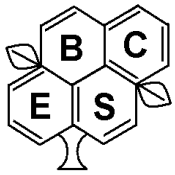

THE EFFECT OF SODIUM PYRUVATE ON SOME QUALITY PROPERTIES OF FRESH BEEF MUSCLE *SEMITENDINOSUS*

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ABSTRACT

Fresh beef semitendinosus muscles injected with 10% sodium pyruvate in water (SPW) solution (10% Weight/Weight), water (W) (10% Weight/Weight), or injected only with the injection needle as a control (C) were sliced into six steaks of 2.54 cm thickness. Two steaks were displayed for 5 d at 3±2ºC and the remaining were subjected to aging periods of 2 and 7 additional d at 2ºC. SPW-injected muscles exhibited improved Warner- Bratzler shear force (WBSF) values, higher pH values, and higher water holding capacity (WHC) percentage. Redness (a* values) were higher in C compared to SPW- and W-injected muscles. C muscles showed less drip percentage and overall losses compared to SPW or W muscles. No difference was observed in cooking loss percentage between C and SPW treated muscles; however, C and SPW treated muscles had less cooking loss percentage than W-injected muscle. These results indicate that SPW improved tenderness and WHC of beef semitendinosus muscles.

Keywords: Sodium Pyruvate; Beef; Semitendinosus; Tenderness; WHC; Color.

INTRODUCTION

Overall tenderness of beef is an important quality aspect affecting the beef industry. Koohmaraie (1995) stated that, at the consumer level, inconsistency in beef tenderness is considered one of the major problems facing the beef industry. Less tender meat is perceived as undesirable for consumers due to the difficulty that they

experience during eating. Tenderness variability in pork and lamb is of minor concern compared to beef due to the age of slaughter for beef and the maturity of its collagen (Dikeman, 1996). Sources of variation in beef tenderness have been identified and long-term research programs to control beef tenderness throughout its critical points are on-going (Miller et al., 1996).

Glycolysis and its products are the cause of the majority of quality changes that take place postmortem because pH decline is one of the most important critical control points of meat tenderness (Miller et al., 1996). The relationship between pH and glycogen content of muscles could be clarified by studying glycolysis and its products. Three major products of glycolysis are produced in a total of nine reactions: chemical energy in the form of ATP, chemical energy in the form of NADH, and pyruvate (Berg et al., 2002; Caret et al., 1993). The reduction of pyruvate into lactate by the enzyme lactate dehydrogenase has been responsible for the accumulation of lactate and, consequently, the ultimate pH in muscles.

Tran (1975) indicated that the addition of sodium pyruvate to fish fillets greatly improved their hydration capacity upon frozen storage. Also, sodium pyruvate showed a tenderizing effect on cod fish fillets when flooded with 10% sodium pyruvate solution in a shallow pan and stored for different periods of time (8, 22, 54, and 180 d of storage at -23°C) (Tran 1975).

Even though lactate as an end product of glycolysis and its effect on the quality and safety of meat have been the subject of many researchers (Whiting and Strange, 1990; Duxbury, 1990; Papadopoulos et al., 1991b; Papadopoulos et al., 1991a), pyruvate has received less attention. No data have been published on the effect of sodium pyruvate on the quality of beef. Therefore, the main objective of this study was to investigate the possible effect of sodium pyruvate on some of the quality traits of beef semitendinosus muscle.

MATERIALS AND METHODS

Sample Preparation:

Beef semitendinosus muscles (27 whole muscles) were obtained at 48 h postmortem from a commercial processing plant. Vacuum-packaged/fresh semitendinosus muscles (US Choice) were trimmed from external fat and assigned to one of the three treatments: control (C) (injected with the needle only), injected with water (W) 10 % of

the weight, and injected with 10% sodium pyruvate in water solution (SPW) (Sigma-Aldrich, St. Louis, MO, USA) (10% Weight/Weight) (three muscles per treatment). Three replications were employed in three different days. Injection was conducted using a plastic 50 cc syringe with a single needle (1.6x38 mm). After treatments, muscles from each treatment were sealed in a plastic bag, tumbled in a drum tumbler (Holly Sales model 100, Wichita, KS) for 30 min, and then sliced into six 2.54 cm in thick steaks.

Display and color evaluation:

Two steaks of each muscle/treatment (total of six steaks per treatment) were displayed in an open-top retail case (Model DMF8, Tyler Refrigeration Corporation, Niles, MI) at 3 ± 2°C, with two defrosting cycles per day, for 5d under 1614 lux of Phillips 40W DLX warm white, fluorescent lights. Steaks were placed on polystyrene trays with absorbent pads and wrapped in polyvinyl-chloride film with oxygen transmission rate of 26350 cc/m^2/24 hr/atm at 37.5 °C and 90 % RH.

Color was evaluated by daily scanning of all samples during the display period (5 days) with a LabScan 2000 Spectrocolorimeter (Hunterlab, Inc., Reston, VA). As an average from three different locations on each steak, the CIE L*, a* and b* values were measured using Illuminant C and a 10° observer with a 2.54 cm aperture diameter.

Aging:

The remaining four steaks from each muscle/treatment were vacuumed packaged and stored in a cooler at 2°C. Two steaks were stored for 2 d and the other two were stored for 7 d.

Grinding and sampling:

One steak from each aging period was ground two times through a fine blade using Oster electric meat/food grinder (Oster, Milwaukee, Wisconsin, USA). Ground samples were divided into three small pouches for additional analysis.

Proximate Analysis:

Moisture and fat were determined by AOAC (2002) method using CEM technology (CEM Corporation, Matthews, North Carolina). Ground beef (4.0 ± 0.5 g) were spread onto the rough side of one glass fiber pad (square pad) and covered with a second pad.

Samples were dried for 5 min. at 90% power microwave (LabWave 9000, CEM Corporation, Matthews, North Carolina). After drying, the pad was placed in the extraction unit (Fat Extraction System model FES, CEM Corporation, Matthews, North Carolina). Automatically, the percentage of fat and moisture content were calculated and printed as a final result. Protein content of the sample was determined by difference.

pH Determination:

pH values were measured according to AOAC (2002) using Fisher Scientific Accumet Basic pH meter with single electrode (Fisher Scientific, Pittsburgh, PA, USA). Ground sample (10 g) was diluted with 100 ml of distilled water inside a stomacher bag and homogenized to assure proper dispersion and uniform suspension of the sample in water by using a stomacher 400 LAB Blender. Duplicate samples were tested for each steak.

Water Holding Capacity (WHC) Determination:

WHC was evaluated using Jauregui et al., (1981) method that was partially modified by DeLopez (1990). Three pieces of Whatman #50 circle filter paper (hardened 70 mm in diameter) and one piece of Whatman # 3 circle filter paper (qualitative 90 mm in diameter) were weighed on a Denver Instrument scale (Denver Instrument Company, model A-160). Ground meat samples (1.5 ± 0.3 g) were weighed on the #50 filter papers after zeroing the scale (run in duplicate per steak). All three #50 filter papers were folded on the sample as an inner cover and covered by the #3 filter paper as an outer cover. Covered samples were placed in a 50 ml high-speed polycarbonate tubes and centrifuged using a Beckman Induction Drive Centrifuge Model J-6B for 45 min. at room temperature (21 °C) and speed of 4200 rpm (3640 X G). After centrifugation, the filter papers that contained meat samples were removed from the tubes with forceps, the meat removed from the filter papers using spatula, and then the papers reweighed. The difference between the weight of the filter papers after centrifugation and the weight of dry filter papers was the weight of the expressible moisture. In order to calculate the percent of water holding capacity (%WHC) of meat samples, % expressible moisture for a sample was divided by % moisture content of the same sample and the result was subtracted from 1 as in the following equation:

%WHC = 1 – (% Expressible Moisture / % Moisture Content)

Tenderness and moisture loss measurement:

The second steak from each treatment was cooked to an internal temperature of 70°C in a Blodget oven (NSF Testing Laboratory, Ann Harbor, MI) set at 163°C. Cooking was monitored using thermocouple wires attached to a recording thermometer (Minitrend 205, VAF Engineering, San Francisco, CA). Samples were turned up side down once at 32°C internal temperature to prevent over cooking on one side. Then, samples were stored in a cooler at 2°C to the following day. After cooling, six 1.27 cm diameter cores were removed parallel to the muscle fibers from each steak and sheared using Instron Model 4201 Universal Testing Machine (Instron Corporation, Canton, MA) with a Warner-Bratzler shear attachment. The compression load was set at 50 kg and crosshead speed was 250 mm/min.

Statistical Analysis:

The statistical design was a two-way split plot for injection treatments (C, SPW, and W) and aging treatments (2 d and 7 d). Data were analyzed using the GLM procedure of SAS (2000). The statistical model included effect of injection treatments, aging treatments and all possible interactions. Least-squares means were used to determine significance when a significant F-ratio was obtained in the analysis of variance.

The statistical design for display color evaluation was split plot with repeated measurements for injection treatments (C, SPW, and W) and display treatments (day 1, 2, 3, 4, and 5). Data were analyzed using the mixed procedure of SAS (2000). The statistical model included the effects of injection treatments, display treatments, and all possible interactions. Least-square means were used to determine significance (at 5% level) when a significant F-ratio was obtained in the analysis of variance.

RESULTS AND DISCUSSION

The statistical results indicated that there were no interactions ($P > 0.05$) between injection treatments (SPW, W, and C) and aging periods (2 d and 7 d) for all traits evaluated of this study. Thus, overall main effects were compared.

Proximate Analysis:

I. Injection Treatments:

Table (1) contains the proximate analysis results. Fat content showed no difference (P >0.05) among C, W, and SPW treated muscles. Moisture percentage was less (P <0.05) for C compared to both SPW and W treatments, with no difference (P >0.05) between SPW and W treatments. These results were expected because the C treatment did not include the addition of water, while W and SPW treated muscles were injected with 10% of their weight with water or water plus sodium pyruvate, respectively. Protein content was estimated by difference.

Table 1: Least squares means for proximate analysis, pH, and %WHC of beef semitendinosus muscle by treatments.

Treatments[1]	% Fat	% Protein	% Moisture	pH	%WHC
Injection:					
C*	3.36[a]	25.51[a]	71.27[b]	5.54[b]	39.84[b]
SPW**	2.53[a]	24.56[b]	72.90[a]	5.74[a]	43.84[a]
W***	3.34[a]	24.55[b]	72.08[a]	5.51[b]	40.77[b]
Aging:					
2-Day	3.10[a]	25.24[a]	71.68[b]	5.59[a]	42.18[a]
7-Day	3.05[a]	24.51[b]	72.49[a]	5.60[a]	40.79[a]

[1]=No statistical interaction between injection and aging treatments, main effect should be considered for each treatment independently.
[ab]Means in the same column with different superscript letters differ (P<0.05)
* C = Control, ** SPW = Sodium Pyruvate + Water, *** W = Water

II. Aging Periods:

Data indicated that there was no difference (P >0.05) in fat content of all samples over aging periods of 2 d or 7 d (Table 1). However, moisture content was higher (P <0.05) for 7-d aged muscles compared to 2-d aged muscles. This difference may be because all steaks were aged in vacuum packages, which may have caused chemical changes that increased water absorption. Protein content was estimated by difference.

pH Values

I. Injection Treatments:

The pH results (Table 1) indicated that SPW treated steaks were higher (P <0.05) in pH compared to C and W treatments, with no difference (P >0.05) between C and W treatments. This result may be attributed to the effect of sodium pyruvate, which has pH around 5.5 to 6.

II. Aging Periods:

The results indicated no pH difference (P >0.05) over the aging periods employed (Table1).

Water Holding Capacity (WHC):

I. Injection Treatments:

The WHC of SPW treated steaks was higher (P <0.05) than for C and W, with no difference (P >0.05) between C and W (Table1). This increase in water holding capacity may be credited to the significant increase in the pH of SPW treated steaks. As pH increases, the WHC increases because of the distribution of the negative charges within proteins that causes more water to be held between myofilaments after their repulsion (Wismer-Pederson, 1987).

II. Aging Periods:

The results indicated no WHC difference (P >0.05) over the aging periods (Table1).

% Drip, Cooking and Overall Losses:

I. Injection Treatments:

Results for percentage drip, cooking, and overall losses over injection treatments are presented in Table (2). Percentages of drip and overall losses of W-treated steaks were the highest (P <0.05). Also, percentages of drip and overall loss of SPW treated steaks were higher (P <0.05) than for C steaks. Percentage of cooking loss of W steaks was higher (P <0.05) than SPW and C treatments; however, there was no difference (P >0.05) between SPW and C treatments.

II. Aging Periods:

Table (2) shows the results of drip, cooking and overall losses over aging treatments. The results indicated no difference (P >0.05) in cooking and overall loss over aging periods (2 d and 7 d); however,

drip loss was higher (P <0.05) in 2-d aged steaks compared to 7-d aged steaks (11.3% and 9.66 %, respectively).

Table 2: Least squares means for shear force (kg), %drip loss, %cooking loss, %overall loss, and color (L* a* b*) values of beef semitendinosus muscle by treatments.

Treatments[1]	Shear Force (kg)	% Drip Loss	% Cooking Loss	% Overall Loss	Color		
					L*	a*	b*
Injection							
C*	4.56[a]	7.21[c]	30.71[b]	35.71[c]	38.96[b]	18.65[a]	23.32[a]
SPW**	3.78[b]	10.43[b]	31.00[b]	38.19[b]	40.06[b]	15.54[b]	22.96[a]
W***	4.77[a]	13.80[a]	35.05[a]	44.00[a]	42.40[a]	16.64[ab]	23.83[a]
Aging							
2-Day	4.56[a]	11.30[a]	32.18[a]	39.79[a]	N/A	N/A	N/A
7-Day	4.16[b]	9.66[b]	32.33[a]	38.81[a]	N/A	N/A	N/A

[1]=No statistical interaction between injection and aging treatments, main effect should be considered for each treatment independently.
[ab]Means in the same column with different superscript letters differ (P<0.05)
*C = Control, ** SPW = Sodium Pyruvate + Water, *** W = Water
N/A = Not Applicable

Warner-Bratzler Shear Force Values:

I. Injection treatments:

The results (Table 2) indicated that SPW reduced (P <0.05) WBSF values compared to both W and C steaks. The reduction in WBSF values of SPW steaks were 17.1 % and 20.8 % compared to C and W steaks, respectively. However, there was no difference (P >0.05) between W and C treatments. This result may be attributed to the hydration effect of sodium pyruvate that was indicated by the increase in WHC of the meat.

II. Aging Treatments:

Table (2) presents the effects of aging periods on WBSF values. As was expected, steaks held in for 7-d were more tender (P <0.05) than those held for 2-d. These results have been accepted as a fact in meat industry for long time. The reduction was almost 9% in 7-d aged steaks compared to 2-d aged steaks.

Color:

Table (2) displays the results of the effect of sodium pyruvate on beef color. No differences (P >0.05) were observed in color yellowness (b* values) over all treatments. Beef treated with water (W) was lighter (P <0.05) in color (L*) than C and SPW. Redness color values (a*) were higher (P <0.05) in C compared to SPW and W treated steaks. This result indicates the deteriorating effect of sodium pyruvate (SPW) and water (W) on the color of treated steaks. This reduction in redness of meat was expected because of the addition of water that dilute the Myoglobin color of the meat. Some of the redness reduction is due to the addition of sodium pyruvate, but the mechanism of this effect is not well known yet. However, after cooking, changed color was disappeared by dominated color of cooked meat.

Display color results were presented in Table (3). No effects were observed (P <0.05) in lightness (L*) and yellowness (b*) values over all display days. Steak color of day 1 was significantly the best (P >0.05) in color than all days. Steak color of day 2 was better than days 3, 4, and 5. No differences (P <0.05) were observed in the color of steaks of day 3, 4, and 5.

Table 3: Least squares means for color values (L* a* b*) stratified by display days over treatments.

	Treatment C*			Treatment W**			Treatment SPW***		
Display Day	L*	a*	b*	L*	a*	b*	L*	a*	b*
1	39.17	21.67^{a}	23.05	44.11	19.02^{a}	24.49	40.45	20.19^{a}	24.20
2	40.39	19.66^{a}	23.46	43.42	18.21^{a}	23.21	42.20	15.89^{b}	23.39
3	38.46	17.80^{b}	23.61	41.30	15.20^{b}	24.30	39.94	14.83^{b}	22.31
4	38.21	17.54^{b}	23.81	41.44	15.59^{b}	24.11	38.70	13.61^{b}	23.11
5	38.57	16.57^{b}	22.66	41.76	15.18^{b}	23.06	39.02	13.19^{b}	21.78

^{ab}Means in the same column with different superscript letters differ (P<0.05)

- C = Control, ** W = Water, *** SPW = Sodium Pyruvate + Water

Conclusion

Addition of sodium pyruvate to beef muscle improved the water holding capacity and the tenderness. Even though the increase in the pH of the meat, due to the addition of sodium pyruvate, is very small, however was significant to increase the water holding capacity. The

tenderness increase maybe due to the increase in water holding capacity or due to the effect of pyruvate directly. Future investigation to determine the cause of the tenderness improvement is needed. The differences between muscles in pyruvate content need to be identified. Correlation between muscle content of pyruvate and tenderness should be investigated.

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تأثير بيروفيت الصوديوم على بعض خصائص الجودة للعضلة النصف وترية البقرية الطازجة

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حقنت العضلات النصف وترية الطازجة من الأبقار بمحلول بيروفيت الصوديوم 10% (10% من وزن العضلة)، أو بالماء فقط (10% من وزن العضلة) ، أو تم حقنها بالإبرة فقط للمقارنة، ثم تم تقطيعها إلى 6 شرائح بعرض 2.54 سم. شريحتين عرضتا في ثلاجة العرض المبردة لمدة 5 أيام والباقي تم إنضاجهم لمدة 2 إلى 7 أيام. العضلات التي حقنت بالبيروفيت أظهرت تحسن في قيم قوى القطع لوارنر –براتزيلر (تحسن في الطراوة)، ارتفاع طفيف في قيم الحموضة (pH)، ومقدرة أعلى على الاحتفاظ بالماء (احتباس الماء) مقارنة بالعضلات من المعاملات الأخرى. قيم الاحمرار للون العضلات التي لم تحقن بالماء أو بالمحلول كانت أعلى وأفضل، كما أنها أظهرت نسبة راشح أقل وفقد عام للرطوبة أقل من العضلات المحقونة بالماء أو بالبيروفيت. لم يكن هناك فروقات معنوية بين نسبة فقد الطبخ للعضلات المحقونة بالبيروفيت مقارنة بالعضلات التي حقنت بالإبرة فقط ، ولكن كان فقد الطبخ لهما أقل من العضلات التي حقنت بالماء فقط. هذه النتائج بينت أن الحقن ببيروفيت الصوديوم كان له الأثر الفعال في تحسين طراوة العضلة النصف وترية البقرية الطازجة وأيضا تحسين مقدرتها على احتباس الماء.