January 2002

Use of Sodium Citrate to Enhance Tenderness and Palatability of Pre-Rigor Beef Muscles

Christian Perversi
University of Nebraska-Lincoln

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

Jesus Velazco
Instituto Tecnológico de Estudios Superiores de Monterrey, Monterrey, México

Use of Sodium Citrate to Enhance Tenderness and Palatability of Pre-Rigor Beef Muscles

Christian Perversi
Chris Calkins
Jesús Velazco[1]

Pre-rigor muscles pumped with a 400 mM solution of sodium citrate were almost always more tender than controls when evaluated objectively (Warner-Bratzler shear force) and subjectively (taste panel).

Summary

The objective of this project was to evaluate the response in tenderness and consumer acceptability of three muscles from the chuck that were pumped pre-rigor with different concentrations of sodium citrate solutions to inhibit glycolysis, while maintaining skeletal restraint for 24 hours. Controls were left on carcass, while the other three treatments had the thoracic limb removed and muscles pumped post-mortem to 10% of their weight with solutions of 0 mM, 200 mM or 400 mM sodium citrate. Although tenderness ratings were not always statistically different (comparing controls vs. 400 mM solution), there was a clear trend showing higher concentrations of sodium citrate make beef more tender and acceptable to consumers.

Introduction

Glycolytic inhibition diminishes post-rigor pH decline by preventing the formation of lactic acid from anaerobic degradation of glycogen within the muscle during rigor mortis. Injection of muscles with glycolytic inhibitors enhanced beef tenderness and palatability despite causing substantial contraction by injecting and tumbling of pre-rigor muscles (*2000 Beef Report*, p. 80). In the experiment reported here, skeletal restraint was maintained for 24 hours to help stop the muscles from shortening.

Knowledge of the appropriate concentration of sodium citrate, the glycolytic inhibitor that makes pre-rigor beef more tender, can help make the muscles from the chuck more valuable to the consumer and the industry. The objective of this study was to determine if sodium citrate in different solutions is effective in enhancing tenderness and consumer acceptability of beef when injected pre-rigor and with 24 hour skeletal restraint of the muscles.

Procedure

Steers (n=14) were slaughtered and thoracic limbs were removed and pumped (within two hr post-mortem) to 10% of muscle weight with water, 200 mM or 400 mM sodium citrate solutions (they had been previously randomly assigned to one of the four treatments). They were then left to chill in the carcass cooler for 24 hours. Unpumped, control limbs were left on the carcasses. Muscle pH was measured immediately prior to pumping and 24 hours post mortem. Steaks (1-inch thick) were removed after 24 hours from the *Infraspinatus*, *Supraspinatus*, and *Triceps brachii* muscles and randomly assigned either to be frozen immediately or aged for six more days. Samples of each muscle were placed with random number identification in a retail display for five consecutive days with daily subjective (performed by a trained operator) and objective color evaluation (performed with a HunterLab MiniScan XE Plus colorimeter with a 1-inch port), and microbial growth determination at entry and exit times of the retail display case.

A consumer taste panel (30-35 participants) evaluated palatability (juiciness, tenderness, connective tissue amount, and flavor desirability) on *Infraspinatus* and *Triceps brachii* steaks using 9-point hedonic scales (1 being very undesirable and 9 being very desirable) for each trait. Warner-Bratzler shear force values were determined on 0.5 inch-diameter cores from steaks that were broiled to an internal temperature

(Continued on next page)

of 158 F on Farberware Open Hearth electrical grills and then cooled.

Results

Significantly higher pH's were obtained through the glycolytic inhibition when measured 24 hours postmortem (5.79 and 5.80 for the 200 mM and 400 mM sodium citrate treated steaks respectively vs. 5.67 and 5.76 for the untreated steaks and the ones pumped with water, respectively).

Treatment with 400 mM sodium citrate improved shear force values over the controls at day 1 and day 7 for all muscles except the *Triceps brachii* and *Infraspinatus* on day 1 (Table 1). Tenderness ratings followed the same trend, except for the *Infraspinatus.* Connective tissue amount, flavor and juiciness of the 400 mM citrate treated-steaks (*Infraspinatus* and *Triceps brachii*) were rated as more desirable ($P < 0.10$) than the controls at day 1 and day 7 (data not shown). Characteristics of steaks treated with 200 mM sodium citrate were usually between the controls and the 400 mM concentration. Pumping with water was generally detrimental to tenderness and palatability. These data indicate that a 400 mM sodium citrate solution may be applied to pre-rigor beef muscles (constrained from contraction) to enhance tenderness and palatability.

Steaks treated with 200 mM or 400 mM sodium citrate were about 1 unit darker than controls for the first one or two days of retail storage , respectively, when visually rated on a 5-point scale (Table 2). No differences were observed during additional retail storage. Objective assessment of lightness (L*) revealed that *Supraspinatus* and *Triceps brachii* treated with sodium citrate were darker than their controls (Table 3). Similar to visual evaluation, differences in degree of redness (a*) and yellowness (b*) that existed on the initial day of retail display rapidly disappeared (Tables 4 and 5).

Table 1. Shear force (measured in lb) and sensory ratings of steaks treated with sodium citrate.

		Infraspinatus		*Triceps brachii*		*Supraspinatus*	
Trait	Treatment[a]	day 1	day 7	day 1	day 7	day 1	day 7
Shear Force	Control	7.94^{bc}	7.70^{cd}	8.16^{b}	7.90^{c}	11.52^{c}	10.51^{c}
	0 mM	8.71^{c}	8.34^{d}	9.97^{c}	9.70^{d}	11.26^{c}	10.78^{c}
	200 mM	7.85^{bc}	6.86^{bc}	8.47^{b}	7.85^{c}	8.99^{b}	8.43^{b}
	400 mM	7.30^{b}	6.14^{b}	7.81^{b}	6.80^{b}	8.60^{b}	8.87^{b}
Tenderness	Control	5.4^{bc}	5.5^{b}	4.7^{c}	4.6^{c}		
	0 mM	5.0^{c}	4.9^{c}	4.0^{d}	4.1^{d}		
	200 mM	5.4^{bc}	5.7^{b}	5.0^{bc}	4.8^{c}		
	400 mM	5.7^{b}	5.9^{b}	5.3^{b}	5.5^{b}		
Flavor	Control	5.2^{bc}	4.8^{c}	5.0^{b}	4.7^{c}		
	0 mM	5.0^{c}	4.7^{c}	4.6^{c}	4.5^{c}		
	200 mM	5.3^{bc}	5.4^{b}	5.2^{b}	4.9^{b}		
	400 mM	5.5^{b}*	5.4^{b}	5.3^{b}*	5.2^{b}		

[a]Control means these muscles were left unpumped on the carcass; 0 mM means these steaks were pumped with water; 200 mM and 400 mM means these steaks were pumped with 200 mM and 400 mM solutions of sodium citrate, respectively.
[b,c,d]Means in the same column within each trait with different superscripts differ significantly ($P < 0.05$).
*Control versus 400 mM differ significantly at $P < 0.10$.

Table 2. Visual color of steaks treated with sodium citrate.

Day	Control	0 mM	200 mM	400mM
0	3.3^{b}	2.9^{a}	3.7^{c}	4.1^{d}
1	3.8^{b}	3.4^{a}	4.0^{bc}	4.2^{c}
2	4.2^{b}	3.2^{a}	4.1^{b}	4.3^{b}
3	4.1^{b}	3.4^{a}	4.2^{b}	4.3^{b}
4	4.1^{b}	3.2^{a}	4.1^{b}	4.3^{b}
5	4.4^{b}	3.5^{a}	4.1^{b}	4.3^{b}

[a,b,c,d]Means within the same row with different superscripts are significantly different ($P < 0.05$).
A 5 point scale was used; 1= Pale cherry red, 3= Bright cherry red, 5= Dark purple red.

Table 3. L* Values of steaks treated with sodium citrate.

Muscle	Control/carc	Control/water	200mM NaCit	400mM NaCit
ISP	42.87^{a}	45.64^{b}	43.55^{a}	43.19^{a}
SSP	38.80^{b}	39.45^{b}	36.60^{a}	36.02^{a}
TBR	36.99^{b}	42.01^{d}	38.91^{c}	34.92^{a}

[a,b,c,d]Means within the same row with different superscripts are significantly different ($P < 0.05$)
ISP = *Infraspinatus*, SSP = *Supraspinatus*, and TBR = *Triceps brachii*.

Table 4. a* Values of steaks treated with sodium citrate.

Day	Control/carc	Control/water	200mM NaCit	400mM NaCit
0	26.64^{a}	27.47^{a}	23.92^{b}	23.94^{b}
1	23.28^{b}	24.56^{a}	23.44^{ab}	23.33^{b}
2	21.19^{b}	23.12^{a}	22.18^{ab}	21.40^{b}
3	20.23^{b}	21.86^{a}	20.84^{ab}	20.66^{b}
4	18.64^{b}	20.69^{a}	20.11^{a}	19.87^{a}
5	18.79^{b}	20.32^{a}	20.80^{a}	19.73^{ab}

[a,b]Means within the same row with different superscripts are significantly different ($P < 0.05$)

Table 5. b* Values of steaks treated with sodium citrate.

Day	Control	Water	200 mM Sodium Citrate	400 mM Sodium Citrate
0	19.68[b]	21.23[a]	17.37[c]	17.19[c]
1	19.35[b]	21.41[a]	20.13[ab]	20.14[ab]
2	18.99[b]	21.32[a]	19.72[b]	18.55[b]
3	18.92[b]	21.05[a]	19.22[b]	18.84[b]
4	17.97[b]	20.33[a]	18.79[b]	18.25[b]
5	18.90[b]	20.37[a]	19.90[ab]	19.34[ab]

[a,b,c]Means within the same row with different superscripts are significantly different ($P < 0.05$)

Table 6. Logarithmic Microbiological Growth Values.

Day	Control	0 mM	200 mM Sodium Citrate	400 mM Sodium Citrate
day 0	2.08[a]	2.50[ab]	2.58[b]	2.72[b]
day 5	3.59[c]	5.70[d]	5.45[d]	5.11[d]
difference	1.50[c]	3.21[d]	2.88[d]	2.40[d*]

[a,b]Means within the same row with different superscripts are significantly different ($P < 0.05$) - note the main effect of treatment was not significant ($P < 0.10$)
[c,d]Means within the same row with different superscripts are significantly different ($P < 0.05$)
* 400 mM differs from control ($P < 0.10$)

The handling required to inject muscles increased the initial microbial counts over the untouched controls. The increase in microbial numbers that naturally occurs during retail storage was similar for the controls and muscles injected with 400 mM sodium citrate ($P > .10$).

Conclusion

These data indicate that treatment of pre-rigor beef muscle with 400 mM sodium citrate results in meat that is more tender and flavorful, but is darker in color.

[1]Christian Perversi, graduate student; Chris Calkins, professor, Animal Science, Lincoln; Jesús Velazco, Instituto Tecnológico de Estudios Superiores de Monterrey, Monterrey, México.