Animal Science Papers and Reports vol. 36 (2018) no. 3, 311-322
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Minerals, trace elements, cholesterol and fatty acids content in various muscles of emu (*Dromaius novaehollandiae*)

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(Accepted August 17, 2018)

The differences in the minerals composition, cholesterol level and fatty acids profile between various muscle types from 6 emu male (15-years old) were evaluated. After slaughter, carcasses were cut into two and chilled for 24 hours at 4°C. From each left half of the carcass we cut two drumstick muscles (*M. gastrocnemius pars externa*, *M. gastrocnemius pars interna*) and three thigh muscles muscles (*M. obturatorius medialis*, *M. flexor cruris lateralis*, *M. iliotibialis lateralis*). The results showed that the most abundant mineral was potassium, with an content from 3325.07 to 3849.18 mg/kg. The muscle *flexor cruris lateralis* proved to be the richest vc source of sodium (530.97 mg/kg), whereas *M. obturatorius medialis* – of magnesium (285.05 mg/kg). The microelements occurring in the highest concentrations in the emu muscles were iron (39.59-47.12 mg/kg), followed by silicon (31.16-41.69 mg/kg) and zinc (13.73-30.39 mg/kg). Total cholesterol content was similar in the analysed muscles and averaged 66.39 mg/100g. Saturated fatty acids (SFAs) represented 34.42% of all the fatty acids of the analyzed tissue lipids. Their lowest percentage was found in *M. gastrocnemius pars externa* (31.99%). Dominant SFA were palmitic and stearic acids. Monounsaturated fatty acids (MUFAs) represented nearly 30% of the acids, with the highest content in *M. flexor cruris lateralis* (33.42%). Oleic acid was the dominant MUFA, with a higher content observed in the thigh muscles. Polyunsaturated fatty acids (PUFAs) averaged 36%, with the highest fraction found in *M. gastrocnemius pars externa* (40.74%). Linoleic and arachidonic acids were most common.

KEYWORDS: *Dromaius novaehollandiae* / cholesterol / fatty acids / meat / minerals

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The emu (*Dromaius novaehollandiae*), which is endemic to Australia, is considered a versatile farm species world-wide; however, it is mainly the meat and fat that are harvested, due to their unique dietary qualities [Horbańczuk and Wierzbicka 2016, Sales, Horbańczuk 1998, Sales *et al.*1999]. Ratitae meat including emu meat is supreme, as compared to other meats [Horbanczuk *et al.* 2007, Poławska *et al.* 2016]; despite its similarity to red meat, emu meat exhibits the properties of white meat. The American Heart Association recommends its consumption, since emu meat is rich in proteins and low in fat and cholesterol. Its fatty acid profile is very favourable for humans, and the meat is rich in minerals, vitamins and creatine [Pegg *et al*. 2006, Naveena *et al*. 2013].

Meat is a valuable and nearly indispensable foodstuff containing many nutrients important in the human diet. It is very important to be aware of the content and function of food components or groups of compounds present in the food, especially in terms of diet composition and design.

Genetic and environmental factors shape the composition of animals tissues, and affect therefore production performance of the animal. Besides these factors, meat quality also depends on the muscle it has been harvested from, since there are natural differences between muscles which result from differences in their structure, role and physiological function.

The literature in the field includes few reports on the emu meat fatty acid profile [Wang *et al*. 2000, Beckerbauer *et al*. 2001] and minerals [Pegg *et al*. 2006], and it should be noted that the research involves emus slaughtered at age 12-20 months. An emu breeding flock, however, may be utilized over several years, usually more than ten laying seasons. Poultry meat production involves mainly young broilers, but also laying hens on their completion of the egg-laying life slaughtered for human consumption. In most poultry species, this age falls within the first year of the production life. We have decided to carry out an analysis of meat of emu slaughtered at the end of their reproductive lives. We hypothesized that meat from 15-year-old emu has a satisfactory nutritional quality to be considered as a valuable food for people. In order to evaluate the nutritional potential of emu meat, and to extend current knowledge, the present study aimed at evaluation of minerals composition, cholesterol level and fatty acids profile of emu meat as influenced by muscle.

Material and methods

Emus used for the study (6 males) were slaughtered at age 15 years after completion of the reproductive period of life. The birds were kept on the experimental farm of the Department of Poultry and Ornamental Bird Breeding, West Pomeranian University of Technology Szczecin, Poland. All birds originated from our own hatching and rearing. Until slaughter, emus were housed in a shed with a large, open-air pen, with unrestricted access to it regardless of the weather and year season. The birds were ad libitum fed a standard complete feed in the form of pellets, based on barley, maize, wheat and soybean meal, formulated according to the nutritional requirements of the

species. The feed contained 18.00% total protein, 6.70% crude ash, 5.20% crude fiber, 2.10% crude fat and 10.63 MJ EMN in 1 kg. The content of macro- and microelements as well as fatty acids are presented in Tables 1 and 2.

Before slaughter, emus fasted for 24 hours. Thereafter, stunned birds were restrained, hoisted and bled by opening the jugular vein and the carotid artery just behind the head. After feather and skin had been removed, the birds were eviscerated. Carcasses were cut into two and chilled for 24 hours at 4°C. Subsequently, legs and thighs were excised from the pelvic limbs.

Considering that emu meat is often marketed in the form of single muscles, from each left halves of the carcasses (n=6) we cut two drumstick muscles (*M. gastrocnemius pars externa*, *M. gastrocnemius pars interna*) and three thigh muscles (*M. obturatorius medialis*, *M. flexor cruris lateralis*, *M. iliotibialis lateralis*). Muscle identification was performed according to the methodology provided by Lamas *et al.* [2014].

Analytic sample preparation involved removing any membranes or fat from the surface of the muscles. The samples were frozen and stored at -18°C until analysis.

The muscles were measured for macro- and microelements content and fatty acid profile along with cholesterol.

The levels of macro- and micronutrients in offal were determined by inductively coupled plasma optical emission spectrometry (ICP OES) using the Optima 2000 DV (Perkin Elmer) following digestion in a microwave oven (Anton Paar) equipped with a system of continuous temperature and pressure control in each quartz vessel.

Gas chromatography-mass spectrometry (GC-MS) was used to determine the level of cholesterol and the fatty acid profile.

The results of the analyses were processed statistically using Statistica 13.1 PL package [IBM corp., SPSS Statistics for

Table 1. Macro- and microelements content (mg/kg) in emu feed

Mineral	Average (±SEM)
P	11572.9 (270.8)
K	8240.4 (53.5)
Na	1634.7 (29.9)
Mg	2472.1 (7.9)
Ca	16391.4 (145.0)
Fe	419.2 (24.6)
Zn	120.4 (6.8)
Si	379.4 (14.7)
Cu	12.6 (0.5)
Mn	154.5 (8.3)
Ba	7.3 (0.3)
Cr	0.94 (0.04)
Sr	30.0 (1.5)
Pb	0.23 (0.01)
Se	0.1966 (0.0003)
Cd	0.026 (0.001)

Table 2. Fatty acids profile (% of total FAME) of the emu feed

Fatty acid	Average (±SEM)
C14:0	0.110 (0.001)
C16:0	22.50 (0.08)
C17:0	0.205 (0.001)
C18:0	3.680 (0.004)
C20:0	0.213 (0.001)
C15:1	0.154 (0.003)
C16:1	0.219 (0.003)
C18:1n9t	2.49 (0.02)
C18:1n9c	22.50 (0.12)
C20:1	0.288 (0.001)
C24:1	0.09 (0.001)
C18:2n6c	40.70 (0.66)
C18:3n3	2.83 (0.05)
C20:3n3	0.116 (0.001)
C20:3n6	0.12 (0.001)
C20:4n6	0.255 (0.002)
C20:5n3	0.156 (0.002)
C22:6n3	0.283 (0.004)
Other	4.03 (0.04)

Other - ∑ (C6:0, C8:0, C10:0, C11:0, C12:0, C13:0, C14:1, C15:0, C17:1, C18:3n6, C20:2, C21:0, C22:0, C221n9, C22:2, C23:0, C24:0).

Windows, version 23.0., New York, NY: IBM Crop]. One-way ANOVA was used with muscle as a fixed effect. Significance of differences was in each case tested with the Tukey test at $P \leq 0.05$ and $P \leq 0.01$.

Results and discussion

The most abundant mineral was potassium, with an content from 3325.07 to 3849.18 mg/kg (Tab. 3). Pegg *et al*. [2006] also found potassium as the most abundant mineral, however its level was about 187 mg/kg lower compared to its lowest concentration which we found in *M. flexor cruris lateralis* (3325.07 mg/kg). Compared to other ratites, emu meat contains more potassium [Sales and Hayes 1996; Majewska *et al*. 2009; Ramos *et al*. 2009]. Potassium is responsible for many basic and important functions in the body, including proper functioning of the nervous and muscular systems and blood pressure control. It is believed that increased potassium levels in the diet can protect against hypertension [Karakök *et al*. 2010].

In terms of their average concentration, the other minerals may be ranked the same as in the report by Pegg *et al*. [2006]: P>Na>Mg>Ca. The same sequence has been observed in the meat of ostriches [Sales and Hayes 1996; Majewska *et al*. 2009]. In the muscles if the rhea, on the other hand, there was a higher content of phosphorus than potassium [Ramos *et al*. 2009]. Phosphorus and calcium content in all the analyzed muscles was similar, 2167.83-2365.48 and 48.23-55.44 mg/kg, respectively. Similar results in the ostrich meat were found by Pegg *et al*. [2006], Sales and Hayes [1996] and Majewska *et al*. [2009]. On the other hand, the average phosphorus content in rhea muscles was higher by about 1600 mg/kg, and calcium content was lower by nearly 32 mg/kg [Ramos *et al*. 2009].

The muscle *flexor cruris lateralis* proved to be the richest source of sodium (530.97 mg/kg), whereas *M. obturatorius medialis* – magnesium (285.05 mg/kg), with the averages for both metals similar to data published by Pegg *et al*. [2006]. In ostrich meat, however, *Majewska et al*. [2009] found by nearly 192 mg/kg less soidum in *M. flexor cruris lateralis* and by 32 mg/kg less magnesium in *M. obturatorius medialis*. These authors reported that the highest sodium level was found in *M. ambiens* (390 mg/kg), whereas magnesium in *M. flexor cruris lateralis*, the level of which was close to our own research. Amongst the ratites, rhea meat is characterised by a much higher sodium content (586-691 mg/kg), and lower magnesium content (about 150 mg/kg), which has been demonstrated by Ramos *et al*. [2009]. Thus, emu muscles represent a rich source of magnesium, which is the fourth most abundant element in the human body and the most widespread intracellular divalent cation. Magnesium is involved in more than 300 enzymatic reactions in the conversion processes of proteins, lipids, nucleic acids and high-energy phosphates. Its deficiency impairs a range of cognitive abilities and processes, leading to poor concentration, fatigue, nervousness and increased aggression [El Baza *et al*. 2016].

Table 3. Macro- and microminerals content (mg/kg fresh weight) in emu muscles - average (±SEM)

Mineral	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*
K	3837.56^{A} (76.82)	3849.18^{B} (92.90)	3740.12^{C} (38.08)	3325.07^{ABCD} (55.83)	3793.70^{D} (34.60)
P	2188.98 (37.61)	2178.95 (40.72)	2365.48 (106.70)	2167.83 (46.63)	2294.79 (27.76)
Na	426.00 (15.44)	441.25 (33.45)	448.44 (26.84)	530.97^{a} (26.56)	406.43^{a} (20.40)
Mg	270.29^{a} (3.46)	279.73^{A} (3.14)	285.05^{B} (4.26)	251.42^{ABCa} (3.53)	274.68^{C} (5.72)
Ca	52.67 (3.27)	55.44 (2.89)	48.23 (1.69)	52.30 (1.67)	49.82 (1.55)
Fe	40.04 (2.35)	45.57 (2.43)	47.12 (2.41)	39.59 (3.16)	39.59 (4.05)
Si	31.66 (3.45)	31.59 (2.74)	31.16 (3.83)	41.69 (4.17)	31.39 (2.24)
Zn	27.79^{A} (1.47)	28.09^{B} (2.69)	13.73^{ABC} (1.82)	21.44 (2.69)	30.39^{C} (2.39)
Cu	1.35^{a} (0.08)	1.57 (0.13)	1.97^{a} (0.20)	1.60 (0.18)	1.42 (0.02)
Mn	0.012 (0.002)	0.012 (0.001)	0.014 (0.001)	0.013 (0.001)	0.010 (0.001)
Ba	0.009 (0.002)	0.012 (0.004)	0.013 (0.002)	0.008 (0.001)	0.008 (0.002)
Cr	0.024 (0.004)	0.026 (0.002)	0.028 (0.008)	0.023 (0.002)	0.020 (0.001)
Sr	0.021 (0.002)	0.034^{a} (0.007)	0.024 (0.003)	0.023 (0.004)	0.016^{a} (0.002)
Pb	0.033 (0.003)	0.030^{a} (0.002)	0.029^{b} (0.002)	0.052^{ab} (0.010)	0.036 (0.002)
Se	0.013 (0.001)	0.012 (0.002)	0.010 (0.002)	0.011 (0.002)	0.013 (0.002)
Cd	0.008 (0.001)	0.008 (0.001)	0.009 (0.001)	0.010 (0.001)	0.009 (0.001)

$^{aA...}$Means bearing with the same superscripts differ significantly at: small letters Significant differences between emu muscles are marked with the same letter – P≤0.05; capitals – P≤0.01.

The microelements occurring in the highest concentrations (Tab. 3) in the emu muscles were iron (39.59-47.12 mg/kg), followed by silicon (31.16-41.69 mg/kg) and zinc (13.73-30.39 mg/kg). Higher iron (50 mg/kg) and zinc (36 mg/kg) levels in emu meat were measured by Pegg *et al*. [2006], however in young birds. Sales and Hayes [1996], on the other hand, noted a lower content of iron and zinc in ostrich meat, by 19 and 4 mg/kg, respectively. Majewska *et al*. [2009], who also studied ostrich meat, observed a lower content of iron and silicon, by 11 and 20 mg/kg, respectively, and a higher level of zinc, by 7 mg/kg, as compared to the averages that we have calculated. In the meat of rheas, Ramos *et al*. [2009] observed about 10 mg/kg lower

concentration of both iron and zinc compared to the average contents of these elements in our studies.

Among micronutrients, iron is particularly important in human nutrition as an essential element in hematopoiesis and many cellular metabolic reactions. In addition, iron contained in meat is more bioavailable than from plant products [Lombardi-Boccia *et al*. 2002]. Thus, emu can be a very good source of dietary iron, especially for those suffering from anemia, for elderly persons and pregnant women, i.e. in cases of increased iron demand [Cooper 1999, Hernández Ruiz de Eguílaz *et al*. 2010]. Emu meat is also characterized by a high content of silicon and zinc. Silicon plays an important role in the development of the skeletal system and it has positive influence on the proper neurological function [Chumlea 2007, Jugdaohsingh 2007]. Zinc, on the other hand, is essential in the healing of wounds and the proper functioning of the immune system. Just like iron, this element contained in meat is better absorbed and used by the body than from plant-derived food [Karakök *et al*. 2010].

Copper levels varied from 1.35 (*M. gastrocnemius pars externa*) to 1.97 mg/kg (*M. obturatorius medialis*) and were similar to ones reported for the meat of other ratites [Sales and Hayes 1996, Majewska *et al*. 2009, Ramos *et al*. 2009]. The content of other microelements – except for lead, which highest content was found in *M. flexor cruris lateralis* (0.05 mg/kg) – were similar irrespective of the muscle. The EU regulations on lead [Commission Regulation (EU) 2015/1005] and cadmium [Commission Regulation (EU) No. 488/2014] in foodstuffs restrict the levels of the contaminants in beef, pork, mutton and poultry to maximum 0.10 and 0.05 mg/kg for lead and cadmium, respectively. It should be noted that the concentrations of both metals in the analysed emu meat does not exceed the allowed maximum levels despite the long-term management of the birds in the free-ranging system. As with lead, the highest concentration of cadmium was found in *M. flexor cruris lateralis*.

Total cholesterol content (Tab. 4) was similar in the analysed muscles and averaged 66.39 mg/100g. Horbańczuk *et al*. [1998] and Girolami *et al*. [2003] did not find significant differences between the muscles in terms of this steroid levels in intramuscular fat, either. Daniel *et al*. [2000], who analyzed cholesterol in full rump, found a level higher by about 32 mg/100 g. Beckerbauer *et al*. [2001] found cholesterol in five emu muscles ranging from 26.2 to 44.1 mg/100 g, however, the dietary fat in this study came from soybean oil and beef tallow. In ostrich muscles, cholesterol content ranged from 50.10 mg/100 g in *M. Iliotibialis* [Girolami *et al*. 2003] to 68.38 mg/100g in *M. gastrocnemius* [Horbańczuk *et al*. 1998]. In the rhea, these values remained within the range 56.00-81.50 mg/100 g [Filgueras *et al*. 2010].

The American Heart Association recommends the maximum daily intake of cholesterol at a level lower than 300 mg, for a healthy person, or 200 mg per day, for those with a high risk of cardiovascular disease. It can therefore be concluded that emu meat meets the today's dietary requirements, since a serving of 100 g provides about a quarter of that limit.

Table 4. Cholesterol level (mg/100g), fatty acid profile (%) and health-related (atherogenicity and thrombogenicity) indices in emu muscles - average (±SEM)

Item	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*
Cholesterol	65.54 (2.54)	64.93 (1.93)	65.42 (1.85)	68.86 (1.71)	67.20 (1.86)
SFA	31.99^{ab} (0.98)	33.77 (0.81)	36.27^{a} (1.01)	36.14^{b} (1.34)	33.93 (0.48)
MUFA	27.27^{a} (1.21)	26.88^{A} (0.68)	30.79 (0.92)	33.42^{Aa} (1.83)	30.04 (1.26)
PUFA	40.74^{Aa} (2.16)	39.35^{b} (1.17)	32.94^{a} (1.65)	30.44^{Ab} (2.46)	36.03 (1.66)
UFA/SFA	2.14^{ab} (0.10)	1.97 (0.07)	1.77^{a} (0.08)	1.78^{b} (0.10)	1.95 (0.04)
MUFA/SFA	0.85 (0.01)	0.80 (0.03)	0.85 (0.03)	0.93 (0.05)	0.88 (0.03)
PUFA/SFA	1.29^{Aa} (0.11)	1.17 (0.06)	0.92^{a} (0.07)	0.86^{A} (0.09)	1.07 (0.06)
n3	0.98^{a} (0.05)	1.67^{a} (0.21)	1.27 (0.12)	1.09 (0.26)	1.19 (0.10)
n6	39.75^{Aa} (2.14)	37.67^{b} (1.18)	31.66^{a} (1.72)	29.34^{Ab} (2.54)	34.83 (1.70)
n6/n3	40.77 (2.29)	24.34 (3.07)	26.40 (3.38)	34.46 (6.54)	30.90 (3.96)
IA	0.26 (0.02)	0.27 (0.02)	0.32 (0.02)	0.33 (0.03)	0.29 (0.01)
IT	0.87^{ab} (0.04)	0.90 (0.03)	1.03^{a} (0.04)	1.04^{b} (0.04)	0.93 (0.02)

$^{aA...}$ Means bearing with the same superscripts differ significantly at: small letters Significant differences between emu muscles are marked with the same letter – $P \leq 0.05$; capitals – $P \leq 0.01$.
SFA – $\sum$ (C8:0, C10:0, C11:0, C12:0, C13:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0, C21:0, C22:0, C23:0, C24:0); MUFA – $\sum$(C14:1, C15:1, C16:1, C17:1, C18:1n9t, C18:1n9c, C20:1, C22:1n9, C24:1); PUFA - $\sum$ (C18:2n6c, C22:2, C18:3n3, C20:3n3, C20:3n6, C20:4n6, C20:5n3, C22:6n3); UFA – $\sum$ (MUFA, PUFA); n3 – $\sum$ (C18:3n3, C20:3n3,C20:5n3, C22:6n3); n6 – $\sum$ (C18:2n6c, C20:3n6, C20:4n6); AI – atherogenicity index = (C12:0+4*C14:1+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)).

Saturated fatty acids (SFAs, Tab. 4) represented 34.42% of all the fatty acids of the analyzed tissue lipids. Their lowest percentage was found in *M. gastrocnemius pars externa* (31.99%). Dominant SFAs (Tab. 5) were palmitic (C16:0) and stearic (C18:0) acids, with an average share 19.11 and 14.87%, respectively, in the general composition. In the analysies of the meat of the emu [Wang *et al*. 2000; Beckerbauer *et al*. 2001], ostrich [Horbańczuk *et al*. 1998, Girolami *et al*. 2003, Wang *et al*. 2014, Horbańczuk *et al*. 2015] and rhea [Sales *et al*. 1999; Romanelli *et al*. 2008, Filgueras *et al*. 2010] the percentage of SFAs in the fatty acid profiles was similar. Thus, it can

Table 5. Content of selected fatty acids (%) in emu muscles – average (±SEM)

Fatty acids	*M. gastrocnemius pars externa*	*M. gastrocnemius pars interna*	*M. obturatorius medialis*	*M. flexor cruris lateralis*	*M. iliotibialis lateralis*
C14:0	0.11 (0.03)	0.17 (0.03)	0.17 (0.01)	0.12 (0.05)	0.07 (0.01)
C16:0	17.49 (1.26)	17.62 (0.91)	20.38 (1.18)	20.98 (1.27)	19.07 (0.79)
C17:0	0.092 (0.016)	0.112^{a} (0.014)	0.135^{A} (0.012)	0.056^{Aa} (0.004)	0.104 (0.015)
C18:0	13.93 (0.52)	15.66 (0.52)	15.47 (0.33)	14.89 (0.49)	14.41 (0.44)
C20:0	0.245^{Ab} (0.085)	0.053 (0.015)	0.022^{a} (0.003)	0.048^{b} (0.014)	0.183 (0.058)
C15:1	0.87^{a} (0.20)	0.57 (0.04)	0.46 (0.04)	0.29^{Aa} (0.09)	0.92^{A} (0.11)
C16:1	1.85 (0.46)	2.04 (0.25)	2.80 (0.44)	2.76 (0.60)	1.62 (0.50)
C18:1n9t	2.50^{Aa} (0.09)	2.92 (0.11)	3.54^{AB} (0.21)	3.37^{Ca} (0.30)	2.49^{BC} (0.07)
C18:1n9c	21.96^{a} (1.06)	21.20^{A} (0.67)	23.83 (0.69)	26.86^{Aa} (1.52)	24.90 (0.86)
C20:1	0.023^{AB} (0.005)	0.061 (0.009)	0.105^{AC} (0.010)	0.085^{Ba} (0.021)	0.028^{Ca} (0.004)
C24:1	0.037 (0.006)	0.038 (0.004)	0.019 (0.003)	0.022 (0.004)	0.045 (0.011)
C18:2n6c	18.84 (0.52)	18.48 (0.29)	17.63 (1.04)	16.46 (0.91)	18.08 (0.69)
C18:3n3	0.57 (0.06)	0.74 (0.12)	0.55 (0.07)	0.54 (0.13)	0.68 (0.06)
C20:3n3	0.061^{ab} (0.004)	0.131^{ac} (0.024)	0.128^{bd} (0.012)	0.084 (0.019)	0.058^{cd} (0.007)
C20:3n6	0.024^{ab} (0.003)	0.061^{ac} (0.009)	0.062^{bd} (0.009)	0.036 (0.013)	0.018^{cd} (0.004)
C20:4n6	20.89^{Aa} (1.84)	19.12^{b} (1.11)	13.97^{a} (0.69)	12.85^{Ab} (1.75)	16.74 (1.25)
C20:5n3	0.10 (0.02)	0.29 (0.10)	0.28 (0.07)	0.24 (0.07)	0.11 (0.04)
C22:6n3	0.24^{a} (0.04)	0.51^{ab} (0.06)	0.31 (0.04)	0.23^{b} (0.09)	0.33 (0.08)

$^{aA...}$ Means bearing with the same superscripts differ significantly at: small letters Significant differences between emu muscles are marked with the same letter – P≤0.05; capitals – P≤0.01.

be concluded that the fatty acid profile in ratites is stable, regardless of age, sex and applied management system.

Monounsaturated fatty acids (MUFAs, Tab. 4) represented nearly 30% of the acids, with the highest content in *M. flexor cruris lateralis* (33.42%). Polyunsaturated fatty acids (PUFAs) averaged 36%, with the highest fraction found in *M. gastrocnemius pars externa* (40.74%). Oleic acid (C18:1n9c) was the dominant monounsaturated fatty acid (Tab. 5), with a higher content observed in the thigh muscles, especially *M. flexor cruris lateralis* (26.86%).

The PUFAs (Tab. 5), linoleic (C18:2n6c) and arachidonic (C20:4n6) acids were most abundant. The content of linoleic acid was similar in all muscle types and on average accounted for 18% of total fatty acids. On the other hand, most of the arachidonic acid (20.01%) was found in the drumstick muscles (*M. gastrocnemius pars externa* and *M. gastrocnemius pars interna*). Girolami *et al*. [2003], analyzing the ostrich muscles, also found a greater proportion of arachidonic acid in the drumstick muscles. Compared to ostrich and rhea, emu meat is a richer source of arachidonic acid, which is a precursor of many eicosanoids regulating the function of most organs and systems [Pawlosky and Salem 1996, Morris 2004].

Wang *et al*. [2000], who studied fatty acid profiles in the meat of 12-month emus, observed a higher level of MUFAs (41.95%) compared to PUFAs (24.08%). A similar pattern was observed by Beckerbauer *et al*. [2001], with MUFAs and PUFAs representing, respectively, 64 and 36% of the total unsaturated fatty acids (UFAs). The differences are probably due to the fact that animal tissue fatty acid profiles depend on many variables, including age, genotype, sex, and fatty acid profile in the ration [De Smet *et al*. 2004]. The cited authors [Beckerbauer *et al*. 2001] reported that oleic acid was dominant, with a level twice as high as that observed in our study.

Authors analysing ostrich meat [Sales *et al*. 1996; Horbańczuk *et al*. 1998, 2015, Horbańczuk, Wierzbicka 2018, Girolami *et al*. 2003, Poławska *et al*. 2011, 2013, 2016 Wang *et al*. 2014, Zdanowska-Sąsiadek *et al*. 2018] reported higher fractions of MUFAs and oleic acid, ranging 31.50-42.01% and 25.01-32.65%, respectively. The PUFAs share was lower (21.90 to 34.60%), with the content of linoleic acid being similar to that obtained in our analysis.

Sales *et al*. [1999] stated that the proportions of MUFAs and PUFAs in the intramuscular fat of the rhea were similar; however, the authors noted a 10% higher percentage of linoleic acid and a 7% lower fraction of arachidonic acid, as compared with our results. Other rhea studies reveal that MUFAs share in *M. gastrocnemius pars interna* may range from 24.70 to 42.36%, whereas PUFAs from 29.71 to 45.15% [Romanelli *et al*. 2008; Filgueras *et al*. 2010). The levels we have measured in the same muscles remained within these ranges (MUFAs, 26.88%; PUFAs, 39.35%).

The mean ratios of MUFAs/SFAs (0.86), PUFAs/SFAs (1.06) and UFAs/SFAs (1.92) (Tab. 4) were similar to those noted in the intramuscular fat of emus [Wang *et al*. 2000], ostriches [Horbańczuk *et al*. 1998, Girolami *et al*. 2003, Wang *et al*. 2014, Horbańczuk *et al*. 2015] and rheas [Sales *et al*. 1999, Romanelli *et al*. 2008, Filgueras *et al*. 2010]. This is due to the fact that the relationships between individual acid groups (SFAs, UFAs, MUFAs and PUFAs) do not exhibit species-specific variability within the *Paleogniathae* subclass, to which these bird species belong.

According to World Health Organization/Food And Agriculture Organization the minimum PUFAs/SFAs ratio recommended for the human health is 0.4-0.5. Our results showed that emu meat fulfills this requirement. In addition, the SFAs and MUFAs content increases with an increase in fat content faster than the PUFAs content, leading to a decrease in the relative share of PUFAs, and hence to a lower

PUFAs/SFAs ratio [De Smet *et al*. 2004]. However, despite the large amount of subcutaneous fat, emu meat has a favorable ratio of these acids.

From the point of view of the quality of poultry products and their dietary value, indices of atherogenicity and thrombogenicity (IA and IT), based on the average content of fatty acids, are also important. Differences in fatty acid composition affected the index of thrombogenicity, as its lowest value (0.87) was found in the drumstick *gastrocnemius pars interna* muscle*,* whereas the highest values (1.03-1.04) in the thigh muscles (*M. obturatorius medialis* and *M. flexor cruris lateralis*). The muscles we analysed did not differ significantly in relation to atherogenicity. Ulbricht and Southgate [1991] considered the IA and IT as better indices of atherogenicity and thrombogenicity compared to the PUFAs/SFAs ratio. IA and IT provide information on the degree the given dietary component containing fatty acids contributes to the coronary heart disease incidence. The lower the value of either index, the lower the risk of arteriosclerosis and thrombosis in humans.

The average n-6:n-3 ranged between more than 24:1 to 41:1. Similar ratios have been reported by Sales *et al*. [1999] and Romanelli *et al*. [2008] in muscular tissue lipids of the rhea, 22:1 and 31:1, respectively. A narrower ratio of n-6 to n-3 was reported in the emu, about 7:1 [Wang *et al*. 2000], ostriches, 3:1-11:1 [Horbańczuk *et al*. 1998, Girolami *et al*. 2003, Wang *et al*. 2014, Horbańczuk *et al*. 2015] and also in the rhea, 7:1-8:1 [Filgueras *et al*. 2010]. The n-6:n-3 ratio is variable and depends on the diet rather than on genetic factors [De Smet *et al*. 2004, Jasińska, Kurek 2017].

Emu muscles are a rich source of valuable dietary nutrients, such as potassium, magnesium, iron, zinc and silicon, as well as polyunsaturated fatty acids, especially arachidonic acid. The research on emu meat quality should be carried out, with a particular focus on the nutrition strategy aimed at increasing intramuscular fat PUFAs content, n-3 acids in particular. Should such goals be achieved, emu meat could be classified as a health-enhancing foodstuff.

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