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Muscle fat composition of pheasants (*Phasianus colchicus*), wild ducks (*Anas platyrhynchos*) and black coots (*Fulica atra*)

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Abstract The aim of this investigation was to characterise the fatty acid composition within intramuscular fat (IMF) of two muscles (breast and thigh) from 28 pheasants, ten wild ducks and 27 black coots from Slovakia. A high variability for all single fatty acids (FA) and the total fat concentration in muscles of wild birds was identified. Black coots deposited the highest fat in breast muscle whereas wild ducks and pheasants accumulated more lipids in thigh muscle. In general, the content of polyunsaturated fatty acids (PUFA) of the IMF in wild bird muscles was high, and the saturated FA concentration was lower compared with muscles of domestic farm animals. The ratio between PUFA and saturated fatty acids (PSQ) ranked between 0.6 and 1.2, and the ratio of *n*-6/*n*-3 fatty acid was favourably low in black coot and wild pheasants (3.2 and 2.9,

respectively). Farmed pheasants had increased IMF and more saturated and *n*-6 fatty acids deposited in thigh muscle but not in breast muscle.

Keywords Wild duck · Pheasant · Black coot · Muscle · Fatty acid profile

Introduction

There is growing interest in safety and quality of meat, resulting in health-conscious consumers demanding low fat and low cholesterol products. Many consumers are interested in alternatives to conventional meat products, with meat from wild animals normally low in fat content (Hoffman and Wiklund 2006; Nuernberg et al. 2009). To accommodate consumer demand for such products, the quality attributes of meat from wild animals should be well established. Beside game animals like deer and wild pigs, wild birds (wild ducks, pheasants) are also hunted, but only few reports can be found in the literature on meat quality from wild animals (Cobos et al. 2000; Vecerek et al. 2005; Hoffman and Wiklund 2006; Strakova et al. 2010). In particular, there are few reports available on the fatty acids (FA) profile of wild bird meat.

Meat is an excellent source of high biological value protein, a significant source of long-chain *n*-3 fatty acids, vitamins (A, B₆, B₁₂, D, E), and highly bioavailable forms of essential minerals and trace elements such as: zinc, copper, and iron (Arneth 2003; Biesalski 2005; Dannenberger et al. 2007; Mahecha et al. 2009). In red meat, the essential amino acids are well balanced with respect to the need of humans. Therefore, meat is considered a source of high-quality protein (Pensel 1997). Meat from wild animals seems to be a good source of protein, vitamins, micronutrients (iron,

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zinc, selenium, calcium), and essential FA (Suchy et al. 2009). The protein content of game meat seems to be higher compared with commercially produced animals (Ristic et al. 2001; Hascik et al. 2010). Meat from wild game contains little fat and has a typical specific taste and smell. Lean meat of wild animals [red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), fallow deer (*Dama dama*), or wildfowl] consists of 74% water, 21–23% protein, 1–2% fat, 1% minerals, and less than 1% carbohydrates (Nuernberg et al. 2009; Suchy et al. 2009). The nutritional value of meat from wild animals can be calculated by the macro-nutrient composition (protein, fat, water, minerals) and also by the fatty acid concentration (e.g., *n*-3 fatty acids and conjugated linoleic acids). The intramuscular fat and adipose tissues are of most interest in relation to FA composition and human health. The relationships between dietary fat and incidence of lifestyle diseases, particularly coronary heart disease, are well established, and this has contributed towards the development of specific guidelines from different nutrition and health organisations in relation to fat in the diet (WHO 2003; DGE. Referenzwerte für die Nährstoffzufuhr 2008). The recommendation for fat intake is 25–30% of the total daily energy intake depending on the age and on activity of people (DGE. Referenzwerte für die Nährstoffzufuhr 2008). Reducing the intake of saturated fatty acids (SFA; which is known to raise total and low-density lipoprotein cholesterol) to <10% and increasing the intake of *n*-3 long-chain polyunsaturated fatty acids (PUFA) up to 3 g per day is particularly encouraged. Among the *n*-3 PUFA, eicosapentaenoic acid (20:5*n*-3, EPA) and docosahexaenoic acid (22:6*n*-3, DHA) are the most protective for cardiovascular health (Warburg 2004; Mozaffarian and Rimm 2006; Wang et al. 2006). The ratio between PUFA of the *n*-6 and *n*-3 series is an index commonly used to evaluate the nutritional value of fats. The intake of *n*-3 PUFA in many industrialised countries is relatively low, and its increased consumption has protective and modifying effects on such diverse conditions as arteriosclerosis, ventricular arrhythmias, multiple sclerosis, major depression, and inflammatory and autoimmune diseases. To improve the *n*-6/*n*-3 balance in human nutrition, it is necessary to increase the consumption of food sources containing these *n*-3 PUFA. There are many nutritional approaches to enhance beneficial FA in ruminant fat (see reviews Wood et al. 2003; Scollan et al. 2006; Givens and Gibbs 2006). In experiments with ruminants (bulls, lambs), linolenic acid (C18:3*n*-3, ALA) contained within the lipids of grass was absorbed and deposited into the different lipid classes of muscle and subcutaneous fat in both bulls (*Bos p. taurus*) and lambs (*Ovis aries*). This resulted in the proportion of *n*-3 fatty acids in the different lipids of grazing bulls and lambs being significantly higher compared with concentrate-fed animals (Nuernberg et al. 2005a, b, c; Nuernberg et al. 2008; Herdmann et al. 2010). The *n*-6/*n*-3

ratio in muscle of grazing lambs was 1.2 in contrast to 2.3 of the animals kept in stable. The proportion of CLA*cis*-9, *trans*-11 (1.9% vs 1.1% in muscle, 2.5% vs 1.4 % in subcutaneous fat, 0.7% vs 0.4 % in phospholipid) of lambs was also ($P=0.05$) higher by grazing pasture compared with concentrate feeding, respectively (Nuernberg et al. 2005a).

There are results on fatty acid profile and meat quality of pasture-fed reindeer (*Rangifer tarandus*) compared with commercial-fed reindeer (Wiklund et al. 2001, 2003; Samples et al. 2006). Pasture-fed reindeer accumulated more *n*-3 fatty acids and a lower ratio of *n*-6/*n*-3 FA in two muscles. The same findings in male fallow deer were reported by Volpelli et al. (2003). Recently, there have been published results regarding fat content and lipid profile of different wild animals such as: wild pigs (*Sus scrofa*), red deer, fallow deer, and roe deer (Nuernberg et al. 2009). The ratio of the sum of *n*-6/*n*-3 fatty acids of muscle lipids in red deer, roe deer, and fallow deer game was lower compared with farm ruminants (Nuernberg et al. 2009). Little information exists regarding the lipid composition of wild birds. The basic feeding substrates of wild birds in forests are: plants, seeds, berries, insects, worms, grass, buds, and fruits. It is hypothesised that the dietary fat also affects the FA composition of wild bird, and these effects are comparable to farm animals. The purpose of the present investigation was to study the FA of muscle tissues from different wild birds (pheasant, black coots, wild ducks) in the Slovak Republic. Furthermore, the differences between two muscles on the FA profile of pheasants, wild ducks, and black coots were investigated. The comparison between wild-living pheasants and farmed pheasants was also included in the study.

Materials and methods

The collection of the muscle samples from the carcasses left (entire breast and thigh muscle) started in summer and ended in winter 2007 in the region around Nitra (Slovak Republic). In total, 27 (54 muscles) black coots (habitat: Bohelov), 28 (56 muscles) pheasants (habitat: Kolinany and Cabaj), and ten (20 muscles) wild ducks (habitat: Bohelov and Nitra) were collected. Twenty-eight-week-old pheasants were fed at a farm (belonging to the Slovak Agricultural University of Nitra) in Kolinany from August–December 2007. Muscle samples were stored at -20°C until FA analyses. The intramuscular fat of 2 g muscle tissue was extracted with chloroform/methanol (2:1, *v/v*) by homogenisation (Ultra Turrax, 3×15 s, 12,000 revolutions per minute) at room temperature (RT). All solvents contained 0.005% (*w/v*) of butyl-hydroxy-toluene in order to avoid peroxidation of PUFA. The extraction mixture was stored at 5°C for 18 h in the dark and subsequently washed

with 0.02% aqueous CaCl_2 . The organic phase was dried with Na_2SO_4 and K_2CO_3 (10:1, *w/w*), and the solvent subsequently removed under nitrogen at RT. The lipid extract was re-dissolved in toluene, and 20 mg was used for methyl ester preparation. To prepare the fatty acid methyl esters (FAME), 0.5 M sodium methanolate was added, and the mixture was shaken in a water bath at 60°C for 10 min (Nuernberg et al. 2009). Then, 0.5 ml BF_3 in methanol (14%, *w/v*) was added to the solution and shaken in a water bath at 60°C for 10 min. FAME were extracted two times with *n*-hexane in the presence of distilled saturated solution of NaHCO_3 and vortexed. The upper phase containing FAME was pooled, and the solvent was eliminated by evaporation under nitrogen flow. FAME were resolved in 100 μl *n*-hexane and stored at -20°C until GC analysis. An aliquot of this FAME mixture was used for the gas chromatographic analyses of total FA. The FA composition of muscle lipids was determined by capillary GC on a CP SIL 88, 100 m \times 0.25 mm \times 0.25 μm capillary column (Chrompack, Varian, USA) installed in a Perkin Elmer gas chromatograph Autosys XL (Perkin Elmer Instruments, Shelton, USA) with a flame ionisation detector and split injection. Initial oven temperature was 150°C, held for 5 min, subsequently increased to 200°C at a rate of 2°C min⁻¹, held for 10 min, then to 220°C at 1.5°C min⁻¹, held for 35 min. Hydrogen was used as the carrier gas at a flow rate of 1 ml min⁻¹. The split ratio was 1:40; the injector was set at 260°C and the detector at 280°C. The quantitative (milligrams per 100 g) and qualitative (%) composition of muscle fat was calculated using the internal standard method (C19:0 methyl ester) of TotalChrom 6.3.1 software. A reference standard (Sigma FAME mixture 189-19) added contained: C18:1*trans*-11 methyl ester, C22:5*n*-3 methyl ester, CLA*cis*-9,*trans*-11 methyl ester, C18:1*cis*-11 methyl ester, C18:4*n*-3 methyl ester and C22:4*n*-6 methyl ester (Sigma-Aldrich, Deisenhofen, Germany and Matreya, Pleasant Gap, USA) and used to determine recoveries and correction factors for individual FA in intramuscular fat (IMF). The sum of *n*-3 fatty acids consisted of C18:3*n*-3 + C18:4*n*-3 + C20:5*n*-3 + C22:5*n*-3 + C22:6*n*-3, and the sum of *n*-6 fatty acids was calculated as C18:2*n*-6 + C18:3*n*-6 + C20:2*n*-6 + C20:3*n*-6 + C20:4*n*-6 + C22:2*n*-6 + C22:4*n*-6.

Statistical analysis

First, a univariate description (mean, standard deviation, minimum, maximum) of selected FA for all three birds (black coots, pheasants and wild ducks) was carried out without distinction of sex and muscle (Table 1).

To investigate the effect of the factors bird (three levels), sex (two levels) and muscle (two levels) a three-way analysis of variance (ANOVA) model with fixed factors bird and sex, and a repeated factor muscle, and

corresponding two- and three-way interactions were used (Table 2, Figs. 1 and 2). The effect “treatment” (wild vs. farmed) could be analysed for pheasants only. Therefore, a three-way ANOVA model with fixed factor “keeping” (two levels) and sex, and a repeated factor muscle, and corresponding two- and three-way interactions were used (Table 3). The data were analysed with procedure MIXED of software package SAS (2009).

In all tables, only the main FA are shown whereas 38 individual FA were identified, and all are used for calculation of proportion in percent, and the concentration in milligrams per 100 g muscle tissue. Least-squares means and the standard error of the mean are presented in the tables and figures. Pearson correlation coefficient was used for the relationship between selected fatty acids and IMF.

Results

Table 1 shows the descriptive statistics (means, standard deviation, minimum and maximum values) of selected FA (mg/100 g muscle tissue) and the IMF content. For all fatty acids and the total fat concentration, a high variability was measured in muscles of wild birds. The most abundant saturated fatty acid in IMF was the palmitic acid (C16:0), with black coots accumulating the highest concentration. Linoleic acid (C18:2*n*-6, LA) was found at a high level in all bird species whilst ALA was high in black coots.

There was no effect of sex on fat profile, and the interaction with sex and muscle was not significant. Therefore, Table 2 shows only the FA composition of the three different wild birds (black coot, pheasant and wild duck) and the two muscles (breast and thigh) investigated. Differences between the two muscles were found (Table 2). Black coots deposited more IMF in breast muscle whilst wild ducks and pheasants contained more lipids in the thigh muscle. In parallel, the single saturated fatty acids and the sum of SFA were high in black coot breast muscle but highest in thigh muscle of the other two birds. Highest differences between individual birds were identified for the *n*-3 and *n*-6 fatty acid concentration in muscle (Table 2). Muscle fat of black coots contained higher levels (milligrams per 100 g muscle) of PUFA, especially *n*-3 fatty acids when compared with pheasants and wild duck. The monoenoic acid (C16:1 and C18:1*cis*-9) concentrations were extremely high in black coots and the lowest in pheasants. The relative proportion of PUFA of the IMF of wild bird muscles (25–44%) was high (Fig. 2), and the percentage of SFA was low (Fig. 1).

Table 3 contains the LSMs of two muscles and the two feeding groups of pheasants (wild vs. farmed). In pheasants, thigh muscles accumulated more IMF compared

Table 1 Statistical measures of IMF content and selected fatty acids of wild bird species

Bird species (number of muscles)	Black coot (<i>n</i> =54)	Wild duck (<i>n</i> =20)	Pheasant wild (<i>n</i> =16)	Pheasant farmed (<i>n</i> =40)
IMF (%)				
Mean	4.6	2.6	1.5	2.2
Standard deviation	1.8	0.7	0.4	1.1
Minimum	1.9	1.3	1.0	0.8
Maximum	10.0	3.9	2.7	4.9
C14:0, mg/100 g				
Mean	29.9	13.2	4.3	10.8
Standard deviation	18.2	7.1	2.4	9.6
Minimum	8.0	3.5	1.1	1.5
Maximum	86.1	28.8	10.1	38.5
C16:0, mg/100 g				
Mean	844.8	471.2	193.4	409.9
Standard deviation	355.6	211.1	57.4	320.7
Minimum	307.2	112.2	104.3	107.1
Maximum	2,157.6	880.6	290.6	1,238.5
C18:0, mg/100 g				
Mean	367.1	296.8	195.0	266.1
Standard deviation	131.3	51.3	61.5	138.6
Minimum	167.2	176.0	117.9	92.2
Maximum	642.0	425.1	335.2	535.6
C18:1 <i>cis</i> -9				
Mean	1512.7	844.6	261.0	603.6
Standard deviation	727.9	465.2	95.1	521.2
Minimum	337.6	205.2	118.8	112.9
Maximum	4,090.3	1,766.4	497.3	2,066.3
C18:2 <i>n</i> -6				
Mean	493.8	338.6	409.4	690.2
Standard deviation	221.6	124.7	292.6	545.4
Minimum	140.8	166.4	155.9	90.1
Maximum	1,078.7	666.1	1,277.9	2,380.6
C18:3 <i>n</i> -3				
Mean	146.7	18.6	21.5	10.4
Standard deviation	109.1	8.6	37.9	10.1
Minimum	13.6	11.0	3.6	1.1
Maximum	508.4	44.6	149.3	36.3
C20:4 <i>n</i> -6				
Mean	150.3	171.8	87.0	77.8
Standard deviation	54.7	54.4	15.4	14.7
Minimum	83.0	107.8	59.5	55.9
Maximum	266.1	292.3	123.4	123.0
C20:5 <i>n</i> -3				
Mean	33.2	19.3	3.4	3.2
Standard deviation	23.7	15.6	4.1	4.3
Minimum	7.3	4.9	0.4	0.2
Maximum	99.9	71.6	18.1	18.5

Table 2 Effect of muscle and bird species on fatty acid composition (milligrams per 100 g) in muscle fat

Bird species	Black coot		Pheasant		Wild duck		Significant ($P \leq 0.05$)
	Breast	Thigh	Breast	Thigh	Breast	Thigh	
	LSM _{SEM}	LSM _{SEM}	LSM _{SEM}	LSM _{SEM}	LSM _{SEM}	LSM _{SEM}	
Fat (%)	5.5 _{0,3}	3.6 _{0,3}	1.28 _{0,5}	1.82 _{0,5}	2.3 _{0,5}	2.8 _{0,5}	A, AxM
C14:0	29.7 _{3,1}	29.5 _{3,1}	3.3 _{6,2}	6.4 _{6,2}	8.2 _{5,2}	17.0 _{5,2}	A, M
C14:1	6.7 _{0,5}	6.7 _{0,5}	0.5 _{1,0}	1.1 _{1,0}	0.8 _{0,8}	2.0 _{0,8}	A
C16:0	900.9 ₆₀	738.1 ₆₀	171.2 ₁₁₉	235.2 ₁₁₉	356.4 ₁₀₁	567.4 ₁₀₁	A, AxM
C16:1	257.3 ₁₉	223.8 ₁₉	14.6 ₃₇	28.7 ₃₇	42.2 ₃₂	95.7 ₃₂	A, AxM
C18:0	462.1 ₁₅	265.0 ₁₅	141.6 ₃₀	231.2 ₃₀	282.2 ₂₆	300.6 ₂₆	A, AxM
Σ trans C18:1	14.1 _{1,4}	13.2 _{1,4}	0.8 _{2,8}	2.3 _{2,8}	6.0 _{2,4}	8.9 _{2,3}	A
C18:1cis-9	1622.9 ₁₂₂	1291.7 ₁₂₂	218.9 ₂₄₃	316.4 ₂₄₃	536.5 ₂₀₆	1137.2 ₂₀₆	A, AxM
C18:1cis-11	88.3 ₅	65.2 ₅	29.3 _{9,9}	27.3 _{9,9}	34.1 _{8,34}	37.6 _{8,3}	A, AxM
C18:2n-6	600.2 ₄₀	366.5 ₄₀	248.4 ₈₀	483.2 ₈₀	323.7 ₆₈	359.0 ₆₈	AxM
C18:3n-3	171.4 ₁₈	128.4 ₁₈	11.9 ₃₇	25.5 ₃₇	16.4 ₃₁	18.7 ₃₁	A
C20:4n-6	191.2 ₆	107.6 ₆	84.9 ₁₂	86.5 ₁₂	218.9 ₁₀	122.7 ₁₀	A, M, AxM
C20:5n-3	49.5 _{3,2}	18.1 _{3,2}	2.3 _{6,4}	4.0 _{6,4}	25.8 _{5,4}	10.2 _{5,4}	A, M, AxM
C22:5n-3	31.2 _{1,2}	26.3 _{1,2}	11.3 _{2,4}	7.1 _{2,4}	12.4 _{2,0}	14.8 _{2,0}	A, AxM
C22:6n-3	38.7 _{2,0}	34.8 _{2,0}	43.7 _{4,0}	26.0 _{4,0}	26.1 _{3,4}	26.1 _{3,4}	A, M
CLAc9,tr-11 ^d	1.5 _{0,1}	1.2 _{0,1}	0.2 _{0,3}	0.3 _{0,3}	0.6 _{0,2}	1.0 _{0,2}	A, AxM
SFA ^a	1480.5 ₇₉	1087.1 ₇₉	340.2 ₁₅₇	504.7 ₁₅₇	692.3 ₁₃₃	924.2 ₁₃₃	A, AxM
PUFA	1142.4 ₅₂	719.4 ₅₂	416.9 ₁₀₄	649.2 ₁₀₄	663.5 ₈₈	586.6 ₈₈	A, AxM
Σ n-3 FAs ^b	295.8 ₂₂	213.1 ₂₂	69.5 ₄₄	64.5 ₄₄	82.8 ₃₇	73.5 ₃₇	A
Σ n-6 FAs	831.7 ₄₀	502.0 ₄₀	346.5 ₇₉	583.7 ₇₉	579.5 ₆₇	512.0 ₆₇	A, AxM
Ratio n-6/n-3	3.2 _{0,4}	2.9 _{0,4}	5.0 _{0,9}	10.1 _{0,9}	7.8 _{0,8}	7.2 _{0,8}	A, M, AxM

LSM least square means, SEM Standard Error of LSM, A significant influence of bird species, M significant effect of muscles, A×M interactions between A×M at $P \leq 0.05$, no significant effect of sex, interaction sex×bird species, and interaction sex×muscle

^a Sum of saturated fatty acids: 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

^b Sum of C20:3n-3+C22:6n-3+C22:5n-3+C20:5n-3+C18:4n-3+C18:3n-3

^c Sum of C22:2n-6+C20:2n-6+C18:3n-6+C22:4n-6+C20:3n-6+C18:2n-6+C20:4n-6

^d Coelution with C18:2trans-7,cis-9 and C18:2trans-8,cis-10

Fig. 1 Effect of muscle on saturated fatty acids (percent) of wild bird species

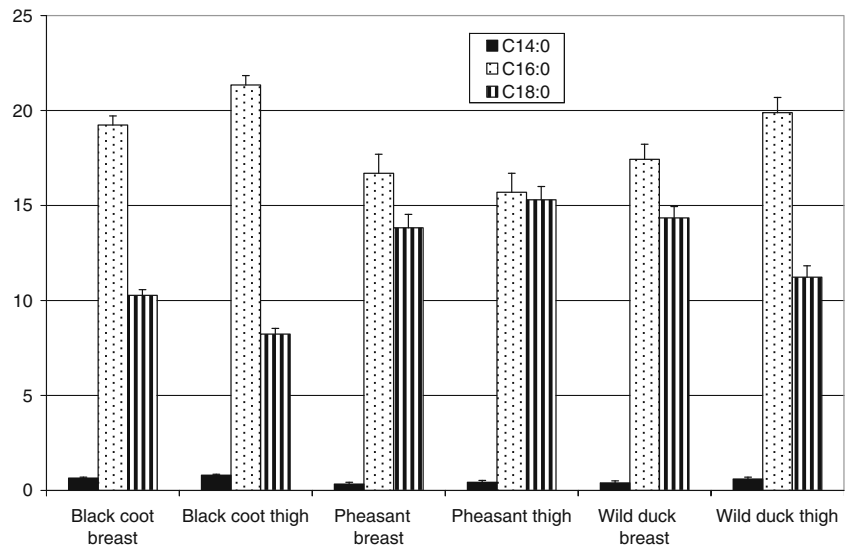


Fig. 2 Effect of muscle on selected PUFA (percent) of wild bird species

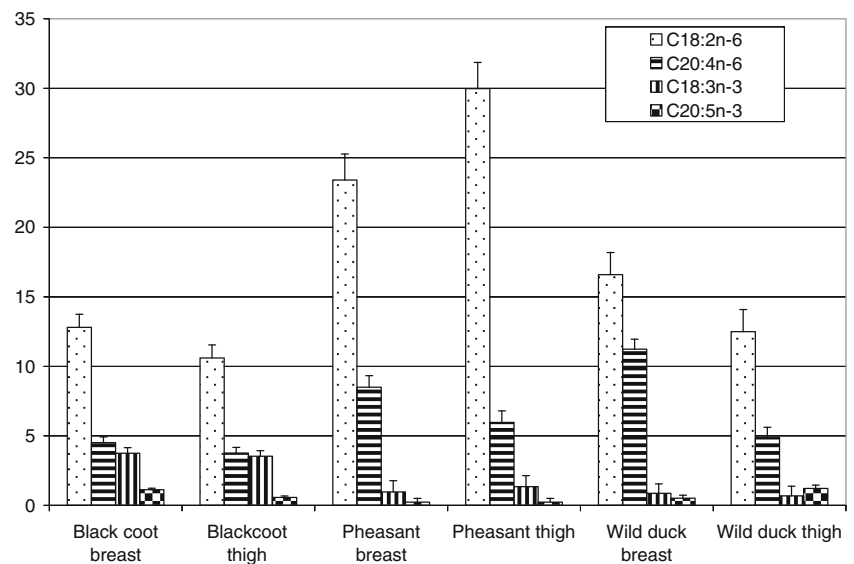


Table 3 Fatty acid composition (milligrams per 100 g) in two muscles of wild and farmed pheasants

Muscle	Breast muscle		Thigh muscle		Signific.
	Wild LSM _{SEM}	Farmed LSM _{SEM}	Wild LSM _{SEM}	Farmed LSM _{SEM}	
Fat (%)	1.3 _{0,2}	1.2 _{0,1}	1.8 _{0,2}	3.2 _{0,1}	F, M,
C14:0	3.3 _{2,4}	4.0 _{1,3}	6.4 _{2,4}	17.5 _{1,3}	F, M, MxF
C14:1	0.5 _{0,7}	0.5 _{0,4}	1.1 _{0,7}	3.3 _{0,4}	M, MxF
C16:0	171.2 ₈₁	178.3 ₄₄	235.2 ₈₁	634.3 ₄₃	F, M, MxF
C16:1	14.6 _{2,5}	18.1 _{1,4}	28.7 _{2,5}	115.5 _{1,3}	F, M, MxF
C18:0	141.6 ₂₀	135.8 ₁₁	231.2 ₂₀	390.9 ₁₁	F, M, MxF
∑ <i>trans</i> C18:1	0.8 _{1,1}	1.2 _{0,6}	2.3 _{1,1}	6.6 _{0,6}	M, MxF
C18:1 <i>cis</i> -9	219.0 ₁₂₃	208.8 ₆₈	316.4 ₁₂₃	986.3 ₆₆	F, M, MxF
C18:1 <i>cis</i> -11	29.3 _{7,9}	20.9 _{4,3}	27.3 _{7,9}	57.3 _{4,2}	M, MxF
C18:2 <i>n</i> -6	248.4 ₁₄₇	291.2 ₈₀	483.2 ₁₄₇	1068.7 ₇₈	F, M, MxF
C18:3 <i>n</i> -3	11.9 ₉	4.6 _{4,7}	25.5 ₉	16.3 _{4,7}	
C20:4 <i>n</i> -6	84.9 _{5,1}	69.3 _{2,8}	86.5 _{5,1}	86.1 _{2,7}	M, MxF
C20:5 <i>n</i> -3	2.3 _{1,6}	1.1 _{0,9}	4.0 _{1,6}	5.3 _{0,8}	M
C22:5 <i>n</i> -3	11.3 _{0,9}	4.7 _{0,5}	7.1 _{0,9}	3.7 _{0,5}	F, M, MxF
C22:6 <i>n</i> -3	43.7 _{3,6}	32.9 _{1,9}	26.0 _{3,6}	22.9 _{1,9}	M, MxF
CLAcis-9, <i>trans</i> -11 ^d	0.2 _{0,9}	0.2 _{0,5}	0.3 _{0,9}	1.9 _{0,5}	
SFA ^a	340.2 ₉₅	334.8 ₅₂	504.7 ₉₅	1085.1 ₅₁	F, M, MxF
PUFA	416.9 ₁₄₅	416.8 ₇₉	649.2 ₁₄₅	1227 ₇₇	F, M, MxF
∑ <i>n</i> -3 FA ^b	69.5 ₁₁	43.5 _{5,7}	64.5 ₁₁	50.1 ₆	
∑ <i>n</i> -6 FA ^c	346.5 ₁₄₅	372.6 ₇₉	583.7 ₁₄₅	1175.8 ₇₈	F, M, MxF
Ratio <i>n</i> -6/ <i>n</i> -3 FA	5.0 _{5,6}	10.5 _{3,0}	10.1 _{5,6}	29.0 _{3,0}	F, M, MxF

LSM least square means, SEM Standard Error of LSM, F significant influence of keeping, M muscles and interactions between muscle and keeping MxF at $p \leq 0.05$

^a Sum of saturated fatty acids: 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

^b Sum of C20:3*n*-3+C22:6*n*-3+C22:5*n*-3+ C20:5*n*-3+ C18:4*n*-3+ C18:3*n*-3

^c Sum of C22:2*n*-6+C20:2*n*-6+C18:3*n*-6+C22:4*n*-6+C20:3*n*-6+C18:2*n*-6+C20:4*n*-6

^d Coelution with C18:2*trans*-7,*cis*-9 and C18:2*trans*-8,*cis*-10

with breast muscles. In parallel, the SFA and the monoenoic acids (C18:1*cis*-9, C16:1, C14:1) were higher in thigh muscle. Only the long-chain *n*-3 fatty acid C20:5*n*-3 was incorporated to a higher extent in thigh whereas C22:6*n*-3 was accumulated mainly in breast muscle. Farmed pheasants accumulated double the amount of SFA and PUFA, especially *n*-6 fatty acids in thigh muscle when compared with wild pheasants. Keeping pheasants in farms induced a higher ratio of *n*-6/*n*-3 fatty acids.

Discussion

The consumption of meat in Germany (Bundesverband der deutschen Fleischwarenindustrie eV et al. 2010) and in the Slovak Republic (ZMP-Marktbilanz 2008) in 2009 was about 88.2 and 64.9 kg/head, respectively. Meat from game has a specific taste. People only consume a small amount of meat from wild animals (0.9 kg/head/year in Germany), but there is increasing interest in meat from wild game in both countries. The IMF is one of the most important meat quality traits. The composition of the muscle fat can be affected by different factors. In this study, the factors: sex and muscle type on intramuscular fat composition of pheasants, black coots and wild ducks were calculated. A high variability of all single FA and the total fat concentration in muscles of wild birds was found. Highest differences between individual birds were identified for the *n*-3 fatty acid. It can be suggested that data reflect a wide range of dietary components which birds consume and probably also age differences of the birds. In general, the proportion of PUFA in IMF of wild bird muscles (25–44%) is very high compared with muscles from domestic farm animals [pig: app. 13–31% (Nuernberg et al. 2005b); bulls: 9–14% (Nuernberg et al. 2005a; Herdmann et al. 2010)] but comparable with wild animals (red deer: 39%; Nuernberg et al. 2009). Dietary guidelines recommend 0.6–1.2 % of energy intake should be ALA and up to 10% of this can be EPA and DHA (Warburg 2004; Gebauer et al. 2006). The meat from wild birds contains a high amount of PUFA, the ratio of PUFA and saturated fatty acids showed a range from 0.6–1.2. Nutritional guidelines recommend a ratio of about 0.4 (Department of Health, 1994). It seems that intramuscular fat of meat from wild birds provide a positive lipid profile for human nutrition.

The fat content of breast and thigh muscles was significantly different between wild birds. Black coots accumulated the highest fat content in both muscles but with higher content in breast muscle compared with thigh muscle. Hascik et al. (2006) also measured a high fat (approximately 7%) content in breast and thigh muscles of coots. The pheasants demonstrated the lowest intramuscular fat for both muscles (breast muscle, 1.3%; thigh muscle,

1.8%). In accordance with results published by Hascik et al. (2010), fat content in breast muscle was lower compared with thigh muscles of pheasants. Vecerek et al. (2005) reported a clear increase of the intramuscular fat of thigh muscle during growth of common pheasants but only slight accumulation of fat in breast muscle. In line with the total fat concentration, the sum of SFA and all single saturated fatty acids (C14:0, C16:0 and C18:0) were significantly higher in black coots compared with pheasants and wild ducks. The total intramuscular fat content generally depends on the amount of triacylglycerols synthesised. There was a positive relationship between IMF and the concentration of saturated fatty acids (milligrams per 100 g) $r=0.97$ in this study. That means, with increasing intramuscular fat, the amount of de novo synthesised SFA also increased. This relation is also found in other animals. For example, in pigs, positive phenotypic correlations between back fat thickness and C14:0, C16:0 and C18:0 ($r=0.22$, 0.43 and 0.21, respectively) were calculated (Cameron et al. 1990).

In the present study, the monoenoic acid (C16:1 and C18:1*cis*-9) concentrations were high in black coots and lowest in pheasants. It seems that the oleic acid concentration is also related to the accumulated fat in muscle. In this study, the correlation between IMF and C18:1*cis*-9 content was $r=0.94$. Herdmann et al. (2010) reported a correlation between SFA deposited in longissimus muscle of bulls and the C16:1 concentration of $r=0.9$. Doran et al. (2006) reported a relation of $r=0.73$ between pig muscle fat and the protein expression of stearoyl-CoA desaturase which produced monoenoic acids in different tissues. Kazala et al. (2006) found significant associations between degree of marbling and 18:1*cis*-9 ($r=0.79$; $P<0.001$) acids in beef longissimus muscle. It can be concluded from the present data and the literature that there must be a signalling function of C18:1*cis*-9 and C16:1 according to fat deposition.

Pheasants showed a high relative proportion of LA, especially in thigh muscle (Fig. 2). The wild ducks accumulated a moderate proportion of LA in both muscles according to the IMF content. Surprisingly, black coots deposited the highest ALA concentrations and proportions (Table 2, Fig. 2). A lower ALA content was expected because black coots deposited the highest fat in both muscles (3.6% and 5.5%). The diet of these birds is probably high in *n*-3 fatty acids. The ratio between *n*-6 and *n*-3 fatty acids was lower in both muscles of black coots when compared with pheasants and wild ducks.

Only for pheasants, the two feeding systems (wild pheasant vs. farmed pheasant) were compared. In pheasants, thigh muscles accumulated more intramuscular fat compared with breast muscles. Similar results were also reported by Vecerek et al. (2005) in pheasants and Baeza et

al. (2010) for chicken. The higher de novo fat synthesis in thigh muscle was connected with higher SFA independent from the feeding type. Only the long-chain *n*-3 fatty acid C20:5*n*-3 is incorporated to a higher extent in thigh muscle whereas C22:6*n*-3 is accumulated mainly in breast muscle. To clarify this phenomenon further, investigations are needed. A clear effect of muscle type was found for LA and the sum of *n*-6 fatty acids.

Farm feeding of pheasants increased the SFA and also the *n*-6 fatty acid concentration. The high energy intensity of the farm feed compared with wild-kept pheasants pushed the biosynthesis of saturated fat. Probably, the higher *n*-6 fatty acid proportion of the grain in the feed from farmed pheasants resulted in the high concentration of LA in thigh muscle. From the nutritional point of view, the farming conditions for pheasants diminished the nutritional value by higher ratio between *n*-6 and *n*-3 fatty acids compared with wild-living pheasants. The dietary fatty acid composition affects the fatty acid profile of different tissues in all monogastric animals and also in wild bird. The selection of dietary components with higher *n*-3 fatty acid proportion can improve the FA profile of farmed pheasants.

Meat of wild birds will always be a niche product, but it can be used for the diversification of human diet. Meat from wild bird species studied here showed a low fat content with the exception of black coot breast muscle.

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