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A MODIFIED HOT PROCESSING STRATEGY FOR BEEF

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INTRODUCTION

Traditionally in North American abattoirs beef carcasses are split into sides and chilled from an internal deep hip temperature of about 40°C to 7°C. This approach is convenient when the commercial objective is to simply market whole carcass sides and it has relatively predictable effects on meat quality. However, it fails to provide each of the inherently different carcass segments with processing treatments that are optimal or uniquely suited to their minimum requirements for retail preparation. As well, chilling of the dressed sides imposes a large energy demand on the commercial operation, accounting for about 30% of the total electrical energy required to run a modern abattoir. Hot processing (or hot-boning) eliminates the necessity of chilling unwanted tissues such as bone and excess fat. Unfortunately, the removal of skeletal restraint and the difficulty in finding an optimum chilling system for hot-boned meat often results in serious decreases in tenderness as a result of cold shortening (Reagan, 1983). An alternative processing approach was therefore conceived for the purposes of maintaining quality in the high value cuts, utilizing the lower value cuts for immediate processing and reducing the overall energy consumption for chilling and processing. An evaluation of this strategy, referred to as "modified hot processing" (MHP), is reported herein.

MATERIALS AND METHODS

Upon entering the abattoir, all animals used in these studies were stunned, bled, skinned, eviscerated, split, electrically stimulated (470 volts for 1 minute, 20 pulses/min) and washed prior to further processing. 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 where they were hot-boned.

To investigate the effects on fresh meat quality paired sides from 36 Angus heifer carcasses, one conventionally processed (CP) and the other MHP, were held in a pre-chiller for about one hour prior to blast chilling at -20°C for three hours. Sides were then chilled at 2°C for the remainder of the 24-hour period. Temperature and pH measurements were made at three locations, the anterior (AL) and posterior (PL) *longissimus* (at the 6th thoracic and 5th lumbar vertebrae, respectively) and the *semimembranosus* (SM; approximately 5 cm from the aitch bone) pre- and post-electrical stimulation, post-blast chilling and at 24 hours. At 24 hour cooler shrink was determined, carcasses were graded and samples were removed for determination of sarcomere length. Portions of the *longissimus* (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 side and CP sides were used for meat quality determinations which included drip loss, objective CIE colour readings and Warner Bratzler shears. The remaining wholesale cuts (rib, loin, sirloin butt and hip) on the MHP side were weighed and broken down into their constituent tissues. Weights of lean, fat and bone were recorded. The chucks from the CP sides were cut out, weighed, broken into lean, fat and bone, weighed and further processed to use as control samples to hot-boned meat from the MHP side.

To determine the effects of MHP on the processing and quality of the utility grade meat, the meat from the chucks of the MHP (hot-boned; HB) and the CP (cold-boned after 24 hours; CB) sides of 20 carcasses was ground, salted with one of five different levels of NaCl (0.0, 0.5, 1.0, 1.5, 2.0%) and thoroughly mixed within two hours post-mortem. At this stage the pre-blends were vacuum packaged, frozen and shipped to St. Hyacinthe for further processing and analysis. In commercial practice, MHP low value cuts could be processed without any prior chilling or freezing, to avoid unnecessary refrigeration costs. However, pre-blending, which maintains the superior processing characteristics of HB meat, allows more flexibility between the killing and boning line and the sausage kitchen and would offer the possibility of transport to remote locations. At St. Hyacinthe, pre-blends were analyzed for their proximate composition and NaCl content for the formulation of bolognas and patties. Measurement of 2-thiobarbituric acid (TBA) values extractable protein concentrations and emulsion capacities were also carried out on the pre-blends. Bolognas were formulated (23% fat, 2% salt, 0.5% sugar, 0.33% spices, 0.295% nitrites, 0.05% erythorbarte and 15% water) and technological yield, colour and texture measurements were made on the product. In addition, a third bologna batter was made from CB pre-blends which incorporated 0.5% sodium tripolyphosphate (STP) into the formulation. Patties were formulated (25% fat, 1.5% salt, 0.5% sugar, 0.41% spices and 10% water) and cooking losses, colour and texture measurements were made.

To ascertain the potential energy savings associated with the MHP strategy, fifty-two Angus bulls in batches of either six or eight were prepared into MHP or CP sides as described above. CP sides and/or MHP sides were assembled and held prior to chilling until the full complement of sides was ready to allow a direct comparison between the maximum refrigeration energy demands associated with the blast chilling of batches of either CP or MHP carcasses. Once a complete batch of sides were assembled in the pre-chill room and fitted with muscle temperature sensors they were moved into the blast chiller and chilled for up to three hours. The electrical power and total energy required to chill batches of either MHP or CP carcasses were obtained by monitoring the blast chiller power demand using a programmable recording power meter (Model 808, Dranetz Engineering Labs Inc., Edison, NJ, USA). The mean electrical power consumption for each run was calculated from the raw power data, and the total energy for blast chilling over an arbitrary 2.5 hour period was calculated by numerical integration. The blast chiller was also operated in the empty condition so that the chiller system power consumption could be measured. The net refrigeration energy load imposed by each carcass batch was calculated as the difference between the power (or energy) measured with and without the chiller loaded with carcasses. The results of this investigation were also checked by engineering calculations based on the measured quantities of dissected lean meat, fat and bone in each portion of the carcass.

RESULTS AND DISCUSSION

Dissection results from both the Angus heifer and bull carcasses indicated that the low value cuts removed from the MHP carcass sides prior to chilling accounted for about 51% of the total carcass side weight (data not shown). The composition (proportion of lean, fat and bone) of the excised MHP tissue was almost identical to the composition of the tissue remaining on the carcass. As well, the lack of differences in temperature decline patterns and cooler shrink losses indicated that the surface to volume ratios of the CP and MHP carcass sides remained similar. Together these data indicate that the theoretical energy savings in the MHP strategy should be approximately 51%.

There were no differences in pH decline, grade fat, rib-eye area or marbling as a result of the different processing methods. However, MHP carcass sides tended to have a slightly darker colour (lower CIE a* and b* colour values) at the grade site 24-hours post-mortem which disappeared by six-days post-mortem. The objective measures of meat quality showed some differences between CP and MHP carcasses (Table 1). Shear force in the AL location of MHP carcasses was approximately 7% higher ($P \leq 0.05$) and tended to be slightly higher (approximately 5%) in the PL location. Since the differences in shear force ($\approx$0.4kg) observed in the present study are much lower than the 1kg of shear force normally required for consumer detection, it is unlikely that they would affect the consumer acceptability of MHP carcasses. The changes in shear force probably resulted from the significantly shorter muscle sarcomere lengths in the AL and PL location (Table 1) which resulted from the removal of skeletal restraint and reduction of carcass weight at the anterior loin when the low value cuts were removed. The shorter sarcomere lengths also resulted in significantly higher drip losses in the AL (26%) and PL (16%) locations due to changes in the structural arrangement of the muscle fibres. The higher drip losses may result in a lower meat value, due in part to the weight loss but also due to the negative appearance of drip losses in retail packages. Further studies would be required to confirm this finding.

A partial inhibition of glycolysis occurred in the HB meat from MHP carcasses at 1% NaCl, but 2% NaCl was necessary to eliminate the significant difference between pH values of the HB pre-blends measured after salting and their ultimate values obtained after thawing. There were no differences between TBA values of HB and CB pre-blends ($P>0.05$), but TBA values increased linearly with salt concentration ($P\leq0.05$) due to the oxidative effect of salt in meat (Ellis *et al.*, 1968). Antioxidants such as nitrite or phosphate could be used in the pre-blends to circumvent this problem (Abu-Bakar *et al.*, 1982; Choi *et al.*, 1987). As expected, significantly more salt soluble proteins were extracted in HB than in CB pre-blends ($P\leq0.05$) and the amount extracted increased linearly with the level of NaCl added to HB pre-blends ($P\leq0.05$). The emulsifying capacity of the extracted proteins was not influenced by either boning or salting treatments ($P>0.05$). Pre-blending meat from MHP carcasses with 2% NaCl was necessary to fully achieve the pre-rigor salting effect, confirming the results of Hamm (1981) for non-stimulated beef. At this level of NaCl, technological yields, colour (data not shown) and texture were identical between bolognas made from HB pre-blends and phosphate containing CB pre-blends, and both were superior to bolognas prepared from CB pre-blends ($P\leq0.05$; Table 2). Cooking losses were lower for patties made from HB compared to CB pre-blends ($P\leq0.05$). As well, cohesiveness and chewiness were always superior in patties made from HB pre-blends.

As expected, the net energy demand per unit of actual carcass mass chilled was virtually identical for the MHP and CP sides (61.3kJ/kg vs. 61.1kJ/kg; $P\leq0.01$), reflecting the almost identical tissue composition of the MHP and CP sides. The net energy consumption for chilling MHP sides was only 49.2% ($P\leq0.05$) that found for chilling CP sides on an equivalent "per head" basis. This result, indicating a maximum 51% chill-energy saving, compares very favourably with the theoretical result of 51%. To fully realize this potential saving would require that the commercial processor further process the "hot" meat cuts for the MHP sides in a non-refrigerated condition as in the manufacturing of sausages or bologna. Should the processor wish to market all of the low-value cuts from the anterior portion as fresh, chilled meat, the maximum energy saving would be reduced from 51% to a minimum of about 17%. Most processors would likely be in a position to realize energy savings that would be intermediate between these two values. An important result, revealed in Table 3, is that the total energy required to chill MHP sides, per unit weight of actual carcass chilled, actually exceeded the total energy required to chill CP carcasses. This confirms the principle that a refrigeration system should be sized according to the actual load in order to maximize energy efficiency. That is, since MHP sides demand about half the refrigeration, the blast chill system should, for the same numbers of head processed, be designed accordingly for peak efficiency. If this were done, it is probable that the resulting small "MHP" chill system would not benefit from the same economy of scale that would apply to the larger CP chill system, and the anticipated maximum energy savings (i.e. 51%), on a per head basis could be marginally lower. On the other hand, an abattoir could conceivably double its throughput of animals with roughly the same chilling cost. In any case, the energy savings that would result from the adoption of an MHP strategy would be very substantial, and very likely worth the necessary investment in overall plant lay-out and design.

CONCLUSION

The MHP strategy described in this paper resulted in minor changes in the fresh meat quality of the high value cuts, improved processing characteristics of the low value cuts and an energy savings of between 17 and 51%. On this basis, further investigation of this modified hot processing strategy is warranted.

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REFERENCES

ABU-BAKAR, A., REAGAN, J. O., WYNNE, R. L., and CARPENTER, J. A. 1982. Storage, functional and processing characteristics of pre- and postrigor beef preblends for Wiener production. *J. Fd. Sci.* 47:374-379, 385.

CHOI, Y. I., KASTNER, C. L., and KROPF, D. H. 1987. Effects of hot boning and various levels of salt and phosphate on microbial, TBA, and pH values of preblended pork during cooler storage. *J. Fd. Prot.* 50:1037-1043.

ELLIS, R., CURRIE, G. T., THORNTON, F. E., BOLLINGER, N. C., and GADDIS, A. M. 1968. Carbonyls in oxidizing fat. II. The effect of pro-oxidant activity of sodium chloride on pork tissue. *J. Fd. Sci.* 33:555-561.

HAMM, R. 1981. Postmortem changes in muscle affecting the quality of comminuted meat products. In: LAWRIE, R. (ed). *Developments in Meat Science, Volume 2.* Applied Science Publishers Ltd., London, U. K. pp. 93.

REAGON, J. O. 1983. Hot processing of pork whole muscle cuts. Recipr. Meat Conf. 36:71-73.

WELLINGTON, G. H. 1953. Recommended procedure for cutting beef. Recipr. Meat Conf. 6:73-79.

Table 1. The effect of MHP on fresh meat quality in three carcass locations.

Quality characteristics	Location AL CP	AL MHP	PL CP	PL MHP	SM CP	SM MHP
Shear, kg	6.10*	6.51*	6.76	7.10	8.54	8.47
Sarcomere length, μ	1.83*	1.64*	1.84*	1.75*	1.96	1.98
Drip loss, $g.kg^{-1}$	17.3*	21.8*	15.4*	17.8*	23.6	23.4
CIE colour						
L*	38.2	38.3	37.2	37.5	38.0	38.4
a*	22.9	22.6	21.5	24.8	24.8	25.0
b*	9.9	9.7	8.9	8.8	11.9	12.1

* Conventionally processed sides are significantly different ($P \leq 0.05$) than modified hot processed sides within locations.

Table 2. The effect of MHP on the texture of bolognas and meat patties formulated from HB (MHP), CB (CP) and CB with phosphate (CPB) pre-blends.

Quality characteristics	Bolognas HB	CP	CPB	Meat Patties HB	CB
Technological yield[1], %	97.6[a]	90.2b	97.8[a]	-	-
Cooking losses, %	-	-	-	34.0*	36.8*
Hardness[1,2]	16.36	14.86	17.71	369.28	367.00
Springiness[1,3]	2.87[a]	2.76b	2.86[b]	3.58	3.43
Cohesiveness[1,4]	0.67	0.58	0.63	0.60*	0.52*
Chewiness[1,5]	31.81[a]	24.06b	34.91[a]	791.30*	653.88*

[1] Results shown are from preblends that had 2% salt added immediately post-boning.
[2] Peak height in first compression as a force (N).
[3] Distance to peak in second compression (cm).
[4] Ratio of second peak area to first peak area.
[5] Chewiness=hardness x springiness x cohesiveness.
[ab] Means in the same row with different superscripts are significantly different ($P \leq 0.05$).
[*] Boning treatments had a significant effect on cooking losses, cohesiveness and chewiness ($P \leq 0.05$).

Table 3. Energy and power requirements to chill CP and MHP carcasses for 2.5 hours.

Carcass or Process Characteristics	CP	MHP	CP-MHP difference
Total hot dressed weight, kg	8816.7	8747.4	NA
Total chilled carcass weight, kg	8816.7	4220.8	NA
Per kg of actual chilled carcass			
Total[1] average power, watts/kg	14.52	25.03	-10.51
Net[2] average power, watts/kg	6.79	6.81	-0.02
Net[2] energy, KJ/kg	61.07	61.32	-0.25
Per kg of pre-MHP dressed carcass			
Total[1] average power, watts/kg	14.52	12.18	2.34
Net[2] average power, watts/kg	6.79	3.41	3.44
Total[1] energy, KJ/kg	130.68	109.64	21.03
Net[2] energy, KJ/kg	61.07	30.07	30.99

[1] Total denotes electrical demand (power or energy) to run entire blast chill facility.
[2] Net denotes electrical demand (power or energy) for carcass chilling only.