experimental animals. The overall decrease was greater for the Herefords, 219 μ, than for the Charolais crossbreds, 83 μ, suggesting that the Herefords were earlier maturing in long bone growth than the crossbreds.

Serum alkaline phosphatase activity data followed the same general trends as did the metacarpal epiphyseal cartilage measurements, showing a decrease ($P<0.01$) with animal weight and age. The overall drop in serum alkaline phosphatase activity from the 500 pound to the 1100 pound weight groups was 1.85 times greater, on the average, for the Hereford steers.

Results from this test suggest that with refined techniques for obtaining blood samples, serum alkaline phosphatase activity might be used as a non-destructive procedure on live cattle to estimate the state of physiological maturity of bone in beef cattle. Further testing, starting with younger cattle of known chronological age, and selected for this type of study seems warranted.

The Effect of Electrical Stimulation on the Rate of Post-Mortem Glycolysis in Some Bovine Muscles

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Story in Brief

Processing beef prior to the onset of rigor results in an unsatisfactory product. Electrical stimulation will hasten rigor by accelerating post-morten metabolism. The purpose of this manuscript is to describe the effect of electrical stimulation on the rates of post-mortem glycolysis in the choice bovine carcass.

Sides from six choice carcasses weighing 310 - 367 Kg. were stimulated for 30 minutes beginning an hour after death. Sides from seven carcasses were stimulated for 15 minutes beginning 30 minutes post-mortem. In each instance the opposite side from the same carcass was held as an unstimulated control. All electrical parameters were held constant in all stimulated sides. Samples were taken from the longissimus dorsi (LD), psoas major (PM),

semimembranosus (SM), and supraspinatus (SS) muscles of all sides. The pH was estimated at 0.5, 1,2,4,6,8,12, and 24 hours post-mortem.

Significant ($P<0.05$) differences were found in the rate of pH decrease between corresponding muscles of stimulated and unstimulated sides, except in the case of the PM.

Introduction

With the realization that post-mortem carcass treatments exert the greatest influence on beef palatibility, and for a number of economic reasons, this research was directed toward establishing a method to hasten the post-mortem changes that convert muscle to meat. Muscle from freshly slaughtered animals, if prepared and consumed immediately, will produce tender meat. As the inherent supplies of adenosine triphosphate (ATP) and its precursors are depleted, the muscle becomes inextensible, and tenderness is at its low ebb. This change is temperature dependent, proceeding faster at elevated temperatures. Aging the bovine carcass by conventional chilling methods at temperatures of 0 - 2° C for 10 - 14 days has, in the past, been regarded as necessary to allow autolytic and bacterial enzymes to partially digest the meat to obtain a state of satisfactory tenderness.

Recently there has arisen some interest in the use of electrical stimulation to accelerate the rate of post-mortem muscle metabolism and the development of associated palatibility characteristics. Originally conceived as a method of tenderization, carcass stimulation has hastened ATP depletion and pH drop in chicken; increased glycolytic rates in *Rana*, and rabbit; hastened post-mortem glycolysis, prevented cold shortening, and increased tenderness in lamb; and improved tenderness and flavor in beef.

Materials and Methods

Thirty-minute stimulation

Six hereford heifers ranging from 310 to 367 Kg. were delivered to the Meat Science Abattoir 24 hours prior to slaughter. The heifers were slaughtered, dressed, and split according to normal practices. The sides, weighing from 94 to 114 Kg were then removed to a 16° C room. One side from each carcass was designated as the stimulated side and was connected to a pulse generator via two leads. One lead was a set of eight stainless steel shroud pins connected by a copper wire and spaced by a teflon band, and was inserted into the muscles of the round. The other lead was connected to three similar pins which were inserted into holes drilled in the third, fourth, and fifth cervical vertebrae.

Stimulation was initiated one hour after death and continued for 30 minutes. The pulse generator delivered a direct current square wave pulse, with a frequency of 400 cycles per second, and a duration of 0.5 miliseconds.

Voltage was rapidly increased to 300 volts and remained at this level until stimulation was concluded.

Four hours after death, muscles were dissected from the carcass and removed to a 1.1° C cooler for the duration of the experiment.

Fifteen-minute stimulation

Two steers and five heifers of approximately the same grade (choice) were slaughtered in the conventional manner. The live weights of these animals ranged from 363 to 447 Kg., and side weights were from 122 to 140 Kg. The electrical stimulation procedure was the same as for the previous group, except it was initiated at 30 minutes post-mortem and was continued for 15 minutes. Muscles were dissected and removed to the cooler at two hours post-mortem.

Sampling and pH estimation

Just before the electrical stimulation was initiated, 0.5 inch cores were removed from the longissimus dorsi at the level of the tenth rib; from the semimembranosus at an area two inches posterior to the posterior border of the symphysis pubis; from the medial third of the supraspinatus; and in the case of the thirty minute stimulation period, from the anterior third of the psoas major.

These samples were weighed and homogenized in ten volumes of doubly distilled water. The homogenates were then estimated by a pH meter fitted with a combination electrode. Subsequent samples were taken at 2, 4, 6, 8, 12, and 24 hours post-mortem.

Results and Discussion

Thirty-minute stimulation

Results of the 30-minute stimulation are shown in Table 1. Before stimulation, the pH of the corresponding muscles from each side was not significantly different. Following stimulation, the longissimus dorsi and the semimembranosius exhibited significantly ($P<0.05$) lower pH readings in the stimulated muscles. In the case of the LD, there was no significant difference in pH after 24 hours as the control had fallen to its ultimate level. There was no significant change in the pH of the stimulated LD after six hours.

Differences between SM muscles from stimulated and control sides remained significant throughout the sampling period, the control muscles did not arrive at their ultimate pH within 24 hours.

The PM showed no treatment difference in pH at any of the sampling periods. This implies that electrical stimulation did not increase the rate of post-mortem glycolysis in this muscle. This assessment is contradictory to the findings of Davey *et.al.* (J. Agric. Res. 19:13) who found accelerated pH decline in the PM of stimulated beef sides. The primary difference between the two

Table 1. Muscle pH from control and stimulated sides at each sampling period. Stimulation initiated at one hour post-mortem and continued for 30 minutes

Hr. post-mortem	L. Dorsi		P. Major		Semimembranosus		Supraspinatus	
	Control	Stimulated	Control	Stimulated	Control	Stimulated	Control	Stimulated
1	6.74±.12	6.68±.12	6.22±.15	6.20±.19	6.76±.14	6.77±.06	6.65±.14	6.66±.16
2	6.62±.21	6.18±.10[1]	6.00−.22	5.96−.17	6.56±.28	6.22±.09[1]	6.56±.22	6.34±.14
4	6.31±.24	5.77±.31[1]	5.56±.22	5.64±.14	6.51±.12	6.02±.15[1]	6.34±.10	6.02±.14[1]
6	6.07±.15	5.50±.19[1]	5.47±.19	5.55±.15	6.25±.23	5.82±.23[1]	6.04±.22	5.86±.19
8	5.87±.26	5.42±.17[1]	5.35±.14	5.34±.10	6.20±.14	5.43±.14[1]	5.89±.18	5.78±.15
12	5.68±.12	5.37±.06[1]	5.38±.07	5.34±.04	5.86±.30	5.34±.09[1]	5.88±.22	5.68±.21
24	5.39±.08	5.33±.04	5.35±.05	5.35±.04	5.51±.12	5.26±.06[1]	5.80±.26	5.63±.20

[1]denotes significant (P<0.05) difference between stimulated and control means for a muscle at a sampling period.

Table 2. Muscle pH from control and stimulated sides at each sampling period. Stimulation initiated at 30 minutes post-mortem and continued for 15 minutes

Hr. post-mortem	L. Dorsi		Semimembranosus		Supraspinatus	
	Control	Stimulated	Control	Stimulated	Control	Stimulated
½	6.74±.15	6.73±.12	6.85±.12	6.85±.12	6.79±.15	6.85±.16
1	6.65±.22	6.28±.13[1]	6.78±.12	6.30±.06[1]	6.72±.15	6.29±13[1]
2	6.43±.12	5.29±.13[1]	6.48±.09	6.06±.12[1]	6.58±.17	6.08±.18[1]
4	6.17±.31	5.43±.21[1]	6.30±.16	5.68±.19[1]	6.32±.11	5.77±.17[1]
6	5.99±.22	5.26±.07[1]	6.09±.25	5.40±.18[1]	6.08±.11	5.59±.16[1]
8	5.86±.28	5.35±.05[1]	5.96±.27	5.42±.17[1]	6.08±.15	5.57±.13[1]
12	5.73±.21	5.35±.10[1]	5.90±.30	5.33±.16[1]	5.92±.19	5.58±.22[1]
24	5.46±.15	5.34±.14	5.45±.14	5.32±.04[1]	5.71±.13	5.57±.18

[1]denotes significant (P<0.05) difference between stimulated and control means for a muscle at a sampling period.

studies was the electrical considerations, Davey *et. al.* used a greater voltage and a slower frequency.

Carse (J. Food Tech. 8:163) concluded that voltage, but not frequency, exerts an influence on the rate of post-mortem glycolysis. He showed that glycolytic metabolism is accelerated with increased voltage from 0 to 250 V. Bendall (J. Sci. Food Agric. 27:819), however, maintained that very high voltages are unnecessary to obtain the optimum rate of pH fall.

Clearly the source of the discrepancy is the psoas major itself, as the other muscles examined in this study gave results comparable to those found in the literature. The positioning of this muscle, the stretching it receives when the carcass is suspended, the amount of connective tissue it contains or surrounding depositions of fat may make the psoas major unsuitable for this type of study.

The supraspinatus from stimulated sides differed in pH from the unstimulated controls only at the four hour post-mortem sampling period. This muscle, located in the forelimb, is not in the direct path of the stimulating current and may not have received the degree of stimulation to which the other muscles were subjected.

Fifteen-minute stimulation

Results from the 15-minute stimulation are shown in Table 2. All muscles showed nonsignificant differences in pH between sides before stimulation. The stimulated LD reached its ultimate pH within four hours post-mortem, while its unstimulated control required 24 hours.

The semimenbranosus from this stimulation period showed the same pattern observed for the 30-minute stimulation. The control sides did not exhibit a pH drop comparable to the stimulated sides at the end of the 24-hour period.

The supraspinatus responded, to a greater degree in this study, than in the proceeding one. Since the stimulation was started at 30-minutes post-mortem, the musculature would be expected to have a greater glycogen supply at the initiation of stimulation than the group whose stimulation started at one-hour post-mortem. Thus, being in a "fresher" state may have attributed to the differences observed in the supraspinatus of the two stimulation groups.

The reduction of stimulation time from 30 to 15 minutes did not adversely affect the rate of pH decline in the stimulated sides.

Conclusions

This study confirms previously published conclusions that electrical stimulation is an excellent method of increasing post-mortem metabolism and quickly initiating the rigor process. Such a process has been shown to preclude the dangers of cold shortening and thaw contracture.

Work is under way to determine the feasibility of removing muscles from stimulated sides quickly post-mortem. This approach has advantages in streamlining slaughter and fabrication operations, a reduction in required cooler space, and the associated energy requirement.

Although electrical stimulation seems a practical method for hastening rigor, muscles in deep rigor do not exhibit satisfactory tenderness. Other research is required to establish methods to quickly age this meat to achieve a satisfactory end product.

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