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Introduction

Many studies have evaluated changes that occur in muscle during the aging process and how they relate to meat tenderness. Other research has shown that subjecting carcasses to higher temperatures soon after slaughter speeds the aging process that ultimately results in improved tenderness. Several things may explain this effect. The higher temperature causes the pH (acidity) of the muscle to decrease faster. Also, the combination of lower pH and higher temperature could promote an earlier release of calcium into the muscle, which normally occurs in muscle tissue after slaughter. This increase in calcium concentration in turn activates the calpain enzyme system (a naturally occurring enzyme system that is found in muscle tissue). When calpain is activated by calcium, it has the potential to degrade certain muscle proteins that must be degraded for meat to be tender. A discussion of this is found in the previous article. Therefore, because meat from *Bos indicus* breed crosses often is less tender than meat from *Bos taurus* breeds, we studied whether tenderness could be altered by carcass high-temperature conditioning and, if so, what mechanisms are involved.

Procedures

Seven heifers and four steers of 5/8 Sahiwal x Angus, Hereford or Angus x Hereford weighing an average of 986 lb were slaughtered at 15 to 17 mo of age. Carcasses were not electrically stimulated. Eleven carcass sides were high-temperature conditioned (HTC) at 72°F for 6 hr, then chilled at 30°F for 18 hr. The opposite control sides were chilled at 30°F for 24 hr. Muscle pH and temperature were monitored at 3 hr intervals for 12 hr, and recorded again at 24 hr. After 24 hr, the loin muscles were removed from both carcass sides. Steaks one inch thick were cut, vacuum-packaged, and aged at 39°F for 3, 7, and 14 days. Tenderness was determined on steaks 1 and 14 days post-slaughter by Warner-Bratzler shear force, which measures the amount of force required to sever a 1/2 inch cooked meat core. Also, cooked steak samples were evaluated by a trained sensory panel. The ease to which muscle fibers break (fragment) under controlled homogenization (known as muscle fiber fragmentation) also was measured at 1, 3, 7, and 14 days. To determine the activity of the calpain enzyme system, loin muscle samples were removed within 1 hr (0 hr), 6 hr, and 24 hr after slaughter. Loin muscle samples also were obtained to measure muscle cell length and the activity of other enzymes, known as cathepsins. However, no treatment differences were found for muscle cell length or cathepsin enzyme activity; therefore, those data will not be presented.

Results

As expected, muscle temperature remained higher in the HTC carcasses at 3, 6, 9, and 12 hr than in the control loin muscle (Figure 1). However by 24 hr, the HTC muscles had cooled to the temperature of the control muscles. Figure 2 indicates that the muscle pH of HTC sides was lower than the pH of control muscles at 6, 9, and 12 hr post-slaughter, indicating that the higher temperature hastened the rigor process.

High-temperature conditioning did prove successful in improving tenderness to a small degree in the *Bos indicus* carcasses; however, the sensory panel detected more of an off-flavor in the HTC steaks at day 14. Cooked loin steak samples from HTC sides were more tender as indicated by lower Warner-Bratzler shear force values than control steaks at 1 day post-slaughter (Table 1). However, sensory-panel scores failed to reveal this difference. At day 14, neither Warner-Bratzler shear force values nor sensory panel scores were significantly different, statistically. However, the muscle fiber fragmentation values, that indicate the amount of protein degraded which allows muscle fibers to fragment more easily, were greater at day 3, 7, and 14 in samples from HTC loin steaks than from control steaks. Therefore, it appears that the higher temperature treatment increased the rate that muscle proteins were degraded or, in other words, the tenderization process. However, by 14 days the control steaks had had enough time to decrease the amount of difference in tenderness.

Because differences in the rate of muscle protein degradation occurred, one would expect to find differences in the activity of the enzyme system responsible for these changes. Activities of the μ-calpain and calpastatin (a protein that inhibits calpain activity; see previous article) were determined at 0, 6, and 24 hr post-slaughter. Figure 3 reveals that μ-calpain declined more rapidly in HTC muscle than in control muscle. By 6 hr postmortem, 81 and 62% of the initial activity was lost in the HTC and control samples, respectively. At 24 hr, additional declines of 7% for HTC samples and 3% for control samples were observed. Therefore, control muscle had more activity remaining at 24 hr post-slaughter, which could indicate that less μ-calpain was utilized in degrading muscle proteins, because once μ-calpain is activated by sufficient calcium, it slowly loses its activity. Also, calpastatin loses activity in muscle tissue after slaughter; and high-temperature conditioning hastened its loss of activity. In the HTC samples, 35% activity was lost by 6 hr, whereas control muscles maintained almost all initial (0 hr) activity. Calpastatin activity remained higher in the control muscle at 24 hr.

Results from this study indicate that high-temperature conditioning marginally improved tenderness of loin steaks from 5/8 Sahiwal crosses and, of all the biological traits measured, only calpain and calpastatin activity were affected by this treatment. Therefore, μ-calpain and(or) calpastatin probably play a major role in tenderizing meat.

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[2]The full report of this work was published in J. Anim. Sci. 68:3654-3662, 1990.

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Table 1—Least-squares means for Warner-Bratzler shear values, sensory-panel scores and muscle fiber fragmentation values

Trait	High-temp. conditioned	Control
Day 1		
Warner-Bratzler shear, lb[a]	18.3	21.1
Sensory panel		
Tenderness[b]	3.7	3.6
Juiciness[c]	4.9	5.1
Off-flavor[d]	2.6	2.7
Day 14		
Warner-Bratzler shear, lb	15.2	16.9
Sensory panel		
Tenderness	4.5	4.4
Juiciness	5.1	4.8
Off-flavor	2.5	2.8
Muscle fiber fragmentation[e]		
Day 1	40	35
Day 3	45	32
Day 7	55	42
Day 14	65	55

[a] A higher shear force value indicates less tender meat.

[b] A score of 6=moderately tender,... 4=slightly tough.

[c] A score of 6=moderately juicy,... 4=slightly dry.

[d] A score of 4=none; 1=intense.

[e] A higher muscle fiber fragmentation value indicates that more protein has been degraded; thus, muscle fibers are easier to fragment.

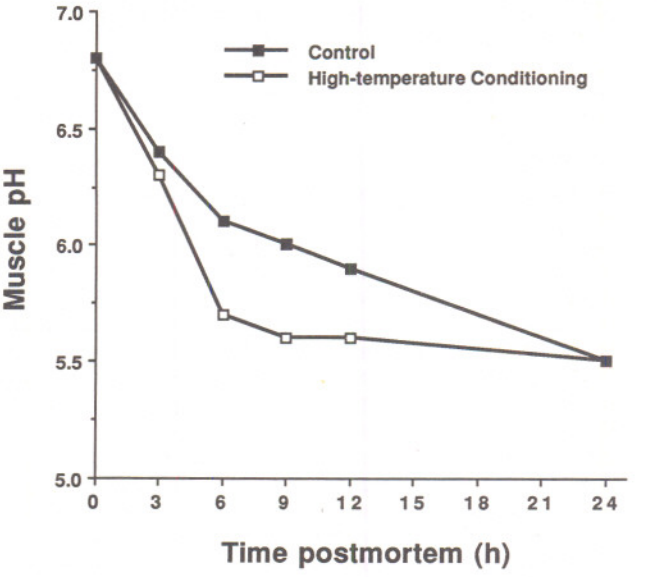

Figure 2 – Effect of high-temperature conditioning on pH of the loin muscle.

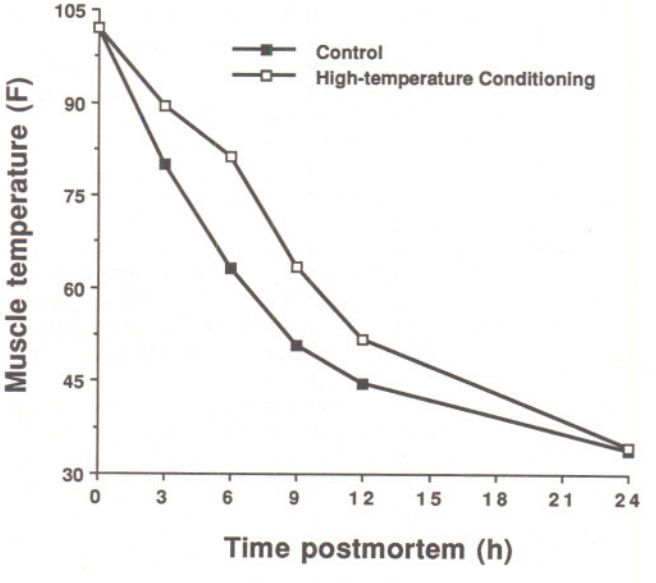

Figure 1 – Effect of high-temperature conditioning on temperature of the loin muscle.

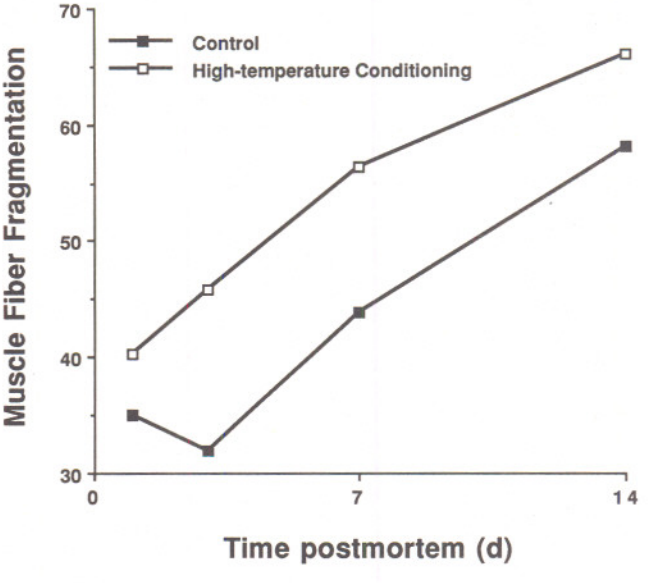

Figure 3 – Effect of high-temperature conditioning on loin muscle fiber fragmentation during postmortem storage.