EFFECT OF POSTMORTEM TENDERIZATION STRATEGIES (ENHANCEMENT, BLADE TENDERIZATION AND PRE-TUMBLING) ON PROPERTIES OF THE *GLUTEUS MEDIUS* FROM MATURE BEEF COWS

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***Abstract*—The impact of individual and combined tenderness enhancement strategies, including pre-tumbling (PT), blade tenderization (BT) and moisture enhancement (ME), on processing characteristics and eating quality of *gluteus medius* (GM) muscles from youthful (<18 months) and mature beef was investigated. The results of this study indicate that muscles from mature beef cows were inherently less tender, but several postmortem tenderization procedures produced meat that was similar in tenderness to that of youthful cattle. All tenderization strategies significantly (*$p<0.05$*) reduced Warner-Bratzler shear force (WBSF) of GM muscles with combinations of BT or PT with ME being the most successful in shear force reduction. However BT followed by ME was the most effective in improving sensory tenderness. Moisture enhancement significantly (*$p<0.001$*) reduced WBSF values and improved tenderness and juiciness of GM muscles. Pre-tumbling was equally effective as blade tenderization and is a non-invasive tenderization strategy that may offer modest improvements to tenderness of muscles that are relatively low in connective tissue such as the gluteus. Of the different tenderization strategies evaluated, injection with a salt and phosphate solution was the most effective single strategy for improving tenderness and juiciness of top sirloin butt (*gluteus medius)* steaks.**

***Index Terms*—beef tenderness, blade tenderization, moisture enhancement, pre-tumbling**

I. INTRODUCTION

Following the first case of BSE in Canada in 2003, various trade restrictions have slowed movement of live cattle and beef products. This has resulted in greater availability of D-grade (commercial) beef from mature cows within Canada. Canada has over 5 million beef cows, and normally culls between eight and ten per cent each year. Previous research has shown that while the flavour and juiciness of commercial beef is often equivalent, or even superior, to beef from youthful cattle, its tenderness is inferior. As a result, it has failed to provide customer satisfaction. Even modest improvements in the processing of mature cattle to create higher-valued beef products would result in millions of dollars of benefit to the beef industry. Various postmortem tenderization strategies are becoming more popular and may help to mitigate the toughness of mature beef. It may be possible to use these techniques to increase the overall marketability of commercial beef.

The top sirloin (*gluteus medius, GM*) is an economical alternative to more expensive "middle meat" cuts, but has been reported to be inconsistent in eating quality, resulting in diminished customer satisfacation (Savell, Lorenzen, Neely, Miller, & Reagan, 1999). King, Wheeler, Shackelford, Pfeiffer, Nickelson, and Koohmaraie (2009) concluded that longer aging could be used to augment tenderness for *longissimus* steaks but not for *gluteus* steaks. Injection of a combination of ingredients such as sodium tripolyphosphate, sodium chloride, and sodium lactate has been demonstrated to improve less tender beef cuts and aid in meeting the demands of consumers for more consistent, higher quality and convenient meat products (McGee, Henry, Brooks, Ray & Morgan, 2003). Blade tenderization has been shown to be effective for some cuts but not others. Tatum, Smith, and Carpenter (1978) reported that mechanical tenderization offers no advantages when using meat that is already of acceptable tenderness. It was suggested that the effects of tenderization on shear or sensory tenderness were insignificant when used with meat of very high functional quality or tenderized by other methods but more favorable in low-quality tougher muscles. George-Evins, Unruh, Waylan, and Marsden (2004) observed improved ratings for myofibrillar tenderness, connective tissue amount and overall tenderness for blade tenderized top sirloin butt steaks from youthful cattle. Tenderization of muscles from mature animals may require a combination of intervention strategies.

There is increased concern about the potential food safety risks of nonintact meat products and processors are seeking strategies to ensure adequate meat tenderness without blade tenderization. Pre-tumbling or massaging may be useful as a non-invasive method to aid in tenderizing steaks. Pietrasik and Shand (2005) found that pre-massaging of beef semimembranosus roasts for 30 min increased cook yield by 1% and decreased shear by about 0.8 kg. Further exploration of its effects on other cuts is warranted.

The objective of this study was to study the effects of postmortem technology combinations (blade tenderization, moisture enhancement and pre-tumbling) on cooking characteristics and tenderness of gluteus medius steaks from top sirloin butts from youthful and mature beef cattle.

II. MATERIALS AND METHODS

Meat selection and processing- Twelve beef heifers (AA or higher, average age 17 months), twelve D1 and twelve D2 cows (average age of 76 and 88 months, respectively) were conventionally slaughtered. Following 48 h chilling at 4°C, the *gluteus medius* (GM) muscles from both sides were collected, labeled to maintain carcass and side identity, and vacuum packaged. All muscles were aged at 3°C until 12 d postmortem. Then, the GM was trimmed of visible, external fat and connective tissue (completely denuded). The dorsal end of the GM muscle had a grain that is inconsistent with the fibre direction of the rest of the cut so the dorsal portion of the GM was first removed along the fat seam and then the remaining section was cut in half perpendicular to the fiber direction, to create three muscle locations: dorsal, anterior and posterior. The roasts from one side were assigned to one of three treatments, that is, non-treated beef (C), blade tenderized (BT), pre-tumbled for 30 min (PT). The roasts from the other side received one of the following treatments: moisture enhanced treatment (ME), blade tenderized followed by moisture enhancement (BT+ME) and pre-tumbling followed by moisture enhancement (PT+ME). Location within muscle was balanced to ensure that all treatments are assigned to all locations. Non-injected roasts (C) were placed directly into bags, vacuum packaged and refrigerated for 48 h at 4°C. The roasts designated for blade tenderization (BT and BT+ME treatments) were blade tenderized by one pass through a Jaccard®, Model H # B4590 meat tenderizer (Jaccard®, Orchard Park, NY, USA). The PT and PT+ME treatments were subjected to pre-tumbling (8.5 rpm) for 30 min at 4-6°C in a Vario-Vac tumbler (Model #VV1-150, Killvoangen, Germany) with no vacuum. Roasts designated for injection (ME, BT+ME, and PT+ME treatments) were then injected using a Reiser Fomaco multi-needle injector (Model FGM 20/40, Fomaco Reiser Ltd., Burlington, ON) to 112% over the raw meat weight with brine formulated to give 0.4% salt and 0.3% sodium tripolyphosphate in the final product. After injection, the muscle samples were vacuum packaged and stored for 48 h at 4°C. Then, two 2.54 cm thick steaks were obtained by cutting perpendicular to the muscle fiber orientation. The steaks were vacuum packaged, frozen in a blast-freezer and stored at –30°C until evaluation.

Proximate analysis and pH- Total moisture (Method No. 950.46 B), crude protein (Method No. 981.10) and total collagen (Method No. 990.26) contents were determined in duplicate following AOAC (2000) procedures. The pH values of raw beef were measured in duplicate on a homogenate of 20 g sample in 80-mL deionized water.

Warner-Bratzler shear force- Steaks were thawed in a cooler at 4°C for 24 h, cooked using a Garland electric grill (preheated to 210°C) until the internal temperature reached 35ºC, turned and cooked to 71ºC. The shear force of 7-9 core samples (1.27x1.27x2.54cm) cut parallel to the fibre direction from each cooked steak was determined. Samples were sheared perpendicular to the fibre direction using a TMS-Pro texture system (Food Technology Corp., Sterling, VA, USA) fitted with a Warner-Bratzler shear attachment, and with crosshead speed set to 200 $mm \cdot min^{-1}$. Force-deformation curves from the Warner-Bratzler shear device were used to determine WBSF, myofibrillar component (SF-Myo) and WBSF connective tissue component (SF-Ct). The initial yield (height of the first peak) corresponded to SF-M and the final yield (height of the second peak) corresponded to SF-Ct, both of which were measured from the shear curves as suggested by Møller (1981). Maximum peak force recorded during the test was reported as Warner-Bratzler shear force (WBSF).

Cooking loss and yield, and expressible moisture (EM)- Cooking loss = (raw weight at cooking -cooked weight /raw weight at cooking) x 100, was recorded for each steak. Cooking time / 100g = (the time taken by each steak to reach 71°C internal temperature / weight of the steak) x 100, was also calculated for each steak. Cooking yield was expressed as a percentage of green weight (*i.e.,* cooked weight/raw non-injected weight x 100). EM was determined on grilled steak samples by a modified method as described by Pietrasik & Li-Chan (2002).

Sensory properties- Steaks were thawed in a cooler at 4°C for 24 h, and cooked as previously described. Using an eight-point scale, an experienced 10-member sensory panel scored samples for initial and overall tenderness, juiciness, flavor intensity, connective tissue amount and off-flavor intensity (8=extremely tender, juicy, intense, none, none; 1=extremely tough, dry, bland, abundant, and intense).

Statistical analysis- The experimental design was a split-plot with twelve replications. Beef grades were the main plot treatment. Sub-plot treatments included the six tenderization treatments. All variables were analyzed using SAS PROC MIXED. Least-squares means were calculated for main effects or interactions that were represented by a significant *F*-test.

III. RESULTS AND DISCUSSION

Table 1 and 2 show effects of grade and tenderization treatment on cooking properties, shear values and sensory data. There were no significant interactions of grade with the six tenderization treatments, indicating that both youthful and mature beef were similarly affected by various tenderization treatments. No difference among grades was observed for cooking loss **(Table 1).** Blade tenderization significantly ($p<0.05$) increased cooking losses compared to the control but no significant effect on cook loss was found due to pretumbling or moisture enhancement. Injection of brine containing salt/phosphate after blade tenderization was able to bring the cook loss back up to the value observed for control samples. Moisture enhancement had a beneficial effect on overall yield of cooked samples. Cooking yield expressed as a percentage of green weight for injected samples was significantly ($p < 0.05$) higher compared to non-injected muscles **(Table 1).**

Expressible moisture (EM) is a measure of free water in the cooked product and may be an indicator of purge to be expected in the packaged product (Shand, 2000). Cooked steaks from muscles obtained from D2 mature cattle had significantly lower EM than did steaks from youthful animals but did not differ from D1 samples in amount of released fluid (**Table 1**). EM was also significantly ($p<0.05$) affected by the tenderization treatments. Injected steaks had significantly higher EM than beef steaks made from non-injected meat indicating that there is more free moisture in the product as a result of brine addition. The muscles that had been subjected to blade tenderization exhibited lower EM compared to those that were not tenderized, likely due to the greater cook loss experienced by the BT steaks.

Muscles from youthful cattle had significantly lower shear force values than muscles from mature animals (**Table 1**). There was no significant difference in shear force values between the two grades of mature cattle. All tenderization strategies significantly ($p<0.05$) reduced shear force of GM muscles **(Table 1)** with combinations of BT or pre-tumbling (PT) with ME being the most successful in WBSF reduction. However BT followed by ME was the most effective in improving sensory tenderness. PT provided equivalent tenderization to BT for not injected steaks but it did not bring additional benefits to moisture enhanced steaks. All tenderization treatments were able to reduce WBSF of GM from mature cattle to the level of control samples from youthful animals.

Enhancement with salt/phosphate solution had a beneficial effect on juiciness and sensory tenderness of *gluteus medius* steaks **(Table 2)**. In general, non-enhanced steaks were less juicy and also received lower scores for initial and overall tenderness and amount of connective tissue than those injected with salt/phosphate brine. Mechanical tenderization and pretumbling applied alone (not followed by ME) also improved ($p<0.05$) initial and overall tenderness and made the connective tissue less perceptible compared to controls. However, BT or PT did not bring any additional benefits to ME steaks. Blade tenderization significantly ($p<0.05$) decreased juiciness but only in non enhanced muscles. Sensory tenderness of moisture enhanced GM muscles from mature cattle was equivalent to that of not treated youthful beef. Injection with the phosphate/chloride solutions increased panel ratings for salty flavor compared with not-enhanced steaks, however this did not lead to adverse effects on beef flavour. In fact none of the tenderization treatments negatively affected beef flavour intensity.

IV. CONCLUSION

Top sirloin steaks from youthful cattle had significantly lower shear force, higher tenderness values and lower amounts of perceived connective tissue than that from mature animals. There was no significant difference in palatabililty between the two grades of mature cattle. Of the different tenderization strategies evaluated, BT followed by injection with a salt and phosphate solution resulted in the lowest WBSF values and was more effective in improving tenderness than pre-tumbling and blade tenderization applied alone, which gave similar reductions in shear force. Moisture enhancement also resulted in steaks with the highest juiciness and greatest yield after cooking. Pretumbling was non-invasive and offered some tenderization to the *gluteus*. Several of the postmortem tenderization strategies allowed meat from mature cows to be of similar tenderness to that of the youthful cattle used in this study, thus explanding possible uses for GM from mature cattle.

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Table 1. Processing characteristics and Warner Bratzler shear force of beef *gluteus medius* steaks.

	pH	Cook loss [%]	Cook time [min]	Yield [%]	EM[w] [%]	WBSF[w] (N)	SF-Myo (N)	SF-Ct (N)
Grade								
D1	5.55	32.4	22.1	70.3	14.5ab	58.5a	56.1a	51.3a
D2	5.55	31.9	23.1	72.5	14.0b	56.6a	52.9a	50.7a
Y1	5.56	31.0	22.4	71.9	15.5a	47.7b	46.8b	37.5b
SEM[y]	0.01	0.49	0.84	0.8	0.47	2.05	1.90	2.12
Treatment								
Control (C)	5.44b	31.4bc	25.4a	68.1c	14.3b	64.9a	63.2a	51.1a
Blade tenderized (BT)	5.47b	32.5a	22.8b	66.7c	12.7c	55.5bc	54.4b	45.4b
Pretumbled (PT)	5.47b	30.9c	22.5b	68.1c	13.8b	58.1b	55.3b	50.8a
Moisture enhanced (ME)	5.66a	31.3bc	22.4b	76.4a	16.0a	52.3cd	48.9c	46.2b
BT+ME	5.61a	32.3ab	20.8b	74.4b	14.6b	45.7e	44.1d	40.3c
PT+ME	5.66a	32.2ab	21.2b	75.5ab	16.5a	49.1de	45.6cd	45.2b
SEM[y]	0.01	0.43	0.75	0.70	0.43	1.74	1.66	1.70

a-e, Means with different letters in the same column (within each main effect) are significantly different (P<0.05); [w]EM, expressible moisture; [y]SEM, standard error of the mean
[w]WBSF, peak shear force value; SF-Myo, myofibrillar component of WBSF; SF-Ct, connective tissue component of WBSF

Table 2. Mean ratings for sensory attributes[w] of *gluteus medius* steaks from young and mature cattle.

	Initial tenderness	Juiciness	Beef flavour intensity	Saltiness	Amount of connective tissue	Overall tenderness
Grade						
D1	5.0b	4.2	3.9	6.8	5.4b	5.1b
D2	5.1b	4.4	3.8	6.7	5.4b	5.1b
Y1	6.0a	4.3	3.9	6.8	6.5a	6.2a
SEM[y]	0.14	0.11	0.07	0.04	0.13	0.13
Treatment						
Control (C)	4.7d	3.8b	3.9ab	7.4a	5.4d	4.9c
Blade tenderized (BT)	5.3c	3.5c	4.1a	7.4a	5.9ab	5.2b
Pretumbled (PT)	5.1c	3.9b	3.9ab	7.4a	5.6cd	5.2b
Moisture enhanced (ME)	5.6b	5.0a	3.7b	6.2b	5.8bc	5.8a
BT+ME	6.0a	4.7a	4.0a	6.2b	6.1a	6.0a
PT+ME	5.6b	4.8a	3.7b	6.2b	5.7bc	5.8a
SEM[y]	0.12	0.10	0.07	0.04	0.09	0.10

a-c, Means with different letters in the same column (within each main effect) are significantly different (P<0.05);
[w]Intensity of sensory attributes was evaluated based on an 8-point scale (8=extremely tender, juicy, intense, none, none; 1=extremely tough, dry, bland, abundant, and intense). [y]SEM, standard error of the mean.