1988

Factors Associated with Tenderness of Three Beef Muscles

Mohammad Koohmaraie
U.S. Meat Animal Research Center

Steven C. Seideman
Bryan Meats

John D. Crouse
U.S. Meat Animal Research Center

Factors Associated with Tenderness of Three Beef Muscles

Mohammad Koohmaraie, Steven C. Seideman, and John D. Crouse[1]

Introduction

Tenderness is the prominent quality determinant and probably the most important sensory characteristic of beef steak and roast meat. Currently postmortem aging (storage of carcass at refrigerated temperatures for 8 to 14 days) appears to be the best method for producing tender meat. Although the improvement in meat tenderness as a result of postmortem aging is measurable both subjectively and objectively, the exact mechanism responsible for this improvement in tenderness is unknown.

It is well known that different muscles within the same carcass react differently to postmortem storage; for example, tenderloin is tender to begin with and does not improve significantly with postmortem storage, while ribeye is the toughest muscle initially and improves greatly with postmortem storage. The purpose of these experiments was to attempt to answer the following questions: 1) Why are some muscles (e.g., tenderloin) tender at 24 hr postmortem and nonresponsive to postmortem aging? and 2) Why do some muscles (e.g., ribeye and tenderloin) respond differently to postmortem aging?

Procedure

Eight heifers with similar backgrounds were slaughtered. At 45 min postmortem, one-half of the Longissimus dorsi (LD; ribeye), Psoas major (PM; tenderloin), and Biceps femoris (BF; bottom round) were removed from one side of each carcass. Each muscle was then cut into samples for extraction of calcium-dependent protease-I (CDP-I), CDP-II, CDP inhibitor, and lysosomal enzymes, and for determination of moisture, fat, and collagen (amount and solubility). Shear force was determined on cooked steaks from each muscle after days 1 and 14 postmortem storage.

Results

On wet or dry basis, the PM had the highest fat content, followed by LD, and then BF (Table 1), while the exact opposite pattern was observed for moisture content. Data regarding the amount and solubility of collagen are reported in Table 3. BF had significantly more collagen than LD and PM. In terms of collagen solubility, PM had the highest percentage of soluble collagen followed by LD and BF (differences between PM and LD were not statistically significant).

Shear force values at different postmortem times are presented in Table 1. At day 1, PM was the most tender muscle (shear force = 8.71), while LD muscle was the toughest (shear force = 18.15), and BF had the shear force value of 13.55. After seven days of postmortem storage, PM was still the most tender muscle but, most importantly, was virtually unaffected by postmortem storage. BF had a shear force of 13.55 at day 1 and 10.30 at day 14 (a 3.25 lb decrease in shear force value as a result of postmortem storage). LD had a shear force value of 18.15 at day 1 and 10.90 at day 14 (a 7.25 lb decrease). Therefore, in terms of aging response (decrease in shear force values as a result of postmortem storage), LD had the highest aging response, followed by BF and PM.

CDP-I, -II and CDP inhibitor activities are reported in Table 2. LD had the highest CDP-I, CDP-II, and inhibitor activities, followed by BF and then PM. LD muscle had approximately twice the CDP-I, -II, and inhibitor activity of PM muscle. Results of this experiment indicate that, for all three muscles, the ratio of CDP-I:CDP-II was approximately 1:1 and the ratio of CDP-I + CDP-II:inhibitor was also 1:1.

Unlike the results of CDP activities, no particular pattern was observed for catheptic enzymes (Table 2). The activities of cathepsins B, H, and B + L are almost identical between muscles.

Results of sarcomere length and fiber type characteristics are presented in Table 3. PM had the longest sarcomeres, followed by BF and LD. These differences were statistically significant.

Fiber type characteristic results (Table 2) indicate that PM had the highest percentage of red fibers and the smallest percentage of intermediate fibers when compared to LD and BF ($P < 0.05$). LD and BF were similar in fiber type characteristics. PM had the smallest average fiber area; BF, intermediate ($P < .05$); and LD, the largest.

Results of this experiment demonstrate that, at 24 hr postmortem, these three muscles differ significantly in shear force. How could one explain these differences? It has been theorized that two muscle components, collagen and the contractile apparatus, determine tenderness. It is now clear that collagen quality is much more significant than quantity. However, we cannot explain these large differences in shear force values (Table 1), neither in terms of collagen amount nor solubility. Collagen solubilities are 7.40% and 6.94% for PM and LD, respectively. This small difference in collagen solubility cannot explain the differences between 8.71 and 18.15 lb of shear force. Of all the parameters examined in this experiment, average fiber size is the only basis on which the differences between these muscles could be explained. We have consistently observed the effect of fiber size on meat tenderness regardless of breed or sex. However, at this point, we cannot offer an explanation for the relationship between fiber size and meat tenderness.

Table 1—Moisture, fat, collagen, and shear force of Longissimus dorsi (LD), Biceps femoris (BF), and Psoas major muscles (PM)

	LD	BF	PM
Moisture, %	72.51[a]	74.23[a]	72.95[a]
Fat, wet basic, %	3.89[a]	2.33[b]	4.56[a]
Fat, dry basic, %	14.00[a]	8.99[b]	16.60[a]
Total collagen, mg/g	3.40[a]	6.16[b]	2.23[c]
Soluble collagen, %	6.94[a]	5.05[b]	7.40[a]
Shear force, lb day 1	18.15[a]	13.55[b]	8.71[c]
Shear force, lb day 7	10.90[a]	10.30[a]	8.40[a]

[abc]Means with different superscripts within a row differ ($P < .05$).

[1]Koohmaraie is a research food technologist and Crouse is the research leader, Meats Unit, MARC; and Seideman is employed by Bryan Meats, West Point, Mississippi (formerly a research food technologist, MARC).

In terms of aging response, LD had the highest aging response, followed by BF, while PM basically did not change from day 1 to day 7. In attempts to understand the differences between LD and PM, we measured the activities of two well-known classes of muscle proteases. It has been postulated that one class of these proteases or their synergistic action is responsible for postmortem tenderization of meat. It is logical to assume that the class of protease responsible for postmortem aging should have high activity in the muscle with a high aging response and vice versa. The results of this experiment indicate that, regardless of the magnitude of aging response, the activities of cathepsins B, H and B + L were basically the same for all three muscles. However, in the case of CDP, its activity followed the same pattern as aging response. Based on the results of this experiment and others, it was concluded that initial levels of CDP-I activity determine the aging response of a given muscle.

If indeed our hypothesis is correct and CDP-I is responsible for postmortem aging, then its inactivation, or postmortem handling of the carcasses to provide unfavorable conditions for its activation should prevent the postmortem aging. We are now addressing this particular point by attempting to deactivate CDP-I in animals and then examining postmortem changes.

Table 2—Ca^{2+}-activated proteases, their inhibitor, and catheptic enzyme activity in Longissimus dorsi (LD), Biceps femoris (BF), and Psoas major (PM) muscles

	LD	BF	PM
CDP-I[d]	91.35[a]	60.63[b]	49.70[c]
CDP-II[e]	108.02[a]	79.87[b]	50.40[c]
Inhibitor[f]	-152.44[a]	-148.57[a]	-90.20[b]
Cathepsin B[g]			
unsedimentable fraction	17.25[a]	22.09[a]	22.08[a]
sedimentable fraction	1.80[a]	1.63[a]	2.23[a]
Cathepsin H[g]			
unsedimentable fraction	48.83[a]	45.73[a]	42.99[a]
sedimentable fraction	10.23[a]	9.04[a]	9.67[a]
Cathepsin L + B[g]			
unsedimentable fraction	41.58[a]	41.78[a]	37.55[a]
sedimentable fraction	3.80[a]	3.98[a]	4.71[a]

[abc]Means with different superscript within a row differ ($P < .05$).
[d]Low calcium-requiring calcium-dependent protease (A_{278}/200 g muscle).
[e]High calcium-requiring calcium-dependent protease (A_{278}/200 g muscle).
[f]Inhibitor of CDP-I and CDP-II (A_{278}/200 g muscle).
[g]Units/min/mg of protein.

Table 3—Sarcomere length and fiber type characteristics of Longissimus dorsi (LD), Biceps femoris (BF), and Psoas major (PM) muscles

	LD	BF	PM
Sarcomere length (μm)	1.68[a]	2.15[b]	3.55[c]
Area of white fiber (μm)	6140.50[a]	5077.37[b]	2230.12[c]
Area of intermediate fiber (μm)	3831.25[a]	3382.12[a]	1524.62[b]
Area of red fiber (μm)	3029.12[a]	2638.00[a]	1460.62[b]
White fiber (%)	40.38[a]	45.18[a]	38.37[a]
Intermediate fiber (%)	28.58[a]	24.37[a]	16.34[b]
Red fiber (%)	31.03[a]	30.43[a]	45.28[b]
Average fiber area (μm)	4333.62[a]	3699.17[b]	1737.45[c]

[abc]Means with different superscripts within a row differ ($P < .05$).