Physicochemical characteristics, proximate analysis and mineral composition of ostrich meat as influenced by muscle

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A B S T R A C T

The influence of muscle on the physicochemical characteristics, proximate analysis, and mineral composition of meat from 10 ostriches (10–12 months old), slaughtered according to commercial abattoir procedures, were evaluated. Muscle had no influence (p > 0.05) on \( L^* \)-values (32.5), \( a^* \)-values (11.9), water-holding capacity (11.9%), final pH (pH24) values (6.07), and ash contents (1.12 g/100 g edible meat). However, intramuscular lipid contents varied (p < 0.05) from 0.88 (M. fibularis longus) to 1.44 (M. flexor cruris lateralis) g/100 g edible meat, at a mean value of 1.16 g/100 g edible meat for 10 different muscles. Sodium (34.7 mg/100 g edible meat) and iron (3.14 mg/100 g edible meat) contents, both influenced (p < 0.05) by muscle, possessed substantially lower and higher values, respectively, than values reported for beef and chicken.

1. Introduction

Despite domestication of the ostrich (Struthio camelus) in the middle of the 19th century due to a fashion for ostrich feathers, this animal remained unknown as a potential meat producer till the beginning of the 1990s. At this time the single channel marketing scheme was lifted by the Klein Karoo Agriculture Co-operative, Oudtshoorn, South Africa, and ostriches and ostrich products could be marketed freely worldwide (Drenowatz, Sales, Sarasqueta, & Weilbrenner, 1995). Surprisingly, notwithstanding little and fragmented research, several reviews (Balog & Almeida Paz, 2007; Hoffman, 2005, 2008; Paleari, Corsico, & Beretta, 1995; Sales, 1999; Sales & Horberačczuk, 1998; Sales & Oliver-Lyons, 1996) have been produced on ostrich meat. From the above it has been concluded that ostrich meat is characterised, relatively to meat from other species, by a

(1) high (>6.0) final pH (pHf), which is beneficial for the colour and water-binding capacity of meat, but is undesirable for keeping quality and flavour,
(2) low intramuscular lipid content,
(3) low sodium (Na) content, and
(4) high iron (Fe) content.

Although several studies have evaluated the lipid and fatty acid composition of ostrich meat, a single study (Sales & Hayes, 1996) has determined the mineral profile of ostrich meat, with concentrations of iron (Fe) (Lombardi-Boccia, Lanzi, & Aguzzi, 2005; Lombardi-Boccia, Martinez-Dominguez, & Aguzzi, 2002), selenium (Se) (Duan & Åkesson, 2004), zinc (Zn) (Lombardi-Boccia et al., 2005), and copper (Cu) (Lombardi-Boccia et al., 2005) reported by some others. Furthermore, mineral concentrations have been evaluated in a limited number of different muscles, the unit used to sell ostrich meat. In addition to diet, hormones, age, gender and region, mineral concentrations vary among different muscles in the animal carcass, due to varying intensity of physical activity and the effects of fibre type (Doornenbal & Murray, 1981; Lin et al., 1989).

In order to evaluate the nutritional potential of ostrich meat, and to extend current knowledge, the present study aimed at evaluation of selected physicochemical characteristics, proximate analysis, and mineral composition of ostrich meat as influenced by muscle.

2. Materials and methods

2.1. Animals and sampling

Ostriches, predominantly from the subspecies S. camelus australis (Blue Neck), were reared on a commercial ostrich farm in Paprotno, Poland, on a commercial ostrich starter (16% crude...
protein, 9.6% fibre, 9.7 MJ/kg) feed mixture (pellets) till 3 months of age, whereafter a commercial (14.5% crude protein, 10.7% fibre, 9.5 MJ/kg) ostrich grower (pellets) was supplied. Ten ostriches (males) were slaughtered at the age of 10–12 months in a commercial abattoir for cattle and swine in Chrusćina, Poland, with the slaughtering process adapted for ostriches. Ostriches were fasted for 24 h, and stunned with a captive bolt stunner. The unconscious birds were shackled by one leg, hoisted to a height and bled by severance of the heart, carotid artery and jugular vein through the thoracic inlet, anterior to the sternum plate. After feather and skin removal internal organs were removed. Carcasses were divided into two sides, and chilled for 24 h at 4 °C. Subsequently, legs and thighs were excised from the pelvic limbs.

The following 10 muscles were excised from the left side of each carcass: M. gastrocnemius, M. fibularis longus, M. obturatorius medialis, M. flexor cruris lateralis, M. iliofibularis, M. femorotibialis medius, M. iliobasalis lateralis, M. iliofemoralis externus, M. ambiens, and M. iliobasalis cranialis. External fat and epimysial connective tissue were removed and muscles were divided perpendicularly to their longitudinal axis into two equal parts. Whereas the caudal part of each muscle was stored at −18 °C till analysed for thawing and cooking losses, the cranial part was ground twice through a 4 mm sieve to ensure homogeneity of samples. The latter was portioned into two separate parts, with one of them being stored at −18 °C for proximate analysis and assaying mineral concentrations, and the second used fresh for immediate determination of meat colour, water-holding capacity (WHC), and final pH (pHf).

2.2. Physicochemical characteristics

Six muscles (M. gastrocnemius pars interna, M. fibularis longus, M. iliobasalis medius, M. iliobasalis lateralis, and M. iliobasalis cranialis) were used for evaluation of physicochemical characteristics. To evaluate thawing and cooking losses of the thawed meat, the caudal part was weighed and then frozen at −18 °C for 2–3 months. Meat juice losses during thawing were calculated based on the difference of sample weight before freezing and after a 24-h thawing period at 4 °C (in a household refrigerator). These losses were expressed as a percentage in relation to the weight of the sample before freezing.

For determination of cooking losses, 100 g samples, 20 mm thick, were cut from the muscles after thawing, and placed in 500 ml glass jars and covered with 300 ml water. Glass jars with meat samples were closed and placed in a water bath until a temperature of 85 °C was obtained inside the muscles, according to Baryłko-Pikielna, Kossakowska, and Baldwin (1964). Thereafter, meat samples were removed from the glass jars and exposed to dripping and cooling in a household refrigerator at 4 °C for a period of 30 min. Cooking losses were calculated based on the difference in sample weights before and after cooking, expressed as a percentage of sample weight before cooking.

The following determinations were made on fresh ground meat tissue from the cranial part of each muscle.

2.2.1. Colour measurements

These were taken after keeping ground meat samples in measurement cells in a household refrigerator at 4 °C for 20 min, to enable myoglobin oxygenation on the surface layer of meat. Colour was measured using a HunterLab Miniscan XE Plus 45/0 apparatus with a measuring port diameter of 31.8 mm, adopted for measuring the colour of ground meat, applying the CIELAB L*ab* scale (Commission Internationale de l’Eclairage (CIE), 1976) and a D65 illuminant and 10° standard observer. Standardisation of the apparatus was done in relation to black and white colour standard references with the following coordinates: X = 78.5, Y = 83.3 and Z = 87.8 (for D65 illuminant and 10° standard observer).

2.2.2. Water-holding capacity

This was based on the percentage of free water in meat, according to the method of Grau and Hamm (1953), as modified by Pohja and Niinivaara (1957). Ground meat samples, 0.3 g each (weighed accurately to 0.001 g), placed on Whatman No. 1 paper-filter, were exposed to 2 kg pressure between two glass plates for a period of 5 min. Thereafter, using a planimeter, the area of two spots created by extruded meat juice and meat, respectively, was determined (in cm²). In order to determine the percentage of free water in meat, the infiltrate area expressed in cm² obtained from the difference in the areas of these two spots was divided by the weight of the sample.

2.2.3. pHf measurement

This was done 24 h after slaughter with a combined glass electrode (ESAgP-306 W type) of a CyberScan 10 pH-meter (Eutech Cybernetics Pte Ltd., Singapore) in a water extract (distilled water), with a 1:1 meat to water ratio, after 1 h of extraction.

2.3. Proximate analysis

The following chemical constituents were determined on thawed ground samples of all muscles according to the official methods of analysis of the AOAC (2003): moisture content by oven drying a ca. 2-g test sample at 102 °C to a constant weight (950.46B, see p. 39.1.02); ash content by igniting a ca. 3–5-g test sample in a muffle furnace at 550 °C until light grey ash results (920.153, see p. 39.1.09); crude protein content by the classical macro-Kjeldahl method (981.10, see p. 39.1.19); and lipid (crude) content by petroleum ether extraction using a Soxhlet apparatus (960.39 (a), see p. 39.1.05).

2.4. Mineral composition

Chemical elements in the examined material were determined by inductively-coupled argon plasma optical emission spectrometry (ICP-OES), using a Perkin–Elmer Optima 2000 DV system, after prior mineralisation in an Anton Paar Multiwave microwave oven (Anton Paar Ltd., Herford, UK). Meat samples, ca. 0.5 g each, were weighed exactly to four decimal places, and transferred to pressurised quartz vials, into which 5.0 ml 65% HNO3 and 0.5 ml 35% HCl were added. Vials were sealed with Teflon plugs, secured in mineralisation bomb units, and placed in a microwave oven equipped with a permanent temperature and pressure control system in each quartz vessel. Mineralisation was conducted after selecting the “Meat” procedure proposed by the equipment manufacturer: 0–5 min – power gradient from 100 to 600 W; 6 to 10 min – 600 W (constant); 11 to 20 min – 1000 W or less after reaching critical values (75 MPa or 300 °C); 21 to 35 min – vial cooling. The cooled mineralisate was diluted with deionised water to a final volume of 10 ml. The following minor chemical elements were determined in the prepared solutions: boron (B), barium (Ba), cobalt (Co), chromium (Cr), Cu, Fe, manganese (Mn), nickel (Ni), Se, silicon (Si) and Zn. In order to obtain an optimum concentration range for the ICP method, calcium (Ca), potassium (K), magnesium (Mg), Na and phosphorus (P) concentrations were determined after a 100-fold dilution of the mineralisate. As a standard, the certified multi-element standard solution “ICP Multi-element Standard IV” (Merck, Darmstadt, Germany) was used.

2.5. Statistical analysis

Results were analysed using the ANOVA procedures of the software STATISTICA (data analysis software system, Version 7.1; StatSoft, Tulsa, OK). Individual animals were used as blocks to remove variation, due to differences among animals, from the error sum of
3. Results and discussion

3.1. Physicochemical characteristics

Measured objective values for lightness ($L^*$), and the difference between red and green ($a^*$), did not differ ($p > 0.05$) among the six muscles evaluated for colour. However, the $M. \text{iliotibialis cranialis}$, compared to the $M. \text{gastrocnemius pars interna}$, $M. \text{fibularis longus}$, $M. \text{femorotibialis medius}$, and $M. \text{iliotibialis lateralis}$ (Table 1), showed a higher ($p < 0.05$) intensity of yellow than blue ($b^*$).

Although present values for $L^*$ correspond to values (27.4–34.4) reported for 10 different muscles from different subspecies (South African Black, Zimbabwean Blue, hybrids) of ostriches by Hoffman, Muller, Cloete, and Brand (2008), the latter study found significant differences among muscles, with the $M. \text{fibularis longus}$ possessing the darkest muscle. Similarly, significant differences in $a^*$-values (10.7–17.1) have been indicated among muscles in the latter study. However, in agreement with present results, the highest (8.3–9.3) and lowest (6.0–6.7) $b^*$-values have been found in $M. \text{iliotibialis cranialis}$ and $M. \text{fibularis longus}$, respectively. Results for lightness found in the present study are contrary to subjective colour measurements presented by Morris et al. (1995), who found significant differences in lightness among 10 different muscles from the ostrich carcass, with the highest degree of lightness in the $M. \text{iliotibialis cranialis}$. The above differences among studies could partly result from the use of different post-hoc statistical tests, to identify differences among muscles. However, colour determination on ground meat in the present study versus whole muscles in other studies could be another contributing factor. Fragmentation of the muscle structure by grinding assists in the release of liquids from the interior of muscle cells, including soluble protein such as myoglobin, and destruction of some of the muscle's aerobic-reducing system, which could influence colour development in the final product (Fernández-López, Pérez-Alvarez, & Aranda-Catalá, 2000).

### Table 1

<table>
<thead>
<tr>
<th>Muscle</th>
<th>$L^*$</th>
<th>$a^*$</th>
<th>$b^*$</th>
<th>Water-holding capacity (%)</th>
<th>Thawing losses (%)</th>
<th>Cooking losses (%)</th>
<th>$pH_{44}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M. \text{gastrocnemius pars interna}$</td>
<td>31.8 ± 1.36</td>
<td>16.7 ± 1.14</td>
<td>11.3 ± 0.64</td>
<td>11.3 ± 2.33</td>
<td>3.11 ± 1.44</td>
<td>41.7 ± 2.21</td>
<td>6.07 ± 0.06</td>
</tr>
<tr>
<td>$M. \text{fibularis longus}$</td>
<td>31.5 ± 1.97</td>
<td>17.1 ± 2.25</td>
<td>11.3 ± 1.50</td>
<td>11.0 ± 4.08</td>
<td>2.53 ± 0.92</td>
<td>41.1 ± 2.59</td>
<td>5.99 ± 0.07</td>
</tr>
<tr>
<td>$M. \text{fibularis longus}$</td>
<td>33.5 ± 0.43</td>
<td>17.2 ± 2.21</td>
<td>12.5 ± 1.07</td>
<td>13.2 ± 3.87</td>
<td>3.26 ± 1.19</td>
<td>43.7 ± 2.34</td>
<td>6.01 ± 0.04</td>
</tr>
<tr>
<td>$M. \text{femorotibialis medius}$</td>
<td>32.6 ± 2.46</td>
<td>16.9 ± 1.84</td>
<td>11.4 ± 1.22</td>
<td>13.8 ± 3.89</td>
<td>3.88 ± 1.42</td>
<td>45.1 ± 3.11</td>
<td>5.99 ± 0.02</td>
</tr>
<tr>
<td>$M. \text{femorotibialis medius}$</td>
<td>32.8 ± 4.83</td>
<td>18.5 ± 5.74</td>
<td>11.4 ± 2.41</td>
<td>11.9 ± 4.87</td>
<td>4.21 ± 1.08</td>
<td>38.2 ± 10.09</td>
<td>6.01 ± 0.04</td>
</tr>
<tr>
<td>Mean</td>
<td>32.5 ± 2.36</td>
<td>17.7 ± 2.86</td>
<td>11.9 ± 1.54</td>
<td>11.9 ± 3.57</td>
<td>3.16 ± 1.28</td>
<td>41.7 ± 5.18</td>
<td>6.07 ± 0.01</td>
</tr>
</tbody>
</table>

$*$-Values with different superscript letters in the same column are different ($p < 0.05$).

### Table 2

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Dry matter</th>
<th>Protein</th>
<th>Intramuscular lipid</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M. \text{gastrocnemius pars interna}$</td>
<td>23.3 ± 1.20</td>
<td>21.3 ± 0.73</td>
<td>0.90 ± 0.16</td>
<td>1.05 ± 0.05</td>
</tr>
<tr>
<td>$M. \text{fibularis longus}$</td>
<td>23.3 ± 1.12</td>
<td>21.5 ± 0.81</td>
<td>0.88 ± 0.23</td>
<td>1.12 ± 0.05</td>
</tr>
<tr>
<td>$M. \text{obturatorius medialis}$</td>
<td>24.5 ± 0.69</td>
<td>21.7 ± 0.49</td>
<td>1.22 ± 0.27</td>
<td>1.14 ± 0.08</td>
</tr>
<tr>
<td>$M. \text{flexor cruris lateralis}$</td>
<td>24.2 ± 1.39</td>
<td>21.5 ± 0.92</td>
<td>1.44 ± 0.31</td>
<td>1.14 ± 0.06</td>
</tr>
<tr>
<td>$M. \text{iliotibialis lateralis}$</td>
<td>22.8 ± 0.93</td>
<td>20.7 ± 0.52</td>
<td>1.10 ± 0.25</td>
<td>1.07 ± 0.07</td>
</tr>
<tr>
<td>$M. \text{femorotibialis medius}$</td>
<td>23.0 ± 1.14</td>
<td>20.8 ± 0.67</td>
<td>0.95 ± 0.11</td>
<td>1.15 ± 0.07</td>
</tr>
<tr>
<td>$M. \text{femorotibialis lateralis}$</td>
<td>23.8 ± 1.05</td>
<td>21.4 ± 0.59</td>
<td>1.21 ± 0.22</td>
<td>1.17 ± 0.08</td>
</tr>
<tr>
<td>$M. \text{iliofibularis externus}$</td>
<td>23.8 ± 1.29</td>
<td>20.7 ± 0.79</td>
<td>1.22 ± 0.12</td>
<td>1.14 ± 0.14</td>
</tr>
<tr>
<td>$M. \text{ambiens}$</td>
<td>24.1 ± 1.04</td>
<td>21.3 ± 0.23</td>
<td>1.34 ± 0.35</td>
<td>1.09 ± 0.06</td>
</tr>
<tr>
<td>$M. \text{iliotibialis cranialis}$</td>
<td>24.4 ± 1.49</td>
<td>20.6 ± 0.78</td>
<td>1.36 ± 0.24</td>
<td>1.13 ± 0.12</td>
</tr>
<tr>
<td>Mean</td>
<td>23.7 ± 1.24</td>
<td>21.2 ± 0.76</td>
<td>1.16 ± 0.29</td>
<td>1.12 ± 0.08</td>
</tr>
</tbody>
</table>

$*$- and $b$-Values with different superscript letters in the same column are different ($p < 0.05$).
edible meat in the *M. flexor cruris lateralis* (Table 2). Studies of the influence of muscle on lipid content of ostrich meat are contradictory (summarised by Hoffman, 2005). Substantially lower values (mean of 0.48 g/100 g edible meat) have been reported for 10 different ostrich muscles and muscle groups by Sales (1996). However, similarly to present results, the *M. flexor cruris lateralis* (0.82 g/100 g edible meat) and *M. fibularis longus* (0.24 g/100 g edible meat) were the muscles with the highest and lowest lipid contents, respectively. It is important to emphasise that lipid contents will depend on the methodology of the lipid analysis, with different solvents used for extraction causing different results (Jensen, 2004). In accordance with findings by Sales (1996), ash content did not differ (p > 0.05) among muscles (Table 2), and were comparable to an overall mean value of 1.14 g/100 g edible meat presented by the former study.

### 3.3. Mineral composition

Although mean Ca values varied from 4.76 (M. iliopsoas externus) mg/100 g edible meat, no significant differences were detected among muscles (Table 3). The *M. flexor cruris lateralis* was the muscle with the highest (p < 0.05) mean contents of Mg (25.4 mg/100 g edible meat) and P (228 mg/100 g edible meat), whereas the lowest (p < 0.05) contents of Mg (23.3 mg/100 g edible meat) and K (234 mg/100 g edible meat), and highest (p < 0.05) content of Na (39.0 mg/100 g edible meat), were found in the M. ambiens.

Values for Ca, a mineral receiving a great deal of attention in nutrition, are somewhat lower than 7.29–9.00 mg/100 g edible meat reported for ostrich *M. gastrocnemius pars interna, M. iliofibularis* and *M. femorotibialis medius* by Sales and Hayes (1996), with no significant differences due to muscle found in the latter study. However, higher contents than in the present study for Na (40.6–46.6 mg/100 g edible meat) and K (266–272 mg/100 g edible meat), and contents of Mg as 20.6–22.7 mg/100 g edible meat, were presented by Sales and Hayes (1996). Calcium showed a mean overall value of 5.43 mg/100 g edible meat, comparable to 7 mg/100 g reported for lean beef (Holland et al., 1991), but considerably lower than a value of 12 mg/100 g for chicken without skin (USDA, 1979). With the adverse effects of excessive Na consumption, ostrich meat, with an overall mean Na content of 34.7 mg/100 g edible meat found in the present study, would be beneficial compared to values of 61 (Holland et al., 1991) and 77 (USDA, 1979) mg/100 g reported for lean beef and chicken without skin, respectively.

Iron content varied from a mean value of 2.32 in the *M. iliofibularis* to 4.02 mg/100 g edible meat in the *M. flexor cruris lateralis* (Table 3), with an overall mean value of 3.14 mg/100 g edible meat, substantially higher than 2.1 mg/100 g found in lean beef (Holland et al., 1991), and 0.9 mg/100 g (USDA, 1979) in chicken without skin. Values in the present study for Fe are higher than 1.97–2.51 mg/100 g edible meat reported (Sales & Hayes, 1996) for ostrich *M. gastrocnemius pars interna, M. iliofibularis* and *M. femorotibialis medius*, and 2.34–2.57 mg/100 g edible meat found in raw ostrich fillet, sirloin and leg (Lombardi-Bocca et al., 2005). Furthermore, contradictory to present results, the highest Fe content (2.51 mg/100 g edible meat) in the former study has been presented by the *M. iliofibularis*.

Contents of Cu, Se, Si and Zn were variable among muscles (Table 3), with overall mean values of 0.14, 0.03, 1.33 and 3.13 mg/100 g edible meat, respectively. These were comparable to 0.08–0.10 mg/100 g edible meat for Cu content, and in the upper limit of values (1.06–3.10 mg/100 g edible meat) for Zn content, reported in earlier studies (Lombardi-Bocca et al., 2005; Sales & Hayes, 1996) on the mineral composition of ostrich meat. Substantially higher values have been found for Se content (0.11 mg/100 g).
of raw emu (Dromaius novaehollandiae) meat (Pegg, Amarowicz, & Code, 2006), and in three muscles (M. obturatorius medialis, M. iliotibialis lateralis, M. iliofibularis) from rhea (Rhea americana) (0.07–0.09 mg/100 g edible meat; Ramos, Cabrera, del Puerto, & Saadoun, 2009). However, Se content of meat is highly correlated to the Se contents of soil, grass, and feed ingredients (Ramos et al., 2009). No differences (p > 0.05) were found in contents of Co, Ni and Ba among muscles, whereas differences (p < 0.05) in contents of Mn and Cr are small, probably without any practical significance (Table 3).

Results from the present study are presented in the way that the product would be traded and is applicable to nutritionists and dieticians, namely a fresh tissue basis (Lin et al., 1989). It the product would be traded and is applicable to nutritionists and Cr are small, probably without any practical significance (Table 3).

References


