Postmortem Tenderness and Drip, Cooking, and Total Loss in brine injected Beef

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Abstract

The effect of postmortem time of calcium chloride injection in conjunction with postmortem aging was determined on 16 beef semimem-branosus muscles. Each muscle was cut into four equal segments that were randomly assigned: (1) no injection (control); (2) $CaCl_2$ at I h postmortem; (3) $CaCl_2$ at 12 h postmortem; or (4) CaCl at 24 h postmortem. Samples were injected with a 0-3 M solution of $CaCl_2$ at 10% by weight. At 24 h postmortem, each segment was divided into two pieces that were randomly assigned to either a 10-day aging period (2°C) or to frozen storage (—29°C). Shear force values were higher (P<0-01) in control samples compared with injected samples and increased linearly (P<0-05) with time of injection. Drip loss was lower (P<001) in control samples compared with injected samples. A linear (P<0-05) effect was found for the increases in cooking and total loss due to injection time. Aging decreased (P < 005) shear force values and cooking loss. $CaCl_2$ injection at 1 h postmortem was most effective in reducing shear force values and preventing excessive moisture loss. However, injection at 12 or 24 h postmortem was also effective in lowering shear force values.

INTRODUCTION

The majority of explainable differences in tenderness of young animals is due to myofibrillar components (Savell & Shackelford, 1992). Additionally, Morgan *et al.* (1996) concluded from the National Beef Tenderness Survey that improved meat tenderness, primarily for retail cuts from the round and chuck, is needed.

Flavor, juiciness, and tenderness are the primary determinants of eating quality with tenderness being the most important (Breidenstein & Carpenter. 1983). Both subcutaneous (Smith *et al.,* 1976; Bowling *et al.,* 1977) and intramuscular (Tatum *et al.,* 1980; Dolezal *et al.,* 1982) fat have been linked to improved palatability of meat products. The amount and crosslinking of connective tissue also influence tenderness (Bailey & Light, 1989).

Postmortem methods for improving tenderness of meat have been studied in the last 25 years (Breidenstein & Carpenter, 1983), most recently $CaCl_2$ has been shown to improve meat tenderness when applied either to carcasses (Koohmaraie *et al.,* 1988, 1990; Koohmaraie & Shackelford, 1991) or to specific cuts of meat (Koohmaraie *et al.,* 1990; Morgan *el al,* 1991a; Wheeler *el al.,* 1992). Most studies have evaluated the effects of $CaCl_2$, when injected/infused immediately after death. However, applying $CaCl_2$, at a later stage *postmortem* may prove to be more adaptable by industry. Wheeler *et al.* (1992) found that injection of

muscle at either 0 or 24 h *postmortem* resulted in increased tenderness, with greater tenderization seen in the prerigor-injected muscle. Injection of $CaCl_2$, at a time between 0 and 24 h might improve tenderness more effectively than at 24 h, while maintaining application desirability for industry use. This research determined the effects of $CaCl_2$, injection at 1, 12, and 24 h *postmortem* on beef tenderness and drip, cooking, and total loss and the facilitation of postmortem aging on the $CaCl_2$-induced tenderization process.

MATERIALS AND METHODS

Sixteen steers (490 to 680 kg live weight) of Pinzgau breeding were fed a grain diet until 12th rib fat thickness reached at least 10 mm as determined by visual estimation and real-time ultrasound, at which time they were slaughtered in the Unicarm slaughterhouse. Within 20 min of exsanguination, the *semimembranosus* muscle was removed from the right side of each carcass and trimmed of all external fat, connective tissue and surrounding muscles. Each *semimembranosus* muscle was immediately cut into four equal segments that were randomly assigned to one of four treatments: (I) no injection (control); (2) $CaCl_2$, at 1 h *postmortem;* (3) $CaCl_2$, at 12 h *postmortem;* and (4) CaCl, at 24 h *postmortem.* From the time of excision until the time of injection, muscle segments were held at 2°C in polyethylene/nylon vacuum packages (oxygen and water vapor transmission rates of 0-6/645-2 cnr/24 h/0°C, Koch Supplies, Inc., Kansas City, MO). At the time of injection, pH values of each muscle segment were taken using a spear tip combination electrode (Cole-Parmer, Niles, IL) placed in the geometric center of the muscle. Each segment was then injected with a 0,3 M $CaCl_2$ solution at 10% by weight using a hand-held, single-needle stitch pump. After injection, each segment was vacuum packaged. At 24 h *postmortem,* each package was opened and all segments were cut into two steaks of approximately 2-54 cm in thickness which were then vacuum packaged. At random, one steak was assigned to a 10-day aging period (2°C) and the other steak was assigned to frozen storage (-29°C). At the end of the aging period, aged samples were placed in frozen storage (— 29°C), and all samples were held until evaluated. At 24 h *postmortem,* USDA yield and quality grade factors (USDA, 1989) were evaluated on carcasses and recorded.

Prior to evaluation, samples were thawed at 2°C for 24 h. While still sealed in the vacuum bag, each sample was weighed to determine a total weight. Weight of the wet sample was tare weight of an unused bag subtracted from the total weight. The sample was removed from the bag

and blotted with paper towels to remove excess surface moisture. The blotted sample weight was subtracted from the wet sample weight to give the drip loss weight. Percentage of drip loss was determined by dividing drip loss weight by wet sample weight.

The samples were broiled on a Farberware Open-Hearth Broiler (Farberwarc Co., Bronx, NY) according to AMSA guidelines (1978) to an internal temperature of 70°C. Samples were turned once at 40°C. Internal temperature was monitored using constantan-copper thermocouples connected to a strip chart recorder (Honeywell, Inc., Fort Washington, PA). Each cooked sample was cooled to room temperature, blotted dry, and weighed. Percentage of cooking loss was determined by dividing the difference in blotted uncooked and cooked weights by the weight of the blotted sample (uncooked).

Total loss percentage was determined by adding together the weights of both the drip loss and the cooking loss then dividing this sum by the weight of the wet, uncooked sample.

The same samples used for drip, cooking, and total loss determinations were used for shear force determination. After being cooked and weighed, the samples were stored in an unsealed polyethylene bag at 4°C for approximately 12 h. Three cores of 27 cm diameter were removed from each sample parallel to the muscle fibers and sheared twice perpendicular to the grain of the muscle fiber using an Instron Model 4501 Universal Testing Instrument (Instron, Canton, MA) equipped with a Warner-Bratzler shearing device with a cross-head speed of 100 mm/min.

Data were analyzed as a split plot design. The whole plot consisted of injection and the split plot consisted of the storage treatments (aged and non-aged) within injection treatments (control, 1 h, 12 h, and 24 h). The model included main effects of muscle (from each animal), injection, and storage treatments and an interaction between injection and storage treatments. Error terms included muscle injection for the whole plot and the residual error for the split plot and interaction term.

Analysis of variance and single degree of freedom contrasts were used in analyzing data (Steel & Torrie, 1980). The contrasts were designed to allow for the use of non-injected samples as controls in the experimental design. Contracts for linear and quadratic effects were performed using injected samples only (excluding controls). These contrasts analyzed the effect of time of injection only. A final contrast was performed to analyze control samples against injected samples as affected by injection treatment.

Although experimental designs necessitating injected control samples (with water) could have been included in the study, the present design (non-injected control samples) allowed for a more realistic comparison. Under typical industry conditions, beef is not injected with any type of solution. Therefore, in order to more realistically assess the effects of $CaCl_2$ injection on tenderness and moisture loss, non-injected controls provided the appropriate comparison.

RESULTS AND DISCUSSION

Table 1 contains means and standard deviations for carcass traits of steers used in the study. These carcasses were typical of young, grain-finished steers.

The contrast between control samples and injected samples revealed that injection of $CaCl_2$ reduced (P<001) shear force values (Table 2). A statistical linear (P<005) effect was found for changes in shear force values with injection time. Muscles injected at 1 h *postmortem* had the lowest shear force values indicating that injection early postmortem is most effective in reducing shear force values as compared with injections at 12 or 24 h. Previous studies (Koohmaraie *et al.,* 1988, 1990; Koohmaraie & Shackelford, 1991; Morgan *et al.,* 1991a; Wheeler *et al.,* 1991, 1992; Whipple & Koohmaraie, 1992) support the effectiveness of $CaCl_2$ in decreasing shear force values. Wheeler *et al.* (1992) found that injection of prerigor meat (30 min *postmortem)* was more effective in reducing shear force values than injection of postrigor meat (24 h *postmortem).*

Although shear force values were higher in samples injected at 12 or 24 h *postmortem* compared with samples injected at 1 h, these values were lower than those of the control samples. Shear force measurements were reduced 28-6, 10-5, and 9-4% in samples injected at 1. 12, and 24 h, respectively, compared with controls (Table 2). The pH values of samples at the time of injection (I h = 6-56; 12 h = 5-63; 24 h = 5-61) indicated that samples injected at 1 h *postmortem* could be considered prerigor tissue and samples injected at 12 or 24 h *post- mortem* could be considered postrigor tissue (Lawrie, 1985).

Therefore, injection of $CaCl_2$ into either pre- or postrigor muscle tissue is an effective means of improving meat tenderness. The 10-d aging period prior to frozen storage decreased (P<0-01) shear force values compared with non-aged samples (Table 3). These results were expected due to aging-induced postmortem proteolysis (Koohmaraie, 1988). No interaction was found between injection and storage treatments for shear force (Table 4). Injection at 1 h *postmortem*

resulted in a 16-3% reduction in shear force values compared with non-injected (control) samples that were aged for 10 days (Table 4). This indicated that $CaCl_2$, injection at 1 h *postmortem* was a more effective means of improving meat tenderness than postmortem aging. However, use of both methods resulted in a greater reduction in shear force values than with either single method.

The contrast of control vs injected samples indicated a difference (/><0-01) in drip loss, with injected samples having more drip loss (Table 2). This was expected because of the addition of the $CaCl_2$ solution at 10% by weight in the injected samples. A linear trend was found for the change in drip loss due to time of injection. The slight decrease between samples injected at 1 and 12 h *postmortem* might suggest that a quadratic effect would be more appropriate.

TABLE1

Means and Standard Deviations of Carcass Traits

Trait	*Mean*	*SD*
Hot carcass weight (kg)	348-1	44-7
Fat thickness (cm)	11	04
Longissimus dorsi muscle area	74-6	96
Kidney, pelvic and heart fat (%)	2-5	0-4
USDA vield grade	3-3	0-8
Overall maturity"	190-9	192
Marbling score*	393-8	105-4
USDA quality grade'[1]	5 1	14

TABLE 2

Effect of $CaCl_2$ Injection on Shear Force and Drip, Cooking, and Total Loss of Beef *Semimembranosus* Muscles

Variable	*Injection treatme*				*SEM*	*Contrasts*	
	Control	*1 h*	*12 h*	*24 h*		*Control vs injected*	*Linear injection lime*
Shear (kg)	7-33	5-23	6-56	6-64	036	005	005
Drip loss (%)	13-48	16-03	15-88	17-03	0-49	005	010
Cooking loss	28-52	26-40	28-45	29-32	0-91	NS	005
Total loss (%)	38-12	37-96	39-75	41-32	0-82	NS	005

TABLE 3

Effect of Storage Treatment on Shear Force and Drip, Cooking, and Total Loss of Beef *Semimembranosus* Muscles

Variable	*Storage treatments*		*SEM*
	Non-aged	*Aged*	
Shear(kg) Drip	7-04	5-78	017
loss (%)	15-44	15-65	034
Cooking loss (%)	29-03	27-21	054
Total loss (%)	39-76	38-59	055

TABLE 4

Interaction of Injection and Storage on Shear Force of Beef *Semimembranosus* Muscles

Storage	Infection			
	Control	1 h	12 h	24 h
Non-aged	773	5-81	7-59	7-07
Aged	6-94	464	5-53	600

Shear force measured in kg. Pooled SEM = 0-34.

Aging of samples had no influence on drip loss percentages (Table 3). Similar results were reported by Savell *et al.* (1978) who found that aging had a nonsignificant effect on drip loss of their control samples. No interaction was found between injection and storage treatments for drip loss.

Cooking loss of control samples was not different from that of injected samples (Table 2), which agreed with the work of Morgan *et al.* (1991a). A linear ($P<005$) effect was found for the increase in cooking loss due to time of injection. As time of injection was delayed, cooking loss increased. Wheeler *et al.* (1992) reported that cooking loss was higher in meat injected with $CaCl_2$ at 24 h *postmortem* compared with 0 h *postmortem.* As shown in Table 2, cooking loss was lower in samples injected at 1 h *postmortem* and higher in samples injected at 24 h *postmortem* compared with control samples. These results confirm the findings of Wheeler *et al.* (1992). Non-aged samples displayed higher cooking losses than aged samples (Table 3). Hamm (1986) stated that it is possible that an increase of pH and/or proteolytic disintegration during aging may result in increased water retention. This may account for less cooking loss in the aged samples. However, Parrish *et al.* (1969) and Morgan *et al.* (1991a) found no differences in cooking loss due to aging when *semimembranosus* muscles were aged for 4, 7, and 11 days or 1, 7, and 14 days, respectively. No interaction was found between injection and storage treatments for cooking loss. During the cooking process, components other than moisture, such as fat, are broken down and removed (Hamm, 1986). Therefore, the term 'total loss' was used to

denote weight loss from all factors and should not be mistaken as total moisture loss. No significant difference in total loss was found between control samples and injected samples (Table 2). Total loss increased linearly due to time of injection, with injection at 1 h resulting in the least loss. Control samples and samples injected at 1 h *postmortem* had similar total loss. These results indicated that $CaCl_2$, if injected into prerigor muscle tissue, will not result in an increase in total loss of product, even though drip loss may be adversely affected. Although nonaged samples had slightly more total loss than aged samples (Table 3), storage treatment did not have a significant effect on total loss. No interaction was found between injection and storage treatments for total loss.

CONCLUSIONS

In conclusion, $CaCl_2$ injection of beef *semimembranosus* muscles was an effective means of lowering shear force values, without adversely affecting cooking or total loss. Although the greatest degree of tenderization was seen in injection of prerigor muscle (1 h *postmortem),* injection at 12 and 24 h *postmortem* was also beneficial in lowering the shear force requirements of muscle. Therefore, $CaCl_2$ injection could be implemented into current industry practice as a feasible and effective means of improving meat tenderness, provided that flavor remains acceptable to consumers.

REFERENCES

1. AMSA (1978). *Guidelines for Cookery and Sensory Evaluation of Meat.* Chicago, IL. Bailey, A. J. & Light, N. D. (1989). *Connective Tissue in Meat and Meat Products.* Elsevier Applied Science, New York, p. 148.
2. Bowling, R.A., Smith, G. C, Carpenter, Z. L., Dutson, T. R. & Oliver, W. M. (1977). /.*Anim. Sci.,* 45, 209.
3. Breidenstein, B. C. & Carpenter, Z. L. (1983). *J. Anim. Sci.,* 57, (Suppl. 2), 119.
4. Dolezal, H. C, Smith. G. C, Savell, J. W. & Carpenter, Z. L. (1982). *J. Food Sci..* 47, 397.
5. Hamm, R. (1986). In *Muscle As Fond,* ed. P. J. Bechtel. Academic Press, Orlando, p. 135.
6. Koohmaraic, M. (1988). *Proc. Ret: Meal Conf,* 41, 89.
7. Koohmaraie. M. & Shackelford, S. D. (1991). *J. Anim. Sci., 69,* 2463.
8. Koohmaraie, M, Babiker, A. S., Schroeder, A. L., Merkel, R. A. & Dutson, T. R.(1988). *J. Food Sci.,* 53, 1638.
9. Koohmaraie, M., Whipple. G. & Grouse, J. D. (1990). / *Anim. Sci.,* 68, 1278.
10. Lawrie, R. A. (1985). *Meat Science,* 4th cdn. PErgamon Press. New York, p. 43.
11. Morgan, J. B., Miller, R. K., Mendez. F M., Hale, D. S. & Savell. *1.* W. (1991a). *J. Anim. Sci.,* 69, 4469.
12. Morgan, J. B., Savell, J. W.. Hale, D. S., Miller, R. K., Griffin, D. B.. Cross, H. R. & Shackelford, S. D. (1991/J). / *Anim. Sci.,* 69, 3274.
13. Parrish. F. C. Jr, Rust. R. E., Popenhagen, G. R. *&* Miner, B. E. (1969). *J. Anim. Sci.,*29, 398.
14. Savell, J. W. & Shackelford, S. U. (1992). *Proc. Rec. Meat Conf,* 45, 43.
15. Savell, J. W., Smith. G. C. & Carpenter, Z. *L.* (1978). ./. *Food Sci.,* 43, 1666.
16. Smith, G. C, Dutson, T. R , Hostetlcr, R. L. *&* Carpenter, Z. L. (1976). *J. Food Sci.,* 41, 748.
17. Steel, R. G. D. & Torrie, J. II. (1980). *Principles and Procedures of Statistics: A Biometrical Approach,* 2nd edn. McGraw-Hill Book Company, New York.
18. Tatum, J. D., Smith, G. C, Berry, B. W., Murphey. C. E., Williams, F. L. *&* Carpenter, Z. I,. (1980). ./. *Anim. Sci.,* 50 833.
19. USDA (1989). *Official United States Standards for Grades of Carcass Beef.* USDA, Agric. Marketing Service, Washington, DC.
20. Wheeler, T. L., Koohmaraie, M. & Crouse, J. D. (1991). *J. Anim. Sci.,*9, 4871.
21. Wheeler, T. L.. Crouse, J. D. & Koohmaraie, M. (1992). *J. Anim. Sci.,* 70, 3451.
22. Whipple, G. & Koohmaraie, M. (1992). ./. *Anim. Sci.,* 70, 3081.