Animal Science Papers and Reports vol. 36 (2018), no. 2, 205-218
Institute of Genetics and Animal Breeding, Jastrzębiec, Poland

Proximate composition, selected minerals, fatty acid profile and cholesterol levels in edible slaughter by-products of the emu (*Dromaius novaehollandiae*)

Mateusz Bucław*, Danuta Majewska, Danuta Szczerbińska

West Pomeranian University of Technology Szczecin,
Department of Poultry and Ornamental Birds Breeding,
Klemensa Janickiego 29 St., 71-270 Szczecin, Poland

(Accepted March 4, 2018)

Animal edible internal organs represent a valued meat industry by-product, which may either be marketed directly by assortment groups or used as raw material in food processing. Poultry offal meats, or giblets, include hearts, livers and gizzards. The emu internal organs (heart, liver and gizzard) were analysed for proximate chemical composition, macro- and micromineral contents, fatty acid profile and cholesterol level. The flock consisted of 14 emus, 8 females and 6 males. The results revealed high nutritional and dietary values of emu offal meats. The liver, however, is the most noteworthy organ. Minor differences were found between sexes in terms of the proximate composition, nutrient and micronutrient levels, and fatty acid profiles of emu hearts, gizzards and liver. Two-way ANOVA with interactions, however, revealed no significant effect of sex or sex × giblet type interaction, which suggests that giblets harvested both from males and females constitute a valuable animal product.

KEYWORDS: chemical composition / emu (*Dromaius novaehollandiae*) / fatty acids / giblets / offal / minerals

Animal edible internal organs represent a valued meat industry by-product, which may either be marketed directly by assortment groups or used as raw material in food processing. Poultry offal meats, or giblets, include hearts, livers and gizzards. The low price of animal by-products is definitely an advantage; however, sensory

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

values, cooking simplicity, as well as high contents of nutritious proteins, minerals, micronutrients and vitamins – all these add to the value of poultry offal meats [Jokanović *et al.* 2014]. The most common animal internal organ is the liver, used to make many popular products, such as liverwurst and liver pâté [Devatkal *et al.* 2004].

Nutritional awareness has been constantly growing over recent decades, and so have the expectations of consumers, who increasingly often choose better food quality, even if it means higher prices. The decision whether to buy a food item or not often depends on the product's nutritional properties. Nutritional and dietetic values of ratite meat, including that of the emu [Horbańczuk and Wierzbicka 2017, Sales and Horbańczuk 1998, Sales *et al*. 1999], have been thoroughly studied lately [Horbańczuk *et al.* 2007, 2008, Poławska *et al*. 2011, 2013]. As a result, emu meat is rated high in terms of its use in human nutrition. The meat is lean, aromatic, low in cholesterol, has a positive fatty acid profile, and is a good source of proteins, vitamins (A and E, primarily), iron and creatine [Cooper *et al*. 2007, Horbańczuk *et al.* 1998]. Health benefits of oil extracted from emu fat are widely recognized as well [Jeengar *et al*. 2015, Horbańczuk and Wierzbicka 2016].

The literature, however, lacks detailed reports on the nutritional value of emu organ meats, as the species has a relatively short history in poultry production.

The aim of the study was to determine the proximate chemical composition, the content of selected macro- and micronutrients, cholesterol and the fatty acid profile in emu giblets (gizzard, liver, heart) in terms of their nutritional values.

Material and methods

The material comprised adult emus (15 years of age) after completion of the reproductive period of life. The flock consisted of 14 emus, 8 females and 6 males, raised on the experimental facility of the Department of Poultry and Ornamental Birds Breeding of the West Pomeranian University of Technology in Szczecin, Poland. All birds came 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.

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. Internal organs were harvested after feather and skin removal.

The internal organs (heart, liver and gizzard) were analysed for their proximate chemical composition, macro- and micronutrient contents, the fatty acid profile and cholesterol level.

The offal was minced twice and distributed to several containers, which were next frozen at -80°C until analysis.

Proximate chemical composition (dry matter, protein, fat, ash) was determined by the following conventional methods [AOAC, 2005].

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.

Significance of differences was in each case tested with Tukey's test at $P \leq 0.05$ and $P \leq 0.01$. In addition, two-way analysis of variance was performed to test the effects of sex, type of giblets, and the sex × type of giblets interaction on the proximate chemical composition, macro- and micronutrient contents, cholesterol and the total fatty acid profile. The computations were performed using Statistica 13.1 PL package (IBM corp., SPSS Statistics for Windows, version 23.0., New York, NY: IBM Crop).

Results and discussion

Basic chemical components significantly affect the properties and quality of animal food products. Emu giblets (Tab. 1) had a high water content (77.63%). The highest water content was found in the gizzard (80.23%) and heart (79.61%), which both significantly differed from the liver by 7.18 and 6.56 pp, respectively. Other authors, who analysed broiler chicken giblets, also recorded the highest water content in gizzards (79.50-81.5%), whereas that property in the heart was lower compared to our data and ranged from 70.49 to 77.36%. Liver water content reported by other

Table 1. Proximate composition of emu giblets (means with their standard deviations)

Proximate chemical composition (g/100 g)	Sex	Giblets					
		gizzard		liver		heart	
		mean	SD	mean	SD	mean	SD
Moisture	♀	80.32^{A}	0.53	73.22^{AB}	1.58	79.45^{B}	1.32
	♂	80.11^{A}	0.63	72.83^{AB}	0.98	79.82^{B}	0.61
	♀+♂	80.23^{A}	0.56	73.05^{AB}	1.32	79.61^{B}	1.06
Protein	♀	18.64	0.68	18.52	2.85	18.41	0.74
	♂	18.59	0.26	19.91	2.14	18.51	0.57
	♀+♂	18.62	0.53	19.12	2.58	18.45	0.65
Fat	♀	1.58	0.60	2.59	0.72	2.31	1.27
	♂	1.68	0.80	2.15	0.57	1.17	0.11
	♀+♂	1.62	0.66	2.40	0.67	2.05	1.15
Ash	♀	0.92^{*A}	0.05	1.64^{A}	0.30	1.23^{A}	0.14
	♂	1.00^{*A}	0.08	1.87^{AB}	0.21	1.17^{B}	0.11
	♀+♂	0.95^{A}	0.07	1.74^{A}	0.28	1.20^{A}	0.12

Significant differences between means for males and females within each giblet group are marked with asterisks – $*P \leq 0.05$; $**P \leq 0.01$.

$^{aA...}$Means for males, females, and their total mean within each giblet group bearing the same superscripts differ significantly at: small letters $P \leq 0.05$; capitals – $P \leq 0.01$.

authors was higher than in our analysis, ranging between 75.38 and 76.68% [Demirbaş 1999, Pereira *et al*. 2002, Shang *et al*. 2005, Jokanović *et al*. 2014]. Zouari *et al*. [2011] reported a 72.3% water content in turkey liver, which was most similar to our results measured on emus.

All giblets were characterised by similar protein (18.73% on average) and fat contents (2.02% on average). Jokanović *et al*. [2014] and Seong *et al*. [2015] reported that chicken livers and gizzards contain 15.70-17.70 and 13.60-7.26% protein, respectively. The lowest fat content in chicken giblets – as in our studies – was found in gizzards (0.81-1.50%), whereas liver fat content fell within the range of 2.89-4.10%. According to Zouari *et al*. [2011], turkey liver contains much protein (21.90%), with a fat content around 2.9%. It is possible that the low fat content found in the studied emu giblets, as compared to other poultry species, is due to the open system of housing; the birds were allowed to move freely within a large pen, hence no excessive fat deposition accumulated in their internal organs.

Except for ash content in the gizzards, there were no sex-related differences in the proximate composition of emu organs. The highest ash content was found in livers (1.74%), followed by hearts (1.20%) and gizzards (0.95%). Pereira *et al*. [2002] and Jokanović *et al*. [2014], who studied chicken giblets, reported a similar order; however, ash content in the emu organs was higher. Nevertheless, two-way ANOVA failed to show an effect of sex, type of giblets or sex × type of giblets interaction on the total proximate composition of the emu giblets.

The contents of minerals in animal tissues depend on many factors, including breed, age, sex, physiological status, management and feeding systems [Połtowicz and Doktor 2013].

The main macroelement in terms of its tissue content (Tab. 2) was potassium. Its levels ranged from 3284.66 mg/kg (heart) to 3728.49 mg/kg (gizzard). The other elements may be ranked as follows in relation to their content: P>Na>Mg>Ca. The richest potassium source was the liver (2964.25 mg/kg), while for magnesium it was the heart (220.87 mg/kg). The levels of sodium and calcium were similar in all the offal meats, at 785.18 and 49.61 mg/kg, respectively. Hearts and gizzards had significantly higher contents of sodium. In relation to the total microelements in the giblets, these results did not imply any significant differences.

Demirbaş [1999] and Jokanović *et al*. [2014] found a similar rank of major elements in chicken offal meats, whereas Jokanović *et al*. [2014] found the highest K concentration in the liver (2676 mg/kg) and the lowest in gizzards (1947 mg/kg). The same study also showed lower concentrations of K and P in all giblets and Na in the gizzard, as well as higher concentrations of other macronutrients compared to our research. Majewska *et al*. [2015] found higher concentrations of P and K in livers of ostriches, turkeys and chicken broilers, while the other macronutrients were ranked in the same way. On the other hand, Zouari *et al*. [2011] reported lower concentrations of K (1390 mg/kg) and Mg (23 mg/kg) in turkey livers, with the other major elements recorded at higher concentrations.

Table 2. Macromineral contents in emu giblets (means with their standard deviations)

Macromineral (mg/kg fresh weight)	Sex	Giblets					
		gizzard		liver		heart	
		mean	SD	mean	SD	mean	SD
P	♀	1248.72^{A}	53.13	2888.00^{A}	155.45	1981.61^{A}	90.45
	♂	1279.77^{A}	60.80	3065.91^{A}	226.98	2009.85^{A}	115.15
	♀+♂	1262.03^{A}	56.53	2964.25^{A}	202.92	1993.71^{A}	98.57
K	♀	3739.84^{AB}	245.02	3339.20^{A}	197.83	3277.65^{B}	137.19
	♂	3713.37^{Aa}	242.08	3429.47^{a}	196.00	3294.01^{A}	95.72
	♀+♂	3728.49^{AB}	234.63	3377.89^{A}	194.83	3284.66^{B}	117.17
Na	♀	781.17*	47.10	762.19	118.52	773.57*	39.51
	♂	845.00^{*A}	45.10	705.81^{AB}	82.00	856.24^{*B}	58.92
	♀+♂	808.53	55.24	738.03	104.83	809.00	63.07
Mg	♀	158.63^{A}	4.07	197.60^{A}	15.60	220.47^{A}	7.95
	♂	154.04^{AB}	3.32	211.65^{A}	9.05	221.42^{B}	13.71
	♀+♂	156.66^{A}	4.33	203.62^{A}	14.65	220.87^{A}	10.32
Ca	♀	48.52	4.95	52.38	5.89	47.92	2.93
	♂	51.93	8.35	49.01	6.34	47.88	1.97
	♀+♂	49.98	6.56	50.93	6.09	47.91	2.47

Significant differences between means for males and females within each giblet group are marked with asterisks – *P≤0.05; **P≤0.01.

$^{aA...}$Means for males, females, and their total mean within each giblet group bearing the same superscripts differ significantly at: small letters P≤0.05; capitals – P≤0.01.

In terms of microelements (Tab. 3) we found a significant effect of sex on the contents of selenium, manganese, barium and chromium in gizzards, and zinc and barium in hearts. However, ANOVA showed only an effect of type of giblets on total microelement contents.

Iron is an important micronutrient that ensures the normal functioning of blood cells and its deficiency leads to anaemia, especially in pregnant women and children [Seong *et al*. 2015]. The mean iron level in the liver (2880.86 mg/kg) is more than 48 times higher than in hearts (58.73 mg/kg) and as much as 243 times higher than in gizzards (11.83 mg/kg). Ghimpeteanu *et al*. [2012] found 41.8-109.6 mg/kg of iron in the livers of 40-day broilers. A higher Fe concentration (418.7 mg/kg) was found in the liver of 35-day broilers [El-Husseiny *et al*. 2012]. In turkeys, liver Fe ranged from 106.5 mg/kg [Makarski and Gortat 2011] to 161 mg/kg [Zouari *et al*. 2011]. Majewska *et al*. [2015] when analysing the livers of broiler chickens, turkeys and ostriches, noted the highest content of this element in the liver of ostriches, 947.85 mg/kg, which shows that this concentration in emu livers was three times greater. Such a high iron level means that emu liver may be one of the richest dietary sources of this micronutrient. What is more, the heme iron in animal products such as organ meats is characterised by many times higher absorption rates to the intestinal lumen as compared to the non-heme iron present in other food products [Simpson and McKie 2009].

Other elements of dietary importance are also zinc and copper. Their highest concentrations were found in livers (41.45 and 4.37 mg/kg) and the lowest in gizzards (31.40 and 0.58 mg/kg). A similar pattern was found by Jokanović *et al*. [2014]. It should be stressed, however, that emu giblets were higher in zinc and lower in

Table 3. Micromineral contents in emu giblets (means with their standard deviations)

Micromineral (mg/kg fresh weight)	Sex	Giblets					
		gizzard		liver		heart	
		mean	SD	mean	SD	mean	SD
Fe	♀	11.08^{A}	1.79	2523.50^{AB}	1025.31	58.79^{B}	3.90
	♂	12.86^{A}	3.71	3357.34^{AB}	979.68	60.98^{B}	8.23
	♀+♂	11.84^{A}	2.80	2880.86^{AB}	1057.63	59.73^{B}	5.96
Zn	♀	32.41^{A}	2.29	43.75^{AB}	9.12	33.12**^{B}	1.77
	♂	30.06^{Aa}	1.61	38.39^{A}	6.04	36.51**^{a}	1.37
	♀+♂	31.40^{A}	2.30	41.45^{AB}	8.15	34.58^{B}	2.33
Si	♀	34.33^{A}	4.39	83.48^{AB}	23.60	30.30^{B}	2.81
	♂	34.72^{A}	10.01	90.43^{AB}	37.52	30.17^{B}	4.15
	♀+♂	34.53^{A}	6.99	86.46^{AB}	29.23	30.24^{B}	3.30
Cu	♀	0.59^{AB}	0.05	4.26^{A}	0.82	3.81^{B}	0.22
	♂	0.57^{AB}	0.05	4.51^{A}	0.49	3.95^{B}	0.52
	♀+♂	0.58^{AB}	0.05	4.37^{Aa} (	0.69	3.87^{Ba}	0.37
Mn	♀	0.013*^{Aa}	0.003	0.096^{AB}	0.024	0.033^{Ba}	0.002
	♂	0.019*^{A}	0.006	0.111^{AB}	0.026	0.034^{B}	0.008
	♀+♂	0.016^{Aa}	0.005	0.102^{AB}	0.025	0.033^{Ba}	0.005
Ba	♀	0.019*^{A}	0.005	0.117^{AB}	0.065	0.008*^{B}	0.001
	♂	0.033*^{A}	0.017	0.156^{AB}	0.045	0.016*^{B}	0.008
	♀+♂	0.025^{A}	0.013	0.134^{AB}	0.059	0.012^{B}	0.006
Cr	♀	0.029*^{A}	0.007	0.056^{AB}	0.016	0.020^{B}	0.002
	♂	0.021*^{A}	0.005	0.071^{AB}	0.014	0.020^{B}	0.003
	♀+♂	0.025^{A}	0.007	0.062^{AB}	0.017	0.020^{B}	0.002
Sr	♀	0.035^{A}	0.010	0.034^{B}	0.010	0.019^{AB}	0.003
	♂	0.045^{A}	0.016	0.034	0.013	0.019^{A}	0.004
	♀+♂	0.039^{A}	0.013	0.034^{B}	0.011	0.019^{AB}	0.003
Pb	♀	0.034^{A}	0.005	0.161^{AB}	0.079	0.042^{B}	0.009
	♂	0.039^{A}	0.009	0.246^{AB}	0.074	0.036^{B}	0.006
	♀+♂	0.036^{A}	0.007	0.198^{AB}	0.086	0.039^{B}	0.008
Se	♀	0.014**^{A}	0.001	0.048^{AB}	0.011	0.014^{B}	0.005
	♂	0.009**^{A}	0.004	0.039^{AB}	0.016	0.013^{B}	0.006
	♀+♂	0.012^{A}	0.004	0.044^{AB}	0.014	0.014^{B}	0.005
Cd	♀	0.024^{A}	0.007	0.082^{AB}	0.034	0.005^{B}	0.001
	♂	0.021	0.006	0.049^{A}	0.033	0.005^{B}	0.003
	♀+♂	0.023^{A}	0.007	0.067^{AB}	0.03	0.005^{B}	0.002

Significant differences between means for males and females within each giblet group are marked with asterisks – *P≤0.05; **P≤0.01.

$^{aA\cdots}$Means for males, females, and their total mean within each giblet group bearing the same superscripts differ significantly at: small letters P≤0.05; capitals – P≤0.01.

copper compared to chicken offal [Uluozlu *et al*. 2009]. Zinc levels in ostrich livers were by 6.05 mg/kg higher compared to our data [Majewska *et al*. 2015]. Silicon content in the liver (86.46 mg/kg) was three times greater than in gizzards (34.53 mg/kg) and heart (30.24 mg/kg), but also higher compared to the livers of other poultry species [Majewska *et al*. 2015]. The concentrations of other microelements were also highest in the liver, except for strontium. Uluozlu *et al*. [2009], who studied trace elements in chicken tissues, observed the highest Se and Mn concentrations in the liver, which were greater compared to the results we measured by 0.87 and 2.40 mg/kg, respectively. The authors found the highest levels of chromium in the gizzard

(0.05 mg/kg). As compared to our results, chromium concentrations in the hearts of chickens were higher (0.03 mg/kg), but lower in livers where its level was highest (0.06 mg/kg). Majewska *et al*. [2015] found the highest concentration of chromium in ostrich livers (0.01 mg/kg), which suggests that emu liver is a good source of this trace element compared to ostrich liver.

Heavy metal absorption from the gastrointestinal tract is rapid, they pass easily through the biological barriers and are characterised by a high rate of accumulation. According to the regulations of the European Commission, the maximum level of heavy metal contamination in organ meats is 0.5 mg/kg for both cadmium (Commission Regulation (EU) No. 488/2014) and lead (Commission Regulation (EU) 2015/1005). In our study, these two elements did not exceed their acceptable levels. The highest concentrations of lead and cadmium at approx. 0.20 and 0.07 mg/kg, respectively, were measured in the liver. The relatively high concentrations of these elements may be due to the fact that the birds were kept in an open-air housing system and were slaughtered at an old age. It is known that absorption and accumulation of cadmium depends on many factors, including sex and age [Demirbaş 1999; Niedziółka *et al*. 2010]. In our study, however, there was no effect of sex; as far as the age is concerned, comparative studies should be carried out on conventional emu slaughtered at the age of about 12-14 months.

The highest cholesterol level was found in the liver (547.83 mg/100 g), whereas steroid levels in the gizzard and heart were lower by 214.99 and 388.23 mg/kg, respectively (Tab. 4). Two-way ANOVA also revealed only an effect of giblet type. Cholesterol levels in the studied giblets were similar in both sexes. Comparing the results with those by Majewska *et al*. [2016], one may conclude that emu giblets are most similar to broiler livers in terms of cholesterol concentration (563.10 mg/100 g) and contain more cholesterol than ostrich (429.59 mg/100 g) or turkey livers (329.33 mg/100 g). On the other hand, Ouf *et al*. [2012] recorded even higher concentrations of cholesterol in chicken and turkey giblets at 641 and 566 mg/100 g, respectively.

Cholesterol is essential for the proper functioning of the body. It is an important component of steroids, vitamins and bile acids. However, a high intake of cholesterol is also associated with an increased risk of cardiovascular diseases such as ischemic heart disease, hypertension and diabetes [Kratz 2005]. Since high cholesterol content found in animal internal organs [Ockerman and Basu 2004] raises consumer concerns, giblets should be consumed in reasonable quantities.

The fatty acid composition of the product has a strong effect on its quality. It determines the firmness/oiliness of the adipose tissue and oxidative stability of muscles, which in turn affects the taste, smell and color [Wood *et al*. 2008].

Saturated fatty acids (SFAs) represented on average nearly 39% of the total fatty acid quantity (Tab. 4). Its highest content was found in the liver (42.38%). The giblets contained similar quantities of MUFAs and PUFAs. The highest concentration of MUFAs was found in the gizzard (33.68%), while that of PUFAs in the heart (33.82%).

Table 4. Fatty acid profile and cholesterol levels in emu giblets (means with their standard deviations)

Item	Sex	Giblets					
		gizzard		liver		heart	
		mean	SD	mean	SD	mean	SD
Cholesterol	♀	339.76^{A}	27.52	539.47^{A}	28.29	158.25^{A}	15.36
(mg/100 g	♂	323.63^{A}	29.95	558.98^{A}	21.32	161.40^{A}	8.78
fresh weight)	♀+♂	332.84^{A}	28.66	547.83^{A}	26.57	159.60^{A}	12.62
	♀	39.76	3.77	42.37^{a}	2.85	38.12^{a}	3.34
SFA (%)	♂	37.13^{a}	3.57	42.39^{Aa}	1.48	37.02^{A}	2.60
	♀+♂	38.64^{A}	3.79	42.38^{AB}	2.28	37.65^{B}	2.99
	♀	33.29	8.80	28.39	2.69	28.44	5.34
MUFA (%)	♂	34.19^{a}	6.23	27.02^{a}	2.98	28.65	2.95
	♀+♂	33.68^{ab}	7.54	27.80^{a}	2.79	28.53^{b}	4.33
	♀	26.94	7.50	29.24	4.21	33.43	8.18
PUFA (%)	♂	28.68	5.17	30.59	2.60	34.32	4.40
	♀+♂	27.68^{a}	6.43	29.82	3.55	33.82^{a}	6.61
	♀	1.59^{A}	0.66	5.00^{AB}	1.02	1.13^{B}	0.27
n3 (%)	♂	1.10^{A}	0.61	4.22^{AB}	1.10	1.21^{B}	0.40
	♀+♂	1.38^{A}	0.67	4.66^{AB}	1.09	1.16^{B}	0.32
	♀	25.35	6.97	24.24	3.73	32.30	8.24
n6 (%)	♂	27.56	4.80	26.37^{a}	2.30	33.10^{a}	4.70
	♀+♂	26.30^{a}	6.03	25.15^{A}	25.15^{A}	32.65^{Aa}	6.72

Significant differences between means for males and females within each giblet group are marked with asterisks – *P≤0.05; **P≤0.01.

$^{aA\cdots}$Means for males, females, and their total mean within each giblet group bearing the same superscripts differ significantly at: small letters P≤0.05; capitals – P≤0.01.

SFA - ∑ (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 - ∑ (C14:1, C15:1, C16:1, C17:1, C18:1n9t, C18:1n9c, C20:1, C22:1n9, C24:1); PUFA - ∑ (C18:2n6c, C22:2, C18:3n3, C20:3n3, C20:3n6, C20:4n6, C20:5n3, C22:6n3); UFA - ∑ (MUFA, PUFA); n3 - ∑ (C18:3n3, C20:3n3,C20:5n3, C22:6n3); n6 - ∑ (C18:2n6c, C20:3n6, C20:4n6).

The study by Wang *et al*. [2000] demonstrated a lower proportion of SFAs in the liver and the heart of emus, by 5.88 and 5.47 pp respectively, compared to those in the present study. Higher percentages of MUFAs and lower of PUFAs were found in the liver, by 10.05 and 4.65 pp, respectively. In the heart, on the other hand, the fraction was lower for MUFAs, by 2.13 pp, and higher for PUFAs, by 1.79 pp. The authors, however, failed to provide information on the age and sex of the emu, which tissues were analysed.

In the case of chicken offal, the highest content of SFAs as in the present study was found in the liver (43.96%), followed by gizzard (39.44%) and heart (36.01%). However, higher MUFA (36.82%) than PUFA contents (27.17%), as compared to our results, were found in the heart [Seong *et al*. 2015]. Similar results on the liver were observed in broiler chickens [Dalkilic *et al*. 2009, Majewska *et al*. 2016], as well as in laying hens [Shang *et al*. 2005]. Inverse proportions in chicken livers were noted by Kartikasari *et al*. [2012], in which MUFA content was 20.2%, and PUFA – 32.8%.

Majewska *et al*. [2016] obtained a higher proportion of SFAs in ostrich liver (58%) and lower of MUFAs and PUFAs, by respectively 3.41 and 12.16 pp. Similar results were obtained for ostriches by Poławska *et al*. [2016], but the share of MUFA (37.3%) was higher by as much as 9.50 pp as compared to this study.

In goose liver Zhang *et al*. [2008] found that MUFAs represented the highest share of FAs (45.54%), which were followed by SFAs (30.86%) and PUFAs (19.17%). The distribution of fatty acids in liver turkey, according to Zouari *et al*. [2011] and Majewska *et al*. [2016], was different: the highest share was that of SFAs (42.5-49.23%), followed by PUFAs (27.41-32.6%) and MUFAs (14.6-23.36%).

Similarly as a majority of animal production traits, fatty acid profiles depend on both genetic and environmental factors. The level of body fatness is also important in terms of the fatty acid profile. The amount of saturated and monounsaturated fatty acids increases with an increase in body fat much more rapidly than the content of polyunsaturated fatty acids, which leads to a reduction in their relative contents [de Smet *et al*. 2004].

Comparing the content of PUFAs in other poultry species, one may observe that emu offal meats are rich sources of polyunsaturated fatty acids, hence their pro-health properties. The beneficial effects of these fatty acids on human health have been well documented in the literature [Czapski *et al*. 2016, Deacon *et al*. 2017].

Not only is the high PUFA content important in the food item, but the appropriate ratio of n-6 to n-3 fatty acids is also a key factor in terms of product quality. In our study the best ratio of these FAs was found in the liver, at approx. 5:1. Human nutrition specialists recommend the n-6 to n-3 ratio in the diet to remain within the range of 1:1 to 5:1 [Wijendran *et al*. 2004, Gebauer *et al*. 2006]. In hearts and gizzards this ratio was 19:1 and 28:1, respectively (Tab. 4). Similar results in emu liver were found by Wang *et al*. [2000], whereas in hearts their ratio (13:1) was more positive compared to our findings (28:1). In chickens the best n-6 to n-3 ratio was observed in the liver (12:1); however, the ratio both in chicken liver and in other chicken giblets was less advantageous [Seong *et al*. 2015] compared to what we found in the emu offal meats. Dalkilic *et al*. [2009] and Aziza *et al*. [2010] reported similar data on broiler chicken liver. Majewska *et al*. [2016] report, however, that the ratio may still be higher in chicken liver (21:1) and particularly in turkey liver (25:1). Ostrich liver seems to be the most similar to that of emu, since depending on the author the n-6 to n-3 ratio ranges from 5:1 to 8:1 [Majewska *et al*. 2016; Poławska *et al*. 2016].

No effect of sex has been found in terms of the fatty acid profile in the analysed tissues, except for a higher content of pentadecanoic acid (C15:1) in the hearts of females. In males, on the other hand, a higher level of stearic acid (C18:0) was found in the heart, as well as docosahexaenoic acid (C22:6n3) in the gizzard and liver (Tab. 5). However, two-way ANOVA for total fatty acids showed no effect of sex, giblet or the sex × giblet interaction.

Among the SFAs, most abundant were palmitic acid (C16:0) and stearic acid (C18:0). Other SFAs represented about 1% of the total fatty acid composition. The highest amount of C16:0 was observed in livers and hearts. Stearic acid is most abundant in the liver (19.58%) and gizzard (18.28%), whereas hearts contained 14.71%

Table 5. Contents of selected fatty acids in emu giblets (means with their standard deviations)

Fatty acid (%)	Sex	Giblets: gizzard mean	gizzard SD	liver mean	liver SD	heart mean	heart SD
C14:0	♀	0.08^{a}	0.03	0.13	0.06	0.19^{a}	0.11
	♂	0.07^{A}	0.03	0.13	0.04	0.20^{A}	0.11
	♀+♂	0.07^{A}	0.03	0.13^{a}	0.05	0.20^{Aa}	0.11
C16:0	♀	20.73	3.07	22.41	3.38	22.41	2.89
	♂	18.87^{aB}	2.68	22.31^{a}	1.38	22.62^{b}	2.58
	♀+♂	19.93^{a}	2.96	22.37	2.62	22.50^{a}	2.66
C17:0	♀	0.04^{A}	0.03	0.05^{B}	0.03	0.12^{AB}	0.03
	♂	0.04	0.02	0.06	0.02	0.14	0.16
	♀+♂	0.04^{A}	0.02	0.05^{B}	0.03	0.13^{AB}	0.10
C18:0	♀	18.64^{a}	3.41	19.52^{A}	1.22	15.30^{*Aa}	1.12
	♂	17.81^{A}	2.50	19.67^{B}	0.96	13.93^{*AB}	0.28
	♀+♂	18.28^{A}	2.97	19.58^{B}	1.08	14.71^{AB}	1.10
C20:0	♀	0.16^{AB}	0.11	0.03^{A}	0.02	0.02^{B}	0.01
	♂	0.19^{AB}	0.11	0.03^{A}	0.01	0.03^{B}	0.02
	♀+♂	0.17^{AB}	0.11	0.03^{A}	0.02	0.02^{B}	0.01
C22:0	♀	0.04^{A}	0.02	0.11^{AB}	0.06	0.014^{B}	0.003
	♂	0.05^{a}	0.03	0.09^{Aa}	0.03	0.017^{A}	0.009
	♀+♂	0.04^{A}	0.03	0.10^{AB}	0.05	0.015^{B}	0.006
C15:1	♀	0.12^{A}	0.08	0.003^{AB}	0.003	0.16^{*B}	0.04
	♂	0.10^{a}	0.06	0.003^{b}	0.001	0.72^{*ab}	0.64
	♀+♂	0.11^{a}	0.07	0.003^{A}	0.002	0.40^{Aa}	0.49
C16:1	♀	1.88	1.19	2.92	1.16	2.82	1.43
	♂	1.39^{a}	0.72	2.70	0.86	2.85^{a}	1.16
	♀+♂	1.67^{ab}	1.01	2.83^{a}	1.01	2.83^{b}	1.27
C18:1n9t	♀	3.51	0.72	3.08^{A}	0.64	4.27^{A}	0.59
	♂	3.59^{a}	0.45	3.40^{A}	0.38	4.27^{Aa}	0.29
	♀+♂	3.55^{A}	0.60	3.22^{B}	0.55	4.27^{AB}	0.47
C18:1n9c	♀	27.46^{a}	7.48	22.12	1.77	20.91^{a}	3.57
	♂	28.73^{AB}	5.80	$20,67^{A}$	2.22	20.56^{B}	2.16
	♀+♂	28.00^{AB}	6.60	21.50^{A}	2.03	20.76^{B}	2.95
C20:1	♀	0.12	0.11	0.09	0.02	0.20	0.15
	♂	0.16	0.11	0.08	0.02	0.15	0.08
	♀+♂	0.14	0.10	0.09^{a}	0.02	0.18^{a}	0.12
C22:ln9	♀	0.03^{A}	0.01	0.02	0.01	0.014^{A}	0.004
	♂	0.04^{a}	0.02	0.02	0.01	0.012^{a}	0.008
	♀+♂	0.03^{Aa}	0.02	0.02^{a}	0.01	0.013^{A}	0.006
C24:1	♀	0.16^{a}	0.09	0.14^{b}	0.12	0.02^{ab}	0.01
	♂	0.18^{A}	0.09	0.12^{a}	0.06	0.02^{Aa}	0.01
	♀+♂	0.17^{A}	0.09	0.13^{B}	0.10	0.02^{AB}	0.01
C18:2n6c	♀	10.50^{A}	1.83	8.95^{B}	1.39	15.17^{AB}	2.62
	♂	11.58^{A}	2.06	10.55^{B}	1.66	15.55^{AB}	1.32
	♀+♂	10.96^{A}	1.93	9.64^{B}	1.67	15.33^{AB}	2.10
C18:3n3	♀	0.40^{A}	0.11	0.93^{Aa}	0.29	0.61^{a}	0.21
	♂	0.46^{a}	0.30	1.37^{ab}	0.71	0.64^{b}	0.31
	♀+♂	0.42^{A}	0.21	1.12^{AB}	0.54	0.62^{B}	0.25
C20:3n3	♀	0.20	0.12	0.27	0.12	0.16	0.06
	♂	0.16	0.07	0.24	0.06	0.16	0.06
	♀+♂	0.18	0.10	0.26^{A}	0.10	0.16^{A}	0.06
C20:3n6	♀	0.11	0.06	0.13	0.10	0.12	0.06
	♂	0.13	0.06	0.22^{a}	0.09	0.11^{a}	0.05
	♀+♂	0.12	0.06	0.17	0.10	0.12	0.05
C20:4n6	♀	14.73	6.67	15.15	2.49	17.02	5.90
	♂	15.85	5.81	15.60	1.25	17.43	3.57
	♀+♂	15.21	6.10	15.34	1.99	17.20	4.87
C20:5n3	♀	0.15^{A}	0.08	1.30^{AB}	0.82	0.25^{B}	0.17
	♂	0.11^{A}	0.11	1.50^{AB}	0.69	0.36^{B}	0.23
	♀+♂	0.13^{A}	0.09	1.39^{AB}	0.74	0.29^{B}	0.20
C22:6n3	♀	0.84^{*A}	0.46	2.49^{*AB}	0.90	0.11^{B}	0.07
	♂	0.37^{*a}	0.19	1.10^{*Aa}	0.62	0.06^{A}	0.04
	♀+♂	0.64^{A}	0.43	1.90^{AB}	1.04	0.09^{B}	0.06

Significant differences between means for males and females within each giblet group are marked with asterisks – $^{*}P \leq 0.05$; $^{**}P \leq 0.01$.

$^{aA...}$Means for males, females, and their total mean within each giblet group bearing the same superscripts differ significantly at: small letters $P \leq 0.05$; capitals – $P \leq 0.01$.

of stearic acid in relation to the total fatty acids. A similar pattern in emu organ meats was reported by Wang *et al*. [2000], although the content of the acids was slightly lower.

In the case of chicken giblets gizzards contain the highest amount of C16:0 (27.72%), i.e. differing by 7.79 pp from emu gizzards. Other organs had only a slightly higher percentage of C16:0. The level of C18:0 in the liver, on the other hand, was similar, although lower than in gizzards or hearts, differing by 7.65 and 3.75 pp, respectively [Seong *et al*. 2015]. Other studies on broiler chicken livers suggest that C16:0 represents 18.62-29.25% of all FAs [Aziza *et al*. 2010, Majewska *et al*. 2016], whereas the value in laying hens is on average 22% [Kang *et al*. 2001; Shang *et al*. 2005]. In other poultry species the proportion is as follows: turkeys 20.0-36.59% [Zouari *et al*. 2011, Majewska *et al*. 2016], geese 22.82% [Zhang *et al*. 2008] and ostrich 34.0-46.40% [Majewska *et al*. 2016, Poławska *et al*. 2016] of the total FA content. In relation to C18:0 its content is usually much lower than C16:0 and represents the following values in various species: broiler chickens 15.97-20.84% [Aziza *et al*. 2010, Seong *et al*. 2015, Majewska *et al*. 2016], laying hens 13.0-24.44% [Kang *et al*. 2001, Shang *et al*. 2005], turkeys 12.27-22.50% [Zouari *et al*. 2011, Majewska *et al*. 2016], geese 5.64% [Zhang *et al*. 2008] and ostrich 9.27-10.76% [Majewska *et al*. 2016, Poławska *et al*. 2016] of the total FA content.

The main monounsaturated fatty acids were oleic (C18:1n9c), elaidic (C18:1n9t) and palmitoleic acids (C16:1), whereas the major polyunsaturated fatty acids present in largest quantities were arachidonic (C20:4n6) and linolenic (C18:2n6c) acids (Tab. 5).

Oleic acid is the predominant MUFA in the livers of different poultry species, with its share in the lipid fraction ranging from 13.15 to 42.40% [Kang *et al*. 2001, Shang *et al*. 2005, Zhang *et al*. 2008, Zouari *et al*. 2011, Aziza *et al*. 2010, Kartikasari *et al*. 2012, Seong *et al*. 2015, Majewska *et al*. 2016, Poławska *et al*. 2016]. Wang *et al*. [2000] found a much higher level of oleic acid in emu livers. In our study the highest level of this particular acid was found in gizzards, while it was lowest in hearts. In contrast, the highest proportion of this acid was found in hearts [Seong *et al*. 2015].

Wang *et al*. [2000] also reported the highest PUFA contents in the heart of emu, although linoleic acid (17.39%) was more abundant than arachidonic acid (15.11%) in the cited study. In the liver, on the other hand, the arachidonic acid fraction was lower by 5.66 pp. However, a similar pattern was observed in chickens, in which the proportion of arachidonic acid in the heart was much lower (5.4%) [Seong *et al*. 2015]. The livers of other poultry species also contained a higher fraction of linoleic acid compared to arachidonic acid [Zhang *et al*. 2008, Zouari *et al*. 2011, Majewska *et al*. 2016, Poławska *et al*. 2016]. This suggests that emu organ meats are characterised by a very high content of arachidonic acid in relation to other species of poultry. Research on the role of this acid reveals that its deficiency may interfere with reproduction in humans and other mammals [Pawlosky and Salem 1996, Morris 2004].

The results revealed high nutritional and dietary values of emu offal meats. The liver, however, is the most noteworthy organ. This organ, similarly as the heart and the gizzard, was characterised by a high content of polyunsaturated fatty acids and the best n-6 to n-3 ratio. Emu livers are also rich in micronutrients, particularly iron, hence this product may represent one of the richest dietary sources of this element.

Minor differences were found between sexes in terms of the proximate composition, nutrient and micronutrient levels and fatty acid profiles of emu hearts, gizzards and liver. Two-way ANOVA with interaction, however, reveal no significant effects of the sex or sex × giblet type interaction, which suggests that the giblets harvested both from males and females constitute a valuable animal product.

REFERENCES

1. AOAC, 2007 – Official methods of analysis of AOAC International. 18th edition, Association of Official Analytical Chemists, Arlington, USA.
2. AZIZA A.E., QUEZADA N., CHERIAN G., 2010 – Feeding Camelina sativa meal to meat-type chickens: Effect on production performance and tissue fatty acid composition. ***The Journal of Applied Poultry Research*** 19, 157-168.
3. COMMISSION REGULATION (EU) NO. 488/2014 of 12 May 2014 amending Regulation (EC) No. 1881/2006 as regards maximum levels of cadmium in foodstuffs (2014). URL http://data.europa.eu/eli/reg/2014/488/oj. Accessed 11.01.17.
4. COMMISSION REGULATION (EU) 2015/1005 of 25 June 2015 amending Regulation (EC) No. 1881/2006 as regards maximum levels of lead in certain foodstuffs (2015). URL http://data.europa.eu/eli/reg/2015/1005/oj. Accessed 11.01.17.
5. COOPER R.G., TOMASIK C., HORBAŃCZUK J.O., 2007 – Avian Influenza in Ostriches (Struthio camelus). ***Avian and Poultry Biology Reviews*** 18,3, 87-92.
6. CZAPSKI G.A., CZUBOWICZ K., STROSZNAJDER J.B., STROSZNAJDER R.P., 2016 – The lipoxygenases: their regulation and implication in Alzheimer's disease. ***Neurochemical Research*** 41, 243-257.
7. DALKILIC B., CIFTCI M., GULER T., CERCI I.H., ERTAS O.N., GUVENC M., 2009 – Influence of dietary cinnamon oil supplementation on fatty acid composition of liver and abdominal fat in broiler chicken. ***Journal of Applied Animal Research*** 35, 173-176.
8. DEACON G., KETTLE CH., HAYES D., DENNIS CH., TUCCI J., 2017 – Omega 3 polyunsaturated fatty acids and the treatment of depression. ***Critical Reviews in Food Science and Nutrition*** 57, 212-223.
9. DEMIRBAŞ A., 1999 – Proximate and heavy metal composition in chicken meat and tissues. ***Food Chemistry*** 67, 27-31.
10. DEVATKAL S., MENDIRATTA S.K., KONDAIAH N., SHARMA M.C., ANJANEYULU A.S.R., 2004 – Physicochemical, functional and microbiological quality of buffalo liver. ***Meat Science*** 68, 79-86.
11. DE SMET S., RAES K., DEMEYER D., 2004 – Meat fatty acid composition as affected by fatness and genetic factors: a review. ***Animal Research*** 53, 81-98.
12. EL-HUSSEINY O.M., HASHISH S.M., ALI R.A., ARAFA S.A., ABD EL-SAMEE L.D., OLEMY A.A., 2012 – Effects of feeding organic zinc, manganese and copper on broiler growth, carcass characteristics, bone quality and mineral content in bone, liver and excreta. ***International Journal of Poultry Science*** 11, 368-377.
13. GEBAUER S.K., PSOTA T.L., HARRIS W.S., KRIS-ETHERTON P.M., 2006 – n-3 fatty acid dietary recommendations and food sources to achieve essentiality and cardiovascular benefits. ***The American Journal of Clinical Nutrition*** 83, 1526-1535.
14. GHIMPETEANU O.M., DAS K., MILITARU M., SCIPPO M.L., 2012 – Assessment of heavy metals and mineral nutrients in poultry liver using inductively coupled plasma-mass spectrometer

(ICP-MS) and direct mercury analyzer (DMA). Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. ***Veterinary Medicine*** 69, 258-266.

15. HORBAŃCZUK J.O., KAWKA M., SACHARCZUK M, COOPER R.G., BORUSZEWSKA K., PARADA P., JASZCZAK K., 2007 – A search for sequence similarity between chicken (*Gallus domesticus*) and ostrich (*Struthio camelus*) microsatellite markers. ***Animal Science Papers and Reports*** 25, 283-288.
16. HORBAŃCZUK J., SALES J., CELEDA T., KONECKA A., ZIĘBA G., KAWKA P., 1998 Cholesterol Content and Fatty Acid Composition of Ostrich Meat as Influence by Subspecies. ***Meat Science*** 50, 385-388.
17. HORBAŃCZUK J.O., TOMASIK C., COOPER R.G., 2008 - Ostrich farming in Poland - its history and current situation after accession to the European Union. ***Avian Poultry and Biology Reviews*** 1, 65-71.
18. HORBAŃCZUK O.K., WIERZBICKA A., 2016 – Technological and nutritional properties of ostrich, emu, and rhea meat quality. ***Journal of Veterinary Research*** 60, 279-286.
19. HORBAŃCZUK O.K., WIERZBICKA A., 2017 – Effects of Packaging Solutions on Shelf-Life of Ratite Meats, J***ournal of Veterinary of Research*** 61, 279-285.
20. JEENGAR M.K., KUMAR P.S., THUMMURI D., SHRIVASTAVA S., GUNTUKU L., SISTLA R., NAIDU V.G., 2015 – Review on emu products for use as complementary and alternative medicine. ***Nutrition*** 31, 21-27.
21. JOKANOVIĆ M.R., TOMOVIĆ V.M., JOVIĆ M.T., ŠKALJAC S.B., ŠOJIĆ B.V., IKONIĆ P.M., TASIĆ T. A., 2014 – Proximate and Mineral Composition of Chicken Giblets from Vojvodina (Northern Serbia). ***International Journal of Biological, Food, Veterinary and Agricultural Engineering*** 8, 943-946.
22. KANG K.R., CHERIAN G., SIM J.S., 2001 – Dietary palm oil alters the lipid stability of polyunsaturated fatty acid - modified poultry products. ***Poultry Science*** 80, 228-234.
23. KARTIKASARI L.R., HUGHES R.J., GEIER M.S., MAKRIDES M., GIBSON R.A., 2012 – Dietary alpha-linolenic acid enhances omega-3 long chain polyunsaturated fatty acid levels in chicken tissues. ***Prostaglandins, Leukotrienes and Essential Fatty Acids*** 87, 103-109.
24. KRATZ M., 2005 – Dietary cholesterol, atherosclerosis and coronary heart disease. ***Handbook of Experimental Pharmacology*** 170, 195-213.
25. Makarski B., Gortat M., 2011 – Effect of supplementation with copper in different chemical forms on selected physiological blood markers and content of minerals in selected tissues of turkeys. ***Journal of Elementology*** 4, 591-602.
26. MAJEWSKA D., SZCZERBIŃSKA D., LIGOCKI M., BUCŁAW M., SAMMEL A., TARASEWICZ Z., ROMANISZYN K., MAJEWSKI, J., 2015 – Comparison of mineral and fatty acid profiles of ostrich, turkey and broiler chicken liver. ***British Poultry Science*** 57, 193-200.
27. MORRIS J.G., 2004 – Do cats need arachidonic acid in diet for reproduction? ***The American Journal of Clinical Nutrition*** 88, 131-137.
28. NIEDZIÓŁKA R., PIENIAK-LENDZION K., HOROSZEWICZ E., 2010. Content of chemical elements in muscular tissue and liver of male kids and ram lambs in central-eastern Poland. ***Journal of Elementology*** 15, 573-579.
29. OCKERMAN H.W., BASU L., 2004 – By-products. In: W. K. Jensen, C. Devine, & M. Dikeman (Eds.), ***Encyclopedia of meat sciences*** (pp. 104-112). Amsterdam, London: Elsevier Academic Press.
30. OUF S.A., ALSARRANI A.Q., AL-ADLY A.A., IBRAHIM M.K., 2012 – Evaluation of low-intensity laser radiation on stimulating the cholesterol degrading activity: part I. Microorganisms isolated from cholesterol-rich materials. ***Saudi Journal of Biological Sciences*** 19, 185-193.
31. PAWLOSKY R.J., SALEM N., 1996 – Is arachidonic acid necessary for feline reproduction? ***Journal of Nutrition*** 126, 1081-1095.

32. PEREIRA N.R., MUNIZ E.C., MATSUSHITA M., DE SOUZA N.E., 2002 – Cholesterol and fatty acids profile of Brazilian commercial chicken giblets. ***Archivos Latinoamericanos de Nutricion*** 52, 203-206.
33. POŁAWSKA E., MARCHEWKA J., COOPER R.,G., SARTOWSKA K., POMIANOWSKI J., JÓŹWIK A., STRZAŁKOWSKA N., HORBAŃCZUK J.O., 2011 – The ostrich meat – an updated review. II. - Nutritive value. ***Animal Science Papers and Reports*** 29, 2, 89-97.
34. POŁAWSKA E., HORBAŃCZUK J.O., PIERZCHAŁA M., STRZAŁKOWSKA N., JÓŹWIK A., WÓJCIK A., POMIANOWSKI J., GUTKOWSKA K., WIERZBICKA A., HOFFMAN L.C., 2013 – Effect of dietary linseed and rapeseed supplementation on fatty acid profiles in the ostrich. Part 1. Muscles. ***Animal Science Papers and Reports*** 31, 3, 239-248.
35. POŁAWSKA E., TOLIK D., HORBAŃCZUK O.K., CIEPŁOCH A., RAES K., DE SMET S., 2016 – The effect of dietary oil seeds on the fatty acid profile and metabolism in ostrich liver. ***Animal Science Papers and Reports*** 34, 173-180.
36. POŁTOWICZ K., DOKTOR J., 2013 – Macromineral concentration and technological properties of poultry meat depending on slaughter age of broiler chickens of uniform body weight. ***Animal Science Papers and Reports*** 31, 249-259.
37. SALES J., HORBAŃCZUK J.O., 1998 – Ratite Meat. ***World's Poultry Science Journal*** 54, 1, 59-67.
38. SALES J., HORBAŃCZUK J.O., DINGLE J., COLEMAN R., SENSIK S., 1999 – Carcase characteristics of emus (Dromaius novaehollandiae). ***British Poultry Science*** 40, 145-147.
39. SEONG P.N., CHO S.H., PARK K.M., KANG G.H., PARK B.Y, MOON S.S., BA H.V., 2015 – Characterization of chicken by-products by mean of proximate and nutritional compositions. ***Korean Journal for Food Science of Animal Resources*** 35, 179-188.
40. SHANG X.G., WANG F.L., LI D.F., YIN J.D., LI X.J., YI G.F., 2005 – Effect of dietary conjugated linoleic acid on the fatty acid composition of egg yolk, plasma and liver as well as hepatic stearoyl-coenzyme a desaturase activity and gene expression in laying hens. ***Poultry Science*** 84, 1886-1892.
41. SIMPSON R.J., MCKIE A.T., 2009 – Regulation of intestinal iron absorption: the mucosa takes control? ***Cell Metabolism*** 10, 84-87.
42. ULUOZLU O.D., TUZEN M., MENDIL D., SOYLAK M., 2009 – Assessment of trace element contents of chicken products from turkey. ***Journal of Hazardous Materials*** 163, 982-987.
43. Wang Y.W., Sunwoo H., Sim J.S., 2000 – Lipid characteristics of emu meat and tissues. ***Journal of Food Lipids*** 7, 71-82.
44. WIJENDRAN V., HAYES K.C., 2004 – Dietary n-6 and n-3 fatty acid balance and cardiovascular health. ***Annual Review Nutrition*** 24, 597-615.
45. WOOD J.D., ENSER M., FISHER A.V., NUTE G.R., SHEARD P.R., RICHARDSON R.I., HUGHES S.I., WHITTINGTON F.M., 2008 – Fat deposition, fatty acid composition and meat quality: A review. ***Meat Science*** 78, 343-358.
46. ZHANG X., WANG B., WANG L., LONG F., YANG Z., YU S., WANG Y., WEI X., JING L., LIU G., 2008 – Effect of dietary conjugate linoleic acid (CLA) on the growth and lipid metabolism of geese and fatty acid composition of their tissues. ***South African Journal of Animal Science*** 38, 12-20.
47. ZOUARI N., FAKHFAKH N., AMARA-DALI W.B., SELLAMI M., MSADDAK L., AYADI M.A., 2011 – Turkey liver: physicochemical characteristics and functional properties of protein fractions. ***Food and Bioproducts Processing*** 89, 142-148.