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A modified hot processing strategy for beef: effects on fresh meat quality

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A modified hot processing (MHP) strategy for beef carcasses using known chilling technology to maintain quality in the higher priced cuts while retaining lower value cuts for further, immediate hot processing was evaluated. Following high voltage electrical stimulation, paired sides from 36 carcasses were either conventionally processed (CP) or reduced in a manner similar to the French pan traité cut. The sides were held in a pre-chiller for 1 h prior to blast chilling at –20°C for 3 h at an air speed of 2·3 m s^{-1}, followed by chilling at 2°C for the remainder of the 24 h period. Overall, MHP of beef carcass sides had minimal effects on fresh meat quality in the *longissimus thoracis et lumborum* (LTL) and the *semimembranosus* (SM) muscles despite removing over 50% of the carcass side weight in the form of lower value cuts. Sarcomere length was significantly shorter ($P \leq 0{\cdot}05$) in the anterior (AL) and posterior (PL) LTL which was attributed to the removal of skeletal restraint and carcass weight. The increase in shear value in the AL, location of MHP sides although statistically significant ($P \leq 0{\cdot}05$) would not likely be perceived by consumers. Hence a non-traditional method of processing carcasses by treating low value and high value primal cuts separately, may be viable.

Keywords: Beef quality, novel processing system.

INTRODUCTION

Traditionally in North America beef carcasses are split into two sides on the slaughter floor and cooled at 0–2°C for 24 h prior to grading. This method of processing is simple and convenient, and has relatively predictable effects on meat quality. However, chilling of tissues of low commercial value (fat, bone and low-priced cuts) is energetically inefficient. To reduce the amount of refrigeration energy required and to accelerate cooling, hot boning (or hot processing) of the carcass prior to chilling has been introduced. Unfortunately the removal of skeletal restraint and problems associated with cold toughening of pre-rigor meat pieces of smaller size (Reagan, 1983) has prevented widespread implementation of hot boning technology.

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The 'rule of thumb' to prevent cold shortening in beef is to prevent the carcass musculature from cooling below 10°C before 10 h post-mortem (Bendall, 1972) or before the pH has fallen below a value of 6 (Davey & Gilbert 1974). This negates the economic benefits of rapid chilling associated with process time and lower moisture loss. However, two alternatives have been suggested which can reduce the development of cold shortening (Locker, 1985). Firstly, electrical stimulation prior to chilling rapidly depletes the supply of ATP, hastening the onset of rigor and thereby eliminating the possibility of cold shortening. Secondly, hanging the carcass by the aitch bone takes advantage of the skeletal restraints and improves the tenderness of the *longissimus* and major muscles of the hind leg (Hostetler *et al.*, 1972; Jeremiah *et al.*, 1985). These muscles are the most valuable retail cuts, yet under normal hanging conditions these muscles are highly susceptible to shortening because of the lack of skeletal restraint.

Recently, Aalhus and Jones (1989) suggested that an alternate method of carcass processing should be explored, in order to separate high and low value cuts at an early time post-mortem. Thus the purpose of this study was to evaluate a novel processing strategy for beef carcasses that would maintain quality in the higher priced cuts while lower value cuts could be trimmed of non-essential tissues (fat and bone) and further processed for maximum overall production efficiency. This system, which is described below, is referred to as a modified hot processing (MHP) system. The results of this study are presented as a series of three papers. The present paper focuses on the effects of MHP on fresh meat quality. A second paper (Gariepy *et al.*, 1994) focuses on the changes to the quality of processed meat products derived from the lower value meat tissues removed by the MHP method. Finally, a paper by McGinnis *et al.* (1994) describes the energy efficiency of this process technique.

MATERIALS AND METHODS

Thirty-six Angus heifers were blocked by weight and randomly assigned within weight blocks to one of six pens. The heifers were finished in the feedlot over a period of 8 weeks to an average weight of 437 ± 19·4 kg and an estimated fat thickness between 4 and 10 mm. Each pen was assigned to a slaughter date on either Tuesday or Thursday for 3 consecutive weeks (a total of 12 animals per week). The day prior to slaughter, animals were removed from feed, transported to a research abattoir, and held overnight with free access to water.

The following morning, one animal was slaughtered and dressed per hour so that individual temperature data [described in McGinnis *et al.* (1994)] could be collected after processing while the carcasses were in the blast chiller. Animals entered the abattoir randomly and were stunned, bled, skinned and eviscerated in the normal commercial manner. After splitting the carcass, pH and temperature readings were recorded at a depth of approximately 3 cm, for the anterior (AL) and posterior (PL) *longissimus thoracis et lumborum* (at the 6th thoracic and 5th lumbar vertebrae, respectively) and for the *semimembranosus* (SM; approximately 5 cm from the aitch bone). Data were recorded using a hand-held Hanna Instruments Model No. HI8424 Microcomputer pH/temperature meter equipped with a Hanna Instruments HI7667 temperature probe (Hanna Instruments, Woonsocket, RI) and an Ingold spear-type electrode (Ingold Messtechnik AG, Urdorf, Switzerland). Both sides of the carcass were then electrically stimulated at 470 V for 1 min (Koch-Britton Stimulator, Kansas City, MO; 1·5 A, 60 Hz, 20 pulses/min). Previous research (Aalhus *et al.*, 1991) indicated electrical stimulation combined with blast chilling resulted in meat quality that was as good as or better than, conventional chilling without electrical stimulation. Immediately following electrical stimulation, pH and temperature were again recorded for the AL, PL and SM locations. At this point each carcass side was assigned to either of the two processing treatments, based on random animal entry to the kill floor. The side of the carcass assigned to the MHP system was reduced in a manner similar to the French pan traité cut by removing the chuck and brisket (anterior to the 6th rib), the short plate and flank as described by Wellington (1953). The cuts that were removed were weighed and immediately moved to the boning room for further processing [described in Gariepy *et al.* (1994)]. The two carcass sides, one conventionally processed (CP) the other MHP, were weighed and hung either from the Achilles tendon (conventional hang), or from the aitch bone (Tenderstretch). The removal of the low value cuts and re-suspension by the aitch bone was accomplished in less than 5 min by experienced meat cutters.

Carcass sides were held in a pre-cooler (ambient temperature set at 2°C) prior to entering the blast chiller at 1·5 h post-mortem. Carcasses remained in the blast chiller for 3 h at –20°C with an air speed of 2·3 m s^{-1}. Upon removal from the blast chiller, pH and temperature were recorded at the AL, PL and SM for all carcass sides. Carcasses were chilled in a conventional cooler at 2°C for the remainder of the 24 h period prior to grading.

After 24 h, pH and temperature were again recorded for the AL, PL and SM. Small samples of muscle (2–5 g) were removed from these locations in both sides of the carcass for the determination of sarcomere length according to the procedure described by Jeremiah *et al.* (1985). Carcass side weights were recorded to determine cooler shrink losses. Both carcass sides were split at the Canadian grade site (between the 12th and 13th rib) and the meat was allowed to bloom for 15–20 min. Meat colour (CIE L*, a* and b* values; Commission Internationale de l'Eclairage,

1976) was measured three times using a Chroma-Meter II (Minolta Canada Inc., Mississauga, ON) and the results were averaged. Subjective marbling scores (devoid = 100, practically devoid = 200, traces = 300, slight = 400, small = 500, modest = 600, moderate = 700, slightly abundant = 800, moderately abundant = 900, abundant = 1000, very abundant = 1100) were determined and Canadian grades (Anonymous, 1992) were assessed on both sides of the carcass by an Agriculture Canada grader. Loin eye area at the 12th rib was traced and the tracings were placed on a Kurta digitizing tablet (Kurta Corp., Phoenix, AZ) for the calculation of muscle area. The remaining wholesale cuts (rib, loin, sirloin butt and hip) on the MHP side were weighed and manually dissected into their constituent tissues. Weights of lean, fat and bone were recorded. The chucks from the CP sides were cut out, weighed, manually dissected into lean, fat and bone, weighed and further processed for use as control samples to hot-boned meat from the MHP side (Gariépy *et al.*, 1994).

Portions of the *longissimus thoracis et lumborum* (anterior to the grading site and anterior to the 5th lumbar vertebrae) and the SM (the proximal third of the muscle) muscles from the MHP and CP sides were used for meat quality analysis. Twenty-four hours post-slaughter a steak was cut from each of the muscle samples and placed in a styrofoam steak tray overwrapped with oxygen permeable polyvinyl chloride film (Vitafilm Choice Wrap, Goodyear Canada Inc., Toronto, ON) for 5 days at 2°C for drip loss determination by measuring weight loss. The remaining portions of the muscle samples were stored in 1016 polythene bags (Union Carbide Performance Plastics, Lamont, AB) at 2°C for 5 days. After 5 days another steak was cut from each of the muscle samples and the ultimate pH was recorded. Final objective CIE colour readings were recorded prior to cooking the steak to an internal temperature of 72°C in a microwave oven (Litton Menumaster XLC20, Minneapolis, MN; 2000 W). After chilling the steaks to 2°C, three 19 mm cores (removed from the mid-portion of three parallel lines transecting the steak into quarters) were sheared on an Ottawa Texture Measuring System (Canners Machinery Ltd., Simcoe, ON) equipped with a Warner-Bratzler head. The Warner-Bratzler head had a single blade with a thickness of 1 mm and an equilateral triangle opening of 45 mm per side. Cross head speed was set at 50 mm min^{-1}.

Statistical analysis

Meat quality data were analysed using the multiple linear regression subset of the General Linear Model computer algorithm of the Statistical Analysis System, Version 5 (SAS Institute Inc., 1985). A separate analysis for each location (AL, PL and SM) was performed using the following symbolic representation of the statistical split plot model:

$$Y_{ijk} = H_i + C(H)_{ij} + P_k + HP_{ik} + e_{ijk}$$

in which Y_{ijk} denotes the dependent quality variable (e.g. colour, shear, etc.), H_i denotes the ith hanging treatment (i = Achilles or aitch bone), $C(H)_{ij}$ denotes the jth carcass of the ith hanging treatment, P denotes processing treatment (k = CP or MHP) and e_{ijk} denotes the total residual error from all effects. The among carcass error term was used to test the significance of factors in the main plot. Linear contrasts with one degree of freedom were used for means separation ($P \leq 0{\cdot}05$).

RESULTS AND DISCUSSION

There were practically no differences in meat quality due to altering the method of suspension between the Achilles tendon and the aitch bone. The only exception was that sarcomere lengths were significantly shorter ($P \leq 0{\cdot}05$) in the AL and PL locations in carcasses hung by the Achilles tendon when compared to carcasses hung by the aitch bone (AL 1·68 vs 1·79 μm, PL 1·69 vs 1·89 μm). Previous reports in the literature have indicated that aitch bone suspension in beef carcasses resulted in a lengthening of sarcomeres in both the *longissimus* and *semimembranosus* muscles (Hostetler *et al.*, 1972; Jeremiah *et al.*, 1984). In the present study, sarcomere lengths in the SM did not vary with method of suspension which may be due to a difference in sampling location between our study and previous reports in the literature.

The low value cuts which were removed from the MHP carcass sides prior to chilling accounted for over 50% (50·1 ± 0·13) of the total carcass side weight. The composition of the tissue which remained on the MHP sides was very similar to the composition of the entire CP sides, having a slightly higher proportion of lean and bone (P = 0·07) and a significantly lower proportion of fat (P = 0·04; Table 1). Despite removing over half the weight of the carcass side, there was no significant difference in cooler shrink between CP and MHP sides (1·12 vs 1·32%, respectively). It seems

Table 1. Means and standard errors for tissue weights and composition (%) of conventionally processed (CP) and modified hot processed (MHP) carcasses

Tissue	CP	MHP	*P*
Number of sides	36	36	—
Fat (kg)	37·0 ± 0·66	17·4 ± 0·66	< 0·01
	(29·6 ± 0·59%)	(278·8 ± 0·59%)	0·04
Lean (kg)	69·0 ± 0·70	35·2 ± 0·70	< 0·01
	(55·1 ± 0·50%)	(56·4 ± 0·50%)	0·07
Bone (kg)	19·1 ± 0·17	9·8 ± 0·17	< 0·01
	(15·3 ± 0·18%)	(15·7 ± 0·18%)	0·07
Total (kg)	125·1 ± 0·85	62·5 ± 0·85	< 0·01

likely that the surface to volume ratios of the CP and MHP carcass sides remained similar, despite the difference in total weight.

The temperature decline patterns provide further evidence that the surface to volume ratios were not drastically altered by the removal of low value tissues. Temperature decline in the PL and SM locations was identical between the CP and MHP sides (Table 2). The only temperature which approached significance ($P \leq 0{\cdot}10$) was the post-blast chill temperature in the AL location which was slightly lower in the MHP side than in the CP side. Hence, the removal of over 50% of the carcass side weight had little influence on the temperature decline in the MHP sides at a depth of 3 cm.

The rate and extent of pH decline post-mortem is known to be influenced by the rate of temperature decline (Forrest *et al.*, 1975). In the present study there were no meaningful differences in pH decline patterns between the CP and MHP carcasses, reflecting the lack of difference in temperature decline patterns. Only the pre-stimulation pH in the SM varied between the CP and MHP sides (Table 2; $P \leq 0{\cdot}05$) and given the magnitude of this difference (0·05 pH units) it is unlikely to have an effect on meat quality.

There was no difference in grade fat, rib eye area or marbling as a result of the different processing methods. However, MHP carcass sides tended ($P \leq 0{\cdot}05$) to have lower CIE a* (19·6 vs 20·4) and b* (8·1 vs 8·7) values at the grade site 24 h post-mortem. These differences were small and unlikely to be of any commercial significance.

Overall MHP had a limited effect on fresh meat quality (Table 3). There was a two-way interaction ($P \leq 0{\cdot}05$) between processing treatment and carcass suspension method for shear force in the SM location. CP carcass sides had significantly ($P \leq 0{\cdot}05$) higher shear force values (6·37 N) in Achilles tendon suspended carcasses than in aitch bone

Table 2. Temperature and pH decline (mean ± SE) in conventionally processed (CP) and modified hot processed (MHP) carcasses at three locations[a]

Measurement	Location					
	AL[b]		PL[b]		SM[b]	
	CP	MHP	CP	MHP	CP	MHP
Number of samples	36	36	36	36	36	36
Temperature (°C)						
Pre-stimulation	39·5 ± 0·04	39·5 ± 0·04	39·4 ± 0·04	39·3 ± 0·04	38·9 ± 0·07	38·9 ± 0·07
Post-stimulation	39·5 ± 0·05	39·6 ± 0·05	39·6 ± 0·05	39·7 ± 0·05	38·6 ± 0·10	38·7 ± 0·10
Post-blast chill	16·3 ± 0·39*	15·3 ± 0·39*	11·2 ± 0·03	11·2 ± 0·03	4·6 ± 0·38	4·7 ± 0·38
24 h	2·8 ± 0·07	2·5 ± 0·07	2·5 ± 0·05	2·4 ± 0·05	4·1 ± 0·05	4·2 ± 0·05
pH						
Pre-stimulation	6·65 ± 0·015	6·66 ± 0·015	6·61 ± 0·011	6·62 ± 0·011	6·63 ± 0·015**	6·68 ± 0·015**
Post-stimulation	6·37 ± 0·015	6·35 ± 0·015	6·27 ± 0·015	6·27 ± 0·015	6·29 ± 0·014	6·28 ± 0·014
Post-blast chill	5·72 ± 0·030	5·69 ± 0·030	5·63 ± 0·014	5·61 ± 0·014	5·96 ± 0·028	5·93 ± 0·028
24 h	5·53 ± 0·011	5·54 ± 0·011	5·56 ± 0·010	5·55 ± 0·010	5·45 ± 0·008	5·46 ± 0·008

[a] All measurements were made at a muscle depth of 3 cm.
[b] AL—anterior *longissimus thoracis*; PL — posterior *longissimus lumborum*; SM — *semimembranosus*.
** Significantly different $P \leq 0{\cdot}05$.
* Significantly different $P \leq 0{\cdot}10$.

Table 3. Quality characteristics (mean ± SE) of conventionally processed (CP) and modified hot processed (MHP) carcasses at three locations

Quality characteristic	Location					
	AL[a]		PL[a]		SM[a]	
	CP	MHP	CP	MHP	OP	MHP
Number of samples	36	36	36	36	36	36
Shear (kg)	59·82 ± 1·00**	63·84 ± 1·00**	66·29 ± 1·75	69·63 ± 1·75	83·75 ± 1·09	83·06 ± 1·09
Sarcomere length (μm)	1·83 ± 0·031**	1·64 ± 0·031**	1·84 ± 0·020**	1·75 ± 0·020**	1·96 ± 0·025	1·98 ± 0·025
Drip loss (g kg^{-1})	17·3 ± 0·82**	21·8 ± 0·82**	15·4 ± 0·79**	17·8 ± 0·79**	23·6 ± 1·01	23·4 ± 1·01
CIE colour						
L*	38·3 ± 0·22	38·3 ± 0·22	37·2 ± 0·19	37·5 ± 0·19	38·0 ± 0·18	38·4 ± 0·18
a*	22·9 ± 0·19	22·6 ± 0·19	21·5 ± 0·21	21·2 ± 0·21	24·8 ± 0·22	25·0 ± 0·22
b*	9·9 ± 0·15	9·7 ± 0·15	8·9 ± 0·15	8·8 ± 0·15	11·9 ± 0·13	12·1 ± 0·13

[a] AL — anterior *longissimus thoracis*; PL — posterior *longissimus lumborum*; SM — *semimembranosus*.
** Conventionally processed sides are significantly different ($P \leq 0{\cdot}05$) than modified hot processed sides within location.

suspended carcasses. In MHP carcass sides there was no difference in shear force due to alternate methods of suspension. The underlying reason for these differences is unclear, since there were no corresponding differences in post-blast temperature or sarcomere length.

Shear force in the AL location was approximately 7% higher (4·02 N) in MHP carcass sides when compared to CP carcass sides (Table 3). Since 9·8 N of shear force is on the borderline for consumers to consistently rate meat as being tougher (Jeremiah, L. E., pers. comm.), it is unlikely that the difference between MHP and CP sides would be noticed by the consumer. The increased shear value in the AL of MHP sides corresponds to a 10% decrease in sarcomere length. Since the temperature in the AL location was 1°C lower post-blast in the MHP carcass sides, it is possible that the differences in sarcomere length and shear value resulted from cold induced shortening. However, in the PL location of MHP carcass sides, there was a significant ($P \leq 0{\cdot}05$) decrease in sarcomere length and a tendency for slightly higher shear force ($P = 0{\cdot}18$) without any concomitant difference in temperature post-blast. Locker (1985) indicated that the total shortening which takes place is actually the sum of cold shortening and rigor shortening. Hence, a more likely explanation for the decreases in sarcomere length is an increase in rigor shortening due to the removal of skeletal restraint and reduction of weight at the anterior portion of the *longissimus thoracis*.

Although cold shortening has been shown to occur in excised beef muscle in the laboratory (Locker & Hagyard, 1963; Davey & Gilbert, 1975), there is some debate as to whether it occurs to any great extent under commercial conditions. Lochner *et al.* (1980) concluded that cold shortening was not a significant determinant of tenderness, except in very rapidly chilled lean carcasses. Previous work at Lacombe (Aalhus *et al.*, 1991) indicated that under blast chill conditions, there was little evidence of cold shortening in the *longissimus thoracis*, even in very lean carcasses (0–5 mm grade fat). Hence, in the present study, the shortening observed in the AL and PL locations is most probably due to the removal of skeletal restraint. This hypothesis is further supported by the fact that neither electrical stimulation nor altered carcass suspension were able to prevent the sarcomere shortening.

In both the AL and PL location, MHP carcasses exhibited a higher drip loss ($P \leq 0{\cdot}05$) which was probably due to the significantly ($P \leq 0{\cdot}05$) shorter sarcomere lengths in the MHP at these locations. Shorter sarcomere lengths can reduce the interfilament spacing, resulting in a greater increase in water loss in the form of drip (Offer & Trinick, 1983). There were no significant differences ($P > 0{\cdot}05$) in the L*, a* and b* colour values between CP and MHP carcasses in any of the three locations measured.

CONCLUSIONS

The results of this study show that the removal of over 50% of the beef carcass weight, comprising utility meat cuts for use in fabricated meat products, had a negligible impact on the overall quality of the remaining high-value portion of the carcass. This sharply contrasts with the situation for

equivalent fresh meat cuts that can readily toughen when subjected to full hot processing procedures. With full hot processing, the removal of skeletal restraint, and the concomitant effects on muscle conformation, fiber tension, and the degree of rigor contraction or sarcomere shortening appears to strongly influence meat tenderness. Also, full hot processing results in meat pieces of smaller size, which increases the potential for too-rapid chilling and the possibility of cold shortening. However, these effects of hot processing appear to be of negligible concern for utility grade meat cuts, since further mechanical processing tends to negate problems associated with toughness or poor water holding capacity.

The modified hot processing strategy described herein avoids the negative effects of full hot processing in the high value meat cuts, whereas full advantage can be made of conventional hot processing of the balance of the carcass. This MHP approach carries several potential advantages in terms of reduced refrigeration energy use, faster processing of the utility-grade cuts of meat (McGinnis *et al.*, 1994), and improved binding characteristics of the contractile, pre-rigor proteins of hot processed muscle used in emulsion meat products (Gariépy *et al.*, 1994). This study therefore supports further scientific and economic exploration of this basic approach.

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