INTRODUCTION

Both the biological type (subspecie) and the age of the animal influence the tenderness of beef. The Bos indicus cattle has a less tender meat when compared with the Bos taurus cattle, which is attributed to the greater activity of calpastatin in meat from B. indicus (Shackelford et al., 1994). Furthermore, meat from older animals, with more mature connective tissue, is also tougher meat (Hunsley et al., 1971).

Among the beef muscles, the biceps femoris is one of the most important muscles because of the size and location in the carcass. Although highly variable in tenderness, this muscle differs in tenderness between B. indicus and B. taurus (Shackelford et al., 1995; Reuter et al., 2002). Reports also indicate that the tenderness varies among the different muscle portions of the biceps femoris (Ramsbottom et al., 1945; Reuter et al., 2002; Rhee et al., 2004).

The meat industry has increased the use of marination with poultry, pork, and beef as an attempt to improve meat quality and yield (Smith and Young, 2007). Marination adds brine to meat, and a more uniform distribution of the brine throughout the meat cut is achieved with use of a tumbler. The primary purpose of marination is to improve the water-holding capacity of meat to improve the yield, juiciness, flavor, and tenderness (Goli et al., 2011; Pérez-Juan et al., 2012).

In studies on the composition of the brine, improved water retention of meat products was observed when hydrolyzed soy protein (HSP) was added to the brine. This was attributed to the high solubility of HSP in water (Adler-Nissen and Olsen,
1979) and to synergistic interactions between the soy peptides and muscle proteins to form a gelatinous matrix capable of immobilizing water (Feng and Xiong, 2002; Xiong, 2005). These properties justify its incorporation into meat and meat products (Feng et al., 2003; Feng and Xiong, 2003; Silva et al., 2011).

Therefore, the objective of this study was to determine if marination with hydrolyzed soy protein added to brine improved the yield, tenderness and other quality attributes in steaks from different portions of the biceps femoris muscle from B. indicus cattle older than 30 mo.

MATERIALS AND METHODS

Sampling and Muscle Portions

After slaughter (72 h postmortem), 6 biceps femoris muscles were collected from the right side of carcasses of B. indicus steers. The steers were between 31 and 35 mo of age with an average carcass weight of 285 ± 2.2 kg and moderate fat thickness (3 to 6 mm). Based on this information, the carcasses would be classified in the USDA quality grade as Select.

The whole muscles were then vacuum packaged and refrigerated for 3 d until tumbling. After refrigeration, the muscles were divided into 3 portions (Fig. 1): origin (OP), insertion 1 (IP1), and insertion 2 (IP2). Each of these portions was subdivided into 5 steaks (2.5 cm thickness), and 4 steaks were tumbled with 2 different brine solutions (2 steaks/brine solution) and 1 steak was used as a control (no tumbling). A total of 90 steaks (15 steaks/muscle) were used in this experiment. The pH, color, shear force, and cooking and drip losses were measured for the steaks as illustrated in Fig. 1.

Table 1. Composition of additives in the final products (g/100 g) using brine without and with hydrolyzed soy protein (HSP)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Without HSP</th>
<th>With HSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>1.80</td>
<td>1.80</td>
</tr>
<tr>
<td>Monosodium glutamate</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Hydrolyzed soy protein</td>
<td>–</td>
<td>0.33</td>
</tr>
<tr>
<td>Sodium tripolyphosphate</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Sodium erythorbate</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Cold water</td>
<td>14.25</td>
<td>13.92</td>
</tr>
<tr>
<td>Total</td>
<td>16.67</td>
<td>16.67</td>
</tr>
</tbody>
</table>

Brine Composition and Preparation

Twenty grams of brine per 100 g steak (weight before the tumbling) was used for the marination by tumbling. Two different brines were used in the tumbling process of steaks, which differed by the HSP content. The brines were prepared by dissolving the ingredients in cold water (mL; Table 1).

The soy protein added to the brine was hydrolyzed with alcalase enzyme at a hydrolysis level of less than 4% as described by Feng and Xiong (2003). Some works showed that soy protein hydrolysates produced under limited hydrolysis conditions have enhanced functional properties such as solubility, foaming, emulsification, and gelation (Adler-Nissen and Olsen, 1979; Xiong, 2005). These authors identified that the HSP with those properties are highly soluble in water and interact with muscle proteins to form a gelatinous matrix capable of immobilizing water. The soy product (SUPRO isolated soy protein) was marketed by Solae Brazil (Barueri, SP, Brazil), which provided the samples for this research.

Tumbling and Storage of Steaks

The steaks were treated with no tumbling (control), tumbling with brine (BR), and tumbling with brine and HSP (BR+HSP). The tumbling was carried out for 45 min in a vacuum tumbler (TF-30VE; Frigomaq, Chapecó, SC, Brazil) with intermittent rotation (15 min on and 1 min off) at 30 rpm. Immediately after tumbling, the steaks were vacuum packaged in gas barrier shrink bags (Univac B320, Unipac Embalagens Ltda.; São Paulo, SP, Brazil) using a vacuum sealer (Selovac model 300B, São Paulo, SP, Brazil) with an absolute pressure of 98.7 kPa. The bags were 90 µm thick with an oxygen transmission rate of 40 cm³ m⁻² d⁻¹ measured at 1 atmosphere of oxygen partial pressure gradient, at a relative humidity and temperature of 77% and 23°C, respectively.
After packaging, the steaks were boxed and stored in a cold chamber for 48 h at 0 ± 2°C to allow the brine to equilibrate in the steaks. After equilibration, the steaks remained in the cold chamber at 0 ± 2°C for 1 or 12 d. The control steaks were stored for only 1 d in the cold chamber. After storage, the steaks were immediately weighed and analyzed in the laboratory.

**The pH Values**

The pH values of raw control steaks and steaks tumbled with brine (IP) and after tumbling at 1 d of storage (FP1) and 12 d of storage (FP12). The yields of the steaks stored for 1 (Y1) and 12 d (Y12) were determined according to the following formulas: Y1 = [(FP1 − IP)/IP] × 100 and Y12 = [(FP12 − IP)/IP] × 100.

**Instrumental Color**

After storage, the vacuum-packaged steaks were removed from the cold chamber and placed on the laboratory bench. Each steak was removed from the package, and after 15 min of blooming time, the color measurements were recorded. The color measurements were conducted with a CR-400 Minolta colorimeter (CR-400 Chroma Meter; Konica Minolta, Mahwah, NJ) in the CIELab color space (CIE, 1976) using illuminant C, with a 2° viewing angle and an aperture diameter of 2 cm. The L* (lightness), a* (green/red intensity), and b* (blue/yellow intensity) values were recorded at 4 random positions on the surface of the steaks.

**Drip Loss**

The drip loss (DL) was determined according to Muchenje et al. (2008), with some modifications. Steak samples (15 mm long by 15 mm wide by 25 mm thick), without adipose and connective tissues, were weighed (IP) and then were suspended from a net within a polyethylene plastic bag at 2 ± 2°C for 72 h. The samples were carefully removed from the bags, partially dried with a towel paper, and reweighed (FP). The following equation was used to obtain the drip loss (%): DL = [(IP − FP)/IP] × 100.

**Cooking Loss and Shear Force**

The analyses of cooking loss (CL) and shear force were performed in accordance with the recommendations of the American Meat Science Association (1995). The CL values were obtained from the weight of steaks before (IP) and after (FP) cooking. The results were calculated according to the following formula: CL = [(IP − FP)/IP] × 100.

For the determination of shear force, the steaks were cooked on an electric clamshell grill (Edanca, São Bernardo do Campo, SP, Brazil) until a core temperature of approximately 71°C was reached, monitored with a food thermometer (TM879, Equitherm; Carlson, Tool and Manufacturing Corporation). The cooked steaks were stored overnight at 3 ± 2°C. Eight to ten cores (1.27 cm in diameter) were then removed from each steak parallel to the longitudinal orientation of the muscle fibers. To measure the tenderness of the meat, the cores were sheared perpendicular to the long axis of the core using a texturometer (CARLSON, GR-200D; Carlson, Tool and Manufacturing Corporation, Manhattan, KS) equipped with a Warner-Bratzler blade. The measurements of the peak shear force were recorded for each core and averaged to obtain a single shear force value for each steak.

**Statistical Analyses**

The experimental design was a randomized complete block with a 3 (muscle portion) × 2 (brine composition) × 2 (storage days) factorial design. A control (steaks from all muscle portions that were not tumbled) as an additional treatment was used in the ANOVA for all the variables. The 6 muscles were considered blocks and the control treatment was compared only at 1 d of storage. The initial weight of the steaks before the tumbling was used as covariate.

All data were analyzed using the MIXED procedure of the SAS statistical software package (version 9.2; SAS Inst. Inc., Cary, NC), and a least squares means comparison was performed using the Tukey–Kramer test (P < 0.05).

**RESULTS AND DISCUSSION**

**The pH Values**

An interaction between brine composition, muscle portion, and storage time was observed (P < 0.05) for the pH values of the steaks (Table 2). Regardless of the brine composition or storage time, the steaks from IP2 had lower (P < 0.05) pH values than the steaks from the OP, which were similar (P > 0.05) to those from IP1, only when they were not tumbled (control) or were tumbled with BR and stored 1 d. The lower
pH values for the insertion portion rather than the OP might be the result of a sharp decline in pH values that is expected to occur in muscles or regions predominantly composed of fast and glycolytic fibers (Gann and Merkel, 1978; Ouali et al., 1983; Gotoh, 2003).

In steaks from the 3 biceps femoris portions that were stored for 1 d, the tumbling with BR or BR+HSP increased ($P < 0.05$) the pH values compared with the control. Tripolyphosphate and salt generally increase the pH values of meat (Keeton, 2001; Sheard and Tali, 2004; Puolanne and Halonen, 2010), particularly in marinated biceps femoris (Baublits et al., 2006). When the steaks tumbled with the different brines were compared, those that tumbled with BR+HSP had higher ($P < 0.05$) pH values than those tumbled with BR. This suggested that an additive effect of HSP with sodium tripolyphosphate occurred to increase the pH values in the steaks tumbled with BR+HSP. The HSP has a buffering effect (with increasing pH) that leads to an increase in the water uptake of meat (Kinsella, 1979).

In all steak portions tumbled with BR or BR+HSP, storage for 12 d decreased ($P < 0.05$) the pH values compared with the steaks stored for 1 d. The marination type, the marinade ingredients, and the vacuum affect the selection and growth of bacteria (Carnobacterium spp, Lactobacillus spp and Lueconostoc spp) during the storage time (Gill and Molin, 1991; Borch et al., 1996). Psychrotrophic acid bacteria spoils and the production of lactic, acetic and formic acids in refrigerated meat products may decrease the pH values (Borch et al., 1996).

**Steak Yield**

As expected, the muscle portions of the control steaks (no tumbling) had lower ($P < 0.05$) yields than those tumbled with brine (BR and BR+HSP pooled; Table 3).

The disruption of the muscle structure and tissue by tumbling facilitates the entry of the brine into the muscle. Additionally, the tripolyphosphate in the brine forms complexes with Ca$^{2+}$ and Mg$^{2+}$ bound to the myofibrilar proteins, which breaks the bonds, loosens the protein structure, and increases the water-holding capacity of the meat (Hamm, 1960). Finally, tripolyphosphate in combination with the salt increased the ionic strength of the brine and promoted the dissociation of the actin–myosin complex, which resulted in swelling of the fibers (Offer and Trinick, 1983). These effects caused by the addition of brine in marination of meat contributed to the increased weights of different raw and cooked meat cuts, as was widely reported (Xiong and Kupski, 1999; Aktaş et al., 2003a,b; Smith and Young, 2007).

**Color**

A significant interaction ($P < 0.05$) among brine composition, muscle portion, and storage time for the $L^*$ and $b^*$ values was detected (Table 4). In all muscle portions after 1 d of storage, the steaks tumbled with brines (BR and BR+HSP pooled) had lower $L^*$ values (darker; $P < 0.05$) and higher $b^*$ values (more yellow; $P < 0.05$) than the control steaks. The salt and phosphate present in the brines increase the water-holding capacity and act as an antioxidant (Trout and Dale,

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**Table 2. Effects of brines of different composition, biceps femoris muscle portions, and storage times on the pH values**

<table>
<thead>
<tr>
<th>Muscle portion</th>
<th>Day 1$^2$</th>
<th>Day 12$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>BR</td>
</tr>
<tr>
<td>Origin</td>
<td>5.57 (0.03)$^{A3}$</td>
<td>5.80 (0.02)$^{Bx}$</td>
</tr>
<tr>
<td>Insertion 1</td>
<td>5.54 (0.03)$^{AB}$</td>
<td>5.76 (0.03)$^{Bx}$</td>
</tr>
<tr>
<td>Insertion 2</td>
<td>5.45 (0.04)$^{A}$</td>
<td>5.69 (0.04)$^{B}$</td>
</tr>
</tbody>
</table>

$^a$-Means followed by different lowercase letters between the brine compositions within a muscle portion and storage time differ significantly at $P < 0.05$.

$^A$-Means followed by different uppercase letters among the muscle portions within a brine composition and storage time differ significantly at $P < 0.05$.

$^3$-Means followed by different lowercase letters between storage times within a muscle portion and brine composition differ significantly at $P < 0.05$.

$^B$-Origin is a portion close to the origin of the biceps femoris muscle; insertions 1 and 2 are portions close to the insertion of the biceps femoris muscle.

$^2$-Day 1 = steak stored for 1 d after brine equalization; Control = steak not tumbled; BR = steak tumbled with brine; BR+HSP = steak tumbled with brine and hydrolyzed soy protein.

$^3$-Day 12 = steak stored for 12 d after brine equalization.

$^4$-Values in parentheses are the SE.

<table>
<thead>
<tr>
<th>Muscle portion</th>
<th>Brine composition</th>
<th>BR and BR+HSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>0.30 (1.41)$^{b}$</td>
<td>13.19 (1.00)$^{b}$</td>
</tr>
<tr>
<td>Insertion 1</td>
<td>0.07 (0.84)$^{b}$</td>
<td>11.66 (0.71)$^{a}$</td>
</tr>
<tr>
<td>Insertion 2</td>
<td>-2.29 (2.27)$^{b}$</td>
<td>15.68 (1.59)$^{a}$</td>
</tr>
</tbody>
</table>

$^a$-Means followed by different lowercase letters between the brine compositions within a muscle portion differ statistically at $P < 0.05$.

$^b$-Origin is a portion close to the origin of the biceps femoris muscle; insertions 1 and 2 are portions close to the insertion of the biceps femoris muscle.

$^2$-Control = steak not tumbled.

$^3$-Values in parentheses are the SE.
Tumbling of Biceps femoris muscle with brines

Table 4. Effects of pooled brine treatments, biceps femoris muscle portions, and storage times on the L* and b* values

<table>
<thead>
<tr>
<th>Muscle portion</th>
<th>Control BR and BR+HSP</th>
<th>Day 12 BR and BR+HSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>39.30 (0.62)b,5</td>
<td>36.18 (0.72)b</td>
</tr>
<tr>
<td>Insertion 1</td>
<td>38.42 (0.72)b</td>
<td>35.51 (0.59)b</td>
</tr>
<tr>
<td>Insertion 2</td>
<td>44.71 (1.13)A</td>
<td>39.67 (0.97)xx</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36.12 (0.86)y</td>
</tr>
</tbody>
</table>

L* = brightness; range from dark to light (–L* to +L*).

b* = chroma; range from blue to yellow (–b* to +b*).

Values in parentheses are the SE.

Means followed by different lowercase letters between storage times at P < 0.05.

Means followed by different uppercase letters among the muscle portions at P < 0.05.

A,b,c Means followed by different lowercase letters between storage times at P > 0.05.

x,y Means followed by different lowercase letters between muscle portions at P < 0.05.

1 Insertion is a portion close to the origin of the biceps femoris muscle; insertions 1 and 2 are portions close to the insertion of the biceps femoris muscle.

2 Day 1 = steak stored for 1 d after brine equalization; Control = steak not tumbled; BR = steak tumbled with brine; BR+HSP = steak tumbled with brine and hydrolyzed soy protein.

3 Day 12 = steak stored for 12 d after brine equalization.

4 L* = brightness; range from dark to light (–L* to +L*).

5 Values in parentheses are the SE.

6 b* = chroma; range from blue to yellow (–b* to +b*).

1990; Xiong, 2005), which may yield a darker and meat with more yellow intensity. From a previous report, after an injection of brine containing phosphates (Baublits et al., 2005a), the L* values in a biceps femoris muscle decreased.

In the control steaks and those tumbled with brines (BR and BR+HSP pooled) stored for 1 d, lighter meat (P < 0.05) was observed for IP2 than in other portions. The predominance of type IIB fibers in IP2 (Xiong, 1994; Taylor, 2004) could account for lighter steaks from that portion. The lower pH values in IP2 (Table 2) might be another explanation for the lighter steaks observed after the tumbling with BR and BR+HSP. Low pH values contributed to a decrease in water retention by meat and resulted in greater L* values (Siegberg et al., 2005). The differences in the L* values among different portions of the semitendinosus muscle were attributed to the profile of glycolytic and oxidative fibers (Dreyer et al., 1977).

No differences (P > 0.05) in the L* values among the muscle portions were detected when the steaks were tumbled with brines (BR and BR+HSP pooled) and stored for 12 d. The longer storage period might have caused significant water loss in all the muscle portions, thus standardizing the L* values. When the steaks tumbled with brines (BR and BR+HSP pooled) were compared for time of storage, the L* values decreased (P < 0.05) in IP2 as storage increased. A decrease in the L* values was also observed when entire biceps femoris muscles were stored for 7 d (Baublits et al., 2005a).

No difference (P < 0.05) in the b* values was found among the muscle portions when control steaks were stored for 1 d. However, the steaks from the OP tumbled with brines (BR and BR+HSP pooled) and stored for 1 or 12 d had higher (P < 0.05) b* values than the other portions. Differences (P < 0.05) were also detected for the b* values between the IP1 and IP2 tumbled with brines (BR and BR+HSP pooled) and stored for 12 d.

For the a* values (red color), an interaction (P < 0.05) occurred between brine composition and muscle portion (Table 5). In the control steaks and those tumbled with BR, the a* values were similar (P > 0.05) among all muscle portions. However, the steaks tumbled with BR+HSP had the highest (P < 0.05) a* values among the OP steaks. Of the OP steaks, the steaks tumbled with BR and BR+HSP had higher (P < 0.05) a* values than the control steaks. For IP1 steaks, the steaks tumbled with BR had the highest (P < 0.05) a* values. The phosphate and nitrite antioxidants in the brines might be responsible for the higher a* values in the tumbled OP and IP1 steaks. Nitrite added to brines results in a redder meat, and this effect might be potentiated by other ingredients also in the brines such as tripolyphosphate and erythorbate (Forrest et al., 1979).

Antioxidants generally prevent the oxidation of oxymyoglobin, which maintains elevated a* values in the muscles (Trout and Dale, 1990). Nevertheless, the mechanism that caused the steaks tumbled with BR+HSP to have increased a* values for the OP but not for the IP1 remains unclear. Perhaps the predominance of oxidative and red fibers in the OP (Kinsella, 1979; Young and West, 2001; Taylor, 2004) was related to these differences.

Table 5. Effects of brines of different composition and biceps femoris muscle portions on the a* values

<table>
<thead>
<tr>
<th>Muscle portion</th>
<th>Control</th>
<th>BR</th>
<th>BR+HSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Origin</td>
<td>19.51 (0.71)p</td>
<td>21.83 (0.61)p</td>
<td>23.30 (0.57)A</td>
</tr>
<tr>
<td>Insertion 1</td>
<td>19.02 (0.48)b</td>
<td>21.66 (0.73)A</td>
<td>19.98 (0.72)pA</td>
</tr>
<tr>
<td>Insertion 2</td>
<td>18.94 (1.01)</td>
<td>18.22 (0.84)</td>
<td>17.96 (0.87)B</td>
</tr>
</tbody>
</table>

Means followed by different lowercase letters between brine compositions at P < 0.05.

Means followed by different uppercase letters among the muscle portions at P < 0.05.

a,b,c Means followed by different lowercase letters between storage times at P > 0.05.

Values in parentheses are the SE.

a,b Means followed by different lowercase letters between brine compositions at P < 0.05.

Table 6. Effects of pooled brine treatments and storage time on the cooking losses (CL) and shear force (SF) values of steaks from the biceps femoris

<table>
<thead>
<tr>
<th>Variable</th>
<th>Day 1</th>
<th>Day 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>BR and BR+HSP</td>
</tr>
<tr>
<td>CL, %</td>
<td>32.55 (0.60)</td>
<td>26.54 (0.43)</td>
</tr>
<tr>
<td>SF, kg</td>
<td>6.67 (0.23)</td>
<td>5.36 (0.16)</td>
</tr>
</tbody>
</table>

a,b Means followed by different lowercase letters between the brine compositions within d 1 of storage differ statistically at P < 0.05.

1 Day 1 = steak stored for 1 d after brine equalization; Control = steak not tumbled; BR = steak tumbled with brine; BR+HSP = steak tumbled with brine and hydrolyzed soy protein.

2 Day 12 = steak stored for 12 d after brine equalization.

Values in parentheses are the SE.

Drip Loss

The brine composition affected (P < 0.05; data not shown) the drip loss of the steaks. The steaks tumbled with brines (BR and BR+HSP pooled) had higher water-holding ability (2.4%; P < 0.05) and lower drip loss values than the control steaks (4.6%). Salt increases the solubility of meat proteins, and tripolyphosphate promotes muscle fiber expansion (swelling) through electrostatic repulsions. When acting together, these compounds enhance water retention in the myofibrils (Offer and Trinick, 1983; Offer and Knight, 1988). A decrease in the drip loss was also observed when the biceps femoris muscle was marinated with salt and/or phosphates (Sultana et al., 2008). Moreover, other authors reported increased water-holding capacity when polyphosphates were added to meat during tumbling (Demirok et al., 2011).

Cooking Loss and Shear Force

An interaction (P < 0.05) was detected between brine composition and storage time for CL and shear force of the steaks (Table 6). After 1 d of storage, the steaks tumbled with brines (BR and BR+HSP pooled) had lower (P < 0.05) shear force and CL values than the control steaks. The use of salt, phosphates, and curing, present in the BR and BR+HSP, was associated with improved meat tenderness (Detienne and Wicker, 1999; Zheng et al., 2001; McMurtrie et al., 2012) by the following mechanisms: 1) changing the pH and inducing the swelling of the muscle fibers and/or connective tissue, 2) accelerating proteolysis and facilitating a weakening of the muscle structure, 3) increasing the solubilization of collagen during cooking, and 4) increasing the water-holding capacity (Offer and Trinick, 1983; Wheeler et al., 1991; Baublits et al., 2005b, 2006). Furthermore, the tumbling of steaks could also weaken muscular structures to promote meat tenderness (Xiong and Kupski, 1999; Smith and Acton, 2001).

In steaks tumbled with brines (BR and BR+HSP pooled), a longer storage time resulted in lower shear force and CL values (P < 0.05) than a shorter time of storage. Greater proteolysis of myofibrillar proteins and a natural meat tenderization via calpains enzymes would be expected in steaks stored for 12 d (Koohmaraie, 1994). Moreover, the lower CL in steaks stored for a longer time might be related to the increased water-holding capacity promoted by the phosphate. Therefore, this additive might be more effective on the meat stored for a longer time, which resulted in lower CL values after 12 d of storage.

The muscle portion also had an effect (P < 0.05) on the shear force values (Fig. 2). The OP had greater (P < 0.05) shear force values than the IP1 and IP2, which were similar to one another (P > 0.05). The more tender steaks from IP1 and IP2 might be a result of the lower pH values (Table 2); low pH values would inhibit calpastatin activity and increase calpains activity, which was responsible for proteolysis (Dransfield, 1993, 1994). In contrast to our results, lower shear force values in the OP region and higher values in the insertion region were observed in unmarinated biceps femoris muscles from B. taurus cattle (Ramsbottom et al., 1945; Reuter et al., 2002; Rhee et al., 2004). In this case, the different type of cattle might explain the discrepancy in the shear force results for the different portions of the biceps femoris muscle.

Implications

This study indicated that the portions of the biceps femoris muscle alone affected the shear force values. The brine composition, the muscle portion, and the storage time interacted to alter the pH values. Overall, the tumbling of the steaks with brines increased the pH values and the yield, which led to a decreased drip loss and CL, with improved tenderness. Additionally, the tumbling with brines yielded a darker (low exudation)
meat with more yellow and red intensity (less oxidation) than meats that were not tumbled.

Hence, marination with brines improved the cut yield, tenderness, and other quality attributes in steaks from different portions of the biceps femoris muscle in B. indicus cattle older than 30 mo. Contrary to expectations, the HSP incorporated into the brine did not change the effect of using the brine alone on any studied variable, except for pH values. However, considerable variation was found for the variables among the different portions of the biceps femoris muscle.

**LITERATURE CITED**


