Acid Marination for Tenderness Enhancement of the Beef Bottom Round

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Summary

Two experiments were conducted to evaluate acid marination to enhance tenderness of the beef bottom round (m. biceps femoris*). Both experiments consisted of 3 acid types (acetic, lactic, and citric) and two concentrations (0.1 and 0.5 M in Exp. 1; 0.75 and 1.5 M in Exp. 2). There were no effects of acid marination on beef tenderness in Exp. 1, although lightness (L*) increased and redness decreased from 0 to 8 hours post-marination. Acetic and lactic acid (0.75 or 1.5 M) improved shear force values above those achieved by citric acid. Both lightness and redness permanently decreased in Exp. 2. Beef can be tenderized using lactic or acetic acid, but discoloration as a consequence of acid treatment may compromise acceptability.*

Introduction

Most meat scientists attribute a substantial portion of the tenderness improvement from acid marination to solubilization of collagen – a pH effect. If that were all, tenderness improvement during acid marination would occur immediately, and there were would be no benefit or detriment to changing the length of marination. That is, it would be possible to treat a muscle with the appropriate acid marinade and the product could then make its way through the distribution system without concern for over-tenderization.

Acids have been shown to enhance tenderness, but little work has been conducted on the interaction of acid strength and the length of time the muscle would stay acceptable to consumers. The objective of the present research was to document the tenderness and color effects of marinating m. *biceps femoris* with various concentrations of lactic, acetic, and sodium citrate dihydrate (food grade citric acid).

Procedure

Seventy-two bottom round (m. *biceps femoris*) muscles were purchased and injected by hand with a multineedle injector with acetic, lactic, or sodium citrate dihydrate (food grade citric acid). In Exp. 1, acid concentrations were 0.1 and 0.5 M pumped to 107% of muscle weight. In Exp. 2, acid concentrations were 0.75 and 1.5 M pumped to 110% of muscle weight. Excess subcutaneous fat and the ischiatic head of the m. *biceps femoris* were removed before injection, leaving one continuous muscle from which to fabricate uniform, 1-inch thick steaks at the appropriate time. Muscles were placed in sealed plastic bags and tumbled for 30 minutes after injection to help distribute the acid marinade. Steaks were removed and frozen at 0 (untreated control), 1, and 8 hours and at 1, 3, 7, 14, 21, and 28 days (except the last 2 sampling days were omitted from Exp. 2). Location of the various steaks was randomized for each bottom round to avoid positional effects on tenderness. The control steaks were removed from random locations immediately prior to injection of the marinade.

Ten muscles were injected for each of the 6 treatments in Exp. 1; in Exp. 2, 3 muscles were injected for each 0.75 M acid marinade, and 4 muscles were injected for each 1.5 M acid marinade. Remaining steak samples were all cut and vacuum-packaged at the 8-hour post-marination sampling time and subsequently frozen on the appropriate day. Color measurements of lightness (L*), redness (a*), and yellowness (b*) were obtained using a Hunter colorimeter with a 1-inch sample port, illuminant A, and a 10-degree standard observer. Color was measured on steaks removed at 0, 1, and 8 hours after a 1-hour bloom time.

After thawing for 23 hours in a 34-36ºF cooler, thawed steaks were grilled on a Hamilton Beach indoor-outdoor grill, turning over once at 95ºF, until they reached an internal temperature of 160ºF, monitored using an OMEGA thermometer with a type T thermocouple. Steaks were chilled overnight in the cooler. Then ½-inch-diameter cores were removed parallel to the fiber direction for determination of Warner-Bratzler shear force on an Instron universal testing machine with a Warner-Bratzler shear attachment.

Results

Experiment 1

No significant differences were observed among the acid treatments (Figure 1). Apparently, the low concentrations of acids used were not sufficient to degrade the connective tissue and improve tenderness. Almost all treatments increased significantly in lightness and decreased in redness from 0 to 8 hours post-marination (Tables 1 and 2). There were few differences among treatments, except meat treated with acetic acid tended to be darker and less red than citric-acid treated muscles. Meat treated with acetic or lactic acid had discoloration at the injection sites (observed subjectively), likely a pH effect. All discoloration was permanent. The acetic and citric acid treatments generally had greatest decreases in overall redness over time compared to the lactic acid treatment (Table 5).

(Continued on next page)

Table 1. Exp. 1. Lightness values (L*) of flat round steaks (m. *Biceps femoris*) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [Significant effect = trt*time ($P = 0.04$)].

Time	Treatments[1]						Contrasts[2]					
	AH	AL	CH	CL	LH	LL	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0[3]	40.20	38.17^{b}	40.57^{a}	36.54^{b}	38.52	38.37^{b}	0.30	0.04	0.94	0.64	0.59	0.94
1	41.33	38.99^{b}	35.79^{b}	37.53^{b}	39.66	42.13^{a}	0.23	0.37	0.21	0.02	0.59	0.005
8	40.41	42.20^{a}	40.28^{a}	42.18^{a}	41.51	42.44^{a}	0.18	0.16	0.49	0.94	0.47	0.43

[abc] Means in the same column having different superscripts are significant.
[1] AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; LL = lactic acid low.
[2] A = acetic acid; C = citric acid; L = lactic acid.
[3] 0hr = control, no treatments applied to sample.

Table 2. Exp. 1. Redness values (a*) of flat round steaks (m. *Biceps femoris*) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [Significant effects = trt ($P = 0.0002$) and time ($P < 0.0001$)].

Time	Treatments[1]							Contrasts[2]					
	AH	AL	CH	CL	LH	LL	Means	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0[3]	24.47	24.03	24.13	25.09	25.30	26.47	24.92^{d}	0.72	0.43	0.34	0.67	0.06	0.14
1	23.31	23.01	23.97	25.56	23.98	26.21	24.34^{d}	0.83	0.28	0.13	0.13	0.07	0.75
8	16.36	19.68	19.76	20.35	17.20	22.08	19.24^{e}	0.02	0.66	0.0012	0.04	0.1	0.66
Means	21.38^{c}	22.24^{bc}	22.62^{bc}	23.67^{ba}	22.16^{bc}	24.92^{a}							

[a,b,c]Means in the same row having different superscripts are significant.
[d,e]Means in the same column having different superscripts are significant.
[1]AH = acetic acid high; AL = acetic acid low; CH = citric acid high, CL = citric acid low; LH = lactic acid high; LL = lactic acid low.
[2]A = acetic acid, C = citric acid, L = lactic acid.
[3]0hr = control, no treatments applied to sample.

Table 3. Exp. 2. Lightness values (L*) of flat round steaks (m. *Biceps femoris*) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [No significant trt *time effect ($P = 0.62$)].

Time	Treatments[1]							Contrasts[2]					
	AH	AL	CH	CL	LH	LL	Means	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0[3]	43.88	43.21	45.46	41.11	42.53	40.39	36.65^{d}	0.76	0.06	0.34	0.87	0.19	0.25
1	39.20	40.78	40.39	37.95	38.99	39.80	4.02^{e}	0.47	0.17	0.71	0.72	0.70	0.98
8	35.11	39.62	39.86	38.58	36.20	38.33	33.67^{e}	0.05	0.57	0.34	0.24	0.95	0.22
Means	39.40^{b}	41.20^{ab}	42.09^{a}	39.22^{b}	39.24^{b}	39.51^{b}							

[a,b,c]Means in the same row having different superscripts are significant.
[d,e]Means in the same column having different superscripts are significant.
[1]AH = acetic acid high, AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; and LL = lactic acid low.
[2]A = acetic acid, C = citric acid, L = lactic acid.
[3]0hr = control, no treatments applied to sample.

Table 4. Exp. 2. Redness values (a*) of flat round steaks (m. *Biceps femoris*) acid-marinated with high and low concentrations of acetic, citric, or lactic acids [Significant trt *time interaction ($P < 0.0001$)].

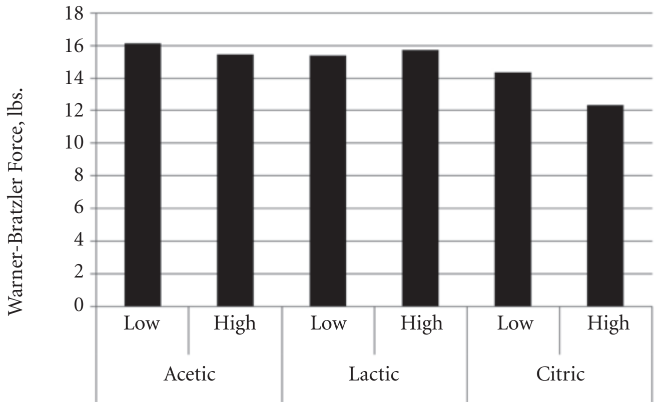
Time	Treatments[1]						Contrasts[2]					
	AH	AL	CH	CL	LH	LL	AH vs AL	CH vs CL	LH vs LL	A vs C	A vs L	C vs L
0[3]	31.84^{a}	32.48^{a}	33.12	34.02	32.48^{a}	32.59^{a}	.51	.35	.98	.04	.52	.16
1	25.17^{b}	27.87^{b}	32.23	33.86	20.27^{b}	25.58^{b}	.20	.44	.01	< 0.0001	.02	< 0.0001
8	17.12^{c}	21.32^{c}	31.64	32.32	20.03^{b}	23.38^{b}	.10	.79	.19	< 0.0001	.17	< 0.0001

[a,b,c]Means in the same column having different superscripts are significant.
[1]AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; and LL = lactic acid low.
[2]A = acetic acid, C = citric acid, L = lactic acid.
[3]0hr = control, no treatments applied to sample.

Table 5. Exp. 1. Treatment and time effects on cooking loss percentage of flat round steaks (m. *Biceps femoris*) acid-marinated with high and low concentrations of acetic, citric, or lactic acids. (P values = trt < 0.0001, time = 0.0073, trt*time = 0.17).

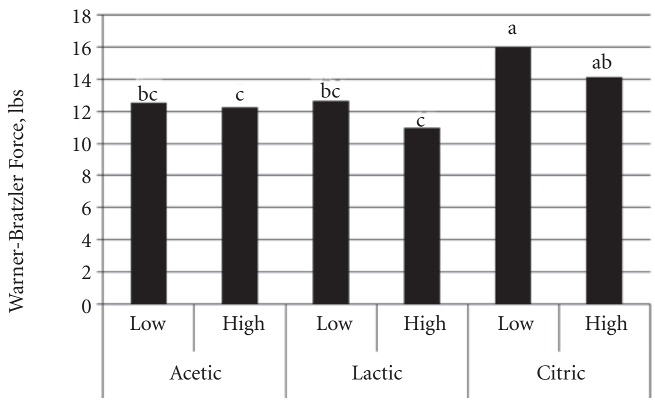
Treatment[1]	Time								
	0 hr[2]	1 hr	8 hr	1 day	3 days	7 days	14 days	21 days	28 days
LL	20.23^{f}	26.32^{f}	24.43^{f}	25.85^{ef}	21.73^{f}	19.76^{f}	24.63^{fg}	21.37^{fg}	24.42^{f}
LH	23.2^{ef}	24.88^{f}	21.75^{f}	21.11^{f}	23.59^{f}	19.73^{f}	19.12^{g}	18.3^{g}	17.31^{g}
AL	24.58^{ef}	35.49^{e}	29.08^{ef}	31.34^{e}	35.27^{e}	29.82^{e}	25.61^{fg}	26.25^{ef}	32.22^{e}
AH	26.19^{be}	34.47^{ae}	33.46^{ae}	32.49^{ae}	34.98^{ae}	31.91^{af}	33.77^{ae}	29.89^{abe}	30.21^{abef}
CL	24.92^{be}	29.82^{abef}	33.20^{ae}	30.70^{abe}	27.29^{bef}	30.64^{abe}	28.05^{abef}	27.67^{abef}	27.75^{abef}
CH	26.3^{abcde}	26.95^{abcf}	23.82^{bcdf}	21.07^{df}	23.10^{bcdef}	21.19^{cdf}	26.11^{abcdefg}	27.52^{abef}	32.04^{ae}

[a,b,c]Means in the same row having different superscripts are significant.
[d,e,f,g]Means in the same column having different superscripts are significant.
[1]AH = acetic acid high; AL = acetic acid low; CH = citric acid high; CL = citric acid low; LH = lactic acid high; and LL = lactic acid low.
[2]0hr = control, no treatments applied to sample.



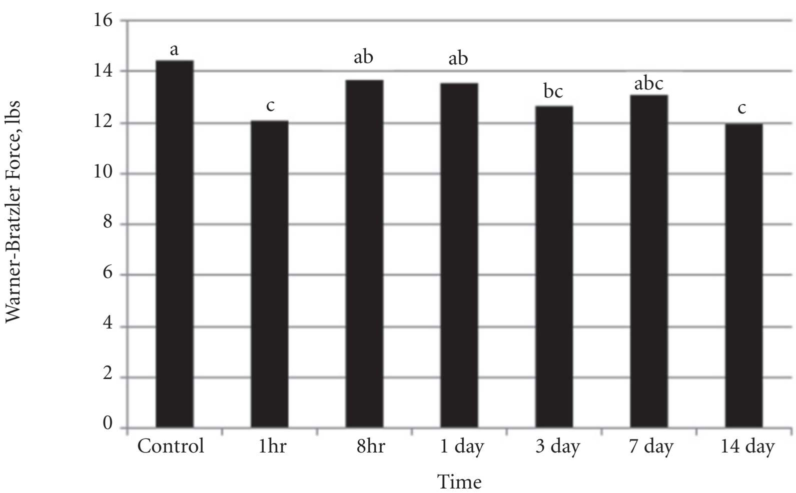
[a,b,c]Means in the columns having different superscripts are significantly different at $P < 0.05$.

Figure. 1. Exp. 1. Treatment effects on Warner-Bratzler shear force measurements of flat round steaks (m. ***Biceps femoris*****) acid-marinated with high and low concentrations of acetic, citric, or lactic acids.**



[a,b,c]Means in the columns having different superscripts are significantly different at $P < 0.05$.

Figure 2. Exp. 2. Treatment effects on Warner-Bratzler shear force measurements of flat round steaks (m. ***Biceps femoris*****) acid-marinated with high and low concentrations of acetic, citric, or lactic acids.**



[a,b,c] Means in the columns having different superscripts are significantly different at $P < 0.05$.

Figure 3. Exp. 2. Time effects on Warner-Bratzler shear force measurements of flat round steaks (m. ***Biceps femoris*****) for all acid treatments.**

Experiment 2

The higher concentrations of lactic and acetic acid marinades significantly increased tenderness (decreased shear force) as compared to either concentration of sodium citrate dihydrate (Figure 2). For all treatments, tenderness immediately improved from 0 to 1 hours and returned to baseline after 8 hours. Significant improvements in tenderness were evident 3 days post-marination (Figure 3). Sodium citrate dihydrate had little to no effect on tenderness (data not shown). This is likely due to the fact that sodium citrate dihydrate is a buffered, food grade citrate with a relatively neutral pH at 8.1. In contrast, the pH readings of the acetic and lactic acid marinades were quite acidic, ranging from 1.65 to 2.2.

Over time, acid marination caused the steaks to become permanently darker (Table 3) and, for acetic and lactic acid, significantly less red (Table 4). The extent and severity of this discoloration was greatest at the injection sites and would create color issues.

Conclusions

Acid marination could be used to increase meat tenderness during distribution. Lactic and acetic acid, at 0.75 or 1.5 M concentration, did not appear to over-tenderize the product during a 2-week period. However, acid marination does pose color acceptability issues that remain unaltered over time.

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