The Influence of Delayed Chilling on Beef Tenderness

P. A. Will, R. L. Henrickson, R. D. Morrison

Story in Brief

The removal of muscle and muscle systems before initial chilling of the bovine carcass has been investigated in recent years to determine the feasibility of this processing method as a future alternative to conventional fabrication. One important consideration relating to the delay chilling process is the tenderness attribute of eating quality. This investigation was initiated to examine meat tenderness as related to three delay chilling periods. Twelve U.S.D.A. choice grade Angus steer carcasses were assigned at random to three holding periods. One side of each carcass was randomly assigned to be delay chilled at 16° C for 3, 5 or 7 hours before fabrication into muscle and muscle systems. The remaining side was likewise processed into muscle and muscle systems following the chilling at 1.1° C for 48 hours.

Meat tenderness was objectively estimated by the use of the Warner-Bratzler Shear, and Nip Tenderometer. Subjective evaluation of meat tenderness was by a trained panel. The muscles utilized in this investigation were the biceps femoris, longissimus dorsi, and semimembranosus. Differences among shear force values between chill and delay chill treatments were small, averaging less than 1.65 kg. Shear force measurements taken by mechanical instruments, therefore, led to the conclusion that no major differences attributed to meat tenderness exsited between beef fabricated 48 hours postmortem at 1.1° C, and that held 3, 5 or 7 hours post-mortem at 16° C. Detectable variations registered by the trained tenderness panel were small between the two treatments, supporting the findings indicated by mechanical instruments that the boning of beef 3, 5, or 7 hours post-mortem before chilling provides beef of satisfactory tenderness.

Introduction

The removal of muscle and muscle systems before initial chilling of the bovine carcass has been investigated in recent years to determine the feasibility of this processing method as a future alternative to conventional bovine fabrication. It is well accepted that meat cooked before the onset of rigor mortis is relatively tender, whereas that meat cooked immediately after rigor mortis is relatively rough. Aging of the bovine carcass by conventional chilling methods at temperatures of 0-2° C for 10-14 days in the past has been regarded as a necessary procedure to obtain retail beef of satisfactory tenderness. An increase in aging temperature has shown to be associated with more rapid tenderization of the bovine carcass. The processing of the porcine carcass to a finished product prior to initial chilling has been shown to have many applications to the meat industry.

Meaningful research conducted by this rapid processing method using the bovine carcass has only recently been investigated. Some investigators have indicated that tenderness is influenced by pre-rigor changes. Many attributes which determine the desirability of muscle as food are established during the first 24-48 hours after death. Researchers have found that bovine muscles excised soon after slaughter were tougher when rigor mortis had developed than uncut muscle which had gone into rigor mortis on the bone. Therefore, the objective of this study was to examine the effect of muscle removal at three delayed chilling periods (3 versus 48 hours, 5 versus 48 hours and 7 versus 48 hours), and relate this to meat tenderness by several independent techniques. The objective instruments used were the Warner-Bratzler Shear, and Nip Tenderometer. Subjective evaluation was by a trained taste panel.

Experimental

Chill and Delay Chill Boning

Twelve U.S.D.A. choice steers of similar age, breed, nutritional feeding, and management with a mean weight of 483.00±11.3 kg. were utilized in the investigation. Animals were slaughtered according to the procedure established at the meat laboratory and consistent with methods currently used in the industry. Each carcass was split and the sides randomly designated to either the chill or delay-chill treatment. In each experiment the designated sides utilized for the chill treatment were held at 1.1° C for a 48 hour post-mortem conditioning period before individual muscles or muscle systems were excised. Upon removal, each muscle or muscle system was placed in Cry-O-Vac bags and held at 1.1° C to prevent surface moisture evaporation. The opposite sides of each pair receiving the delay-chill treatment were randomly designated to either the 3, 5, or 7 hour post-mortem conditioning period, at 16° C, before the muscles or muscle systems were excised. The delay-chill muscles were likewise stored in Cry-O-Vac bags at 1.1° C. Muscles used for the tenderness evaluation were the biceps femoris or outside round (BF), the longissimus dorsi or loin eye muscle (LD), and the semimembranosus or inside round (SM).

Two steaks from specific areas of the muscles were removed from each treatment side for both objective and subjective evaluations. Individual steaks for both evaluations were labeled, tightly wrapped, and stored at —30° C until utilized. Prior to evaluation, the chill and delay-chill treatment steaks were removed from storage and allowed to thaw 24 hours at 4.5° C. The cooking of the steaks was carried out by the deep fat fry method with Frymax cooking oil being preheated to 135° C. Weston model 2261 meat thermometers were inserted into the geometric center of the uncooked steaks to insure uniformity of internal doneness. The individual steaks were completely immersed in the cooking oil and heated to an internal temperature of 65.5° C. When the desired internal temperature was reached, the steaks were removed from the oil, and blotted. The steaks were then covered with plastic food wrap to prevent excess moisture loss and placed in the cold storage at 4° C for 24 hours. Therefore, all measurements were taken at a standardized temperature, 4° C.

Objective Measurements

Cooked steaks from the BF, LD, and SM muscles were analyzed using the mechanically powered Warner-Bratzler Shear (W-B). Three, 1.90 cm. diameter cores were taken per steak by a mechanical boring device. Three shear force measurements were taken per core. These nine values made up the mean shear force reading obtained by the WB shear.

Nip Tenderometer (NT) measurements were taken perpendicular to the muscle fiber orientation. This was accomplished by cutting across a specified region of each steak. The Nip values were taken anterior to the ischiatic head of the BF muscle. The LD muscle Nip readings were taken on the lateral surface away from the throacic and lumbar vertebrae, while the SM muscle readings were from the medial surface adjacent to the adductor muscle. Five Nip Tenderometer readings were taken per steak and made up the mean shear force value.

Subjective Measures

A tenderness panel made up of six trained members was assembled to determine if differences between treatments could be detected. Panelists consisted of both men and women of varying ages.

Statistical Analysis

Data presented in this study were analyzed by the use of the SAS computer programming system. The analysis for determining statistical significance for tenderness in the organoleptic evaluation was accomplished by using a ranking procedure in conjunction with the Chi-square test. The Analysis of Variance was used in the remainder of the statistical evaluation. Each holding period was considered a separate experiment; therefore no statistical comparisons were made among the three, five and seven hour conditioning treatments.

Results and Discussion

Penetration and Shear Force 3 versus 48 hours—The data from two mechanical methods of measuring meat tenderness for three bovine muscles boned 48 or 3 hours post-mortem are shown in Table 1. A significant difference in shear force between the chill and delay-chill biceps femoris (BF) muscle was noted by the Warner-Bratzler (WB) shear. This shear force difference indicated that the chilled BF muscle was less tender than the corresponding BF muscle taken from the delay-chill treatment. The WB shear, in addition to showing differences between 3 versus 48 hours boning treatments for the BF muscle, indicated that steak one and steak two from the two process treatments reacted differently. The anterior end of the BF muscle was noted to be more tender than the posterior end for the 48 hour versus 3 boning teratments. Similar variations in WB shear force measurements with respect to position of steak from the BF have been observed by others. In direct contrast to WB Shear readings the remaining mechanical method of estimating tenderness for the BF muscle indicated equal tenderness between 48 versus 3 hour boning treatment (Table 1).

Data obtained from the WB shear and NT for the longissimus dorsi (LD) muscle indicated products of equal tenderness between 48 versus 3 hour boning treatments (Table 1). Muscle variations within boning treatments for anterior and posterior portions of the muscle were nonsignificant (NS) for the two objective measures. Other researchers have similar results in shear force values with respect to steak location in the LD muscle.

Nip Shear force values and WB Shear in the semimembranosus (SM)

Table 1. Warner-Bratzler Shear (kg) and Nip Tenderometer (kg) Measurements of 3 Versus 48 Hour Treatments from the BF, LD and SM Muscles.

Instrument	Process Treatment	n	BF	LD	SM
WB Shear	Chill (48 Hr)	72	7.87[1]	6.41	8.89
kg	Delay Chill (3 Hr)	72	6.22[1]	6.89	8.74
Carcass by Process Mean Square DF=3			5.33	3.81	4.49
Nip	Chill (48 Hr)	40	4.10	4.49	4.53
kg	Delay Chill (3 Hr)	40	4.29	4.42	4.62
Carcass by Process Mean Square DF=3			6.46	1.58	1.77

[1] Denotes significant difference at $P<0.01$. Nonsubscript denotes nonsignificant difference.

muscle yielded steaks of equal tenderness for the chill and delay-chill meat (Table 1). Differences within the SM muscle for the chill and delay-chill treatments revealed that anterior portion of the muscle was more tender than the posterior portion.

Sensory Evaluation 3 versus 48 hours—The Duo-Trio difference test indicated that sensory panelist were unable to discriminate tenderness differences between the 48 versus 3 hour treatments. These findings held true for the BF, LD, and SM muscles. As noted by the number of right versus wrong responses indicated by the trained panelists (Table 2).

The Preference Test conducted with the panelist revealed a slightly higher frequency for the selection of the chill BF, LD, and SM samples to that of the delay-chill process. This frequency of preference was only a slight trend between the two treatments as significance was not attained for any of the muscles studied (Table 3).

Penetration and Shear Force 5 versus 48 Hours—The shear force methods of measuring meat tenderness for the BF, LD, and SM muscles at the 5 versus 48 hour post-mortem boning periods is shown in Table 4. The two mechanical methods of measuring tenderness for the BF muscle indicated steaks of equal tenderness quality between the 48 or 5 hour boning treatment (Table 4). A trend that the anterior steak was more tender than the posterior steak was noted. This agreed with previous findings in the 3 versus 48 hour conditioning periods.

Shear force readings between chill and delay-chill boning treatments for the LD muscle revealed significant differences for the NT measurement (Table 4). The NT reading indicated the 48 hour treatment was less tender than that of the 5 hour holding period. The differences de-

Table 2. Duo-Trio Comparisons for the BF, LD and SM Muscles at the 3 Versus 48 Hour Treatments.

Duo-Trio Comparison	BF	LD	SM
Total number of comparisons	48	48	48
Total number of correct responses	26	21	25

Table 3. Preference Rank Analysis for the BF, LD and SM Muscles at the 3 Versus 48 Hour Treatments.

Process Treatment	n	BF	LD	SM
Chill (48 Hr)[1]	48	1.58	1.56	1.56
Delay Chill (3 Hr)[1]	48	1.42	1.44	1.44

[1] Larger value denotes increased preference.

Table 4. Warner-Bratzler Shear (kg) and Nip Tenderometer (kg) Measurements of 5 Versus 48 Hour Treatments from the BF, LD and SM Muscles.

Instrument	Process Treatment	n	BF	LD	SM
WB Shear	Chill (48 Hr)	72	6.01	6.28	8.62
kg	DelayChill (5 Hr)	72	6.44	6.68	9.06
Carcass by Process Mean Square DF=3			9.96	9.67	6.93
Nip	Chill (48 Hr)	40	4.15	5.35[2]	5.19
kg	Delay Chill (5 Hr)	40	4.25	4.77[2]	5.19
Carcass by Process Mean Square DF=3			3.24	1.32	0.10

[2] Denotes significant difference at $P<0.05$. Nonsubscript denotes nonsignificant difference.

tected by the WB Shear for the LD muscle revealed tenderness of equal quality for both boning treatments (Table 4).

WB Shear, and NT values for the Semimembranosus (SM) muscle indicated steaks of equal tenderness for the chill and delay-chill boned meat (Table 4). Within muscle variation on the SM muscle was similar to previously cited research and data obtained in 3 versus 48 hour treatment study. The anterior portion of the SM muscle was more tender than that of the posterior end.

Sensory Evaluation 5 versus 48 hours—Sensory panel data as related to muscle tenderness and boning treatment are shown in Tables 5 and 6. The data indicate that the panelists correctly identified 24, 20, and 18 of the 58 trials held with the BF, LD, and SM muscles, respectively (Table 5). To achieve statistical significance at the 5% level panelist

Table 5. Duo-Trio Comparison for the BF, LD and SM Muscles at the 5 Versus 48 Hour Treatments.

Duo-Trio Comparison	BF	LD	SM
Total number of comparisons	48	48	48
Total number of correct responses	24	20	18

Table 6. Preference Rank Analysis for the BF, LD and SM Muscles at the 5 Versus 48 Hour Treatments.

Process Treatment	n	BF	LD	SM
Chilled (48 Hr)[1]	48	1.60	1.54	1.62
Delay Chilled (5 Hr)[1]	48	1.40	1.46	1.38

[1] Larger value denotes increased preference.

would have had to correctly paired 32 of 48 samples presented to them. Therefore, the Duo-Trio comparison test revealed panelist were unable to detect a difference between the two methods of beef fabrication for the BF, LD, and SM muscles.

Rank analysis (Table 6) showed a slight preference for the 48 hour chill treatment as compared to the 5 hour delay chill treatment for the BF, LD and SM muscle. This preference was only a slight trend as no significance was attained for any of the muscles studied.

Penetration and Shear Force 7 versus 48 Hours—Table 7 provides data from the BF, LD, SM muscles for the 48 hour chill versus 7 hour delay-chill boning treatments. The NT, and WB Shear indicated no significant differences between the process treatments for the BF muscle. The LD muscle, as estimated by the two mechanical methods of tenderness measurement indicated acceptable quality for the 48 versus 7 hour post-mortem boning treatments (Table 7).

Significant shear force values for the WB Shear and NT were noted for the chill and delay-chill SM muscle (Table 7). These data are in agreement with other shear force measurements on the SM muscle for the 7 versus 48 hour holding periods. The WB Shear and NT indicated the 7 hour boning treatment be less tender than the 48 hour treatment for the SM muscle. Differences within the SM muscle for the two imposed treatments indicated once again that the anterior portion of the muscle was more tender than the posterior portion.

Sensory Evaluation 7 versus 48 Hour—Results of the trained sensory panel evaluation for meat tenderness as related to treatment are shown in Tables 8 and 9. Analysis of these data showed that the panelists were unable to distinguish between the tenderness of the two boning treatments for the BF, LD, and SM muscles.

The Preference Test in this section of the study agreed well with the previous data presented as no significance was indicated by the

Table 7. Warner-Bratzler Shear (kg) and Nip Tenderometer (kg) Measurements of 7 Versus 48 Hour Treatments from the BF, LD and SM Muscles.

Instrument	Process Treatment	n	BF	LD	SM
WB Shear	Chill (48 Hr)	72	7.15	6.17	8.99[2]
kg	Delay Chill (7 Hr)	72	6.53	5.42	9.81[2]
Carcass by Process Mean Square DF=3			8.56	5.07	2.40
Nip	Chill (48 Hr)	40	4.51	4.22	4.71[2]
kg	Delay Chill (7 Hr)	40	4.46	4.04	5.01[2]
Carcass by Process Mean Square DF=3			2.04	1.47	0.40

[2] Denotes significant difference at $P < 0.05$. Nonsubscript denotes nonsignificant difference.

Table 8. Duo-Trio Comparison for the BF, LD and SM Muscles at the 7 Versus 48 Hour Treatments.

Duo-Trio Comparison	BF	LD	SM
Total number of comparisons	48	48	48
Total number of correct responses	28	29	24

Table 9. Preference Rank Analysis for the BF, LD and SM Muscles at the 7 Versus 48 Hour Treatments.

Process Treatment	n	BF	LD	SM
Chill (48 Hr)[1]	48	1.58	1.38	1.56
Delay Chill (7 Hr)[1]	48	1.42	1.62	1.44

[1] Larger value denotes increased preference.

panelist evaluating the BF, LD, or SM muscles (Table 9). Only a slight trend for the 48 hour boned steak was shown for the BF and SM muscles. The reverse trend was indicated by the panelsits for the LD muscles as a slight preference for the 7 hour boning treatment was noted.

The Use of Phantoms to Determine the Effects of Weight on K^{40} Whole-Body Counting Efficiency

D. M. Stiffler, L. E. Walters, J. V. Whiteman and B. W. Lambert

Story in Brief

This research was initiated to determine the influence of weight or size on K^{40} counting efficiency. Four phantoms, weighing 500, 700, 900 and 1100 pounds were constructed using square one-gallon plastic containers filled with a saturated sodium salt solution and a known quantity of potassium chloride. The potassium chloride served as the source of gamma-radiation (K^{40}). Twenty-four mean net counts were obtained at