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Incidence and Sensory Evaluation of Injection-Site Lesions in Beef Top Sirloin Butts

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ABSTRACT: The effects of ongoing quality assurance initiatives on the national incidence of injection-site lesions and the impact of these lesions on the sensory characteristics of top sirloin butts were examined by a series of audits and two experiments. The national incidence of injection-site lesions in top sirloin butts ($n = 98,192$) has not changed between July 1993 (10.91%) and July 1995 (10.19%). However, during this same period, the mean weight of injection-site lesion trim increased ($P < .05$) from 102.63 ± 12.56 g to 152.81 ± 13.24 g. Eighty percent of lesions examined during this period were classified as chronologically "older," originating from injections given either during preweaning, stocking, or in the early feeding period; however, there was an increase ($P < .01$) in the incidence of nodular scars during the audit period, likely created by intramuscular injections

during the mid- to late-feeding periods. Warner-Bratzler shear measurements of lesion-afflicted steaks taken near the site of lesions and in areas up to 7.62 cm from the lesion center were significantly greater than similar measurements on control top sirloin steaks. Panelist tenderness scores for mildly lesioned steaks were lower ($P < .05$) and had greater within- ($P < .01$) and among- ($P < .05$) steak variation than control (normal) steaks. Mean juiciness ratings were higher ($P < .001$) for lesioned steaks; however, steak flavor intensity variation was greater within injection-site lesioned vs control top sirloin steaks, with undesirable flavors reported by panelists. Injection-site lesions still occur at an unacceptable frequency in the top sirloin butt, and those lesions, if not removed entirely, can dramatically reduce the desirability of top sirloin steaks.

Key Words: Injection, Lesions, Top-Sirloin Butts, Incidence, Tenderness

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Introduction

In the face-to-face interview phase of the National Beef Quality Audit—1991 (Smith et al., 1992) the top concerns of each segment of the beef industry were identified. Results revealed that injection-site lesions ranked second for purveyors, third for retailers, second for restaurateurs, and second for packers. Dexter et al. (1994) reported that the activities of the National Cattlemen's Association, Beef Quality Assurance Task Force had led to a reduction in the incidence of injection-site lesions from 21.27% (July 1991: \$54,967,635 loss per year) to 10.87% (March 1993: \$28,091,123 loss per year).

More recently, a controlled study (George et al., 1995a) reported that the incidence of injection-site

lesions in fed cattle at slaughter was 72.5%, 92.7%, 5.3%, and 51.2% when a 2-mL Clostridial, a 5-mL Clostridial, a vitamin AD mixture, and a long-lasting oxytetracycline, respectively, were administered intramuscularly at branding time (376 d preslaughter), and 46.3%, 79.5%, 10.0%, and 92.3% when the same preparations were administered at weaning time (225 d preslaughter).

Additionally, George et al. (1995b) reported that, in beef outside rounds, both severe architectural and tissue-constituent disruptions occur following intramuscular administration of pharmaceuticals, and that tenderness is significantly reduced in those steaks in areas up to 7.62 cm away from the center of the lesion.

Consequently, a series of audits and experiments was conducted to determine the impact of ongoing quality assurance initiatives on the national incidence and severity of injection-site lesions in top sirloin butts and the potential ramifications of injection-site lesions on tenderness and palatability of beef top sirloins.

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Experimental Procedures

Experiment 1. To quantify accurately the ongoing national incidence and severity of injection-site lesions in the top sirloin butt, data were individually collected from federally inspected steak-cutting facilities during the period of July 1, 1993, to July 31, 1995. Seven national audits were conducted: July 1993, November 1993, March 1994, July 1994, November 1994, March 1995, and July 1995. Facilities audited were selected according to 1) U.S. geographic location and 2) quantities of top sirloin butts processed at that location. At each of these facilities, top sirloin butt subprimals were fabricated into steaks for commercial foodservice and fine-dining restaurant uses. To ensure that adequate quantities of top-sirloin butts were available, prearranged visitations covered two to three 8-h shifts at each of the five plants audited. Three visits were conducted to each facility annually (March, July, and November) to ensure that annual data encompassed cattle from differing production systems and slaughter periods throughout the year. Audit procedures were identical to those described by Dexter et al. (1994). Identification of each top sirloin butt by USDA slaughter-plant establishment number facilitated evaluation of data by U.S. geographical location. In each facility, except one, top sirloin butts were hand-fabricated by steak-cutters into portion sizes ranging from 6 to 12 ounces. In these facilities, the biceps femoris muscle (cap) was removed and fabricated separately from the gluteus medius. At one steak-cutting facility, however, the biceps femoris was left attached to the gluteus medius and steaks were fabricated using a band saw. In all facilities, both the biceps femoris and gluteus medius were audited.

When an injection site was exposed, the affected tissue was excised and weighed (to the nearest .30 g). The lesions were further classified using a 5-point

classification system described by Dexter et al. (1994). This 5-point classification system enabled lesions to be classified according to the estimated chronological stage of the healing process (George et al., 1995a). In addition, during the top sirloin butt audits conducted during July 1994, November 1994, March 1995, and July 1995, an additional subclassification of the woody callus classification was added, which represents, based on controlled studies (George et al., 1995a), lesions created by the intramuscular administration of Clostridial bacterins in an aluminum hydroxide adjuvant. Multiple processing of calves with Clostridial bacterins has been implicated (Lambert, 1991; VS/APHIS/USDA, 1995) as an important contributor to the injection-site lesion incidence reported previously.

Experiment 2. During the top sirloin butt audit conducted in August 1995, a number of normal ($n = 40$) and lesion-afflicted ($n = 160$) center cut, top sirloin butt steaks were collected from two of the purveying facilities audited in Exp. 1 for subsequent laboratory evaluation. These steaks were chosen randomly by in-plant Quality Assurance personnel to represent a "normal" distribution of severity and classification of lesions observed in their facility. All top sirloin butts from which steak samples were selected had been blade-tenderized twice, prior to fabrication into steaks. The mean postmortem age of steak samples collected for evaluation was $20.6 \pm .09$ d. The steaks were immediately vacuum-packaged and placed on dry ice for transportation to Colorado State University. Following arrival, all steaks were individually numbered, repackaged, and transferred to a freezer where they were held at -30°C for approximately 60 d until removal for cooking and shear-force evaluation.

Shear-Force Evaluation. Steak samples were removed from the freezer and allowed to thaw in a 4°C

Table 1. Summary of injection-site damage (incidence and weight of lesions) in beef top sirloin butts

| Time period ^a | Packer locations ^b | Steak cutter locations ^c | Total primal cuts ^d | Incidence of lesions, % ^e | Average weight per lesion, g \pm SE ^f |
|--------------------------|-------------------------------|-------------------------------------|--------------------------------|--------------------------------------|--|
| July 1993 | CO, KS, IA, TX, NE, MI, IL | CA, CO, IA, IL, TN | 14,453 | 10.91 | 102.63 \pm 12.56 ^Z |
| November 1993 | CO, KS, TX, AZ, NE, IL, WI | CA, CO, IA, IL, TN | 11,076 | 13.94 | 103.76 \pm 11.45 ^Z |
| March 1994 | CO, KS, TX, NE, UT, WA, WI | CA, CO, IA, IL, TN | 13,318 | 15.33 | 109.43 \pm 11.96 ^Z |
| July 1994 | CO, KS, TX, NE, UT, IL, WI | AR, CO, IA, IL, TN | 13,302 | 13.73 | 139.20 \pm 10.60 ^{YZ} |
| November 1994 | CO, KS, TX, NE, MI, IL, WA | AR, CO, IA, IL, TN | 13,141 | 11.67 | 156.49 \pm 11.00 ^{XY} |
| March 1995 | CO, KS, TX, NE, AZ, UT, IL | AR, CA, CO, IL, TN | 18,292 | 10.70 | 173.50 \pm 9.36 ^X |
| July 1995 | CO, KS, TX, NE | AR, CO, IL, TN | 14,610 | 10.19 | 152.81 \pm 13.24 ^{XY} |

^aPeriod of time in which injection-site lesion audits were conducted.

^bPacker-location origin of top sirloin butts.

^cSteak-cutting facilities at which top sirloin butts were examined.

^dNumber of top sirloin butts examined.

^ePercentage of top sirloin butts that had injection-site lesions.

^fAverage weight per lesion after excision.

^{x,y,z}Mean values within a column lacking a common superscript letter differ ($P < .05$).

cooler for 24 h before cooking on a Hobart Char Broiler (model CB51, Hobart Corp., Troy, OH) to an internal temperature of 70°C ("medium" degree of doneness). The steaks were then allowed to cool to 21°C before core samples were removed. Before cooking, the injection-site lesion centers were marked with ink to ensure identification after cooking.

Following cooking, cores of 1.27 cm diameter were removed parallel to the muscle-fiber orientation from each steak. A core was removed from the center of the injection-site lesion, and four additional cores were taken at a radial distance of 2.54, 5.08, and 7.62 cm from the injection-site lesion center, as pictorially depicted by George et al. (1995b). Each core was sheared once with a Warner-Bratzler shear machine. The shear-force value at the lesion site and the average of the shear-force measurements for four cores at each distance of 2.54, 5.08, and 7.62 cm from the lesion center were calculated and recorded for each steak. Control steaks, selected from non-lesioned subprimals, had cores removed and shear force values determined in the same anatomical locations as those steaks afflicted with lesions.

Experiment 3. Concurrent with Exp. 2, paired normal ($n = 40$) and mild, chronologically aged, lesioned ($n = 40$) steaks, i.e., two adjacent normal steaks and two steaks from each lesion (such that 20 control subprimals and 20 lesioned subprimals were represented), were collected, transported, and stored as in Exp. 2. In this experiment, one steak chosen randomly from each lesioned steak pair and each normal steak pair was cooked to an internal temperature of 70°C, randomly cored, and sheared. The remaining normal steak and lesioned steak from each pair were then similarly cooked and fed to a trained eight-member sensory panel. All lesion-afflicted steaks identified for this experiment were selected to contain chronologically mature lesions and represented visually and palpably mild degrees of tissue damage such as not to be excessively offensive to the consenting panelists who were asked to consume

them. Steak samples were presented warm, cut into 1-cm \times 1-cm \times steak thickness cubes (Cross et al., 1978), in a darkened room, lit by soft red lights, for trained sensory evaluation. Each panelist independently evaluated each sample for tenderness, juiciness, and flavor intensity on 8-point scales (8 = extremely tender, juicy and intense; 1 = extremely tough, dry and bland).

Statistical Methods. Data representing percentage incidence of injection-site lesions were analyzed using the frequency procedure of SAS (SAS, 1991). Differences between incidence values and lesion classification as associated with the seven audit-time periods were tested for significance using the chi-square statistic. Means representing lesion weights and shear-force values in Exp. 2 and analysis of variance with the fixed effect of injection-site presence were determined using the GLM procedure of SAS (1991). Least significant differences were used to identify statistical differences among lesion weights.

Within each steak submitted for shear-force evaluation (Exp. 3), a mean and a standard deviation among all the individual cores from that steak were calculated. Data from sensory-panelist evaluation (for tenderness, juiciness, and flavor intensity) were Studentized within each panelist, to account for among-panelist variation, as follows: $y'_{ij} = (y_{ij} - \bar{y}_i)/s_i$, where y'_{ij} = Studentized individual panelist rating for an individual steak, y_{ij} = individual panelist rating on an individual steak, \bar{y}_i = individual panelist average, and, s_i = individual panelist standard deviation. Shear values, sensory-panel means, and within-steak standard deviations were analyzed using one-way analyses of variance for treatment (control vs lesioned steaks). Because of the unequal variances between the two treatments, the assumption of homogeneity of variances was violated. However, an overall F -test in an ANOVA is robust to unequal variances (Steel and Torrie, 1980). Therefore, it was not necessary to transform the data because no mean separation techniques were used. Among-steak variances for

Table 2. Percentage incidence of injection-site lesions stratified by packer location (state) for seven audits

| Packer location | July 1993 | November 1993 | March 1994 | July 1994 | November 1994 | March 1995 | July 1995 |
|-----------------|----------------|---------------|------------|-----------|---------------|------------|-----------|
| Colorado | 13.77 | 5.25 | 11.40 | 11.51 | 5.93 | 8.42 | 5.83 |
| Kansas | 9.46 | 18.63 | 17.08 | 13.00 | 14.15 | 10.94 | 7.45 |
| Nebraska | 14.26 | 12.77 | 21.61 | 12.10 | 8.79 | 13.75 | 16.86 |
| Texas | 12.24 | 16.10 | 14.47 | 15.82 | 9.76 | 9.01 | 11.18 |
| Illinois | 12.68 | 14.39 | — | 18.34 | 12.00 | 13.78 | — |
| Wisconsin | — ^a | 11.61 | 14.74 | 10.19 | — | — | — |
| Utah | — | — | 21.04 | 17.36 | — | 6.50 | — |
| Arizona | — | 9.78 | — | — | — | 7.55 | — |
| Washington | — | — | 16.75 | — | 17.33 | — | — |
| Michigan | 10.10 | — | — | — | 9.51 | — | — |
| Iowa | 7.18 | — | — | — | — | — | — |

^aDashes indicate that no data were obtained for cuts from this geographic packer location during this specific time period.

lesioned or control top sirloin steaks were thus compared using *F*-tests. Following statistical analyses, sensory-panel ratings were converted from Studentized values to their original scale using the overall mean and average within-panelist standard deviation.

Results and Discussion

Experiment 1. The average incidence of injection-site lesions in U.S. Choice top-sirloin butts for the time periods sampled are shown in Table 1. The injection-site lesion incidence in beef top sirloin butts did not differ ($P > .05$) during this period and is similar to the injection-site lesion incidence of 10.01% and 10.87% reported by Dexter et al. (1994) for November 1992 and March 1993, respectively. However, during the current audit period, the average weights of injection-site lesions removed from top sirloin butts during fabrication increased ($P < .05$) from 102.63 ± 12.56 during the July 1993 audit period to 152.81 ± 13.24 g during the July 1995 audit period (Table 1).

The reductions in both the national incidence of injection-site lesions and the weight of lesion trim removed during fabrication of top sirloin butts reported by Dexter et al. (1994) have not continued. Although there has been no statistical change in the lesion incidence, the average weight of trim required to remove these lesions has increased, peaking at 173.50 ± 9.36 g during March 1995. Dexter et al. (1994) reported a trend of increases in the national incidence of injection-site lesions in top sirloin subprimals, but not of lesion-trim weight, as is reported in the present study, during the March 1991 and March 1992 audit periods. Those researchers attributed the seasonal increases in lesion incidence to the climatic stress endured by those cattle before slaughter, and thus to the increased requirements to medicate greater numbers of these cattle.

Recently, a 1994 National Animal Health and Monitoring System (NAHMS) cow-calf productivity

survey (VS/APHIS/USDA, 1994) identified the producer-favored anatomical sites for intramuscular injections as 1) upper hip 52.0%; 2) lower hip 9.6%; 3) rump along tail 14.7%; 4) shoulder 3.4%; and 5) neck 19.8%.

Product from the major beef-packing states of Colorado, Kansas, Texas, and Nebraska was examined during each audit period (Table 2). Collectively, these states represent 64.37% of the 25,900,425 fed cattle slaughtered in the United States each year (FSIS/USDA, 1993). Moreover, these central states receive and feed over 17 million feeder cattle annually (Miller, 1995), and thus the feeder cattle population in these states represents an aggregate of many states that have extensive grazing activities but limited feeding facilities. Other states from which top sirloins originated that were included in audits of July 1993 through July 1995 included Illinois, Wisconsin, Utah, Arizona, Washington, Michigan, and Iowa. These data clearly demonstrate that the injection-site lesion problem occurs nationwide and is not peculiar to any one geographical region.

During the audit period, the percentage classifications of lesions as cystic, mineralized scar, clear scar, and woody callus did not differ ($P > .05$) (Table 3). However, the percentage of lesions classified as scar with nodules (lesions containing a central foci of necrosis, surrounded by granulomatous inflammation) representing lesions from the mid-late feedlot stage of production did increase ($P < .01$) during the period from July 1993 to July 1995. Overall, 80% of the lesions examined during the audits were classified as "older" lesions, characterized by an injection-site lesion consisting of organized connective tissue and fat (woody callus) or white fibrous scar tissue (clear scar).

A subclass of woody callus lesions, termed "Clostridial type" lesions, was identified during the audit (see below). Based on a controlled study (George et al., 1995a), 5-mL Clostridial bacterins injected 376 and 225 d preslaughter produced lesion incidence of 92.7 and 79.5%, respectively. Moreover, lesions der-

Table 3. Percentage incidence (of lesions excised) of injection-site lesions in each of five classifications

| Classification | July 1993 | November 1993 | March 1994 | July 1994 | November 1994 | March 1995 | July 1995 |
|--------------------------------|---------------------|---------------------|-------------------|---------------------|---------------------|---------------------|--------------------|
| Cystic ^a | .51 | .52 | .64 | .16 | .46 | .41 | .60 |
| Scar with nodules ^b | 16.38 ^{yz} | 12.24 ^{yz} | 8.91 ^z | 20.36 ^{xy} | 19.03 ^{xy} | 21.96 ^{xy} | 30.83 ^x |
| Mineralized scar ^c | — | — | .05 | — | — | — | — |
| Clear scar ^d | 51.11 | 52.72 | 65.67 | 59.61 | 58.54 | 56.69 | 44.06 |
| Woody callus ^e | 32.00 | 34.52 | 24.73 | 19.87 | 21.97 | 20.94 | 24.51 |

^aCystic = encapsulated lesion containing fluid.

^bScar with nodules = central foci of necrosis, surrounded by granulomatous inflammation.

^cMineralized scar = lesion (scar) containing mineralized remnants of muscle cells.

^dClear scar = older lesion primarily containing clear connective tissue.

^eWoody callus = older lesions that are characterized by the injection-site lesion being infiltrated with organized connective tissue and fat.

^{x,y,z}Means within a row lacking a common superscript letter differ ($P < .01$).

ived from use of both 2-mL and 5-mL Clostridial bacterins were visually distinct, discrete, circumscribed lesions. Histological evaluation identified those "Clostridial type" lesions to contain sheets of mature adipose cells with a few trapped muscle fibers and bands of dense connective tissue (George et al., 1995a). "Clostridial type" lesions, as a subclass, accounted for 5.42, 9.78, 7.31, and 7.66% of total lesions, or an overall lesion incidence of .74, 1.14, .78, and .78% in top sirloin butts during the audit periods of July 1994, November 1994, March 1995, and July 1995, respectively (data not presented in tabular form). The average trim required to remove these injection-site lesions during top sirloin fabrication did not differ ($P > .05$) between audit periods. This small contribution by "Clostridial type" lesions to the total injection-site lesion incidence reported in top-sirloin butts is similar to the (.85%) incidence of "Clostridial type" lesions observed during 1994 bottom-round audits (not reported in the scientific literature) conducted by the authors. This incidence is lower than that reported by a recent Cattle On Feed Evaluation (COFE) survey (VS/APHIS/USDA, 1995) that determined that 13.8% of large feedlots (38% of total feedlots) administer intramuscular Clostridial injections, of which 18.4% and 1.7% are injected into the upper rear leg and lower rear leg, respectively. The latter survey also reported that 23.1% of fed cattle receive greater than one injection of Clostridial vaccine during the feeding period. Overall, results of this survey (VS/APHIS/USDA, 1995) calculate to an approximate 3.13% incidence of Clostridial bacterins originating from the feedlot production phase. Combined, these data suggest that ongoing concentration of effort and resources of the National Cattlemen's Association, Beef Quality Assurance Task Force to lower incidence of injection-site lesions has encouraged the relocation of the majority of Clostridial bacterins (via subcutaneous routes, or intramuscular administration) into the economically lower-valued forequarter of the beef animal.

Examination of the weight \times class data (Table 4) for injection-site lesions collected during the purveyor audits identifies an increase ($P < .01$) in the mass of clear scar lesions from 77.96 ± 11.48 g in November 1993 to 133.81 ± 13.24 g in July 1995. The weights of injection-site lesion trim for those classified as scars with nodules and woody calluses, in top sirloin subprimals during steak fabrication, numerically increased during this period, peaking ($P < .01$) in March 1995. The large size of mature lesions (i.e., clear scars composed of white fibrous scar tissue and woody calluses composed of organized connective tissue and fat) has been attributed to a large volume of an irritant being injected and/or injection at an early age, after which lesions enlarge (George et al., 1995a,b).

However, in studies in which antimicrobials and Clostridial bacterins were administered 30 and 60 d

Table 4. Mean (\pm SE) weight (g) per injection-site lesion in each of five classifications

| Classification | July 1993 | November 1993 | March 1994 | July 1994 | November 1994 | March 1995 | July 1995 |
|--------------------------------|---------------------------------|---------------------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------------|----------------------------------|
| Cystic ^a | 203.76 \pm 84.74 | 199.30 \pm 79.64 | 210.36 \pm 62.94 | 214.04 \pm 102.80 | 307.54 \pm 79.38 | 295.12 \pm 62.94 | 368.83 \pm 79.64 |
| Scar with nodules ^b | 82.19 \pm 17.49 ^y | 100.93 \pm 16.93 ^y | 115.67 \pm 18.54 ^{xy} | 153.94 \pm 15.68 ^{wx} | 157.94 \pm 16.27 ^{wx} | 188.53 \pm 13.83 ^w | 147.42 \pm 19.56 ^{xy} |
| Mineralized scar ^c | — | — | 127.53 | — | — | — | — |
| Clear scar ^d | 91.25 \pm 11.87 ^z | 77.96 \pm 11.48 ^z | 93.27 \pm 12.56 ^{yz} | 114.53 \pm 10.63 ^{xy} | 142.60 \pm 11.03 ^{wx} | 150.26 \pm 9.36 ^w | 133.81 \pm 13.24 ^{wx} |
| Woody callus ^e | 133.48 \pm 16.95 ^x | 149.69 \pm 16.36 ^x | 150.54 \pm 17.92 ^x | 193.35 \pm 15.14 ^{wx} | 184.28 \pm 15.73 ^{wx} | 223.40 \pm 13.35 ^w | 182.29 \pm 18.91 ^{wx} |

^aCystic = encapsulated lesion containing fluid.

^bScar with nodules = central foci of necrosis, surrounded by granulomatous inflammation.

^cMineralized scar = lesion (scar) containing mineralized remnants of muscle cells. Not statistically analyzed due to limited numbers detected.

^dClear scar = lesion primarily containing clear connective tissue.

^eWoody callus = older lesions that are characterized by the injection-site lesion being infiltrated with organized connective tissue and fat.

^{w,x,y,z}Means within a row lacking a common superscript letter differ ($P < .01$).

preslaughter, a correlation coefficient ($P < .05$) of -0.34 was reported between injection-site dimensions (lesion volume and weight) and days before slaughter (Clayton et al., 1991). This suggests that the increase in lesion trim required to remove chronologically immature lesions, scars with nodules, and cystic lesions reported in the present investigation may be attributable to the administration of injections into the top-sirloin butt at times closer to the time of slaughter. VS/APHIS/USDA (1995) reported that 12.8% and 12.6% of feedlots administered intramuscular short-acting and long-acting antibiotics, respectively, into the upper rear leg.

The average total lesion weights, trimmed from top sirloin butts, of 156.49 ± 11.00 , 173.50 ± 9.36 , and 152.81 ± 13.24 g for the audit periods of November 1994, March 1995, and July 1995 are lower than the weight of 211.8 ± 79.88 g reported by George et al. (1995b) for lesions removed from 19,002 round cuts. Clayton et al. (1991) reported differences ($P < .05$) in lesion weight (207.43 vs 336.73 g) between top-sirloin and round cuts, respectively, when antimicrobial compounds were administered intramuscularly 30 to 60 d preslaughter.

Overall, these data suggest that the majority (70 to 80%) of the lesions identified from the 98,192 top sirloin butts audited from July 1993 through July 1995 originated from injections given during preweaning, stocking, and early feeding periods. However, the recent increase in lesion trim and the incidence of scars with nodules suggest that an increased proportion of injection-site lesions originate during the mid- to late-feeding periods.

Experiment 2. Warner-Bratzler shear force measurements for cores from the lesion site and from sites located 2.54, 5.08, and 7.62 cm away from the lesion core (Figure 1) were 5.90, 4.20, 3.57, and 2.98 kg, respectively, for lesion-afflicted steaks ($n = 160$), which was different ($P < .001$) at the lesion core, 2.54 cm away, and 5.08 cm away from the core and different ($P < .05$) 7.62 cm away from the core; corresponding measurements were 1.96, 2.25, 2.29, and 2.17 kg, respectively, for normal (control) steaks ($n = 40$). Eilers et al. (1993) reported that a shear-force value of 3.86 kg or less was an indication of "restaurant quality" beef.

The mean shear force measurements recorded for normal top sirloin steaks in the present study are considerably lower than the 4.85 kg reported by Harris et al. (1992) for steaks aged 21 d and than the 3.73 kg reported for Low Choice steaks in the Beef Customer Satisfaction Study (Reagan et al., 1995). These differences may be attributable to use of the blade tenderization process, which was applied twice to the top sirloin butts from which the steaks used in the present study were derived. The blade tenderization process, which is particularly effective in cuts containing relatively high concentrations of connective

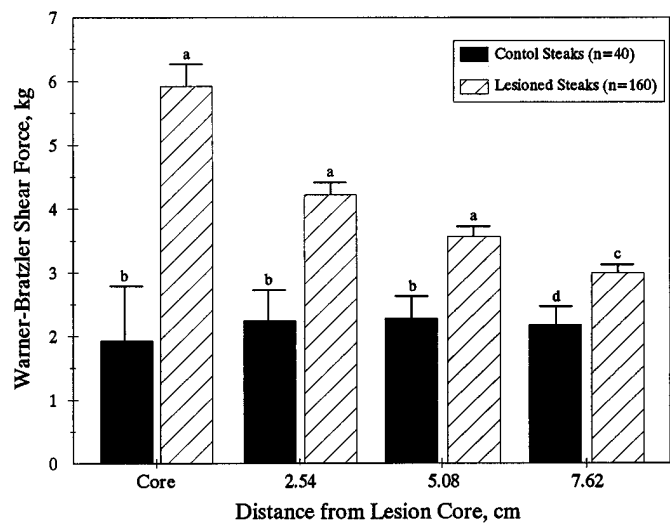


Figure 1. Warner-Bratzler shear force values for control (normal) and lesioned top sirloin steaks. ^{a,b}Means within the same distance from the lesion core lacking a common superscript letter differ ($P < .001$). ^{c,d}Means within the same distance from the lesion core lacking a common superscript letter differ ($P < .05$).

tissue, is reported to improve tenderness ratings by 19 to 32% (Davis et al., 1977; Savell et al., 1977). Light et al. (1985) observed a correlation between toughness and collagen content of muscles. Many researchers, including Smith et al. (1978), have demonstrated a characteristic improvement in beef tenderness during postmortem aging in response to myofibrillar protein degradation by endogenous proteases. Light (1985) concluded that there are minimal effects by muscle proteases on collagen during the conditioning process. Thus, the higher shear force values reported for lesioned steaks as compared to those for control top sirloin steaks in the present study was attributed to higher concentrations of connective tissue (not degraded by postmortem aging), even though a substantial physical disruption of connective tissue is accomplished by the blade tenderization process.

George et al. (1995b) reported Warner-Bratzler shear-force determinations of cores from lesioned bottom round steaks vs those of control (normal) bottom round steaks were 13.87, 10.00, 7.60, and 5.80 kg vs 3.97, 4.11, 4.30, and 3.90 kg, respectively, for cores removed at the site of the lesion (lesion core) and at distances 2.54, 5.08, and 7.62 cm away from the lesion center, respectively. Moreover, the latter researchers reported the concentrations of total collagen at the site of the injection-site lesion and at sites 2.54 and 5.08 cm away from the lesion center were 36.12, 19.85, and 8.16 mg/g, whereas that for control bottom round steaks was 10.67 mg/g. The latter data provide concrete evidence that a fibroproliferative process occurred subsequent to the intramuscular

injection of a pharmacologic agent.

Kakulas (1982) reported that the intramuscular injection of a number of commercially available antibiotics produced skeletal muscle damage in mice. In wound healing, if the original insult disrupts the scaffolding formed by the basal lamina, reticulin network, and(or) if the basic pathologic process does not subside, newly formed muscle fibers will be surrounded by proliferating fibroblasts (Adams et al., 1962).

Although not examined in the present study, Harris et al. (1992) reported a total collagen concentration of 6.91 mg/g for muscle of normal top sirloin steaks, which is lower than the 10.67 mg/g reported by George et al. (1995b) for control bottom round steaks. This suggests that there is less endogenous connective tissue (thus lower fibroblast activity) in top sirloin vs bottom round subprimals, with a concurrent diminished potential to respond (as a fibroproliferative process) during inflammation, which accompanies many intramuscular injections. Thus, the less dramatic increases in shear measurements reported in the present investigation compared to those observed in the bottom round (George et al., 1995b) may be the result of a combination of factors including the lower

fibroproliferative potential of top sirloin butts and the extensive blade-tenderization process applied to these steaks.

Regardless, results of the present study provide substantial evidence that when injections are administered intramuscularly into the top-sirloin butt of beef cattle the shear values of steaks fabricated from those subprimals are increased between 30 and 200% in an area up to 7.62 cm away from the lesion center.

Experiment 3. Mean Warner-Bratzler shear-force values from steaks afflicted with visually and palpably mild injection-site lesions vs those for control (normal) top-sirloin steaks were 3.44 vs 2.06 kg, respectively (Figure 2). These results support the findings reported in Exp. 2. Moreover, closer examination of the shear-force data identified a tremendous amount ($P < .01$) of within-steak variation for the lesioned steaks compared with the control steaks (Figure 2), as well as greater variation ($P < .01$) among lesioned vs control steaks (Figure 3).

Lesioned steaks had greater panelist tenderness rating variation within ($P < .01$) and among ($P < .05$) steaks compared with control top sirloin steaks (Figures 2 and 3). Approximately 50% of the lesioned steaks had tenderness ratings less than 4.5 (midpoint

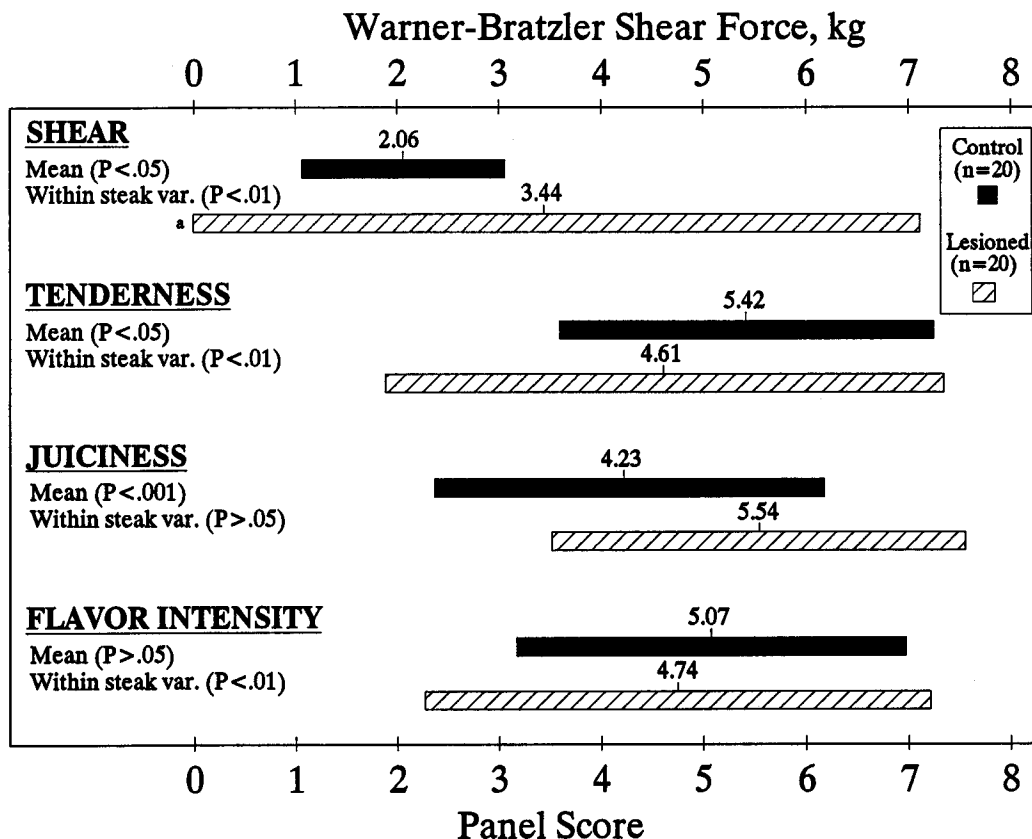


Figure 2. Variation (mean \pm 2 SD) within control and lesioned top sirloin steaks. Sensory panel scores were 8 = extremely tender, juicy, and intense; 1 = extremely tough, dry, and bland. ^aStandard deviation values less than 0 are not shown.

of the rating scale), and of the 50% acceptable lesioned steaks, approximately 50% had portions of that steak with less than acceptable tenderness characteristics. The extensive variation evidenced by shear-force measurements and panel tenderness ratings corresponds to the large variations in collagen concentrations reported within lesioned bottom round steaks (George et al., 1995b).

Mean juiciness ratings were higher ($P < .001$) for lesioned than for control top sirloin steaks (Figure 2). However, variances for juiciness within lesioned vs control steaks, or among lesioned or control top sirloin steaks, did not ($P > .05$) differ (Figures 2 and 3). Smith et al. (1984) reported that steaks from carcasses with higher marbling scores (indicative of more intramuscular fat) were more ($P < .05$) desirable in mean juiciness ratings, for 39.3% of comparisons, than steaks from carcasses with lower marbling scores.

Following muscle trauma, a process of steatosis, the infiltration of an increased amount of organized connective tissue and fat, occurs (Infante-Gil and Costa-Durao, 1990; Herenda and Franco, 1991), the relative proportions of these two tissues depending on the class of compound administered (George et al., 1995a). George et al. (1995b) reported from histologi-

cal sections the relative percentage points of fat at the lesion center and 2.54 cm away and 5.08 cm away from the lesion center to be 19.38, 52.50, and 15.63%, respectively, vs 11.67% for control round steaks. The increase in intramuscular lipid as a part of the normal tissue-repair process apparently contributed positively to the juiciness of injection-site lesion-afflicted steaks.

Sensory evaluation of steak flavor intensity was not different ($P > .05$) between lesioned and control steaks, nor was flavor intensity variation different among lesioned and control top sirloin steaks (Figure 3). However, steak flavor intensity variation was greater ($P < .01$) within injection-site lesion-afflicted vs control top sirloin steaks (Figure 2), and a number of panelists noted undesirable flavors in some of the lesion-afflicted steaks. Recently, Reagan et al. (1995) reported that flavor desirability and tenderness are equally correlated (.86 and .85, respectively) and equally important in determining consumers' overall desirability (like) ratings in beef steaks.

Overall, results of Warner-Bratzler and sensory panelist evaluations of mildly lesion-afflicted top sirloin steaks indicated a significant increase in mean shear force values, a significant decrease in tenderness scores, and increased tenderness variation within

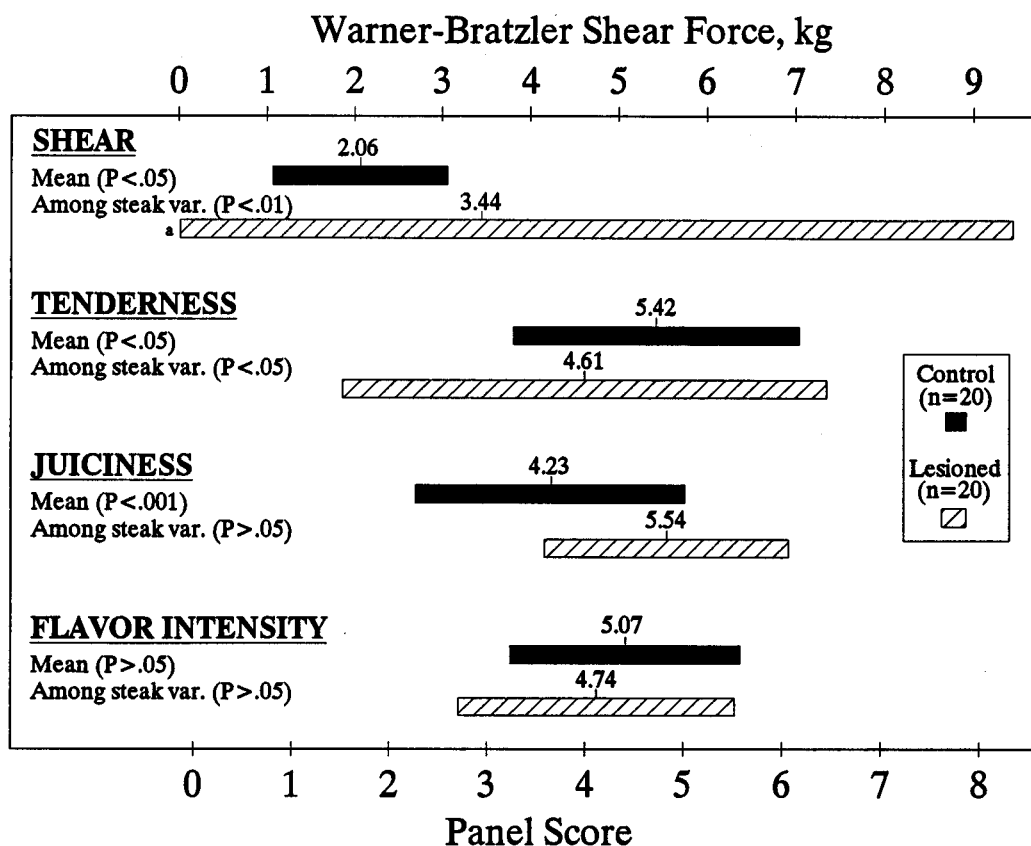


Figure 3. Variation (mean \pm 2 SD) among control and lesioned top sirloin steaks. Sensory panel scores were 8 = extremely tender, juicy, and intense; 1 = extremely tough, dry, and bland. ^aStandard deviation values less than 0 are not shown.

individual and among individual injection-site lesion-afflicted steaks compared with control top sirloin steaks. Although compared to control steaks there was an increase in the juiciness of lesioned steaks, significant variation in flavor intensity observed within these steaks would further contribute to the less than desirable eating experience of consuming a mildly lesion-afflicted steak.

Implications

Injection-site lesions represent a serious quality assurance problem and a huge economic loss to the U.S. beef industry. Utilizing the procedures used previously to document industry losses from injection-site damage in the top sirloin butt, the national cost of a 152.81-g lesion occurring in 10.19% of all top-sirloin butts represents a annual monetary loss of \$30,764,832 to the U.S. beef industry. However, the true costs of injection-site lesions, in terms of customer dissatisfaction from extremely variable and undesirable eating experiences (estimated to occur in approximately 21.6 million meals), as a consequence of inadequate trimming of lesion-afflicted top sirloin butts, may greatly exceed those losses from tissue trim alone.

Literature Cited

- Adams, R. D., D. E. Denny-Brown, and C. M. Pearson. 1962. In: *Diseases of Muscle* (2nd Ed.). Hoeber Publishing Company, New York.
- Clayton, R. P., R. P. Kerschen, M. F. Miller, R. A. Bowling, and C. Huffhines. 1991. Determination of the factors that affect the incidence of injection-site lesions and granulomas in beef steaks. The Final Report of a Study Conducted by Conagra Red Meat Companies Inc., for the National Cattlemen's Association. Warren Analytical Laboratory, Greeley, CO.
- Cross, H. R., R. Moen, and M. S. Stanfield. 1978. Training and testing judges for sensory analysis of meat quality. *Food Technol.* 32(7):48.
- Davis, G. W., G. C. Smith, and Z. L. Carpenter. 1977. Effect of blade tenderization on storage-life, retail caselife and palatability of beef. *J. Food Sci.* 42:1496.
- Dexter, D. R., G. L. Cowman, J. B. Morgan, R. P. Clayton, J. D. Tatum, J. N. Sofos, G. R. Schmidt, R. D. Glock, and G. C. Smith. 1994. Incidence of injection-site blemishes in beef top sirloin butts. *J. Anim. Sci.* 72:824.
- Eilers, J. D., J. D. Tatum, J. B. Morgan, and G. C. Smith. 1993. Quality losses—due to producer-related problems—from cattle in the Strategic Alliance Field Study. In: Final Report of the Colorado State Portion of the Strategic Alliance Field Study. Department of Animal Sciences, Colorado State Univ., Fort Collins.
- FSIS/USDA. 1993. Livestock Slaughtered in USDA-Inspected Establishments. Slaughter Standards and Procedures Division, Food Safety and Inspection Service, U.S. Department of Agriculture, Washington, DC.
- George, M. H., P. E. Heinrich, D. R. Dexter, J. B. Morgan, K. G. Odde, R. D. Glock, J. D. Tatum, G. L. Cowman, and G. C. Smith. 1995a. Injection-site lesions in carcasses produced by cattle receiving injections at branding and at weaning. *J. Anim. Sci.* 73:3235.
- George, M. H., J. B. Morgan, R. D. Glock, J. D. Tatum, G. R. Schmidt, J. N. Sofos, G. L. Cowman, and G. C. Smith. 1995b. Injection-site lesions: Incidence, tissue histology, collagen concentration, and muscle tenderness in beef rounds. *J. Anim. Sci.* 73:3510.
- Harris, J. J., R. K. Miller, J. W. Savell, H. R. Cross, and L. J. Ringer. 1992. Evaluation of the tenderness of beef top sirloin steaks. *J. Food Sci.* 57:7.
- Herenda, D. C., and D. A. Franco. 1991. Musculoskeletal systems. In: *Food Animal Pathology and Meat Hygiene*. p 147. Mosby-Year Book, St. Louis, MO.
- Infante-Gil, J., and J. Costa-Durao. 1990. The carcass—bones, muscles, joints tendons and ligaments. In: *A Color Atlas of Meat Inspection*. p 64. Wolf Publishing, Ltd., London.
- Kakulas, B. A. 1982. Toxic and drug induced myopathies. In: F. K. Mastaglia and Sir J. Walton (Ed.) *Skeletal Muscle Pathology*. pp 592–620. Churchill Livingstone, New York.
- Lambert, C. D. 1991. Lost Opportunities in Beef Production. Presented to the International Stockmen's School. February 14, 1991 in Houston, TX. National Cattlemen's Association, Englewood, CO.
- Light, N. D. 1985. The role of collagen in determining the texture of meat. In: A. M. Pearson, T. R. Dutson, and A. J. Bailey (Ed.) *Collagen as a Food: Advances in Meat Research*. pp 87–107. Van Nostrand Reinhold Company, New York.
- Light, N. D., A. E. Champion, C. Voyle, and A. J. Bailey. 1985. The role of epimysial, perimysial and endomysial collagen in determining texture in six bovine muscles. *Meat Sci.* 13:137.
- Miller, B. 1995. Where the cows are. In: *Beef Today*, March Issue. pp 12–13. Farm Journal Inc., Washington Square, Philadelphia, PA.
- Reagan, J. O., M. J. Buyck, J. Bellinger, M. Schiller, D. F. Haley, J. Dyer, J. D. Tatum, J. W. Wise, J. W. Savell, R. K. Miller, T. R. Neeley, C. L. Lorenzen, and J. F. Taylor. 1995. Beef Customer Satisfaction. Report to the Industry—A Comprehensive In-Home Product Test Among Frequent Beef Consumers. pp 1–38. National Live Stock and Meat Board, Chicago, IL.
- SAS. 1991. SAS User's Guide: Statistics (Version 6, 4th Ed.). SAS Inst. Inc., Cary, NC.
- Savell, J. W., G. C. Smith, and Z. L. Carpenter. 1977. Blade tenderization of four muscles from three weight-grade groups of beef. *J. Food Sci.* 42:868.
- Smith, G. C., Z. L. Carpenter, H. R. Cross, C. E. Murphey, H. C. Abraham, J. W. Savell, G. W. Davis, B. W. Berry, and F. C. Parrish, Jr. 1984. Relationship of USDA marbling groups to palatability of cooked beef. *J. Food Qual.* 7:289.
- Smith, G. C., G. R. Culp, and Z. L. Carpenter. 1978. Postmortem aging of beef carcasses. *J. Food Sci.* 43:823.
- Smith, G. C., J. W. Savell, R. P. Clayton, T. G. Field, D. B. Griffin, D. S. Hale, M. F. Miller, T. H. Montgomery, J. B. Morgan, J. D. Tatum, J. W. Wise, D. L. Wilkes, and C. D. Lambert. 1992. Improving the consistency and competitiveness of beef. The Final Report of the National Beef Quality Audit—1991. pp 1–237. National Cattlemen's Association, Englewood, CO.
- Steel, R.G.D., and J. H. Torrie. 1980. *Principles and Procedures of Statistics: A Biometrical Approach* (2nd Ed.). McGraw-Hill Publishing Co., New York.
- VS/APHIS/USDA. 1994. Beef Cow-Calf Health and Productivity Audit. Part V, Quality Assurance Profile. pp 1–24. Centers for Epidemiology and Animal Health, National Health and Monitoring System, Veterinary Services, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Fort Collins, CO.
- VS/APHIS/USDA. 1995. Cattle on Feed Evaluation. Part II, Feedlot Health Management Report. pp 1–20. Centers for Epidemiology and Animal Health, National Health and Monitoring System, Veterinary Services, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Fort Collins, CO.

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