Sensory properties of hot-deboned ostrich (Struthio camelus var. domesticus) Muscularis gastrocnemius, pars interna

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Abstract

Cold-deboning is currently practiced in South African ostrich abattoirs. However, the advantages of hot-deboning include the reduction of costs and time, but there is always the risk of cold-shortening. The effects of hot-deboning of ostrich M. gastrocnemius, pars interna on meat sensory attributes were investigated. The data showed that the hot-deboned muscles pH48 (6.57 ± 0.18) was significantly negatively correlated \( r = 0.7813; \ P < 0.038 \) to the mean Warner–Bratzler shear force values (71.28 ± 18.62 N, 12.7 mm \( 1 \) diameter) and positively correlated \( r = 0.789; \ P < 0.035 \) to the mean scores for taste panel tenderness (66.39 ± 15.45). After storage for 48 h post-mortem, the hot-deboned muscles were found to be less juicy \( P < 0.004 \) and, according to both sensory tenderness scores and Warner–Bratzler shear force values, tougher \( P < 0.0001 \) than the cold-deboned muscles.

Keywords: Ostrich; Hot-deboning; Cold-deboning; Muscle pH; Sensory analysis; Tenderness; Juiciness; Taste panel

1. Introduction

Tenderness is considered by consumers to be one of the most important attributes of an indication of good eating quality (Issanchou, 1996; Risvik, 1994). It is generally accepted that juicy and tender meats are preferred and that these attributes are generally the most important for the determination of preference in terms of texture (Risvik, 1994). It is well known that there is a risk of toughening when muscles are hot-deboned. With hot-deboning, there is also the risk of cold-shortening in pre-rigor muscles if the temperature falls below 10 C while the pH is still high (pH > 6.0–6.2) and an adequate ATP (adenosine triphosphate) concentration is present (Pearson & Young, 1989). However, the major commercial attraction of hot-deboning is the considerable reduction in time, space and refrigeration capacity required (Taylor, Shaw, & McDougall, 1980–1981). Hot-deboning also prevents weight loss due to evaporation during carcass chilling. It is, thus, essential that packaging be done without delay if weight losses from the cut surfaces of the hot meat exposed during deboning and packaging is to be minimised. In general, the temperature decline in hot-deboned muscles is faster and more uniform than in muscles left on the carcass (Van Laack & Smulders, 1992). This is beneficial for controlling microbial spoilage (Lawrie, 1998) and, therefore, increasing the shelf-life. Furthermore, Taylor et al. (1980–1981) reported that hot-deboning minimised drip loss and produced a more even colour across the large muscles. In ostriches, the different anatomical muscles are not equally susceptible to the risk of cold-shortening. It was suggested by Sales and Mellett (1996) that the risk of cold-shortening would be reduced in the M. iliofibularis since it reached a pH of less than 6.20 at approximately 34 min after slaughter. The apparent ultimate pH was reached rapidly at 2 h post-mortem in the M. iliofibularis (6.00 ± 0.087), and at 6 h post-mortem in the M. gastrocne-

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**mimus, pars interna** (6.12 ± 0.056). It was thus concluded by Sales and Mellett (1996) that there might be a risk of cold-shortening in the *M. gastrocnemius, pars interna* if this muscle is to be separated from the carcass at 30–45 min post-mortem, but not in the *M. iliofibularis*.

The aim of this study was to investigate the effect of hot-deboning (1 h post-mortem) on the eating attributes of ostrich *M. gastrocnemius, pars interna* muscles aged for only 48 h post-mortem, as perceived by a trained taste panel. The mechanical parameter Warner–Bratzler shear force values (*N, 12.7 mm^−1^ diameter) were also investigated to specifically gain a better indication of the effect of hot-deboning on tenderness.

2. Materials and methods

2.1. Ostriches and sampling

Eight randomly selected, well rested (lairage of 12 h) ostriches (*Struthio camelus var. domesticus*) were slaughtered as described by Wotton and Sparrey (2002), on the same day during June 2004 at an European Union approved abattoir in Malmesbury, South Africa. The left leg *M. gastrocnemius, pars interna* (0.96 ± 0.18 kg) from each carcass was removed at approximately 1 h after slaughter (hot-deboned). The hot-deboned muscles were immediately vacuum packaged (AMSA, 1995) and stored for 24 h at <4 °C. The rest of the carcass was also stored at <4 °C in the same refrigerator at the abattoir before the right leg muscles (1.05 ± 0.14 kg) were excised at approximately 24 h post-mortem (cold-deboned muscles). The cold-deboned muscles were vacuum packaged and together with the hot-deboned muscles, transported in cooler boxes to Stellenbosch (60 km) and aged for an additional 24 h at an average temperature of 4 °C (0–7 °C variation). Sensory analysis of all the muscle samples was consequently conducted at 48 h post-mortem on the same day. Freezing of the muscles was avoided, since freezing and thawing increases tenderness above what the actual tenderness of chilled muscle may be 48 h post-mortem (Watanabe & Devine, 1996). It is suggested that some damage caused by ice crystals during freezing, storage and thawing may modify the process of meat aging.

At 1 h post-mortem, muscle pH and temperature (°C) of both the left and right intact *M. gastrocnemius, pars interna* of eight ostriches were measured with the use of a calibrated (standard buffers pH 4.0 and 7.0) portable Crison 506 pH-meter equipped with, respectively, a pH and temperature probe. Muscle pH and temperature (°C) were recorded again immediately after the hot-deboned muscles were excised at approximately 1 h and 10 min (i.e. 10 min after the 1-h pH measurement was recorded). Muscle pH and temperature (°C) were also recorded for the cold-deboned muscles after excision at approximately 24 h post-mortem. To avoid breakage of the seal of the vacuum package, measurements of pH and temperature were not recorded from hot-deboned muscles at 24 h post-mortem. Final muscle pH and temperature (°C) measurements were recorded at 48 h post-mortem before muscle samples were prepared for sensory analysis and Warner–Bratzler shear force (*N, 12.7 mm^−1^ diameter) measurements.

2.2. Sample preparations

At 48 h post-mortem, meat portions of 0.52 ± 0.08 kg were cut from the middle section of each muscle. The meat portions were placed in individual oven bags without added salt or spices and placed on open roasting pans. Four meat portions at a time were oven roasted (AMSA, 1995) in conventional electric ovens (Defy Model 835), preheated to 160 °C, which were connected to a computerised electronic temperature control system (Viljoen, Muller, De Swart, Sadie, & Vosloo, 2001). The internal temperature of the meat portions was measured using a thermocouple probe inserted into the centre of the meat portions and roasting continued until a core temperature of 68 °C was reached. At a core temperature of 68 °C, the meat portions were removed from the oven and left to stand for 5 min. The cooked meat portions were cut into slices of approximately 1.5–2.0 cm thick, perpendicular to the fibre direction. Cooked surfaces were removed from the slices (AMSA, 1995). Cubed samples of 1 cm^3^ were then cut from these meat slices. Samples were individually wrapped in aluminium foil, placed in preheated glass ramekins individually coded with three digit codes and preheated for 10 min at 100 °C before being served to the panellists.

2.3. Sensory analysis

The sensory panel consisted of 8 trained assessors previously selected for their flavour and texture sensitivity according to the guidelines of the American Meat Science Association (AMSA, 1995). The panel was further trained using the consensus method as described by Lawless and Heymann (1999). A 100 mm unstructured line scale, where the left side of the scale corresponded to the lowest intensity (zero) and the right hand side corresponded to the highest intensity (100), was used for attribute intensity evaluation. Separate samples of ostrich *M. gastrocnemius, pars interna* and *M. iliofibularis* (aged for approximately 7 d), as well as the hot and cold-deboned *M. gastrocnemius, pars interna* from one of the eight randomly selected ostriches, were used to train the panel for sensory attributes. The judges agreed on a consensus list of attributes for describing ostrich meat, which included intensity of ostrich aroma, impression of initial juiciness, sustained juiciness, impression of tenderness, the amount of residue, and overall ostrich flavour. Verbal definitions for the sensory attributes evaluated for the ostrich meat are given in Table 1. Hot and cold-deboned ostrich *M.gastrocnemius, pars interna* from a single carcass were used separately to familiarise the judges with differences in tenderness.

Samples were served and evaluated during seven sessions, controlling for carcass by serving hot and...
cold-deboned samples from one carcass within the same session (AMSA, 1995). The panellists were seated individually at sensory booths, which were light and temperature controlled. Meat samples (individually wrapped in aluminium foil and preheated in an oven at 100 °C), each coded with a three digit random code (AMSA, 1995), were presented in a complete randomised order according to carcass. The aroma of the samples was immediately assessed after unwrapping of the aluminium foil. Flavour and texture (tenderness) attributes were assessed on the entire sample. Still mineral water, unsalted biscuits and apple slices were available for assessors to cleanse their palates between samples when evaluating flavour.

2.4. Physical tenderness

From each cooked meat portion, a slice of 1.5–2.0 cm thick was cooled for 24 h at 4 °C before Warner–Bratzler shear force measurements were obtained as described by Wheeler, Shackelford, and Koohmaraie (2001) and Honikel (1998). Seven 12.7 mm wide cores were removed parallel to the muscle fibre from each muscle slice and placed in the Warner–Bratzler device, with a load cell of 2.000 kN, which was attached to the Model 4444 Instron texture machine (Apollo Scientific cc, South Africa), so that the knife blade of the device cut across the fibres at right angles. The maximum (high peak) shear force value (N, 12.7 mm ¹ diameter) to shear a cylindrical core of cooked meat was recorded at a crosshead speed of 200 mm min ¹. Mean maximum shear force values were calculated from the shear force values recorded for seven cylindrical cores from each muscle sample and used in the statistical analyses.

2.5. Statistical analyses

The results obtained by the eight judges were part of a complete randomised block design, performed with two treatments (hot and cold-deboning) replicated in seven blocks (ostrich carcasses). The sensory data were subjected to analysis of variance (ANOVA) using SAS version 8.2 statistical software (SAS, 1999), to evaluate different sources of variation in sensory attributes: ostrich aroma; initial juiciness; sustained juiciness; tenderness; residue and overall ostrich flavour. Ostrich, judge and deboning were the main effects and a two way interaction between main effects was also included. Shapiro–Wilk tests were performed for testing non-normality (Shapiro & Wilk, 1965). Correlation coefficients [r-values at the 5% significance level (P)] were calculated with the use of statistical software Statistica version 6 (StatSoft, 2003). Correlation coefficients were calculated between the sensory attributes of ostrich aroma, initial juiciness, sustained juiciness, tenderness, residue and overall ostrich flavour from the raw data points for hot and cold-deboned muscles, respectively. Correlation coefficients between the data from muscle pH and temperature at 48 h post-mortem and the mean values for the sensory attributes of ostrich aroma, initial juiciness, sustained juiciness, tenderness, residue and overall ostrich flavour for the hot and cold-deboned muscles, respectively, as well as from the pooled data for the hot and cold-deboned muscles, were calculated.

3. Results and discussion

3.1. Muscle pH and temperature

At 1 h post-mortem, the mean muscle pH for the hot and cold-deboned muscles of eight ostriches was 6.82 ± 0.11. This pH value did not differ (P > 0.05) from the pH (6.81 ± 0.15) determined for the hot-deboned muscles excised from the carcass at 1 h and 10 min post-mortem (T1 + 10 min). This indicated that there was no sudden fall in pH during, or right after excision of the muscles at approximately 1 h post-mortem (Table 2). These pH–values also indicated that the excision of the muscles at approximately 1 h post-mortem did not cause the muscles to super contract leading to a sudden fall in muscle pH. In addition, there was no significant difference (P > 0.05) between the temperature of the hot-deboned muscles right after excision (T1 + 10 min) and the temperature of the intact cold-deboned muscles at 1 h post-mortem.

Table 1
Verbal definition of sensory attributes for the sensory analysis of ostrich meat

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Definition</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ostrich aroma intensity</td>
<td>Aroma associated with ostrich meat</td>
<td>0 = No ostrich meat aroma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 = Strong ostrich meat aroma</td>
</tr>
<tr>
<td>Initial juiciness</td>
<td>The amount of fluid exuded on the cut surface when pressed between the thumb and forefinger</td>
<td>0 = Extremely dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 = Extremely juicy</td>
</tr>
<tr>
<td>Sustained juiciness</td>
<td>The degree of juiciness perceived after the first two to three chews between the molar teeth</td>
<td>0 = Extremely dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 = Extremely juicy</td>
</tr>
<tr>
<td>Tenderness</td>
<td>Impression of tenderness after the first two to three chews between the molar teeth</td>
<td>0 = Extremely tough</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 = Extremely tender</td>
</tr>
<tr>
<td>Residue</td>
<td>The amount of residue left in the mouth after the first twenty to thirty chews</td>
<td>0 = High amount of residue left</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 = No residue left</td>
</tr>
<tr>
<td>Overall ostrich flavour</td>
<td>Flavour associated with ostrich meat as a combination of taste and swallowing</td>
<td>0 = No ostrich flavour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 = High ostrich flavour</td>
</tr>
</tbody>
</table>
Table 2
Means (±standard deviation) muscle pH and temperature (°C) at 1 h post-mortem, right after hot-deboning (1 h and 10 min) and cold-deboning (24 h post-mortem), and at 48 h post-mortem

<table>
<thead>
<tr>
<th>Time post-mortem (h):</th>
<th>Hot-deboned muscles</th>
<th>Cold-deboned muscles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle pH&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH&lt;sub&gt;H&lt;/sub&gt;</td>
<td>6.83 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.82 ± 0.10&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>pH&lt;sub&gt;H&lt;/sub&gt; + 10 min</td>
<td>6.81 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
</tr>
<tr>
<td>pH&lt;sub&gt;24&lt;/sub&gt;</td>
<td>-</td>
<td>6.67 ± 0.34&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>pH&lt;sub&gt;48&lt;/sub&gt;</td>
<td>6.57 ± 0.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.63 ± 0.24&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Muscle temperature (°C)&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;</td>
<td>28.90 ± 3.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.36 ± 3.98&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt; + 10 min</td>
<td>30.83 ± 1.38&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
</tr>
<tr>
<td>T&lt;sub&gt;24&lt;/sub&gt;</td>
<td>-</td>
<td>0.03 ± 0.29&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;48&lt;/sub&gt;</td>
<td>6.68 ± 0.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.70 ± 0.24&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Different superscripts for pH differ at P<0.05.
<sup>b</sup> Different superscripts for temperature differ at P<0.05.

The pH<sub>48</sub> of the hot and cold-deboned muscles did not differ significantly (P>0.05). However, the pH at 1 h (6.83 ± 0.09) differed (P<0.05) from the pH at 48 h (6.57 ± 0.18) post-mortem for the hot-deboned muscles (Table 2), but not for the cold-deboned muscles. This difference in pH<sub>H</sub> and pH<sub>H</sub><sub>48</sub> for the hot-deboned muscles, but not for the cold-deboned muscles, could not be explained by muscle temperature, since no significant correlation (P>0.05) could be found between muscle pH and temperature.

Muscle pH for the cold-deboned muscles did not differ significantly between the three different times post-mortem of 1 h (6.82 ± 0.10), 24 h (6.67 ± 0.34), and 48 h (6.63 ± 0.24). However, there was a decrease in pH from 1 to 48 h and, therefore, it is possible that, as was found with the hot-deboned muscles, the pH of the cold-deboned muscles might decrease further if the aging was extended beyond 48 h post-mortem.

At 1 h post-mortem, M. gastrocnemius, pars interna had reached a mean temperature of 27.70 ± 3.02 °C. During storage at <4 °C, the temperature of the cold-deboned muscles, whilst still attached on the carcass, at 24 h post-mortem had decreased to below 0 °C (0.03 ± 0.29 °C). Since the vacuum packaged hot-deboned muscles were kept under the same temperature conditions as the cold-deboned muscles, it was assumed that the temperature of the hot-deboned muscles was similar or even less than that of the cold-deboned muscles at 24 h post-mortem. The temperature of the hot-deboned muscles may have been lower than that of the cold-deboned muscles at 24 h post-mortem, since a larger surface area of the muscle was exposed to the ambient temperature compared to the cold-deboned muscles that were still attached to the carcass. Van Laack and Smulders (1992) showed in pork that the temperature decrease is more uniform and faster in hot-deboned muscles than in muscles left on the carcass.

Although the cold-deboned muscles were cooled at <4 °C at the abattoir for approximately 24 h post-mortem before being excised, it is common practice in the meat industry for the cooler room to be at a temperature just below 0 °C in order to ensure that the temperature of the cooler room is low enough when the refrigerator is filled with the day’s warm carcasses. Therefore, this is the reason why the mean cold-deboned muscle temperature (0.03 ± 0.29 °C) was below 0 °C, 24 h post-mortem. The higher temperatures of both the hot and the cold-deboned muscles at 48 h post-mortem can be explained by the fact that all muscles were transported to Stellenbosch at 24 h post-mortem and stored in a cooler room running at temperatures of 0–7 °C for 24 h. However, it may be postulated that since hot and cold-deboned muscles from the same ostrich were treated similarly at all times, the effect of the temperature differences would be constant within muscles.

### 3.2. Sensory attributes

The analysis of variance (ANOVA) of attributes: ostrich aroma; initial juiciness; sustained juiciness; tenderness; residue and overall ostrich flavour is presented in Table 3. Except for the attribute, residue, no significant (P>0.05) two way interactions were found between judge and debone (treatment) and between ostrich and debone. Due to the significant two way interactions for the attribute, residue, the main effects for the attribute could not be investigated independently. It was also found that the sensory panel was consistent in their judgements, as there were no significant interactions (P>0.05) between judge and treatment (deboning) for the attributes: ostrich aroma; initial juiciness; sustained juiciness and tenderness.

The data obtained showed no differences in ostrich aroma and overall flavour (P>0.05) between hot and cold-deboned muscles (Fig. 1). This is similar to the results of Jeremiah, Martin, and Murray (1985) who reported no significant effect of hot-deboning on juiciness or beef flavour intensity for beef muscles. However, aroma was correlated (P<0.05) to overall flavour (r = 0.518), where this correlation was higher for the cold-deboned muscles (r = 0.651) than for the hot-deboned muscles (r = 0.374). Taste panel scores for initial and sustained juiciness also showed no difference (P>0.05) between the hot and the cold-deboned muscles (Fig. 1). Initial juiciness was significantly (P<0.05) correlated to sustained juiciness for the hot-deboned (r = 0.474) and the cold-deboned (r = 0.512) muscles, respectively. However, cold-deboned muscle tenderness was positively correlated (P<0.05) to initial (r = 0.272) and sustained juiciness (r = 0.533), while tenderness for the hot-deboned muscles was not significantly (P>0.05) correlated to either initial (r = 0.149) nor sustained juiciness (r = 0.201). This indicated that hot-deboning did not influence the juiciness of ostrich meat and that the juiciness of cooked ostrich meat cannot be used as an indicator of tenderness.

Results from both the sensory analysis and the Warner–Bratzler shear force measurements (Table 4) indicate that
Table 3

Analyses of variance (ANOVA) of sensory attributes: ostrich aroma, initial juiciness, sustained juiciness, tenderness, residue, and overall ostrich flavour with ostrich, judge and deboning (debone) as main effects, the two two-way interactions (debone * judge and debone * ostrichs), as well as the Shapiro-Wilk test for non-normality.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Ostrich aroma</th>
<th>Initial juiciness</th>
<th>Sustained juiciness</th>
<th>Tenderness</th>
<th>Residue</th>
<th>Overall flavour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MS</td>
<td>P</td>
<td>MS</td>
<td>P</td>
<td>MS</td>
<td>P</td>
</tr>
<tr>
<td>Ostrich</td>
<td>6</td>
<td>308.07</td>
<td>***</td>
<td>176.94</td>
<td>–</td>
<td>43.04</td>
<td>–</td>
</tr>
<tr>
<td>Judge</td>
<td>7</td>
<td>259.71</td>
<td>***</td>
<td>813.96</td>
<td>***</td>
<td>1322.58</td>
<td>***</td>
</tr>
<tr>
<td>Debone</td>
<td>1</td>
<td>6.51</td>
<td>–</td>
<td>12.89</td>
<td>–</td>
<td>153.22</td>
<td>–</td>
</tr>
<tr>
<td>Debone * ostrich</td>
<td>6</td>
<td>61.95</td>
<td>–</td>
<td>23.91</td>
<td>–</td>
<td>17.70</td>
<td>–</td>
</tr>
<tr>
<td>Sample error</td>
<td>42</td>
<td>32.25</td>
<td>–</td>
<td>18.21</td>
<td>–</td>
<td>16.76</td>
<td>–</td>
</tr>
<tr>
<td>Shapiro-Wilk</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

df, degree of freedom; MS, mean square; P, probability value of F-ratio test.

*, interaction between main effects.

–, NS (not significant) = P > 0.05.

* Experimental error = ostrich * judge.

** P < 0.05.

*** P < 0.001.

Fig. 1. Means (±standard errors) and probability (P) values of the F-ratio test for the main effect, deboning, of taste panel sensory scores for sensory attributes: ostrich aroma; overall ostrich flavour; initial juiciness; sustained juiciness; tenderness and residue for the hot and cold-deboned muscles, respectively. Hot and cold-deboned muscles differed for a particular attribute at the level of P < 0.05. *Scale of rating; taste panel ratings were scored by ticking on an unstructured 100 mm line scale.

Table 4

Mean values (± standard deviation) for tenderness as scored by the taste panel and mean Warner–Bratzler shear force values (N, 12.7 mm$^1$ diameter) for, respectively, the hot and the cold-deboned M. gastrocnemius, pars interna at 48 h post-mortem.

<table>
<thead>
<tr>
<th>Deboning</th>
<th>Means ± standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tenderness taste panel score$^a$</td>
</tr>
<tr>
<td>Hot-deboned muscles</td>
<td>66.39 ± 15.45$^a$</td>
</tr>
<tr>
<td>Cold-deboned muscles</td>
<td>82.75 ± 12.52$^b$</td>
</tr>
</tbody>
</table>

Different superscripts within a column differ at P < 0.05.

* Higher values indicate more tender meat.

When investigating the mean data for the hot and the cold-deboned muscles were pooled, the mean sustained juiciness was positively correlated (P < 0.05) to the muscle pH at 48 h post-mortem (r = 0.575) as well as to the mean taste panel tenderness scores (r = 0.598). Muscle samples that were tender were therefore perceived as being juicier compared to less tender samples. However, Cameron, Warriss, Porter, and Enser (1990) indicated that juiciness and tenderness are independent attributes. When investigating the mean data for the hot-deboned and the cold-deboned muscles separately, muscle pH at 48 h post-mortem was negatively correlated (r = 0.781) to mean Warner–Bratzler shear force values and positively correlated (r = 0.789) to mean taste panel tenderness scores (P < 0.05) only in the case of the hot-deboned muscles. The application of hot-deboning seemed to affect post-mortem glycolysis in such a manner that muscle pH had an affect on meat tenderness; i.e. the higher the pH the more tender the meat was at 48 h post-mortem. These results are in accordance with what has previously been reported for beef and lamb by several authors. It has been observed that a higher ultimate pH is related to more tender meat and that this improvement in tenderness at high pH values is the result of an increased proteolytic activity (Bouton, Harris, Macfarlane, & Shorthose, 1982; Guignet, Touraille, Ouali,
fully be overcome by increased aging periods in the case of veal (Klont et al., 2000). Further investigation is needed to explain the difference in tenderness between hot-deboned and cold-deboned ostrich muscles to conclude whether the difference is due to cold-shortening or reduced post-mortem proteolysis, and/or due to effects of post-mortem pH. It is well known that when pre-rigor muscle attains a temperature of below 10–15 C while the pH is above 6.0–6.4 and ATP levels are still high enough for muscle contraction to occur, there is a risk of cold-shortening and consequent toughening of the meat when cooked (Honikel, Roncalès, & Hamm, 1983; Lawrie, 1998; Pearson & Young, 1989). Morton, Bickerstaffe, Kent, Dransfield, and Keeley (1999) suggested that in beef there is an association between the rate of pH decline post-mortem and the rate of meat tenderisation. O’Halloran, Troy, and Buckley (1997) and Hwang and Thompson (2001) both reported that fast glycolysing muscles were more tender than slow glycolysing muscles. In the present study it was uncertain at which point in time of the rigor mortis process and course of pH decline the M. gastrocnemius, pars interna was when excision of these muscles was performed at 1 h post-mortem. Investigation of the course of rigor mortis and the post-mortem pH decline is required for further elucidation on the post-mortem changes in ostrich muscle. Such investigations will also indicate the time (hour post-mortem) of minimum pH, the rate of pH decline, and the rate of rigor mortis development.

4. Conclusion

The data from both the taste panel tenderness scores and Warner–Bratzler shear force measurements indicated that hot-deboning of ostrich M. gastrocnemius, pars interna caused meat from this muscle to be tougher than that from cold-deboned muscles at 48 h post-mortem. Cold-deboning also resulted in less variation in tenderness attributes when compared to hot-deboned muscles, and therefore would produce meat with a more consistent eating quality in terms of texture. Dransfield et al. (1982) concluded that acceptability to consumers was determined largely by the wide variation in tenderness. The question arises; however, whether the difference in tenderness between hot and cold-deboned muscles as found in the present study for ostrich M. gastrocnemius, pars interna would still prevail with further aging post-mortem? Earlier reports for beef (Smith, Culp, & Carpenter, 1978) showed that aging would increase tenderness, flavour and overall palatability of the majority of muscle cuts when cooked by oven-broiling or roasting. On the other hand, it has been indicated that cold-shortening toughness could not
Table 3