Warner-Bratzler shear (WBS) force determination using an Instron Universal Testing Machine (Model 4201).

Steaks for SP evaluations were thawed for 18 h at 4 C and modified-oven broiled at 165 C to an internal temperature of 70 C (monitored with thermocouples). Uniform cores (1.27 cm in diameter) were removed with a mechanical coring device perpendicular to the cut surface and served warm to an eight-member, trained SP (AMSA, 1978). The SP evaluated juiciness, flavor intensity, myofibrillar tenderness, connective-tissue amount and overall tenderness for each steak based on an 8-point scale (AMSA, 1978; Appendix II). Evaluations were made on eight steaks per session with two steaks randomly

selected from each treatment group per session.

Steaks utilized for WBS determinations were cooked according to the procedures outlined for the SP (AMSA, 1978). Steaks were cooled at room temperature for 2 h before eight 1.27-cm diameter cores were taken perpendicular to the steak surface and sheared through the center with the WBS device (Appendix II).

Heat-Labile Collagen Analysis. Fifteen 12th-rib steaks from each treatment group were thawed at 4 C for 3 hr, and the lateral 1/3 of the LD muscle was pulverized in liquid nitrogen using a Waring Blendor. Pulverized steak samples were stored at -40 C until heat-labile collagen was extracted from duplicate 4-g samples by heating for 70 min at 77 C in .25 strength Ringer's solution (Hill, 1966; Appendix III). Samples were centrifuged to separate supernatant and residual fractions which were then hydrolyzed (autoclaved at 125 C under 1.7 kg/cm²) in 12N HCl for 12 hr. Following neutralization with 5N NaOH, hydroxyproline content was determined in duplicate for both the supernatant and residual fractions by spectrophotometric methods (Bergman and Loxely, 1963; Appendix IV). Collagen content was calculated by multiplying the hydroxyproline content of the residue by 7.25 (insoluble collagen, IC) and that of the supernatant by 7.52 (soluble collagen, SC; Cross et al., 1973). Total collagen (TC) was calculated by adding IC and SC fractions together. Percentage of SC was calculated by dividing SC by the TC and multiplying by 100 (Appendix V).

Calcium Analysis of the Thoracic Buttons. Six cartilaginous caps from the dorsal spinalis processes of the sixth through eleventh thoracic vertebrae of

each wholesale rib were collected and are referred to as thoracic buttons. These thoracic button samples were stored at -10 C until samples were cleaned and dried at 100 C for 12 hr. Following ashing, the samples were solubilized in 12N HCl for 45 min. After diluting the samples in a volumetric flask to 1,000 ml, calcium (Ca) content was determined by atomic-absorption, spectrophotometric methods (Robinson, 1966; Rathery, 1980; Appendix VI). Sample Ca content was calculated on a sample-weight, percentage basis (Appendix V).

Statistical Analysis. Data were analyzed using analysis of variance and mean separations using multiple t-tests calculated by the General Linear Model (GLM) Procedure of the Statistical Analysis System (SAS, 1982). Differences between treatment groups for performance, carcass, meat sensory, collagen, and TB calcification traits in which there was an overall treatment effect ($p < .05$) were evaluated by Least Squares Means Procedures (SAS, 1982). Results were reported and discussed as least-squares means.

Results and Discussion

Heifer Performance. Performance characteristics of treatment groups are given in table 1. Feedlot average-daily-gains were highest ($p < .05$) for 2-OH, and no differences ($p > .05$) occurred among the other treatments. Apparently, the 2-OH were able to convert most of their energy intake above maintenance for gain, whereas 1-SCH and NI-SCH had to use energy above maintenance for both gain and milk production. The advantage in gain for 2-OH over 1-OH likely was due to their larger size and greater feed capacity.

In contrast, Bond et al. (1986) reported that once-calved heifers had higher gains than open heifers. However, the longest feeding period reported by Bond et al. (1986) was only 42 d. Boucque et al. (1980) found once-calved heifers to have higher gains than maiden heifers in one study, while maiden heifers had higher gains than once-calved heifers in the other study.

Both 1-SCH and 2-OH had heavier ($p < .05$) carcasses than 1-OH; whereas, NI-SCH were intermediate in carcass weights. The NI-SCH exhibited the lowest ($p < .05$) dressing percentages (60.7 %); whereas, there were no differences among the other treatments (62.7 to 63.7 %). Numerous researchers have reported that pregnancy and/or calving reduces dressing percentages (Brookes and O'Byrne, 1965; Walker et al., 1985; Bond et al., 1986; Roux et al., 1987). However, this decrease in dressing percentage could have been due to the body composition of a dairy-breed type (Brookes and O'Byrne, 1965; Roux et al., 1987), because of greater rumen fill (Walker et al., 1985), or because of a short feeding period (Bond et al., 1986). Other studies have reported that pregnancy and calving do not significantly effect dressing percentages (Snapp, 1947; Boucque et al., 1980).

TABLE 1. LEAST SQUARES MEANS FOR PERFORMANCE CHARACTERISTICS OF 1-YEAR-OLD-OPEN-HEIFERS, 2-YEAR-OLD-OPEN-HEIFERS, AND IMPLANTED AND NONIMPLANTED SINGLE-CALF-HEIFERS.

Characteristics	Treatments			
	1-OH	2-OH	I-SCH	NI-SCH
Number of heifers	22	26	33	54
Days in feedlot	137	112	137	137
Feedlot average-daily-gain, kg/d	1.1 ^a	1.3 ^b	1.0 ^a	1.0 ^a
Hot carcass weight, kg	296 ^b	338 ^c	326 ^c	319 ^{bc}
Dressing percent	63.7 ^a	63.0 ^a	62.7 ^a	60.7 ^b

a,b Means within a row without a common superscript letter differ ($P < .05$).

Single-calf-heifers had desirable average-daily gains and carcass weights when compared to 1-OH. However, we have no explanation for the low dressing percentage of our NI-SCH.

Carcass Characteristics. There were no differences ($p > .05$) in lean firmness, incidence of heat ring, USDA marbling scores and quality grades among treatment groups (table 2). Therefore, visual quality traits of the LD muscle from heifers that calved were equal to those of 1-OH and 2-OH.

Our marbling results agree with those reported by Snapp (1947), Bouton et al. (1982), Walker et al. (1985), and Bond et al. (1986, study 1). Our results for marbling and quality grade contradict the lower marbling scores for once-calved heifers from study 2 of Bond et al. (1986). However, their longest feeding period was only 42 d, which likely was not adequate for once-calved heifers to deposit amounts of marbling equal to the open heifers.

As expected, 1-OH had the lightest ($p < .05$) colored lean; whereas, there were no lean color differences among the other treatment groups. These results agree with those reported by Snapp (1947), Brookes and O'Byrne (1965), Bond et al. (1986, study 1), and Doumont et al. (1987) that pregnancy and calving had no effect on lean color.

Kidney, pelvic and heart-fat percentages were highest ($p < .05$) for 1-OH, while no differences existed among the other treatments (table 2). Our results agree with those reported by Brookes and O'Byrne (1965). On the other hand, there were no differences ($p > .05$) in fat thicknesses, adjusted fat thicknesses, LD muscle areas, or USDA yield grades among treatment groups.

Contradictory to our results, Bond et al. (1986) found that once-calved heifers had less ($p < .01$) fat over the LD muscle (study 1 and 2), smaller ($p < .01$)

TABLE 2. LEAST SQUARES MEANS FOR QUALITY AND YIELD CHARACTERISTICS OF 1-YEAR-OLD-OPEN-HEIFERS, 2-YEAR-OLD-OPEN-HEIFERS, AND IMPLANTED AND NONIMPLANTED SINGLE-CALF-HEIFERS.

Characteristics	Treatments			
	1-OH	2-OH	I-SCH	NI-SCH
Lean color ^a	2.0 ^f	2.6 ^g	2.6 ^g	2.5 ^g
Heat-ring incidence ^c	1.5	1.3	1.4	1.5
Lean firmness ^b	2.6	2.8	2.5	2.6
USDA marbling score ^d	321	303	301	314
USDA quality grade ^e	300	286	288	289
Fat thickness, cm	.71	.81	.91	.91
Adjusted fat thickness, cm	.71	.91	.91	1.12
Kidney, pelvic and heart fat, %	2.9 ^f	1.8 ^g	1.7 ^g	2.1 ^g
Longissimus area, cm ²	91.0	92.9	92.3	91.0
USDA yield grade	2.0	2.0	2.0	2.2

^a Color of lean: 1 = very light cherry red, 2 = cherry red, 3 = slightly dark red, ..., 7 = black.

^b Firmness of lean: 1 = very firm, 2 = firm, 3 = moderately firm, ..., 7 = extremely soft.

^c Presence of heat ring (dark coarse band): 1 = none, ..., 5 = extremely severe.

^d USDA marbling score: 200-299 = slight, 300-399 = small.

^e USDA quality grade: 200-299 = Select, 300-399 = low Choice.

^{f,g} Means within a row without a common superscript letter differ ($P < .05$).

LD muscle areas (study 1 and 2), and lower ($p < .05$) yield grade numbers (study 1) than open heifers. However, had Bond et al. (1986) fed the heifers for longer than 42 d, the once-calved heifers might have attained the same amount of finish and degree of muscling as the open heifers.

Data from tables 1 and 2 demonstrate that carcass weights and USDA quality and yield grades were equally desirable for 2-OH, I-SCH and NI-SCH. Therefore, having a calf had no negative effects on these traits.

The SCH had higher ($p < .05$) maturity scores than 1-OH for all eight maturity characteristics (table 3). However, I-SCH did not differ ($p > .05$) from NI-SCH in any of the eight maturity characteristics. Also, I-SCH were more mature ($p < .05$) than 2-OH in five (sacral, lumbar, thoracic, overall bone and overall maturity) of the eight maturity characteristics. Our results contradict those of Bond et al. (1986) who reported that there were no differences between open heifers and once-calved heifers for bone maturity and overall USDA carcass maturity. However, our results agree with those reported by Bond et al. (1986) that once-calved heifers had more ($p < .05$) mature bone and overall maturity characteristics than open heifers.

It should be noted that two of the I-SCH and one of the NI-SCH were classified as "C" bone maturity ("hard boned") which decreased their carcass value because their quality grades were different than those of A and B maturity carcasses.

Thoracic-Button Calcification. As expected, the 1-OH had a lower ($p < .05$) percentage of calcium in the thoracic buttons than any of the other treatment groups, which did not differ ($p > .05$) (table 3). However, there was a tendency for the I-SCH to have a higher calcium level than NI-SCH or 2-OH. Our

TABLE 3. LEAST SQUARES MEANS FOR MATURITY CHARACTERISTICS AND THORACIC-BUTTON CALCIFICATION OF 1-YEAR-OLD-OPEN-HEIFERS, 2-YEAR-OLD-OPEN-HEIFERS, AND IMPLANTED AND NONIMPLANTED SINGLE-CALF-HEIFERS.

Characteristics	Treatments			
	1-OH	2-OH	I-SCH	NI-SCH
USDA bone maturity:				
Sacral ^a	75 ^b	89 ^{bc}	108 ^d	100 ^{cd}
Lumbar ^a	69 ^b	83 ^{bc}	101 ^d	94 ^{cd}
Thoracic ^a	64 ^b	88 ^{bc}	114 ^d	99 ^{cd}
Feather bone ^a	80 ^b	101 ^c	106 ^c	114 ^c
Rib bone ^a	89 ^b	100 ^{bc}	114 ^c	110 ^c
Overall bone maturity	74 ^b	93 ^{bc}	113 ^d	105 ^{cd}
USDA lean maturity ^a	55 ^b	81 ^c	87 ^c	79 ^c
USDA carcass maturity ^a	70 ^b	90 ^c	108 ^d	98 ^{cd}
Calcium, %	.52 ^b	3.04 ^c	3.87 ^c	3.19 ^c

^a Scores based on: 0-99 = A maturity, 100-199 = B maturity, 200-299 = C maturity ("hard boned").

^{b,c,d} Means within a row without a common superscript letter differ ($P < .05$).

results indicate that neither calving nor implanting had a negative effect on the percentage of Ca of the thoracic buttons. Grant et al. (1970) reported that percentage of Ca of the dorsal, thoracic-vertebral buttons were greater ($p < .05$) for B-average to B-plus maturity steers than for A-minus to average-A or A-plus to B-minus maturity carcasses.

Sensory Panel and Warner-Bratzler Shear Traits. Cooking loss percentages and SP juiciness and flavor scores did not differ ($p > .05$) among treatment groups (table 4). These results agree with those of Joseph and Crowley (1971) and Bond et al. (1986). However, contradictory to our results, Dumont et al. (1987) reported that steaks from once-calved heifers were always juicier ($p < .05$) than those from maiden heifers. Table 4 shows that SP scores for LD muscles from 2-OH, I-SCH, and NI-SCH did not differ ($p > .05$). Our results agree with those of Stout et al. (1981) and Matulis et al. (1987), who reported no SP differences between implanted and control open, cull cows. Our results also agree with those of Joseph and Crowley (1971) and Bond et al. (1986) who reported no differences in SP traits ($p > .05$) between once-calved heifers and maiden heifers. However, our results contradict those of Dumont et al. (1987) who found that SP tenderness scores for the LD muscle were higher in once-calved heifers than maiden heifers.

Detectable-connective tissue, myofibrillar and overall tenderness scores were higher ($p < .05$) and WBS values were lower ($p < .05$) for 1-OH than for I-SCH and NI-SCH. Additionally, 1-OH had higher ($p < .05$) SP connective-tissue scores than 2-OH. The 2-OH had lower ($p < .05$) WBS values than I-SCH, but did not have lower WBS values than NI-SCH. This indicates that implanting had a negative affect on tenderness. These results indicate that the combined effects

TABLE 4. LEAST SQUARES MEANS (\pm SD) FOR SENSORY PANEL SCORES, COOKING LOSSES, AND WARNER-BRATZLER SHEAR VALUES OF LONGISSIMUS STEAKS FROM 1-YEAR-OLD-OPEN-HEIFERS, 2-YEAR-OLD-HEIFERS, AND IMPLANTED AND NONIMPLANTED SINGLE-CALF-HEIFERS.

Characteristics	Treatments			
	1-OH	2-OH	I-SCH	NI-SCH
Juiciness ^a	5.6 \pm .67	5.7 \pm .56	5.7 \pm .42	5.5 \pm .59
Flavor intensity ^a	6.0 \pm .29	6.1 \pm .26	6.1 \pm .38	5.9 \pm .30
Myofibrillar tenderness ^a	6.3 ^c \pm .83	5.9 ^{c,d} \pm .86	5.5 ^d \pm .66	5.4 ^d \pm 1.0
Connective tissue amount ^a	7.0 ^c \pm .32	6.6 ^d \pm .44	6.5 ^d \pm .45	6.5 ^d \pm .52
Overall tenderness ^a	6.4 ^c \pm .71	6.1 ^{cd} \pm .78	5.7 ^d \pm .63	5.6 ^d \pm .97
Cooking losses, %	19.2 \pm 2.04	19.9 \pm 1.9	20.9 \pm 1.43	20.0 \pm 3.39
Shear force, kg ^b	3.1 ^c \pm .69	3.3 ^{cd} \pm .36	3.9 ^e \pm .48	3.5 ^{de} \pm .61

a A score of 8 = extremely juicy, intense, tender, non and tender; 7 = very juicy, intense, tender, practically none and tender;... 5 = slightly juicy, intense, tender, slight amount and tender;... 1 = extremely dry, gland, tough, abundant amount, tough.

b Warner-Bratzler shear force determinations made on 1.27 cm diameter cores.

c,d,e Means within a row without a common superscript letter differ ($P < 0.05$).

of implanting and having a calf did not have a detrimental effect on LD muscle palatability as determined by a SP, but did for WBS values. However, increased age had a negative effect on SP detectable-connective tissue, and the combined effects of increased age and having a calf had a detrimental effect on all tenderness traits. Yet, having a calf or implanting, independently, had no negative effects on SP tenderness traits. The 1-OH heifers were superior in tenderness to SCH. However, tenderness and other palatability traits of the SCH groups generally were equal to those of 2-OH, except for WBS values of I-SCH. Therefore, the SCH system results in meat palatability that is comparable to that of similar-aged heifers that have not calved.

Collagen Characteristics. There were no differences ($p > .05$) in amount of soluble, insoluble, and total collagen, or percent soluble collagen among treatment groups (table 5). Hall and Hunt (1982) reported that steers slaughtered in the A-maturity range differed little in total collagen amounts or collagen solubility. Our results indicate that the effects of age, calving and implanting had no negative effects on any of these traits.

TABLE 5. LEAST SQUARES MEANS FOR COLLAGEN CHARACTERISTICS OF 1-YEAR-OLD-OPEN-HEIFERS, 2-YEAR-OLD-OPEN-HEIFERS, AND IMPLANTED AND NONIMPLANTED SINGLE-CALF-HEIFERS.

Characteristics	Treatments			
	1-OH	2-OH	I-SCH	NI-SCH
Number of heifers	15	15	15	15
Insoluble collagen, mg/g	1.99	1.91	1.86	2.02
Soluble collagen, mg/g	0.28	0.26	0.20	0.24
Total collagen, mg/g	2.26	2.17	2.06	2.27
Percent soluble collagen	13.53	12.47	10.15	10.91

Summary. Results of our study indicate that it is possible to produce carcasses with desirable weights, USDA quality and yield grades, and SP palatability ratings from heifers that have produced one calf, and then fed a high-grain diet and slaughtered by 30 mo of age. However, LD muscles of SCH were not as tender as those of 1-OH. The combination of implanting and calving did increase ($p < .05$) LD WBS values compared to 2-OH. Implanting heifers that calved may result in more "hard boned" carcasses, but the improvement in dressing percent from implanting should more than offset this disadvantage. Implanting with Synovex-H after calving had no negative effects on performance, USDA quality and yield traits or SP palatability ratings. With more intensive management expertise, the SCH system may have considerable potential for cattlemen.

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Appendix I

Longissimus Quality

Lean Firmness

- 1 = very firm
- 2 = firm
- 3 = moderately firm
- 4 = slightly soft
- 5 = soft
- 6 = very soft
- 7 = extremely soft

Lean Color

- 1 = very light cherry red
- 2 = cherry red
- 3 = slightly dark red
- 4 = moderately dark red
- 5 = dark red
- 6 = very dark red
- 7 = black

Heat Ring (Dark Coarse Band)

- 1 = none
- 2 = slight
- 3 = moderate
- 4 = severe
- 5 = extremely severe

Appendix II

Sensory Panel Evaluation Score Descriptions

Flavor Intensity

- 1 = extremely bland
- 2 = very bland
- 3 = moderately bland
- 4 = slightly bland
- 5 = slightly intense
- 6 = moderately intense
- 7 = very intense
- 8 = extremely intense

Juiciness

- 1 = extremely dry
- 2 = very dry
- 3 = moderately dry
- 4 = slightly dry
- 5 = slightly juicy
- 6 = moderately juicy
- 7 = very juicy
- 8 = extremely juicy

Connective tissue amount

- 1 = abundant
- 2 = moderately abundant
- 3 = slightly abundant
- 4 = moderate
- 5 = slight
- 6 = traces
- 7 = practically none
- 8 = none

Myofibrillar and overall tenderness

- 1 = extremely tough
- 2 = very tough
- 3 = moderately tough
- 4 = slightly tough
- 5 = slightly tender
- 6 = moderately tender
- 7 = very tender
- 8 = extremely tender

INSTRON 4201 WBS SHEAR FORCE DETERMINATION PROCEDURES

Item

Cross Head Speed
Proportion (crosshead: recorder)
Load Range
Load Cell

Technical Setting

200 mm/min
100 mm/min
20%
50 kg

Appendix III

Separation of Soluble (heat-labile) and Insoluble Collagen by a Modified Hill^a Procedure.

1. Weigh out duplicate 4.0 g frozen pulverized meat sample into 50 ml centrifuge tube.
2. Pipette 12 ml of 1/4 strength Ringer's Solution into each centrifuge tube. With a different stirring rod for each tube, stir 10 revolutions to suspend meat sample.
3. Place centrifuge tubes in a water bath preheated to 77 c and heat for 70 min, stirring 5 revolutions every 10 min.
4. Take centrifuge tubes out of water bath and allow to cool for 30 min on lab bench.
5. Place tubes in centrifuge cooled to 2 C running temperature. Centrifuge at 6,000 X G for 10 min (6,600 rpm on the Beckman Refrigerated Centrifuge Model J2-21, with JA17 head).
6. Remove tubes from centrifuge and pipette 8 ml of supernatant into screw top glass test tubes with teflon coated screw caps.
7. Add 8 ml of 1/4 strength Ringer's Solution to each centrifuge tube and resuspend pellet using separate glass stirring rods for each tube.
8. Centrifuge again for 10 min (as in step 5).
9. Remove tubes and pipette 8 ml of supernatant into respective test tubes in step 6.
10. Remove residual from centrifuge tube into 50 ml screw top test tubes with teflon coated screw caps. Add 8 ml of distilled water (used to rinse centrifuge tube) and 10 ml of concentrated (12N) HCl into residual tubes (conduct under hood to prevent inhalation of HCl fumes).
11. To each supernatant tube, add 16 ml concentrated HCl.
12. Screw caps on tightly and autoclave (hydrolyze) for 12 h (overnight) at 16-19 lbs. pressure (120-125 C).
13. Allow to cool at room temperature.
14. Add 500 (\pm 30) mg carbon decolorizing alkaline (to clarify), mix, and filter samples through Whatman No. 1 filter paper into 250 ml beaker.
15. ^bTitrate to a yellow endpoint using 5N NaOH and 7 drops of methyl red indicator.

16. Filter samples through Whatman No. 1 filter paper and dilute supernatants and standards volumetrically to 100 ml and residuals volumetrically to 500 ml with distilled water.
17. Analyze for hydroxyproline content.

Reagents

1. Ringer's Solution - 7.0 g NaCl, 0.026 g CaCl₂, 0.35 G KCl.
1/4 Ringer's Solution - dilute and bring 250 ml Ringer's Solution to volume (1 liter) with deionized/distilled water.
 2. Concentrated (12N) HCl.
 3. 5N NaOH - 200 g NaOH/1 liter deionized/distilled water (highly exothermic reaction).
 4. Methyl red indicator (0.02%) - dissolve 0.04 g methyl red granules in 200 ml volumetrically of 95% ethanol.
 5. Stock hydroxyproline and standards - 0.1 g hydroxyproline per liter, dissolve in 0.001 N HCl, store in refrigerator (discard after 1 month).
-
- a Hill, F. 1966. The solubility of intramuscular collagen in meat animals of various ages. J. Food Sci. 31:161.
- b Standards were begun in procedure after addition of 1.8 ml concentrated HCl for residual standards and 14.5 ml concentrated HCl for supernatant standards (to standardize for possible NaCl formation during titration).

Appendix IV

Determination of Hydroxyproline by a Modified Bergman and Loxley Rapid Procedure.^a

1. Pipette duplicate 1 ml aliquots of each sample into 15 ml screw top tubes, 1 ml distilled water into each blank, and 1 ml aliquots of each standard (2-10 mg/ml).
2. Pipette 2 ml of isopropanol and mix.
3. Pipette 1 ml of oxidant solution, mix well, and allow to stand 4 min (± 10 s) at room temperature (17-21 C).
4. Pipette 2 ml Ehrlich's reagent and mix well, screw on caps to limit evaporation.
5. Heat tubes for 25 min (± 15 s) in a 60 C (± 0.2 C) water bath.
6. Cool tubes for 5 min in running tap water.
7. Mix and measure absorbance at 558 nm against a 0 g/ml blank as soon as possible (20 min maximum) in a 10 mm cuvette (Baush & Lomb Spectronic 21).

Reagents

1. Isopropanol.
2. Oxidant Solution
 - A. 3.5 g Chloramine T dissolved in 50 ml deionized/distilled water, store in refrigerator (discard after 1 month).
 - B. Acetate/citrite Buffer: 34.4 g Sodium Acetate anhydrous, 37.5 g Trisodium citrate-2H₂O, 5.5g citric acid-1H₂O and 385 ml isopropanol. Adjust pH to 6.15 with concentrated acetic acid before addition of isopropanol, then dilute to 1 L with deionized/distilled water (erroneous pH may occur if alcohol is added before the buffer pH is adjusted). Store at room temperature (discard after 1 month).
 - C. Oxidant solution: Mix 1 volume of A with 4 volumes of B. Make fresh daily before use.
3. Ehrlich's Reagent
 - A. 2 g p-Dimethylaminobenzaldehyde (DABA) dissolved in 2.5 ml of 70% perchloric acid (mix under perchloric acid hood).
 - B. Isopropanol
 - C. Ehrlich's reagent: Mix 3 volumes of A with 13 volumes of B. Make fresh daily before use.

^a Bergman, I. and R. Loxley. 1963. Two improved and simplified methods for the spectrophometric determination of hydroxyproline. Anal. Chem. 35:1961.

Determination of Calcium (Ca) by Atomic
Absorption Spectrophotometrics.

1. Prepare a set of working standards (25-300 ppm).
2. Pipette duplicate 9 ml aliquot of each sample and standard.
3. Pipette 1 ml aliquot of strontium chloride ($\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$) into each sample and mix well.
4. Measure absorbance at the following conditions:
Wavelength 422.7 nm
Slit width .5 nm
Flame type Reducing (rich, yellow)
Lamp current 4 mA

Reagents

1. 1 % Strontium Chloride Solution
 - A. 420 g Strontium Chloride ($\text{SrCl}_2 \cdot 6 \text{H}_2\text{O}$) dissolved in 14 l Deionized Distilled Water.
 2. Stock solution 24.9726 g CaCO_3 dissolved in HCl. Dilute volumetrically to 1,000 ml in deionized distilled water.
F.W. 100.09
A.W. Ca 40.08
-

J.W. Robinson. 1966. Atomic Absorption Spectroscopy.

F. Rathery. 1980. Operating Manual of the A.A-1475 Series. Atomic Spectrophotometer.

Appendix V

Calculations for Collagen Analysis

1. Use absorbance to obtain g/ml for each sample. Using absorbances for standards, prepare a regression of g/ml on the X-axis and absorbance on the Y-axis.
2. Multiply g/ml by the total volume to which the sample was diluted, 100 for supernatants and 500 for residual. Divide this value by the grams of sample to get g hydroxyproline/gram sample.
3. Convert hydroxyproline to collagen by multiplying the supernatants by 7.52 (Cross et al., 1973^a) and the residuals by 7.25 to get g collagen/gram of sample.
4. Divide by 1000 to convert g collagen/gram to mg collagen/gram.
5. Report as soluble collagen (supernatant), insoluble collagen (residual), total collagen (soluble + insoluble) and % soluble collagen (soluble/total X 100).

Calculations for Calcium (Ca) Analysis

1. Using absorbance for standards, prepare a regression of ppm on the X-axis and absorbance on the Y-axis.
2. Divide 1,000 ml by the fat-free extracted dried weight of the sample. This value is then multiplied by the ppm from the regression line to get ppm of the sample.
3. Divide the ppm of the sample by 10,000 to convert ppm to percent Ca.

^a Cross, H.R., Z.L. Carpenter and G.C. Smith. 1973. Effects of intramuscular collagen and elastin on bovine muscle tenderness. J. Food Sci. 38:998.

Appendix VI

Bone Cartilage Sampling Procedure.

1. Clean all loose material from cartilage surface.
2. Load bones in large thimble, close end with cotton and dry 12 hr in 100 C oven.
3. Ether extract for 12 hr in soxlet, remove and allow to dry.
4. Repeat step 2 drying. Remove thimble from drying oven and put in dessicator. Allow thimble and sample to cool to approximately room temperature.
5. Acid wash sample dishes and record tare weights.
6. Remove samples from thimble and cotton, place sample in dish and weigh. Note: Calculate fat-free extracted dried sample by subtracting dish tare weight.
7. Ash samples in 525 C oven for 15 hr, remove from oven and cool to room temperature in a dessicator.
8. Weigh ashed samples and subtract bone dish tare weight to get sample ashed weight.
9. Solubilize ashed samples with 12N HCl on a low heat hot plate for 45 min. Do not boil samples. Note: Only heat samples enough to observe a light steam. Rinse sides of dishes often during the heating process.
10. Cool samples and bring to volume in a 1,000 ml volumetric flask, analyze samples by atomic absorption spectrophotometry.

Reagents

1. Concentrated (12N) HCl.

PERFORMANCE, CARCASS, CARTILAGE CALCIUM, SENSORY
AND COLLAGEN TRAITS OF LONGISSIMUS MUSCLES OF OPEN
AND 30-MONTH OLD HEIFERS THAT PRODUCED ONE CALF.

by

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AN ABSTRACT OF A MASTER'S THESIS

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Abstract

One hundred thirteen 3/8 Simmental x 5/8 Hereford heifers were used to determine the effects of age, having a calf, and implantation on performance, carcass and meat sensory traits, muscle-collagen characteristics and thoracic-button calcification. Eighty-seven heifers, which calved at about 2 yr of age, were designated as Single-Calf-Heifers (SCH), either implanted (I-SCH) with Synovex-H or nonimplanted (NI-SCH). Twenty-six, 2-yr-old, open-heifer (2-OH) mates to those that calved served as controls. Additionally, 22 1-yr-old open heifers (1-OH) from the same source were utilized to represent the standard heifer-production system. The 1-OH and 2-OH were slaughtered following 137 and 112 d on a high-grain diet, respectively. The SCH were started on the high-grain diet about 1 mo after calving and were fed for 137 d before slaughter. The SCH assigned to the implantation treatment were implanted when started on the high-grain diet. Calves were early weaned about 5 wk before the SCH were slaughtered. The 2-OH had the highest ($p < .05$) feedlot average-daily-gains; whereas, no differences ($p > .05$) occurred among the other treatments. Dressing percentages were higher ($p < .01$) for I-SCH than for NI-SCH. Carcass weights were lowest ($p = .06$) and kidney knobs were highest ($p < .01$) for 1-OH. Ribeye areas, fat thicknesses, yield grades, marbling scores and quality grades were similar ($p > .05$) for all treatments. Carcasses of I-SCH were more mature ($p < .05$) than those of 2-OH and 1-OH. The 1-OH had the lowest percentage of calcium ($p < .05$) in the thoracic buttons and no differences ($p > .05$) existed among the other treatments. One NI-SCH and two I-SCH carcasses were classified as "hard boned." With this exception, carcass traits were very typical of fed market heifers for all treatments. Longissimus steaks from 15 randomly selected carcasses in each treatment were cooked for sensory-panel palatability, Warner-Bratzler shear and cooking-loss

determinations. Sensory-panel flavor and juiciness scores did not differ ($p>.05$) among treatment groups. Sensory-panel detectable connective-tissue amount, myofibrillar and overall tenderness scores did not differ ($p>.05$) among 2-OH, I-SCH, and NI-SCH. However, 1-OH had the least ($p<.05$) sensory-panel detectable connective tissue and had higher ($p<.05$) myofibrillar and overall tenderness scores than I-SCH and NI-SCH. Shear values of steaks from NI-SCH were not different ($p>.05$) than those from 2-OH; however, shear values of steaks from I-SCH were higher ($p<.05$) than those from 2-OH and 1-OH. The combination of implanting and calving did result in increased maturity and WBS values; however, average daily gains, carcass weights, and carcass traits were comparable to 1-OH characteristics.

Key words: Heifers, Calving, Implant, Performance, Carcass, Palatability.