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The physical traits and fatty acids profile of ostrich meat enriched in n3 fatty acids as influenced by duration of refrigerated storage and type of packaging*

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The aim of the study was to evaluate physical traits and fatty acids profile of ostrich meat enriched in n3 fatty acids as affected by refrigerated storage (for 14 days) and type of packaging (VAC vs. skin-packaging – SP). During refrigerated storage time drip loss after 7 days was significantly (P<0.001) higher in VAC as compared to SP samples. No significant differences in the SFA content in meat during storage in both types of packaging types recorded. Although there were no significant differences (P=0.067), a tendency for higher MUFA values was observed during storage in VAC packed meat. A significant decrease (P<0.05) in the content of PUFA after 7 and 14 days of storage was also observed in VAC packed meat as compared to fresh meat, whereas, when skin packaging was used, no differences in the PUFA concentration were found. Considering this, the SP can be recommended packaging for ostrich meat industry.

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Ratitae meat, especially ostrich meat, is perceived as a healthy meat [Sales *et al*. 1999, Kawka *et al*. 2012ab] characterized by relatively high nutritive value i.e. a low fat and cholesterol content and high amounts of PUFA and iron [Cooper *et al*. 2007, Horbanczuk *et al*. 1998, Horbanczuk and Sales 2001, Sales and Horbanczuk 1998, Poławska *et al*. 2011]. It should be noted that Poland is one of the biggest producers of ostrich meat in Europe with an annual production of 350-500 tons [Horbanczuk *et al*. 2008]. Ostrich meat processors sell fresh and frozen meat, as well as processed meat products, to a variety of markets generally following retail packaging practices [Alonso-Calleja *et al*. 2004]. Modern meat packaging techniques like vacuum or skin pack are intended to maintain the high quality of the product [Fernandez-Lopez *et al*. 2008]. However in the current literature there is a lack of information about the shelf life of ostrich meat enriched with n-3 fatty acids in relation to the type of packaging during chilled storage. Therefore, the aim of this study was to evaluate physical traits of n-3 enriched ostrich meat following linseed feeding and changes in fatty acid composition during 14 days of refrigerated storage in two types of packaging, i.e. vacuum and skin pack.

Material and methods

Birds and diets

The study was conducted on 40 ostriches (*Struthio camelus* var. *domesticus*). From hatching until 5 months of age the birds were fed a commercial ostrich starter diet (215 $g \cdot kg^{-1}$ crude protein and 2850 $kcal \cdot kg^{-1}$ gross energy). From the age of 5 months (*ca.* 40 kg BW) birds were randomly allocated into two groups, i.e. a control group (C) fed a standard diet and a linseed group (L) fed on the same diet where part of energy was replaced by energy from linseed (4% supplementation). The diet composition was presented earlier in Poławska *et al.* [2012].

Sampling and packing

The ostriches were slaughtered in commercial abattoir at 12 months of age when their live weight reached approximately 84.6±3.6 kg. The slaughter procedure was presented in Poławska *et al*. [2012]. Meat samples were taken from randomly chosen ostriches (8 in each group) from the *M. gastrocnemius pars interna* (GM) muscle and transported to the laboratory in insulated containers. The muscles were chopped in 2.5 cm steaks (100-120 g each, 3 steaks per animal) and were packed in two different vacuum packing systems: foil bags (VAC; packing machine model VAC-10DT+GV, Edesa Hostelera S.A., Barcelona) and on trays with skin packaging (SP; packing machine model Cryovac VS-26, Sealed Air GmbH, CH 60-39 Root-Längennbold). The packs were stored in refrigerator at 4°C for the entire duration of the experiment. Samples were analysed at 0 (24h after slaughter), 7 and 14 days of storage.

Meat quality properties

The pH was measured with pH meter (T100) equipped with a combination electrode with a temperature correction system. The measurements of the samples were done according to Polish Standard [PN-ISO 2917, 2001].

Instrumental colour measurements were recorded in steaks at 0, 7 and 14 days after storage for L*, a* and b* using a Minolta CR-400 chromameter calibrated with a white plate (L* = 98.45, a* = -0.10, b* = -0.13), using an 8 mm aperture, illuminate D65 (6500 K colour temperature) at a standard observation of 2°. Data was collected after a 30 min blooming period under refrigerated conditions.

Steaks were weighed before packing and then weighted after opening the packs. Drip loss was calculated from the difference in weight before and after storage.

Fatty acid analyses

Fatty acids were extracted from homogenised samples (5 g) of ostrich muscles with the chloroform-methanol procedure of Folch *et al*. [1957]. Fatty acid methyl esters (FAME) were analysed using a GC-7890 Agilent gas chromatograph and individual fatty acids were identified by comparison of retention times to those of a standard as earlier presented in Poławska *et al.* [2013].

Statistical analysis

Analysis of variance was computed with storage time x type of packaging and the type of diet as the factors using STATISTICA (ver. 9, StatSoft Inc., USA). Tukey-tests were calculated at a 5% significance level to compare treatment means for significant effects.

Results and discussion

Table 1 presents the physical traits in chilled GM muscle as related to the type of packaging: vacuum foil bags (VAC) and skin pack (SP) during refrigerated storage time of meat of ostriches fed control and linseed diet. The supplementation of linseed to the ostrich diet had no effect on the physical traits. A tendency for a slight decrease in a* and b* values after 14 days of storage was observed in both analysed groups. Similar results in air packed *Rhea american* meat, were obtained by Filgueras *et al*. [2010]. These authors reported that after 5 days of storage the colour parameters values decreased, but the decrease in L* and a* values depended on the interaction of storage time and muscle type. In turn, Franco *et al*. [2012] obtained opposite results in beef and found that in the absence of oxygen (vacuum packed samples) the redness values (a*) did not differ during 21 days of storage (7, 14 and 21-day – samples were analysed) for standard and linseed fed calves. However, authors conclude that the colour parameters and oxidative stability of meat were all affected by the triple interaction: diet (different vegetable oils with different vitamin E level) x time (0-21 days) x packaging (MAP and VAC).

Table 1. Physical quality traits of ostrich meat as related to different type of packaging, storage duration and dietary treatment

Item	Diet	Storage duration					Mean	SEM
		day „0”	day 7		day 14			
			type of packaging					
			SP	VAC	SP	VAC		
pH	C	6.16	6.21	6.20	6.28	6.21	6.21	
	L	6.19	6.21	6.25	6.28	6.28	6.24	
	mean	6.17	6.21	6.23	6.28	6.25		0.39
Drip loss%	C	-	0.50	3.50	0.66	3.24	1.98*	
	L	-	0.60	3.24	0.71	3.09	1.91*	
	mean	-	0.55^{A}	3.37^{B}	0.69^{A}	3.16^{B}		0.29
L*	C	32.8	32.8	31.7	32.2	31.6	32.22	
	L	32.5	32.6	32.0	31.7	32.1	32.18	
	mean	32.7	32.7	31.8	31.9	31.9		2.01
a*	C	20.5	20.1	19.2	18.6	18.8	19.44	
	L	18.7	17.5	18.3	17.8	17.0	17.86	
	mean	19.6	18.8	18.75	18.2	17.9		1.21
b*	C	11.6	10.4	10.7	9.9	9.90	10.50	
	L	10.2	10.2	10.5	9.8	9.40	10.02	
	mean	10.9	10.3	10.6	9.85	9.65		0.93

C – control diet/group; L – linseed supplemented diet/group; SP – skin pack; VAC – vacuum pack.
*Mean for day 7 and 14.
^{AB}Means within a row bearing different superscripts differ significantly at P<0.001.

Table 2. Saturated and monounsaturated fatty acids content (g/100gFAME) of ostrich meat as related to different type of packaging, storage duration and dietary treatment

Fatty acid	Diet	Storage duration					Mean	SEM
		day „0”	day 7		day 14			
			type of packaging					
			SP	VAC	SP	VAC		
SFA	C	30.28	30.77	30.72	30.82	30.91	30.70	
	L	29.27	28.66	28.98	27.86	27.70	28.49	
	mean	29.78	29.72	29.85	29.34	29.31		0.99
16:0	C	18.13	18.56	18.02	18.50	18.18	18.28	
	L	14.80	14.48	15.00	14.73	14.22	14.65	
	mean	16.45	16.52	16.51	16.62	16.20		0.69
18:0	C	10.15	10.31	10.80	10.52	10.73	10.50	
	L	12.47	12.17	11.98	11.93	11.78	12.07	
	mean	11.31	11.24	11.39	11.23	11.25		0.50
MUFA	C	37.84	37.04	39.53	36.68	39.02	38.02^{x}	
	L	35.86	35.19	38.59	34.62	39.33	36.72^{y}	
	mean	36.85	36.12	39.04	35.66	39.18		0.85
18:1n-9	C	23.16	23.65	22.99	22.49	21.96	22.85	
	L	22.29	22.39	23.70	22.69	23.92	23.00	
	mean	22.73	23.02	23.34	22.59	22.94		0.57

C – control diet/group, L – linseed supplemented diet/group, SP – skin pack, VAC – vacuum pack, SFA – saturated fatty acids, MUFA – monounsaturated fatty acids.
^{xy}Means within a column bearing different superscripts differ significantly at P<0.05.

Drip loss after 7 days of storage was significantly higher in vacuum packed meat as compared to skin packed meat (3.37% versus 0.55%, $P<0.001$). On day 14 of the storage the drip loss remained on the same level in both types of packaging.

In earlier studies [Poławska *et al*. 2013], authors confirmed positive effect of linseed supplementation on fatty acids profile of ostrich muscles. The linseed supplementation increased PUFA, especially omega 3 fatty acids (ALA, EPA and DHA) and improved omega-6/omega 3 and PUFA/SFA ratios as compared to control and rapeseed feeding. On the base of mentioned study the 4% linseed supplementation was chosen for further studies and the procedure of storage was applied, to maintain the positive effect of linseed supplementation on nutritional value of ostrich meat.

Table 2 shows the average content of chosen saturated and monounsaturated fatty acids in ostrich meat samples packed in SP and VAC stored for 7 and 14 days. No significant differences in the SFA content in meat during storage in both types of packaging types were observed. Zymon *et al*. [2007] obtained similar results in calves' meat samples during long term storage (3 months).

Although there were no significant differences ($P=0.067$), a tendency for higher MUFA values was observed during storage in VAC packed meat. After 7 days of storage the MUFA content increased from 37.8 and 35.9 g/100 g FAME to 39.5 and 38.6 g/100 g FAME in C and L groups, respectively. After 14 days of storage there were no further changes in the MUFA content (39.0 and 39.3 g/100g FAME, C and L group, respectively). The content of the MUFA in the skin packed samples was not affected by storage duration.

A significant decrease ($P<0.05$) in the content of PUFA after 7 and 14 days of storage was observed in VAC packed meat as compared to fresh meat (from 26.0 to 22.0 in day 7 and 21.2 g/100 g FAME in day 14 in C group and from 34.7 to 29.4 and 29.6 g/100 g FAME in 7 and 14 day in L group, respectively). Additionally a tendency for lower content of linoleic and arachidonic acid were observed after 7 and 14 days of storage, although differences were not significant (Tab. 3). When skin packaging was used, no differences in the PUFA content during storage were found. Although the PUFA (omega 6 and omega 3) content in VAC packed meat was lower, there were no differences in omega-6/omega-3 and PUFA/SFA ratios during storage.

A decrease of the PUFA content during storage was also obtained by Dal Bosco *et al.* [2004] in rabbit meat after 8 days. Diaz *et al*. [2011] obtained similar results in lamb meat polar lipid fraction.

The tendency for a lower MUFA content in VAC packed meat is probably connected with the higher drip loss in those samples. Opposite effect on PUFA content is probably related with the fact that fatty acids with longer chains and with a greater degree of unsaturation are more susceptible to oxidation. Thus it can be concluded that the skin packed meat is less susceptible to the oxidation processes.

In general, most of the fatty acids were not affected by the type of packaging and duration of refrigerated storage, apart from PUFA content, where a significant decrease in VAC packed meat occurred, especially in first 7 days of storage. Moreover,

Table 3. Polyunsaturated fatty acids content and fatty acids ratios (g/100gFAME) of ostrich meat as related to different type of packaging, storage duration and dietary treatment

Item	Diet	Storage duration					Mean	SEM
		day „0”	day 7		day 14			
			type of packaging					
			SP	VAC	SP	VAC		
PUFA	C	26.0	24.9	22.0	24.4	21.2	23.70^{y}	
	L	34.7	34.6	29.4	33.7	29.6	32.40^{x}	
	mean	30.4^{a}	29.8^{a}	25.7^{b}	29.1^{a}	25.4^{b}		0.64
	C	23.63	22.76	19.99	22.52	19.42	21.66	
Σ -6	L	26.41	26.78	22.84	25.96	23.24	25.05	
	mean	25.02	24.77	21.41	24.24	21.33		0.41
	C	16.82	16.38	14.29	16.41	13.91	15.56	
18:2n-6	L	18.45	18.97	16.30	18.62	16.33	17.73	
	mean	17.64	17.67	15.30	17.52	15.12		0.33
	C	6.81	6.38	5.70	6.10	5.51	6.10	
20:4n-6	L	7.96	7.81	6.54	7.34	6.92	7.31	
	mean	7.39	7.10	6.12	6.72	6.21		0.29
	C	2.42	2.11	2.00	1.88	1.81	2.04^{y}	
Σ -3	L	8.29	7.85	6.51	7.73	6.34	7.34^{x}	
	mean	5.36	4.98	4.25	4.80	4.08		0.39
	C	1.70	1.46	1.36	1.31	1.27	1.42^{y}	
18:3n-3	L	6.24	6.10	4.78	5.95	4.77	5.57^{x}	
	mean	3.97	3.78	3.07	3.63	3.02		0.38
	C	0.29	0.25	0.23	0.22	0.12	0.22^{y}	
20:5n-3	L	0.44	0.33	0.37	0.38	0.31	0.37^{x}	
	mean	0.37	0.29	0.30	0.30	0.22		0.06
	C	0.42	0.40	0.40	0.36	0.32	0.38^{y}	
22:6n-3	L	1.61	1.42	1.36	1.41	1.26	1.41^{x}	
	mean	1.02	0.91	0.88	0.89	0.79		0.14
	C	9.78	10.78	10.01	11.95	10.75	10.65^{x}	
n-6/n-3	L	3.18	3.41	3.51	3.36	3.66	3.42^{y}	
	mean	6.48	7.10	6.76	7.66	7.21		0.59
	C	0.86	0.81	0.72	0.79	0.69	0.77^{y}	
PUFA/SFA	L	1.19	1.21	1.01	1.21	1.07	1.14^{x}	
	mean	1.03	1.01	0.87	1.00	0.88		0.03

C – control diet/group; L – linseed supplemented diet/group; SP – skin pack; VAC – vacuum pack; PUFA – polyunsaturated fatty acids; Σ -6 – the sum of omega 6 polyunsaturated fatty acids; Σ -3 – the sum of omega 3 polyunsaturated fatty acids; n-6/n-3 – omega 6 and omega 3 polyunsaturated fatty acids ratio; PUFA/SFA – polyunsaturated and saturated fatty acids ratio.
^{ab}Means within a row bearing different superscripts differ significantly at P<0.05.
^{xy}Means within a column bearing different superscripts differ significantly at P<0.05.

the tendency to slightly increase MUFA content in VAC packed meat was observed. In the SP packaging PUFA content was higher in ostrich meat as compared to VAC packaging. Additionally, the drip loss was significantly lower in meat samples in skin pack in comparison with vacuum foil bags packaging. Considering this, the skin pack type of packaging can be recommended for the ostrich meat industry. Further studies in relation to extended period of ostrich meat storage, as well as microbiological quality and sensory characteristics of this meat should be carried out.

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