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Bethany M. Sitz
University of Nebraska-Lincoln

Pennapa Matayompong
University of Nebraska-Lincoln

Christian D. Perversi
University of Nebraska-Lincoln

Chris R. Calkins
University of Nebraska-Lincoln, ccalkins1@unl.edu

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Summary

Thoracic limbs from 20 beef steers were used as post-rigor controls, pre-rigor controls (removed pre-rigor), or treated with combinations of sodium citrate and/or water to evaluate the effect of citrate on meat tenderness. Shear force values on steaks from the infraspinatus, supraspinatus and triceps brachii muscles revealed citrate-treated muscles were more tender than water and post-rigor control treatments. It appears sodium citrate can tenderize meat independent of water injection.

Introduction

Tenderness is the most important factor for consumers in determining acceptability of meat, especially beef. Consumers are willing to pay a premium for meat that is more tender. Brooks et al. (2000) concluded from the 1998 National Beef Tenderness Survey that muscle from the round and chuck are in particular need of improvement in tenderness. Treatments to improve tenderness of chuck and round muscles would add value to the whole carcass.

Previous research in our laboratory indicated beef chucks injected pre-rigor with water were less tender than control samples while those injected pre-rigor with 200 and 400 mM sodium citrate, a glycolytic inhibitor, improved tenderness over the controls. Some muscles injected with water had longer sarcomeres (less contraction). Since calpains are the calcium-dependent protease responsible for postmortem meat tenderization, we hypothesized that pre-rigor water injection diluted intramuscular calcium to the point that contraction and calpain activities were minimized, and that sodium citrate would enhance tenderness independent of this effect. The current study was conducted to determine the effect of pre-rigor water injection and post-rigor sodium citrate treatment on chuck muscle tenderness.

Procedure

Animals

Left and right thoracic limbs of 20 steers were randomly assigned after evisceration to one of five treatments: 1) left on the carcass to enter rigor (post-rigor control), 2) removed pre-rigor and otherwise untreated (pre-rigor control), 3) removed pre-rigor and left untreated for 24 hours, when they were injected to 15% of muscle weight with a solution of 4% sodium citrate (0/citrate), 4) removed pre-rigor, injected to 10% of muscle weight with tap water, then injected post-rigor with 5% more tap water (water/water) and 5) removed pre-rigor and injected to 10% of muscle weight with tepid tap water, then injected post-rigor to 5% of muscle weight with a solution of 12% sodium citrate (water/citrate). Injection of water and solution was done by hand throughout the infraspinatus, supraspinatus and triceps brachii using a five-needle ham injection unit. Pre-rigor and post-rigor injections were done at 2 hours and 24 hours postmortem, respectively. After 48 hours of chilling at 4ºF, the infraspinatus, supraspinatus and triceps brachii were excised from the limbs and sampled for sarcomere length (muscle contraction) determination. At 5 and 12 days post mortem, a one-inch thick steak from each muscle was cut and frozen for Warner-Bratzler shear force determination.

Sarcomere Length

Sarcomere length was measured at 48 hours postmortem on fresh muscle samples (total of 20 fibers per observation) using the neon laser diffraction method.

Warner-Bratzler Shear Force

A one-inch thick steak from each muscle was broiled on a tabletop broiler to a final internal temperature of 158ºF. Temperature was monitored at the geometric center of each steak using a thermocouple thermometer. Cooked steaks were chilled 2 hours at 4ºF, and then eight cores (1/2-inch in diameter) were removed parallel to the muscle fiber orientation. Cores were sheared once each on an Instron

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Table 1. Effect of treatments on shear force values (lbs) of infraspinatus, supraspinatus and triceps brachii muscles at 5 and 12 days post mortem.

		Treatments					
Muscle	Aging	Post-rigor Control	Pre-rigor Control	0 / Citrate	Water / Water	Water / Citrate	SEM
Infraspinatus	5 d	6.65^{c}	5.55^{a,b}	5.70^{a,b,c}	6.56^{b,c}	5.48^{a}	0.33
Infraspinatus	12 d	6.64^{b}	5.46^{a}	5.07^{a}	6.74^{b}	5.24^{a}	0.37
Supraspinatus	5 d	11.52^{b}	10.11^{a}	9.71^{a}	11.52^{b}	9.16^{a}	0.73
Supraspinatus	12 d	11.28^{b}	9.45^{a,b}	8.57^{a}	11.06^{b}	8.02^{a}	0.73
Triceps brachii	5 d	8.63^{c}	8.06^{b,c}	6.67^{a}	8.92^{c}	6.92^{a,b}	0.40
Triceps brachii	12 d	8.14^{b}	8.15^{b}	6.21^{a}	8.57^{b}	5.77^{a}	0.34

^{a,b,c} Within a row, means without a common superscript letter differ ($P < 0.05$)

Table 2. Effect of treatments on sarcomere length (µm) of infraspinatus, supraspinatus and triceps brachii muscles at 48 hours post mortem.

	Treatments					
Muscle	Post-rigor Control	Pre-rigor Control	0 / Citrate	Water / Water	Water / Citrate	SEM
Infraspinatus	1.63	1.92	1.68	2.11	2.01	0.14
Supraspinatus	1.62	1.93	1.66	1.73	1.48	0.12
Triceps brachii	2.01	1.95	1.84	2.19	2.33	0.15

Universal Testing Machine with a Warner-Bratzler attachment and a 250 mm/min crosshead speed.

Statistical Analysis

Data were analyzed by analysis of variance using the MIXED procedures of SAS for a completely randomized design. The model included the main effects of carcass side, animal, and treatment. When the treatment main effect was significant ($P < 0.05$), least squares means were separated using the PDIFF procedure.

Results

For each muscle at each aging time (Table 1), except infraspinatus 0/citrate versus water/water at five days postmortem, citrate-treated muscles (0/citrate and water/citrate, which were not different from each other) were significantly more tender than the water/water and the post-rigor control treatments (which were not different in tenderness from each other). Post-rigor injection with sodium citrate may increase pH and ionic strength of muscles to a level where increased solubilization of myofibrillar proteins occurs. This would be similar to the effect of potassium chloride. The mechanism by which sodium citrate increased meat tenderness may not involve calpain enzymes because sodium citrate is a calcium chelator and calcium is required for calpain activty. Additionally, the concentration of sodium citrate used in this study may inactivate calpains since increased ionic strength decreases calpain activity. The results of this study suggest that citrate can overcome some limits to tenderization caused by pre-rigor injection of water.

There were no differences in sarcomere length ($P > 0.05$) among treatments within muscles (Table 2). Pre-rigor removal of the thoracic limb increased tenderness in the infraspinatus and supraspinatus when compared to the post-rigor control ($P < 0.05$), which likely occurred as a result of altered muscle position. Thus, sodium citrate can tenderize meat independent of water injection. Further research is needed to understand the role of sodium citrate in meat tenderization and its application to low-value muscles.

[1]Bethany M. Sitz, former graduate student; Pennapa Matayompong, graduate student; Christian D. Perversi, former graduate student; Chris R. Calkins, professor, Animal Science, Lincoln.