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Nutritional quality assessment of different muscles derived from 15-year-old female emus (*Dromaius novaehollandiae*): Meat physicochemical traits and sensory scores

Mateusz Bucław[1], Danuta Majewska[1], Danuta Szczerbińska[1], Małgorzata Jakubowska[2]*

[1]Department of Poultry and Ornamental Birds Breeding, West Pomeranian University of Technology Szczecin, Szczecin, Poland

[2]Department of Immunology, Microbiology and Physiological Chemistry, Institute of Food Commodity Sciences, West Pomeranian University of Technology Szczecin, Szczecin, Poland

**Corresponding author: mateusz.buclaw@zut.edu.pl*

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Abstract: The emu (*Dromaius novaehollandiae*) is considered a versatile farm species whose main by-products are meat and oil. At present, there is lack of information on the value of the meat of laying females at the end of their reproductive cycle which hampers the development of a specific market. To fill this gap, the present research aimed at studying the mineral composition, fatty acid profile, cholesterol level, selected physicochemical parameters and sensory quality of the meat of laying females at the end of their reproductive life cycles was carried out. The study should extend the knowledge on the application of this type of meat in food products as well as the available nutritional information on the muscles of female emus slaughtered at the end of their reproductive lives. The research material consisted of eight females slaughtered at the age of 15 years, at the end of their reproductive period. Following exsanguination, plucking and evisceration, the carcasses were cooled at 4°C for 24 h. After this time, five muscles were separated from both halfs of the carcases. The results showed that meat from 15-year-old females is of satisfactory nutritional quality. The rich mineral composition, high protein content, and low intramuscular fat and cholesterol contents deserve special emphasis. For this reason, the meat can be recommended for formulating healthy diets for humans. Its trading development is therefore expectable.

Keywords: emu; meat; proximate composition; minerals; fatty acids

Emu (*Dromaius novaehollandiae*) originates from Australia, where its commercial breeding began in the 1970s. These birds have become popular due to the very good adaptation to different environmental conditions, and they are currently farmed in all continents. For example, there are more than one million emus farmed in the United States, while breeding of these birds in India has expanded to about 3000 farms in over 15 states, which account for about 2.5 million birds (Horbanczuk and Wierzbicka 2016). There are several emu farms in Poland managing

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ten to twenty birds. Local farmers sell eggs and fresh emu meat directly to individual customers (Szczerbinska et al. 2007).

The emu is considered to be an extensively exploitable bird, bred mainly for meat and oil. Emu meat is valuable and its consumption is recommended by the American Heart Association, as it is very low in saturated fat (Pegg et al. 2006). It is characterised by high protein content (20.2–22.9%) and low fat (0.84–1.40%) and cholesterol contents (58.0–82.5 mg/100 g meat). It also has a favourable profile of fatty acids and is rich in minerals (Ca, Fe, K, Mg, Na, P, Zn), vitamins (A, B2, B6, B12, E), and creatine (Pegg et al. 2006; Naveena et al. 2013).

Few reports on the meat of these birds exist in the literature and concern mainly young birds slaughtered at the age of 12–20 months. However, in poultry production, meat is obtained not only from young slaughter birds, but also from adults after their laying period. Emu reproductive stock are used for a dozen or so laying seasons. This is due to the long-lasting quality of the laying of these birds. There is lack of information on the meat of laying females at the end of their reproductive life, as there is no information on its nutritional value and, consequently, no market for it. This research aims to address this gap by determining the basic chemical and mineral composition, fatty acid profile, cholesterol content, selected physicochemical parameters and sensory quality of the meat of emu females slaughtered after the end of their reproductive cycle. The rusults are intended to broaden our knowledge concerning its application in food products, and supplement the available nutritional information on the meat of these production birds.

MATERIAL AND METHODS

Animals. For the research, a total of eight females were used: they were slaughtered at the age of 15 years, at the end of their reproductive cycle. The experiment was conducted on the experimental farm of the Department of Poultry and Ornamental Birds Breeding of West Pomeranian University of Technology in Szczecin, Poland.

Farming conditions. Until slaughter, the birds were kept in an open system, i.e. with the possibility of free use of the run overgrown with grass, regardless of weather conditions and season. The total area of the run was 715 m^2. Female emus were kept together with six males. They were fed with a standard complete mixture in the form of granules based on barley, maize, wheat and soybean meal, prepared according to the nutritional recommendations for this bird species (Jamroz 2005). The mixture contained 18% total protein, 6.7% crude ash, 5.2% crude fibre, 2.1% crude fat and 10.63 MJ net metabolic energy in 1 kg of feed. The birds were fed *ad libitum*. The mineral content and fatty acids (FA) profile of the feed are presented in Tables 1 and 2.

Slaughtering and muscle dissection. The emus were slaughtered in the experimental abattoir of the experimental farm: after 24 h of fasting, the birds were stunned by means of impact on the head with a wooden stick, tethered, suspended and bled by decapitation. The average final body weight of the emus was 41 kg. After exsanguination, defeathering and evisceration, the carcasses were cooled in a cold store at 4°C for 24 h. After this time, five muscles were separated from both halves of the carcases: *M. gastrocnemius pars externa* (495 g), *M. gastrocnemius pars interna* (543 g), *M. obturatorius medialis* (310 g), *M. flexor cruris lateralis* (504 g) and *M. iliotibialis lateralis* (849 g). Muscle identification was performed in accordance with the methodology provided by Lamas et al. (2014).

Table 1. Macro- and microelement contents in emu feed

Minerals	$\bar{x}$ ± SE (mg/kg)
P	11 573 ± 271
K	8 240 ± 54
Na	1 635 ± 30
Mg	2 472 ± 8
Ca	16 391 ± 145
Fe	419 ± 25
Zn	120 ± 7
Si	379 ± 15
Cu	12.6 ± 0.5
Mn	155 ± 8
Ba	7.30 ± 0.3
Cr	0.94 ± 0.04
Sr	30.0 ± 1.5
Pb	0.23 ± 0.01
Se	0.20 ± 0.0003
Cd	0.026 ± 0.001

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Table 2. Fatty acid (FA) profile of emu feed

Fatty acids	$\bar{x}$ ± SE (%)
C14:0	0.11 ± 0.001
C16:0	22.5 ± 0.08
C17:0	0.21 ± 0.001
C18:0	3.68 ± 0.004
C20:0	0.21 ± 0.001
C15:1	0.15 ± 0.003
C16:1	0.22 ± 0.003
C18:1n9t	2.49 ± 0.02
C18:1n9c	22.5 ± 0.12
C20:1	0.29 ± 0.001
C24:1	0.090 ± 0.001
C18:2n6c	40.7 ± 0.66
C18:3n3	2.83 ± 0.05
C20:3n3	0.11 ± 0.001
C20:3n6	0.12 ± 0.001
C20:4n6	0.25 ± 0.002
C20:5n3	0.15 ± 0.002
C22:6n3	0.28 ± 0.004
Other	4.03 ± 0.04

other FA: ∑(C8:0, C10:0, C11:0, C12:0, C13:0, C14:1, C15:0, C17:1, C18:3n6, C20:2, C21:0, C22:0, C22:1n9, C22:2, C23:0, C24:0)

After isolation the muscles were packed in a double foil and stored frozen for 2 months (–18°C). The thawing of samples was carried out at a temperature of 0–4°C for 24 h. Muscles from the left half-carcass were used for chemical, biochemical and physicochemical determinations, and the right half-carcass for sensory evaluation.

Physical analysis. In physicochemical analyses, on each type of muscle, three replicates were made from which the mean was calculated.

pH. The pH value was measured 24 h after slaughter (pH_u) and after the thawing of the samples (pH) using a glass complex electrode (type ESAgP-302W) and a CyberScan 10 pH meter (Eutech Cybernetics Pte Ltd, Singapore) in aqueous extract (distilled water) after 1 h of extraction in a 1 : 1 proportion of meat to water.

Water holding capacity (*WHC*). WHC was determined by the methods of Grau and Hamm (1953), modified by Pohja and Niinivaara (1957). A pair of parallel 300-mg samples was weighed to the nearest 0.001 g on an analytical scale on Whatman 1 blotting paper, and placed between glass plates, which were weighed down with 2 kg for 5 min. The boundaries of the pressed meat and the resulting drip stain were outlined on the blotting paper using an ink pencil. When dried, the areas of both stains were measured and the drip was calculated from plane area differences. Water content was calculated by dividing the drip stain area (in cm^2) by sample weight (g). Subsequently, the percentage of free water content in total water (determined by dry matter) was calculated. WHC was expressed as a percentage of bound water in total water content.

Colour. Colour measurement was carried out using the Mini Scan XE Plus 45/0 (Reston, USA) with a port diameter of 31.8 mm. Colour parameters for individual samples were determined using the CIE L*a*b* scale (Commission Internationale de l'Eclairage (CIE) 1976) and the illuminant/observer D65/10° system.

Drip, thawing and cooking loss. From each of the methodically selected muscles, 100 g of the sample with a thickness of approximately 20 mm was excised to calculate drip loss (24 h, 4°C), thawing loss (2 months, –18°C) and cooking loss (according to the method of Baryłko-Pikielna et al. 1964). Determination of mass loss, by weighing samples before and after storage in refrigerated conditions, freezing and cooking was performed on an electronic balance (Radwag, Poland) with an accuracy of 0.01 g.

Chemical analysis. The chemical composition (proximate composition) of the meat was assessed by determining the percentage of basic chemical components (dry matter, total water, total protein, fat and ash) using conventional methods (AOAC 2007). The muscle samples for the chemical analysis were collected from across the muscles and finely chopped with a knife.

Cholesterol level. The extracts obtained for determining the cholesterol content in the examined muscles are described in the section Fatty acids content and profile (see text below). As with fatty acids, cholesterol was determined by the gas chromatography-mass spectrometry (GC-MS) method. The next steps of sample preparation and appropriate chromatographic analyses were made in accordance with the procedure described by Cuhna et al. (2007).

GC parameters for cholesterol: Capillary column COL-ELITE-5MS 30 m × 0.25 mm × 0.25 µm; carrier gas helium (He) 6.0; gas flow rate 1 ml/min; injection volume 1 µl; split injection ratio (split)

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200 : 1; injector temperature 280°C; p column temperature programme 100°C for 5 min; temperature gradient 20°C/min to 280°C, 280°C for 25 min; transfer line temperature 280°C.

MS parameters for cholesterol: Selected Ion Recording (SIR) analysis: m/c = 329, ionisation energy 70 eV; ion source temperature 200°C.

Macro- and microelements content. The levels of macro- and microelements in muscles were determined by inductively coupled plasma optical emission spectrometry using the Optima 2000 DV ICP-AES (PerkinElmer Inc., Germany) following digestion in a microwave oven type Multiwave (Anton Paar GmbH, Austria) equipped with a system of continuous temperature and pressure control in each quartz vessel. The weighed amount of tissue homogenate (ca. 1 g) was transferred to a pressure quartz glass vessel, into which 5.0 ml of 65% HNO_3 and 0.5 ml of 30% H_2O_2 (both Suprapur, Merck) were successively added. Mineralisation was conducted according to the equipment application mode MEAT: 0–5 min – linear gradient of power 100–600 W; 6–10 min – 600 W (constant); 11–20 min – 1000 W or less after reaching 75 MPa or 300°C; 21–35 min – vessel cooling. The cooled and degassed mineralisate was filled up to 10 ml in volumetric flasks.

Microelements (Ba, Cd, Cr, Cu, Fe, Mn, Se, Si, Sr, Pb and Zn) were directly determined in the solutions prepared this way, whereas mineralisates were diluted 10- or 100-fold for the determination of macroelements (Ca, Mg, Na, K and P) in order to obtain the range of linear dependence of emission signal on the concentration of a given mineral component. Measurements of the intensity of emitted radiation for micro-elements were made selecting a longer, axial optical path (along plasma), whereas macroelements were analysed radially (across plasma). As standard, a certified multi-element solution for ICP (ICP Multielement Standard IV, Merck) was used. Standard solutions were supplemented with the addition of acid used in mineralisation, in the concentration which occurred in mineralised samples. In order to minimise potential interferences in sample introduction to plasma and other physical disturbances, analyses were made using the internal standard method by yttrium (Y) introduction into sample and standard solutions in a concentration of 0.5 mg Y/l.

Fatty acids content and profile. GC-MS was used to determine both the level of cholesterol and the profile of saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs).

Extraction: Before lipid extraction, all muscles of a single bird specimen were placed in a polypropylene container and then, for easy homogenisation, a small, specific volume of demineralised water was added. Homogenisation in a laboratory blender was performed until the obtained mass showed complete homogeneity thereby providing the averaged samples to be collected for analysis. Thereafter, 2 g of homogenate taken from a number of points were placed in amber glass screw-capped vials (7.5 ml) with Teflon seal. Into each vial, 4 ml of chloroform were added and nitrogen was introduced. Then they were closed under continuous stream of nitrogen and vigorously shaken for 2 h. In order to separate the chloroform phase from the non-lipid residue, the vials were centrifuged at 2000 rpm for 20 min. The extraction process was repeated three more times to elute all the lipids completely, and extracts were combined together and filled up with chloroform to 20 ml.

Hydrolysis: The chloroform phase was placed into amber glass vials (4 ml) in an amount corresponding to 5 mg of extracted lipids and chloroform was evaporated under a stream of nitrogen. The vials were then closed with a screw cap equipped with a vent allowing neutral gas and reagents to be introduced without air entering. The vials were immediately filled up with nitrogen, and 400 µl of 0.5M KOH in methanol solution were added and incubated in a heating block at 80°C for 20 min.

Esterification: After cooling, 500 µl of 14% boron trifluoride (BF_3) in methanol solution were introduced into each vial and incubated at 80°C for 35 min. In order to extract fatty acid methyl esters (FAME), 1 ml of saturated NaCl solution and 2 ml of isooctane were added to each cooled vial as an extractant, vigorously shaken for 1 h, and left for 0.5 h until the phases separated. The upper isooctane layer was collected to separate vials containing about 0.6 g of anhydrous sodium sulphate (Na_2SO_4). The vials were then filled with nitrogen and left for 2 h. The dried FAME extracts were placed in vials into an automatic sample changer (autosampler) of the gas chromatograph.

GC-MS: The determination of fatty acid methyl esters in liver lipids was made by the GC-MS method on a PerkinElmer CLARUS® 600 GC/MS with a capillary column COL-ELITE-5MS

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60 m × 0.25 mm × 0.25 µm. A Supelco 37 component mixture (F.A.M.E. Mix C4–C24) was the fatty acid standard.

GC parameters: Carrier gas helium (He) 6.0; gas flow rate 1 ml/min; injection volume 1 µl; split injection ratio 50 : 1; injector temperature 200°C; column temperature programme 110°C for 5 min; temperature gradient 5°C/min to 180°C, 180°C for 15 min; temperature gradient 5°C/min to 290°C, 290°C for 5 min; transfer line temperature 290°C.

MS parameters: SIR analysis according to selected mass/charge (m/c) abundances; ionisation energy 70 eV; ion source temperature 200°C.

Atherogenic index (AI) and thrombogenic index (TI) were calculated on the basis of the formulas given by Ulbricht and Southgate (1991).

Sensory analysis. After 24 h of thawing at 4°C, a 300-g sample was weighed without internal fat, formatted and unified (tendons, membranes and excess meat removed) out of each of the separated muscles for sensory evaluation. The samples were placed in glass jars with a capacity of 1 l and filled with 600 ml of water. The jars were closed and placed in a water bath at 85°C until bath water temperature reached the geometric centre of the product, according to the method described by Baryłko-Pikielna et al. (1964). After the heat treatment, the meat samples were removed from the jars. The heat-treated muscles were cut transversely to representative samples weighing 20 ± 5 g. The samples of cooked meat were evaluated immediately after cutting. The samples of the meat broth were heated again after the break to reach a temperature of 75°C.

The study participants consisted of six individuals: three males and three females aged from 30 to 45 years. The panelists were trained according to Polish guidelines (ISO 8586-1:1999 and ISO 8586-2:1999). They were informed that the object of the study was emu meat, but they did not know the muscle being evaluated.

The testing was conducted at the laboratory of the Institute of Food Commodity Sciences of West Pomeranian University of Technology Szczecin, equipped with individual stations. Throughout the tests, a temperature of 22°C (± 0.5°C) was maintained in the laboratory by a controlled air-conditioning system. Incandescent lighting reached ca. 500 lx (ISO 8589:1988). Six individuals simultaneously conducted the testing.

Directly before the testing, each station was equipped with a white plastic tray onto which five white carton trays and white plastic forks were placed for the first session and five transparent glasses (60 ml) and white plastic spoons for the second session.

The trays and vessels were marked with a three-digit code, with the last digit indicating a specific sample: 1 – *M. gastrocnemius pars externa*, 2 – *M. gastrocnemius pars interna*, 3 – *M. obturatorius medialis*, 4 – *M. flexor cruris lateralis*, and 5 – *M. iliotibialis lateralis*. In the assessment, the samples were always served in the same order. Upon assessing each sample, the panellists neutralised their taste with a sip of bitter, slightly cooled tea. The participants were given pens and evaluation sheets to use during testing. A 5-point scale was used when assessing the sensory characteristics of cooked meat and broth, where 1 point was the worst score and 5 the best (PN-ISO 4121:1998).

Statistical analysis. The results were statistically analysed using the Statistica 13.1 PL software package (IBM Corp.; SPSS Statistics for Windows, Version 23.0, 2016). One-way ANOVA was used with muscle as a fixed effect. Least Squares Means were obtained using the Tukey test and the significance was calculated at a 5% confidence level.

RESULTS AND DISCUSSION

The muscle pH_u after slaughter ranged from 5.69 in *M. obturatorius medialis* to 5.87 in *M. flexor cruris lateralis* (Table 3). A slightly lower pH was obtained by Berge et al. (1997), who found that the average pH value was 5.52–5.66 for emu meat slaughtered at different ages (from 6 to 20 months). Pegg et al. (2006) recorded an even lower pH for emu meat (pH 5.43). The type of muscle significantly affected the pH. Considerably higher pH was recorded in *M. flexor cruris lateralis* (5.85) compared to other muscles, where the pH value ranged from 5.60 to 5.69. A similar pH value was obtained by Naveena et al. (2013). Studies on muscle pH indicated a greater similarity to sheep and red goat meat (5.6–5.8) (Naveena et al. 2013) or beef (pH 5.8) than poultry meat (pH 6.3) (Horbanczuk and Wierzbicka 2016).

Emu meat is rich in myoglobin (8.87 mg/g) and thus naturally dark-coloured (red-cherry) (Naveena et al. 2013). The intense red colour of the meat

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Table 3. Physical traits of different emu muscles ($\bar{x}$ ± SE)

Item	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*	Average value
pH_u	5.76 ± 0.07	5.73 ± 0.07	5.69 ± 0.07	5.87 ± 0.07	5.74 ± 0.07	5.76 ± 0.03
pH	5.69^{b} ± 0.02	5.68^{b} ± 0.02	5.60^{c} ± 0.01	5.85^{a} ± 0.02	5.66^{bc} ± 0.01	5.70 ± 0.01
WHC (%)	72.1^{cd} ± 0.6	76.5^{ab} ± 0.6	77.8^{a} ± 0.7	71.8^{d} ± 0.7	74.7^{cb} ± 0.6	74.6 ± 0.5
L*	27.0^{cb} ± 0.4	26.1^{c} ± 0.3	27.5^{b} ± 0.3	35.1^{a} ± 0.4	26.4^{bc} ± 0.3	28.4 ± 0.6
a*	11.4^{b} ± 0.3	11.3^{b} ± 0.3	11.1^{b} ± 0.3	14.4^{a} ± 0.3	11.3^{b} ± 0.2	11.9 ± 0.2
b*	8.17^{bc} ± 0.12	6.76^{d} ± 0.12	8.55^{b} ± 0.24	12.8^{a} ± 0.3	7.68^{c} ± 0.16	8.78 ± 0.34
Drip loss (%)	0.79^{b} ± 0.03	0.82^{b} ± 0.03	1.90^{a} ± 0.03	1.99^{a} ± 0.04	1.96^{a} ± 0.04	1.49 ± 0.09
Thawing loss (%)	7.85^{c} ± 0.17	9.14^{b} ± 0.26	9.83^{b} ± 0.20	9.25^{b} ± 0.23	11.5^{a} ± 0.3	9.52 ± 0.21
Cooking loss (%)	42.0^{a} ± 0.6	41.2^{ab} ± 0.6	41.3^{ab} ± 0.5	38.7^{c} ± 0.3	39.9^{bc} ± 0.4	40.6 ± 0.3

pH_u = pH value measured 24 h after slaughter, WHC = water holding capacity, L* = lightness, a* = redness, b* = yellowness
$^{a–d}$means in the same row with different superscripts statistically differ ($P \leq 0.05$)

of these birds is also associated with high pigment content – approximately 26 pg Fe/g (Berge et al. 1997). Of the five examined muscles (Table 3), *M. flexor cruris lateralis* was characterised by the brightest colour (L*) (35.1), the highest intensity of red (a*) (14.4), and a high yellow colour proportion (b*) (12.8). Studies by Berge et al. (1997) and Menon et al. (2014) recorded L* values of emu leg muscles similar to those in *M. flexor cruris lateralis*. L* results of the remaining muscles (26.1–27.5), however, were similar to those recorded in *M. iliofibularis* of eight-year-old ostriches, where the L* value decreased with the age of the animals (Hoffman and Fisher 2001). The obtained a* values were similar to those found in emu muscles by Menon et al. (2014), and smaller than those obtained by Berge et al. (1997). The proportion of yellow (b*) in the remaining muscles was lower (6.76–8.55). Lower values of this parameter were found in muscles of 4- to 6-year-old emus, which had been transported for six hours before slaughter (Menon et al. 2014), and where age could be the main influence behind the results. A lower proportion of yellow was also found in the muscles of 14-month-old and 8-year-old ostriches (Hoffman and Fisher 2001; Hoffman et al. 2005). It should be assumed that such a large proportion of the yellow colour in the examined muscles was influenced by age. Emu meat, just like beef, pork, ostrich and chicken, becomes markedly darker and redder as age increases, which is mainly due to a concentration of myoglobin pigment (Hoffman and Fisher 2001).

During cold storage, significantly lower weight losses were found in the lower leg muscles: *M. gastrocnemius pars externa* (0.79%) and *M. gastrocnemius pars interna* (0.82%) compared to thigh muscles, where these values ranged from 1.90 to 1.99% (Table 3). The mean thawing loss for the examined leg muscles was 9.52% after two months of storage at –18°C. The highest losses were found in *M. iliotibialis lateralis* (11.52%), and the lowest in *M. gastrocnemius pars externa* (7.85%). These results are similar to those obtained by Filgueras et al. (2011) from the muscles of nandu. In the case of cooking loss, these values ranged from 38.7% in *M. flexor cruris lateralis* to 42.0% in *M. gastrocnemius pars externa*. It can be assumed that the differences in thawing loss and cooking loss could mainly result from the structure of the muscles and their function during the life of the bird (Lamas et al. 2014). Similar cooking loss at different parameters of thermal processing (temperature 100°C, time 30 min) were demonstrated by Filgueras et al. (2011) in *M. gastrocnemius pars interna* in nandu (41.9%). Botha et al. (2007) obtained lower cooking loss in *M. gastrocnemius pars externa* (36%) in ostrich, using a temperature of 80°C for one hour.

Analysing the proximate composition of different emu muscles (Table 4), higher water content was found, especially in *M. flexor cruris lateralis* (76.5%) and *M. iliotibialis lateralis* (76.2%), which differed significantly from the muscle with the lowest water content – *M. obturatorius medialis* (74.2%); this is, however, within the typical water content range of fresh meat for any animal species. Similar results of water content in emu meat were obtained by Berge et al. (1997), Pegg et al. (2006), Naveena et

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Table 4. Proximate composition of different emu muscles ($\bar{x}$ ± SE)

Item	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*	Average value
Water (%)	75.7^{ab} ± 0.3	75.6^{ab} ± 0.2	74.2^{b} ± 0.3	76.5^{a} ± 0.3	76.2^{a} ± 0.2	75.6 ±0.2
Protein (%)]	23.5^{a} ± 0.3	23.5^{a} ± 0.2	23.9^{a} ± 0.3	22.2^{b} ± 0.3	22.8^{ab} ± 0.2	23.2 ± 0.1
Lipids (%)	0.84^{b} ± 0.07	1.13^{b} ± 0.09	1.83^{a} ± 0.09	2.01^{a} ± 0.08	0.91^{b} ± 0.07	1.34 ± 0.08
Ash (%)	1.19^{b} ± 0.03	1.25^{bc} ± 0.03	1.44^{a} ± 0.04	1.36^{ac} ± 0.02	1.27^{bc} ± 0.03	1.30 ± 0.02
Cholesterol (mg/100 g)	67.6 ± 0.7	67.8 ± 0.9	65.5 ± 1.0	67.2 ± 0.7	66.9 ± 0.8	67.0 ± 0.4

$^{a–c}$means in the same row with different superscripts statistically differ ($P \leq 0.05$)

al. (2013) and Nithyalakshmi and Preetha (2015). *M. obturatorius medialis*, *M. gastrocnemius pars externa* and *M. gastrocnemius pars interna* were characterized by a significantly higher protein content (23.8, 23.5 and 23.5%, respectively) compared to *M. flexor cruris lateralis* (22.2%), with *M. iliotibialis lateralis* (22.8%) showing intermediate results. These fell within the range of 20.2–24.4%, also obtained by other authors (Berge et al. 1997; Pegg et al. 2006; Naveena et al. 2013; Nithyalakshmi and Preetha 2015). *M. obturatorius medialis* (1.83%) and *M. flexor cruris lateralis* (2.01%) were characterised by the highest fat content. Pegg et al. (2006) and Naveena et al. (2013) found 1.40% and 0.84% fat contents, respectively, in differents types of muscles in young emu. Other farm ratites, nandu (Pereira et al. 2006; Romanelli et al. 2008) and ostrich (Hoffman et al. 2005; Kuzelov et al. 2012), have similar contents of both fat and protein in their meat. It can therefore be concluded that ratites in general, the emu included, have meat rich in protein and poor in fat, both of which are features appreciated by modern consumers. The highest ash content was found in *M. obturatorius medialis* (1.44%); the ash content in other muscles ranged from 1.19 to 1.36%, which corresponded to the results obtained by Pegg et al. (2006). According to Naveena et al. (2013), the meat of this species is characterised by a higher mineral content (1.81%).

Cholesterol content (Table 4) was similar in all muscles and ranged from 65.5 to 67.8 mg/100 g. The average cholesterol content in other studies conducted in males at 57 weeks of age was lower by more than half – 32.3 mg/100 g (Beckerbauer et al. 2001), which might be associated with different feeding patterns or the age of the studied birds. Similar results to our research were obtained by Horbanczuk et al. (1998), who analysed the muscles of 12-month-old ostriches. Filgueras et al. (2010) found a large variation in cholesterol content (56.0–81.5 mg/100 g) in the meat of 1-year-old nandu, which depended on the type of muscle examined.

Among the analysed mineral components, a high amount of potassium was found in all muscles tested – on average 3600 mg/kg fresh weight (Table 5). The content of this element was similar in all analysed muscles except for *M. flexor cruris lateralis* (3371 mg/kg), which showed the highest value. The literature review demonstrated that emu muscles are characterised by a higher potassium content compared to younger ostriches (Majewska et al. 2009) and nandu (Ramos et al. 2009). The remaining elements can be arranged in the following order: P > Na > Mg > Ca > Fe > Si > Zn > Cu, followed by elements present in a quantity below 1 mg/kg (Pb, Cr, Sr, Se, Ba, Mn, Cd). A similar sequence was reported by Majewska et al. (2009) in ostrich muscles. Ramos et al. (2009) found a higher content of phosphorus (3840 mg/kg) than potassium (2570 mg/kg) in the muscles of nandu. In the current study, the highest phosphorus content was recorded in *M. iliotibialis lateralis* (2263 mg/kg) and *M. obturatorius medialis* (2238 mg/kg), sodium in *M. flexor cruris lateralis* (517 mg/kg), magnesium and copper in *M. obturatorius medialis* (283 and 2.52 mg/kg), and calcium and iron in *M. gastrocnemius pars interna* (54.2 and 46.8 mg/kg). In turn, *M. iliotibialis lateralis* was characterised by the highest content of zinc and silicon (34.4 and 36.6 mg/kg). Similar values in emu meat were obtained by Pegg et al. (2006). Comparing the average mineral content in different ostrich muscles, Majewska et al. (2009) found a lower content of sodium, iron and silicon, a higher content of zinc, and a similar content of other ele-

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Table 5. Macro- and micromineral contents (mg/kg meat) of different emu muscles ($\bar{x}$ ± SE)

Minerals	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*	Average value
K	3679^{a} ± 27	3646^{a} ± 28	3631^{a} ± 18	3371^{b} ± 31	3673^{a} ± 29	3600 ± 22
P	2096^{b} ± 18	2084^{b} ± 19	2238^{a} ± 21	2079^{b} ± 18	2263^{a} ± 14	2152 ± 15
Na	477^{b} ± 9	489^{ab} ± 9	441^{c} ± 7	517^{a} ± 8	431^{c} ± 7	471 ± 6
Mg	269^{b} ± 4	266^{cb} ± 3	283^{a} ± 3	255^{c} ± 3	277^{ba} ± 2	270 ± 2
Ca	48.4^{cb} ± 1,0	54.2^{a} ± 0.8	46.1^{c} ± 0.6	50.1^{b} ± 0.8	49.8^{b} ± 0.5	49.7 ± 0.5
Fe	40.1^{c} ± 0.9	46.8^{a} ± 0.6	43.9^{ab} ± 0.09	38.8^{c} ± 0.7	42.1^{bc} ± 0.9	42.3 ± 0.6
Zn	29.4^{b} ± 1.2	30.6^{ab} ± 0.9	12.2^{c} ± 0.7	26.8^{a} ± 1.2	34.4^{a} ± 1.1	26.7 ± 1.3
Si	33.5^{ab} ± 1.2	34.6^{ab} ± 1.2	35.0^{ab} ± 0.8	32.6^{b} ± 0.7	36.6^{a} ± 0.9	34.5 ± 0.5
Cu	1.47^{c} ± 0.03	2.08^{b} ± 0.05	2.52^{a} ± 0.04	1.84^{d} ± 0.03	1.69^{d} ± 0.04	1.92 ± 0.06
Pb	0.034^{b} ± 0.001	0.029^{b} ± 0.001	0.032^{b} ± 0.003	0.061^{a} ± 0.009	0.036^{b} ± 0.001	0.038 ± 0.003
Cr	0.0201 ± 0.0007	0.0221 ± 0.0020	0.0233 ± 0.0020	0.0239 ± 0.0026	0.0205 ± 0.0005	0.0220 ± 0.0008
Sr	0.018 ± 0.002	0.027 ± 0.004	0.022 ± 0.003	0.023 ± 0.002	0.017 ± 0.001	0.021 ± 0.001
Mn	0.0095^{b} ± 0.0004	0.0130^{ab} ± 0.0008	0.0161^{a} ± 0.0009	0.0125^{ab} ± 0.0011	0.0122^{b} ± 0.0011	0.0127 ± 0.0005
Cd	0.0089^{b} ± 0.0004	0.0099^{ab} ± 0.0003	0.0103^{ab} ± 0.0007	0.0121^{a} ± 0.0011	0.0099^{ab} ± 0.0004	0.0102 ± 0.0003
Se	0.010 ± 0.001	0.011 ± 0.002	0.010 ± 0.002	0.010 ± 0.002	0.010 ± 0.001	0.010 ± 0.001
Ba	0.007^{b} ± 0.002	0.011^{ab} ± 0.002	0.010^{ab} ± 0.002	0.016^{a} ± 0.003	0.008^{ab} ± 0.002	0.010 ± 0.001

$^{a–d}$means in the same row with different superscripts statistically differ ($P \leq 0.05$)

ments. Ramos et al. (2009) reported significantly lower content of magnesium, calcium, iron and zinc, higher sodium, and similar copper content in nandu meat. It can be stated that, comparing the results of the present research to the mineral composition of broiler chicken and beef meat, emu meat is characterised by a higher content of potassium, phosphorus, iron and copper (Ramos et al. 2009).

Emu muscles contained an average of 35.3% saturated (SFA), 29.3% monounsaturated (MUFA) and 34.8% polyunsaturated fatty acids (PUFA) (Table 6). Wang et al. (2000) reported 33.3% SFA, 42.0% MUFA and 24.1% PUFA in emu drumstick. In turn, Beckerbauer et al. (2001) determined the fatty acid profile in fan fillet and found that it contained 30% SFA, 44.8% MUFA and 25.2% PUFA. Horbanczuk et al. (1998, 2015) found a higher proportion of MUFA (33.5–39.1%) and lower proportion of PUFA (23.7–28.8%) in the total fatty acids of ostrich meat. Similar results were obtained by Romanelli et al. (2008) in nandu meat and Wang et al. (2000) in chicken drumsticks and beef steaks.

The mean proportions of MUFA/SFA (0.85), PUFA/SFA (1.01) and UFA/SFA (1.86) in our studies were similar to those reported by other authors for emu muscles (Wang et al. 2000), ostrich (Horbanczuk et al. 1998, 2015) and nandu (Romanelli et al. 2008; Filgueras et al. 2010).

Palmitic acids (C16:0) and stearic acids (C18:0) were the main SFAs. The study of Wang et al. (2000) and Beckerbauer et al. (2001) showed that these acids had the highest percentage of all SFAs. Similar results were reported in ostrich (Horbanczuk et al. 1998, 2015) and nandu meat (Romanelli et al. 2008; Filgueras et al. 2010).

Palmitoleic acid (C16:1), elaidic acid (C18:1n9t) and oleic acid (C18:1n9c) were important MUFA acids in emu muscles, and their average content in total fatty acids was 2.24, 2.97 and 23.9%, respectively (Tables 6). Wang et al. (2000) and Beckerbauer et al. (2001) found a slightly higher proportion of C16:1 (3.49 and 3.8%) and an almost twice as high proportion of C18:1n9c (35.0 and 41.1%, respectively).

Linoleic (C18:2n6c) and arachidonic acids (C20:4n6) had the largest proportion in PUFA, and their average amount in the muscles was 16.89 and 16.15% of all fatty acids, respectively. Catabolic transformations of lipids show that the more carbons (C) a fatty acid has, the greater the energy effect from its complete combustion (Zalucki 2015). Thigh muscles, *M. obturatorius medialis* and *M. flexor cruris lateralis*, contained significantly more long-chain fatty acids compared to the other muscles of

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Table 6. Fatty acid (FA) profile (% of total FA) of different emu muscles ($\bar{x}$ ± SE)

Item	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*	Average value
C14:0	0.16^{ab} ± 0.03	0.16^{ab} ± 0.03	0.23^{a} ± 0.03	0.07^{b} ± 0.01	0.08^{b} ± 0.02	0.14 ± 0.02
C16:0	18.6^{ab} ± 0.8	18.0^{b} ± 1.0	22.8^{a} ± 1.0	20.3^{ab} ± 1.3	18.1^{b} ± 1.5	19.6 ± 0.6
C17:0	0.10^{ab} ± 0.01	0.15^{a} ± 0.04	0.11^{ab} ± 0.02	0.06^{b} ± 0.01	0.13^{ab} ± 0.02	0.11 ± 0.01
C18:0	14.6^{b} ± 0.3	16.7^{a} ± 0.2	15.5^{ab} ± 0.2	14.8^{b} ± 0.4	14.9^{b} ± 0.5	15.3 ± 0.2
Other SFA	0.22 ± 0.03	0.18 ± 0.03	0.14 ± 0.01	0.12 ± 0.02	0.23 ± 0.10	0.18 ± 0.02
Total SFA	33.7^{b} ± 0.6	35.1^{ab} ± 1.0	38.8^{a} ± 0.9	35.3^{ab} ± 1.2	33.4^{b} ± 1.1	35.3 ± 0.5
C15:1	0.89^{ab} ± 0.17	0.79^{ab} ± 0.19	0.50^{ab} ± 0.10	0.39^{b} ± 0.05	1.00^{a} ± 0.10	0.71 ± 0.07
C16:1	2.24 ± 0.33	1.97 ± 0.42	3.18 ± 0.58	2.36 ± 0.41	1.45 ± 0.37	2.24 ± 0.20
C18:1n9c	21.5^{b} ± 0.9	22.1^{b} ± 0.6	24.3^{ab} ± 0.7	27.3^{a} ± 0.8	24.4^{ab} ± 1.1	23.9 ± 0.5
C18:1n9t	2.51^{b} ± 0.26	2.76^{ab} ± 0.24	3.76^{a} ± 0.40	3.04^{ab} ± 0.25	2.79^{ab} ± 0.17	2.97 ± 0.14
Other MUFA	0.09^{b} ± 0.01	0.15^{ab} ± 0.02	0.21^{a} ± 0.04	0.10^{b} ± 0.01	0.10^{b} ± 0.01	0.13 ± 0.01
Total MUFA	27.2^{c} ± 1.2	27.8^{bc} ± 0.7	32.0^{ab} ± 0.9	33.1^{a} ± 1.2	29.7^{abc} ± 1.2	29.3± 0.6
C18:2n6c	16.9 ± 0.3	16.9 ± 0.8	15.5 ± 0.6	16.9 ± 1.0	18.3 ± 0.9	16.9 ± 0.4
C18:3n3	0.50 ± 0.07	0.71 ± 0.08	0.74 ± 0.06	0.55 ± 0.11	0.50 ± 0.09	0.60 ± 0.04
C20:3n3	0.10^{bc} ± 0.01	0.13^{ab} ± 0.01	0.16^{a} ± 0.01	0.07^{c} ± 0.01	0.06^{c} ± 0.01	0.10 ± 0.01
C20:4n6	20.4^{a} ± 1.1	17.7^{ab} ± 0.8	11.7^{c} ± 0.8	13.5^{bc} ± 1.4	17.5^{ab} ± 1.6	16.2 ± 0.7
C20:5n3	0.21^{b} ± 0.04	0.26^{ab} ± 0.05	0.39^{a} ± 0.04	0.17^{b} ± 0.03	0.11^{b} ± 0.02	0.23 ± 0.02
C22:6n3	0.88^{ab} ± 0.18	1.35^{a} ± 0.25	0.68^{b} ± 0.12	0.40^{b} ± 0.10	0.40^{b} ± 0.10	0.74 ± 0.09
Other PUFA	0.03^{b} ± 0.004	0.06^{a} ± 0.008	0.07^{a} ± 0.010	0.03^{b} ± 0.003	0.03^{b} ± 0.003	0.04 ± 0.004
Total PUFA	39.1^{a} ± 1.4	37.1^{ab} ± 1.3	29.3^{c} ± 1.4	31.6^{bc} ± 2.1	36.9^{ab} ± 2.1	34.8 ± 0.9
UFA/SFA	1.98^{a} ± 0.06	1.86^{ab} ± 0.08	1.59^{b} ± 0.06	1.86^{ab} ± 0.10	2.01^{a} ± 0.10	1.86 ± 0.04
MUFA/SFA	0.81^{b} ± 0.04	0.79^{b} ± 0.02	0.83^{ab} ± 0.03	0.94^{a} ± 0.03	0.89^{ab} ± 0.02	0.85 ± 0.02
PUFA/SFA	1.17^{a} ± 0.06	1.07^{ab} ± 0.07	0.76^{b} ± 0.05	0.92^{ab} ± 0.09	1.13^{a} ± 0.10	1.01 ± 0.04
n3	1.68^{ab} ± 0.27	2.45^{a} ± 0.30	1.97^{ab} ± 0.20	1.19^{b} ± 0.21	1.08^{b} ± 0.18	1.67 ± 0.13
n6	37.4^{a} ± 1.3	34.7^{a} ± 1.4	27.3^{b} ± 1.3	30.4^{ab} ± 2.1	35.8^{a} ± 2.2	33.1 ± 0.9
n6/n3	32.2 ± 10.7	17.1 ± 4.2	14.9 ± 1.7	31.5 ± 5.8	45.1 ± 11.1	28.2 ± 3.7
IA	0.50^{b} ± 0.04	0.51^{b} ± 0.04	0.84^{a} ± 0.07	0.69^{ab} ± 0.08	0.53^{b} ± 0.07	0.61 ± 0.03
IT	0.89^{b} ± 0.02	0.90^{b} ± 0.03	1.08^{a} ± 0.04	0.99^{ab} ± 0.05	0.92^{b} ± 0.04	0.95 ± 0.02

SFA = saturated FA, MUFA = monounsaturated FA, UFA = unsaturated FA, PUFA = polyunsaturated FA
other SFA: ∑(C8:0, C10:0, C11:0, C12:0, C13:0, C15:0, C20:0, C21:0, C22:0, C23:0, C24:0); other MUFA: ∑(C14:1, C17:1, C20:1, C22:1n9, C24:1); other PUFA: ∑(C22:2, C20:3n6); UFA: ∑(MUFA, PUFA); n3: ∑(C18:3n3, C20:3n3, C20:5n3, C22:6n3); n6: ∑(C18:2, C20:3n6, C22:2); AI = atherogenicity index = (C12:0 + 4 * C14:0 + C16:0)/(n3 + n6 + C23:0); IT = thrombogenicity index = (C14:0 + C16:0 + C18:0)/((0.5 * MUFA) + (0.5 * n6) + (3 * n3) + (n3/6))

the thigh and lower leg (Table 6). It can therefore be assumed that the extensive deposition of long-chain fatty acids in the *M. obturatorius medialis* and *M. flexor cruris lateralis* is associated with the physiological function of these muscles at increased physical effort. C18:2n6c content in the study of Wang et al. (2000) was similar (15.19%), and that of C20:4n6 was lower by about 10-fold, while a higher proportion of C18:2n6c, by almost seven folds (23.5%), was found in another study by Beckerbauer et al. (2001). Such large differences could probably be associated with different diets of the birds.

The proportion of n6/n3 acids, important in the human diet, varied significantly between 15/1 and 45/1, depending on the type of muscle examined. A more favourable ratio of n6/n3 (7/1) in much younger emus was noted by Wang et al. (2000). More favourable proportions of n6/n3 were recorded also in ostrich (3/1–11/1) (Horbanczuk

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et al. 1998, 2015) and nandu muscles (7/1–8/1) (Filgueras et al. 2010). Romanelli et al. (2008) obtained similar results to our research for the muscle tissue of nandu – 31/1. As is commonly known, the n6/n3 ratio is variable and depends mainly on diet, not on genetic factors. Therefore, the emu feeding strategy should be directed at increasing the intramuscular PUFA fatty acids in fat, especially those from the n3 group.

The atherogenicity (IA) and thrombogenicity (IT) index is important in assessing the quality and nutritional value of food products. Ulbricht and Southgate (1991) consider the IA and IT indexes to be better aterogenicity and thrombogenicity ratios than the PUFA/SFAs ratio and, in general, the lower the value of each of these indicators, the more preferable it is from a health point of view. The highest IA and IT values were found in *M. obturatorius medialis* (0.84 and 1.08, respectively), which was significantly different from other muscles. In studies conducted on 15-year-old male emus, an average IA index (0.29) and identical IT (0.95) were obtained from the same muscles (Buclaw et al. 2018). In our own research, the average IA and IT were successively 0.61 and 0.95, similar to beef meat (Knight et al. 2003). In tests carried out on broiler chickens by Zdanowska-Sasiadek et al. (2016) more favourable values of IA (0.32) and IT (0.62) were obtained from leg muscles.

Table 7 presents the fatty acid content per 100 g of meat. The data represent supplementary information on emu meat, which can be used by dieticians, food producers required to provide information on the nutritional value of the product, or consumers. The most atherogenic SFAs are C14:0, C16:0 and C18:0. The average contents of these acids measured in our study were 1.81, 256 and 195 mg/100 g, respectively. The data included in the Food Composition Tables (Kunachowicz et al. 2017) show that beef (fillet) contains a significantly higher level of these acids: 110 mg/100 g (C14:0), 880 mg/100 g (C16:0), and 610 mg/100 g (C18:0). In poultry meat, the content of the hypercholesterolemic C16:0 acid may vary from 640 mg/100 g (turkey thigh) to 1112 mg/100 g (chicken thigh). It is commonly known that *cis*-MUFAs, which are synthesized in the human body, positively affect the plasma lipid profile by decreasing its LDL-cholesterol level. The prominent representative of these MUFAs is C18:1n9c, which in the emu meat is the most abundant one of all the analysed fatty acids. Its content ranged from 171 mg/100 g meat in *M. gastrocnemius pars externa*, to 517 mg/100 g meat in *M. flexor cruris lateralis*. The content of C18:1 in the thighs of turkeys and broiler chickens is, respectively, 1120 and 1480 mg/100 g, like in beef sirloin (1260 mg/100 g) (Kunachowicz et al. 2017). The highest levels of PUFAs in the examined muscles were found for C18:2n6c and C20:4n6, 212 mg/100 g and

Table 7. Fatty acid (FA) content (mg/100 g meat) of different emu muscles ($\bar{x}$ ± SE)

Item	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*	Average value
C14:0	1.19^{b} ± 0.24	1.73^{ab} ± 0.41	4.10^{a} ± 0.60	1.29^{b} ± 0.28	0.75^{b} ± 0.21	1.81 ± 0.25
C16:0	146^{b} ± 9	195^{b} ± 21	395^{a} ± 24	387^{a} ± 29	160^{b} ± 21	256 ± 20
C17:0	0.74^{b} ± 0.04	1.51^{ab} ± 0.31	1.93^{a} ± 0.31	1.07^{b} ± 0.11	1.11^{ab} ± 0.15	1.27 ± 0.11
C18:0	117^{b} ± 11	178^{b} ± 14	269^{a} ± 13	282^{a} ± 13	128^{b} ± 9	195 ± 12
C15:1	7.24 ± 1.59	8.42 ± 1.91	8.85 ± 2.12	7.46 ± 1.20	8.82 ± 1.40	8.18 ± 0.72
C16:1	16.9^{c} ± 2.1	22.8^{bc} ± 5.7	53.6^{a} ± 10.0	45.5^{ab} ± 8.2	12.5^{c} ± 3.3	30.4 ± 3.8
C18:1n9c	171^{b} ± 15	237^{b} ± 20	424^{a} ± 28	517^{a} ± 19	210^{b} ± 18	312 ± 23
C18:1n9t	20^{b} ± 3	30^{b} ± 4	65.5^{a} ± 8.2	57.1^{a} ± 4.1	24.7^{b} ± 3.2	39.5 ± 3.6
C18:2n6c	135^{b} ± 12	179^{b} ± 12	270^{a} ± 19	320^{a} ± 21	156^{b} ± 12	212 ± 13
C18:3n3	3.92^{b} ± 0.62	7.75^{ab} ± 1.08	13.0^{a} ± 1.5	10.8^{a} ± 2.4	4.32^{b} ± 0.82	7.96 ± 0.83
C20:3n3	0.76^{bc} ± 0.14	1.38^{b} ± 0.20	2.79^{a} ± 0.27	1.39^{b} ± 0.17	0.57^{c} ± 0.10	1.38 ± 0.15
C20:4n6	166^{b} ± 20	186^{ab} ± 12	204^{ab} ± 18	260^{a} ± 33	151^{b} ± 18	193 ± 11
C20:5n3	1.60^{b} ± 0.25	2.90^{b} ± 0.65	6.76^{a} ± 0.86	3.27^{b} ± 0.62	0.98^{b} ± 0.26	3.10 ± 0.40
C22:6n3	6.95^{ab} ± 1.68	14.7^{a} ± 3.1	11.9^{ab} ± 2.3	8.20^{ab} ± 2.31	3.55^{b} ± 0.97	9.05 ± 1.11

$^{a–c}$means in the same row with different superscripts statistically differ ($P \leq 0.05$)

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Table 8. Sensory profile scores of different cooked emu muscles (in ponts) ($\bar{x}$ ± SE)

Item	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*	Average value
Colour	4.14^{b} ± 0.12	4.08^{b} ± 0.08	4.33^{ab} ± 0.11	4.61^{a} ± 0.08	4.38^{ab} ± 0.09	4.31 ± 0.05
Smell	3.84^{b} ± 0.03	3.87^{ab} ± 0.05	3.91^{ab} ± 0.02	4.03^{a} ± 0.04	3.93^{ab} ± 0.06	3.92 ± 0.02
Tenderness	2.08^{b} ± 0.12	2.24^{b} ± 0.03	3.24^{a} ± 0.07	4.00^{a} ± 0.07	2.83^{a} ± 0.14	2.88 ± 0.12
Juiciness	2.25^{c} ± 0.07	2.60^{c} ± 0.07	3.19^{b} ± 0.12	3.75^{a} ± 0.12	3.01^{b} ± 0.10	2.96 ± 0.09
Tastiness	2.89^{d} ± 0.06	3.08^{cd} ± 0.06	3.43^{ab} ± 0.07	3.66^{a} ± 0.10	3.24^{bc} ± 0.06	3.26 ± 0.05

$^{a–d}$means in the same row with different superscripts statistically differ ($P \leq 0.05$)

Table 9. Sensory profile scores of different cooked emu muscles broth (in ponts) ($\bar{x}$ ± SE)

Item	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*	Average value
Clarity	3.61 ± 0.08	3.69 ± 0.12	4.30 ± 0.14	4.19 ± 0.26	3.68 ± 0.23	3.89 ± 0.09
Colour	3.62 ± 0.13	3.61 ± 0.10	3.47 ± 0.15	3.98 ± 0.14	3.88 ± 0.28	3.71 ± 0.08
Smell	3.78 ± 0.04	3.73 ± 0.03	3.80 ± 0.07	3.79 ± 0.06	3.83 ± 0.09	3.79 ± 0.03
Tastiness	3.72 ± 0.07	3.77 ± 0.07	3.65 ± 0.04	3.68 ± 0.11	3.59 ± 0.08	3.69 ± 0.03

193 mg/100 g on average, respectively. As reported by Kunachowicz et al. (2017), the content of C18:2 in poultry leg meat ranged from 500 mg/100 g (turkey thigh) to 1490 mg/100 g (chicken thigh), whereas C20:4n6 content in these species was 50 mg/100 g. Research on the role of C20:4n6 reveals that its deficiency may interfere with reproduction in humans and other mammals (Morris 2004).

The sensory score (Table 8) showed that cooked emu muscles were characterised by a relative intense colour – 4.31 points on average. Lower leg muscles obtained the lowest scores (4.11 points on average), and they differed significantly from the muscle with the highest score – *M. flexor cruris lateralis* (4.61 points). As mentioned earlier, this muscle was distinguished by the highest L*, a* and b* parameters. A similar relationship was noted in the smell assessment of *M. flexor cruris lateralis* (4.03 points), as well as in the case of tenderness (4.00 points), juiciness (3.75 points) and tastiness (3.66 points).

There was no influence of muscle type on the formation of sensory characteristics in the sensory evaluation of cooked emu meat broth (Table 9). The average scores of all muscles showed that the broth was relatively clear (3.89 points), and was characterised by the right colour (3.71 points), smell (3.79 points) and tastiness (3.69 points). It can, therefore, be concluded that the sensory analysis of the broth was not influenced by the different types of muscles, as opposed to cooked meat, which during the sensory evaluation obtained significantly different scores depending on the type of muscle.

CONCLUSION

In conclusion, it can be stated that the meat from female emus at the end of their reproductive career (15-year-old) has a satisfactory nutritional quality. The rich mineral composition and high protein content with low intramuscular fat and cholesterol contents deserve special emphasis. The results from the present study indicate that the product could be traded and is useful to nutritionists and dieticians, namely as a fresh tissue basis. Furthermore, the basic chemical composition, biochemical parameters, and physicochemical and sensory properties of the selected muscles of 15-year-old emus were studied for the first time, in order to establish a database on the nutrient composition of emu meat for further studies on its fitness for human consumption.

REFERENCES

AOAC (2007): Official Methods of Analysis of AOAC International. 18th Ed. Association of Official Analytical Chemists, Arlington, USA.

https://doi.org/10.17221/140/2018-CJAS

Barylko-Pikielna N., Kossakowska T., Baldwin Z. (1964): Selection of the optimum method of beef and pork preparation for sensory evaluation. Roczniki Instytutu Przemyslu Miesnego, 1, 111–132.

Beckerbauer L.M., Thiel-Cooper R., Ahn D.U., Sell J.L., Parrish Jr. F.C., Beitz D.C. (2001): Influence of two dietary fats on the composition of emu oil and meat. Poultry Science, 80, 187–194.

Berge P., Lepetit J., Renerre M., Touraille C. (1997): Meat quality traits in the emu (Dromaius novaehollandiae) as affected by muscle type and animal age. Meat Science, 45, 209–221.

Botha S.S., Hoffman L.C., Britz T.J. (2007): Physical meat quality characteristics of hot-deboned ostrich (Struthio camelus var. domesticus) Muscularis gastrocnemius pars interna during post-mortem aging. Meat Science, 75, 709–718.

Buclaw M., Majewska D., Szczerbinska D. (2018): Minerals, trace elements, cholesterol and fatty acids content in various muscles of emu (Dromaius novaehollandiae). Animal Science Papers ans Reports, 36, 311–322.

Commission Internationale de l'Eclairage (CIE) (1976): Colorimetry: Official Recommendations of the International Commission on Illumination. Publication CIE No. 15 (E-1.3.1), Boreau Central de la CIE, Paris, France.

Cunha S.S., Fernandes J.O., Oliveira M.B. (2007): Quantification of free and esterified sterols in Portuguese olive oils by solid-phase extraction and gas chromatography-mass spectrometry. Journal of Chromatography A, 1128, 220–227.

Filgueras R.S., Gatellier P., Aubry L., Thomas A., Bauchart D., Durand D., Zambiazi R.C., Sante-Lhoutellier V. (2010): Colour, lipid and protein stability of Rhea americana meat during air- and vacuum-packaged storage: Influence of muscle on oxidative processes. Meat Science, 86, 665–673.

Filgueras R.S., Gatellier P., Ferreira C., Zambiazi R.C., Sante-Lhoutellier V. (2011): Nutritional value and digestion rate of rhea meat proteins in association with storage and cooking processes. Meat Science, 89, 6–12.

Grau R., Hamm R. (1953): A simple method for determining water binding in muscle. Naturwissenschaften, 40, 29–30. (in German)

Hoffman L.C., Fisher P. (2001): Comparison of meat quality characteristics between young and old ostriches. Meat Science, 59, 335–337.

Hoffman L.C., Joubert M., Brand T.S., Manley M. (2005): The effect of dietary fish oil rich in n-3 fatty acids on the organoleptic, fatty acid and physicochemical characteristics of ostrich meat. Meat Science, 70, 45–53.

Horbanczuk J., Sales J., Celeda T., Konecka A., Zieba G., Kawka P. (1998): Cholesterol content and fatty acid composition of ostrich meat as influenced by subspecies. Meat Science, 50, 385–388.

Horbanczuk O.K., Wierzbicka A. (2016): Technological and nutritional properties of ostrich, emu, and rhea meat quality. Journal of Veterinary Research, 60, 279–286.

Horbanczuk J.O., Polawska E., Wojcik A., Hoffman L.C. (2015): Influence of frozen storage on the fatty acid composition of ostrich meat enriched with linseed and rapeseed. South African Journal of Animal Science, 45, 129–136.

Jamroz D. (2005): Ostriches and emu feeding recommendations. In: Smulikowska S. and Rutkowski A. (eds): Dietary Recommendations and Nutritive Value of Feeds. Nutrition Standards of Poultry The Kielanowski Institute of Animal Physiology and Nutrition, Jablonna, Poland.

Knight T.W., Knowles S., Death A.F., West J., Agnew M., Morris C.A., Purchas R.W. (2003): Factors affecting the variation in fatty acid concentrations in lean beef from grass-fed cattle in New Zealand and the implications for human health. New Zealand Journal of Agricultural Research, 46, 83–95.

Kunachowicz H., Przygoda B., Nadolna I., Iwanow K. (2017): Food Composition Tables. PZWL, Warsaw, Poland.

Kuzelov A., Jordanoski M., Gacovski Z., Trajcova D. (2012): Carcass categorization and chemical composition of ostrich meat. Macedonian Journal of Animal Science, 2, 67–69.

Lamas L.P., Main R.P., Hutchinson J.R. (2014): Ontogenetic scaling patterns and functional anatomy of the pelvic limb musculature in emus (Dromaius novaehollandiae). PeerJ, 2: e716.

Majewska D., Jakubowska M., Ligocki M., Tarasewicz Z., Szczerbinska D., Karamucki T., Sales J. (2009): Physicochemical characteristics, proximate analysis and mineral composition of ostrich meat as influenced by muscle. Food Chemistry, 117, 207–211.

Menon D.G., Darin C., Bennett D.C., Uttaro B., Schaefer A.F., Cheng K.M. (2014): Carcass yields and meat quality characteristics of adult emus (Dromaius vaehollandiae) transported for 6 h before slaughter. Meat Science, 98, 240–246.

Morris J.G. (2004): Do cats need arachidonic acid in diet for reproduction? The American Journal of Clinical Nutrition, 88, 131–137.

Naveena B.M., Sen A.R., Muthukumar M., Girish P.S., Praveen Kumar Y., Kiran M. (2013): Carcass characteristics, composition, physico-chemical, microbial and sensory quality of emu meat. British Poultry Science, 54, 329–336.

Nithyalakshmi V., Preetha R. (2015): Effect of cooking conditions on physico-chemical and textural properties of emu (Dromaius novaehollandiae) meat. International Food Research Journal, 22, 1924–1930.

https://doi.org/10.17221/140/2018-CJAS

Pegg R.B., Amarowicz R., Code W.E. (2006): Nutritional characteristics of emu (Dromaius novaehollandiae) meat and its value-added products. Food Chemistry, 97, 193–202.

Pereira A.V., Romanelli P.F., Scriboni A.B., Orlandini F.P. (2006): Slaughtering yield and composition of great rhea meat (Rhea americana). Ciência e Tecnologia de Alimentos, 26, 632–638.

Pohja M.S., Niinivaara F.P. (1957): Determination of water binding of meat by means of constant pressure. Fleischwirtschaft, 9, 193–95. (in German)

Ramos A., Cabrera M.C., del Puerto M., Saadoun A. (2009): Minerals, haem and non-haem iron contents of rhea meat. Meat Science, 81, 116–119.

Romanelli P.F., Trabuco E., Scriboni A.B., Visentainer J.V., de Souza N.E. (2008): Chemical composition and fatty acid profile of rhea (Rhea americana) meat. Archivos Latinoamericanos de Nutricion, 58, 201–205.

Szczerbinska D., Majewska D., Danczak A., Tarasewicz Z. (2007). Emu. Wytdawnictwo Naukowe Akademii Rolniczej w Szczecinie, Szczecin, Poland.

Ulbricht T.L.V, Southgate D.A.T. (1991): Coronary heart disease: Seven dietary factors. Lancet, 338, 985–992.

Wang Y.W., Sunwoo H., Sim J.S. (2000): Lipid characteristics of emu meat and tissues. Journal of Food Lipids, 7, 71–82.

Zalucki G. (2015): Muscles. In: Krzymowski T. (ed.): Animal Physiology. Panstwowe Wydawnictwo Rolnicze i Lesne, Warsaw, Poland.

Zdanowska-Sasiadek Z., Michalczuk M., Polawska E., Damaziak K., Niemiec J., Radzik-Rant A. (2016): Dietary vitamin E supplementation on cholesterol, vitamin E content, and fatty acid profile in chicken muscles. Canadian Journal of Animal Science, 96, 114–120.

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