

Effect of duck genotype on leg muscle properties

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Abstract

The research objective was to compare the nutritive value and some functional properties of duck leg muscles from different flocks. A total of 80 drakes out of three conservative flocks (cross-breeds Pekin type – SB, Miniduck – K2, Pekin originated from Danish Pekin duck – P8) and one maternal breeding strain (P66) aged seven weeks, were used for comparison. The content of protein, lipids, moisture, essential amino acids, fatty acids and cholesterol were estimated. The investigation of functional properties has covered: the determination of the colour parameters – L^* , a^* , b^* , colour difference between individual flocks, total haem pigments' content, sensory evaluation of raw muscles' colour intensity in 10 point scale; pH_{24} ; water holding capacity; cooking loss and shear force. Comparing the basic chemical and amino acid composition, cholesterol content and profile of fatty acids, it could be concluded that the P66 leg muscles coming from a selected breeding strain, are the most favourable from the nutritional point of view. It is evident too, that muscles from all the examined flocks have been characterized by a high nutritional value. Taking into consideration the functional properties, it was concluded that the muscles from the investigated flocks varied in colour and analysed traits. The ducks of K2 had the best functional properties. The advantages of K2 in comparison to the other ducks are: darker colour typical of waterfowl meat, lower cooking loss, higher water holding capacity and lower shear force.

Keywords: duck, leg muscle, chemical composition, functional properties

Zusammenfassung

Auswirkungen des Entengenotyps auf die Beinmuskeleigenschaften

Ziel der Untersuchung war es, den Nährwert und einige funktionelle Eigenschaften des Beinmuskels von verschiedenen Entenherden zu vergleichen. Bei insgesamt 80 Erpeln im Alter von 7 Wochen aus drei Erhaltungszuchten (Kreuzungen aus Pekingtyp [SB], Miniente [K2] und Pekingente dänischer Herkunft [P8]) und einem Mutterzuchtstamm (P66) wurden der Gehalt an Eiweiß, Lipiden, Trockensubstanz, essentiellen Aminosäuren und Cholesterin bestimmt. Bei den funktionellen Eigenschaften wurden untersucht: Farbparameter L^* , a^* , b^* , Farbunterschiede zwischen den Herden, Gesamthaempigment, sensorische Bewertung der Farbtintensität von Muskeln mittels 10-Punkte-Skala, pH_{24} , Wasserhaltevermögen,

Kochverluste und Scherkraft. Der Vergleich von chemischer Zusammensetzung und Art und Anteil der Aminosäuren und des Cholesterins ergab, dass der Beinmuskel des P66-Stamms für die Ernährung am geeignetsten ist. Ebenfalls steht fest, dass die Muskeln aller untersuchter Herden einen hohen Ernährungswert aufweisen. Bei den funktionellen Eigenschaften wurde festgestellt, dass sich die Muskeln der beobachteten Herden farblich und hinsichtlich der untersuchten Eigenschaften unterscheiden. Im Vergleich besaßen die K2-Enten besten funktionellen Eigenschaften: die für Wasservögel typische dunklere Farbe, geringere Kochverluste, höheres Wasserhaltevermögen und kleinere Scherkräfte.

Schlüsselwörter: Ente, Beinmuskel, chemische Zusammensetzung, funktionelle Eigenschaften

Introduction

Although waterfowl is a popular source of meat and makes a significant segment of the agricultural economy in many countries, it makes up only a small proportion of the total poultry meat industry. For the duck production the main problem are the costs. The meat yield of ducks has therefore increased and carcass fattiness has decreased owing to the genetic selection and improvements in bird management. At the same time, the interest in the nutritive value, technological and sensory quality of duck meat has increased. The main species used to produce duck meat are Pekin, Muscovy (mostly in France) and mule ducks (mostly in France for the production of fatty liver, and Taiwan). Other species such as Jinding and Shao ducks in China, Tsaiya ducks in Taiwan, Khaki Campbell, Indian runner and Desi ducks in India, Vietnam, Cambodia and Indonesia are used mainly for egg production and meat is only a by-product (Baéza 2005).

There are many different duck genotypes, and as in other countries in Poland is carried out a breeding program for the preservation of duck genetic resources. These, conservative flocks were used in the development of new breeding and experimental strains and synthetic lines as well as in the search for heterosis effects in commercial sets. Genetic reserve flocks include among others: cross-breeds Pekin type – SB, Miniduck – K2, Pekin originated from Danish Pekin duck – P8, belonging to the conservative flocks, Pekin type breeding strain P66. The unique on international scale populations of birds are kept by *in situ* method at the Waterfowl Genetic Resources Station of the National Research Institute of Animal Production in Dworzyska, Poland. The birds are characterized by very good health, resistance to variable, often adverse climatic conditions of the region of their origin and good conversion of farm-produced feeds (Mazanowski 2002, Książkiewicz 2002, 2003, 2007).

The previous studies about characteristic of conservative duck flocks concerned mainly carcass traits (such as: body weight, percentage yield of muscles, skin with subcutaneous fat and abdominal fat) and nutritive value of breast muscles of only some flocks (Książkiewicz 2003, Kisiel & Książkiewicz 2004, Wołoszyn *et al.* 2006, 2007, 2009, Haraf *et al.* 2009). The percentage yield of leg muscles in the duck carcass is about 20% in relation to age, breed and sex of the birds. However data on the nutritive value and functional traits of leg meat of the specific ducks are scarce and this was the reason for undertaking the investigation on this subject.

The aim of this paper was to characterize and compare the nutritive value (proportion of protein, fat, moisture, cholesterol, amino acid, fatty acid composition), colour (by determining L^* , a^* , b^* parameters, colour difference ΔE between individual flocks), sensory evaluation (SE) of meat colour intensity, total haeme pigment (THP) content), pH_{24} , water holding capacity (WHC), cooking loss (CL) and shear force (SF) of ducks' leg muscles from different flocks.

Materials and methods

The experiment involved ducks from three conservative flocks and one selected breeding strain maintained by *in situ* method in the Waterfowl Genetic Resource Station in Dworzyska near Poznań. The characteristic of the ducks was given in Table 1.

Table 1
Genotypes used for investigation

Flock	Origin of ducks	Short characteristic
P8	Pekins of Danish origin – progeny of Pekin parents imported from Denmark in 1978 (conservative).*	They are characterized by white plumage. Legs and beak are yellow and orange. Weight of adult birds range from 3 200 to 3 400 g. These ducks are characterized by outstanding reproduction and meatiness traits.
SB	Cross – breeds of ducks from three conservative groups A1, A2 and A3, which were progeny of Pekin ducks imported from England in 1977 (conservative).*	Feathers of these ducks are white, legs are orange and yellow, beak is yellow or pale pink. Adult birds weigh from 2 900 g to 3 100 g. The birds are characterized by very good musculature.
K2	Miniduck – crossbred of wild white mallards (<i>Anas platyrhynchos</i> L.) and light Pekin type ducks (conservative).*	It has white plumage with no special feather pattern, white skin, yellow shanks and feet. It is a medium-sized duck with an adult male weighing 1 700 and a female 1 600 g on average. The birds are characterized by very well developed muscles and low fatness.
P66	Maternal strain, selected meat type, bred from Pekins originating from Poland.**	It has the white colour plumage, dark yellow shanks and feet and long orange beak. The adult birds reach about 2 600 g body weight. The A55 male and P66 female ducks have been the parental combination for broiler production. The parental combinations of those strains for production of two strain crosses have been characterized by very good musculature and low fatness.

*Książkiewicz 2002, **Mazanowski 2002

During the testing period ducks were reared up to the 4th week of age in a poultry house of controlled air temperature, and afterwards they were kept on yards of restricted area, partially shaded and covered with straw. All birds were fed *ad libitum* on the same complete feeds (Table 2).

In the 7th week of age, from each flock (comprising 60 birds) 10 males were taken for analysis (two experiments were made – 2×10 birds per genotype) having body weight close to the arithmetic mean of body weight in a particular flock (Table 3).

Table 2
Diet composition used in the trial

Ingredients, %	1-21 days	22-49 days
Wheat meal	72.8	57.6
Soybean meal	17.0	10.0
Barley meal	17.4	-
Rapeseed oil	1.0	1.6
Fish meal	5.4	4.0
Premix KB, vitamin-mineral premix	1.0	1.4
Chemical composition, %/kg of diet		
Crude protein	20.0	16.5
Ether extract	4.00	3.00
Ash	5.50	6.00
Cellulose	3.50	5.00
L-Lysine	1.05	0.820
D-L Methionine	0.490	0.460
Calcium	0.850	0.860
Total phosphorus	0.700	0.800
Vit. A, IU/kg	15 000	14 000
Vit. D ₃ , IU/kg	3 500	2 000
Vit. E, mg/kg	60	50
Metabolizable energy (ME), MJ/kg ^a	12.1	12.3

^aThe caloric value of all-mashes calculated on basis of percentage content of some analytic components of feed, expressed in a megajoule (MJ) metabolizable energy (ME) per 1.0 kg of fed mixture, with a level nitrogen adjusted in following method (Ministry of Agriculture and Rural Development, [2009]): MJ/kg ME = 0.1551 × % crude protein + 0.3431 × % crude fat + 0.1669 × % starch + 0.1301 × % total sugar content (expressed as sucrose).

Table 3
Experimental design

Specification	P66	K2	SB	P8
Number of male birds	60	60	60	60
Slaughtered, n	20	20	20	20
Age at slaughter, weeks	7	7	7	7
Mean weight at slaughter, g	2 583	1 577	2 498	2 675

The slaughter of birds and cutting out of all leg muscles (thigh and drumstick with intramuscular fat and without skin and subcutaneous fat) were done in a local slaughterhouse, according to the referent regulations applied in the poultry industry. The leg muscles were stored at 2-4 °C for 24 h after slaughter and then investigated.

Chemical analyses in homogenates were carried out using the following methods:

- Moisture, protein, and lipids – were determined with standard methods (AOAC 1990).
- Cholesterol – using the enzymatic Human test in an extract prepared by Folch *et al.* (1957) procedure. The saponification was carried out by Rhee *et al.* (1982) method.
- Amino acid composition – was determined using HPLC Agilent Tech. 1200 Chromatograph (Agilent Technologies, Inc., Santa Clara, CA, USA) with a fused silica capillary column Zorbax Eclipse-AAA column – 3.0 × 150 mm × 3.5 μm and diode-array detector (DAD) according to the manufacturer's recommendations. The hydrolysis of meat samples and the analysis were performed following the procedures described by Wołoszyn *et al.* (2006). Coefficients of essential amino acids (R%) were established according to the formula:

$R(\%) = 100\% \times A_m / A_s$, (A_m : essential amino acid content in the duck meat protein; A_s : essential amino acid content in the standard FAO/WHO/UNU [2007]).

- The composition of fatty acids was determined using the gas chromatography technique with the Agilent 6890N Gas Chromatograph (Agilent Technologies, Inc., Santa Clara, CA, USA), equipped with a flame-ionization detector. The methyl esters of fatty acids were separated on the fused silica CP-Sil 88 (ChromPack, Middelburg, The Netherlands) capillary column (100×0.25 mm), helium was used as the carrier gas. The separation was conducted at the programmed temperature from 165 to 220 °C by an increase rate at 2 °C/min. The identification of fatty acids was accomplished by comparison with external standards. The fatty acids were calculated as % of total fatty acids with the Agilent ChemStation v. B.04.02. SP1 (Agilent Technologies, Inc., Santa Clara, CA, USA) programme.

Functional properties were carried out using the following methods:

- The colour parameters in the middle part of the inner side of leg muscles are presented in the L^* , a^* , b^* colour scale (Cie 1986) using an automated Minolta Chroma Meter CR-310 (Minolta Camera Co. Ltd, 2-Chome, Osaka, Japan) with light source D65 and 8 mm measuring cell. L^* is a measure of lightness: 0 equals black - 100 equals white. High positive values of a^* indicate redness and large, negative values indicate greenness. High positive b^* values indicate yellowness and large, negative values indicate blueness. Before measurements the apparatus was calibrated according to the white reference standard: $Y=94.2$; $x=0.313$; $y=0.324$ (CIE 1986). The colour difference (ΔE) was calculated from the formula: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. The ΔL^* , Δa^* and Δb^* were differences between mean L^* , a^* and b^* values for individual flocks.
- Sensory evaluation (SE) of the raw muscles' colour was conducted by the sensory panel (7 trained people) according to Analsens NT programme (Barylko 2000) using 10 point scale (1 – very light colour; 10 – very dark colour) of intensity and expressed in conventional units (CU) (Barylko-Pikielna & Matuszewska 2009).
- The total heam pigments (THP) content was determined in accordance with the Warriss procedure described by Haraf *et al.* (2009).
- The measurements of pH were done using a digital Metrohm pH-meter 654 series (Metrohm Ltd. CH-9100 Harisau, Switzerland), equipped with a combination type of pH spearhead electrode Double Pore Slim (Hamilton Company, Reno, NV, USA) and a thermometer.
- Water holding capacity (WHC) – was determined using a filter paper press method (Grau & Hamm 1957). The minced meat (300 mg) was placed on the Whatman filter paper and next put between two glass plates and exposed to 1 kg pressure for 1h. The WHC was expressed as: $100\% \times M/T$, where M is the area (cm²) of the meat and T is the total area (cm²).
- Cooking loss (CL) – was determined with the Kotter *et al.* (1968) method. The minced meat samples weighing 30 g were placed into a strainer and put to the thermostat at 80 °C for 20 min. Next samples were taken immediately, gently blotted dry and next weighed. Cooking loss was expressed as a percentage of the initial weight.
- Shear force (SF) of muscles was carried out using an Instron Universal Testing Machine Model 5543 (Instron, Norwood, MA, USA). The four 12.7 mm diameter round cores (length=10 mm) were obtained from each muscle. The cores were collected parallel to the muscle fibres, using a hand-hold steel cork borer. The cores were sheared perpendicular to the fibres with a Warner-Bratzler compression – type shear attachment (1 kN load cell, 200 mm/min crosshead speed).

Statistical analysis was based on arithmetic means (\bar{x}) and standard error (SEM). The effect of flock was analysed by one way analysis of variance (ANOVA) in an orthogonal scheme. The significance of differences between the mean values of investigated traits were determined by Duncan's multiple range test with StatSoft 6.0 (StatSoft, Inc. Tulsa, OK, USA).

Results

It was found out that the basic chemical composition of the duck leg muscles depended on the genotype of flock. The significant differences in the lipids and cholesterol content were stated. The K2 leg muscles comprised less ($P \leq 0.05$) lipids than the P66, SB, P8 ones. However the P66 (breeding strain) demonstrated the lowest amounts of cholesterol ($P \leq 0.01$) in comparison to P8, SB and K2 muscles. There were no significant differences in protein and moisture content (Table 4).

Table 4
Chemical composition and essential amino acids (% of total protein) composition of leg muscles

Parameter	P66	K2	Flock SB	P8	SEM	Effect of flock
Protein, %	20.66 ^a	20.57	20.44 ^b	20.56	0.68	ns
Lipids, %	1.83 ^{Aa}	1.47 ^B	1.79 ^A	1.69 ^b	0.08	*
Moisture, %	76.47 ^b	76.55 ^b	76.52 ^b	76.83 ^a	0.25	ns
Cholesterol, mg/100g	85.17 ^B	106.31 ^{AD}	111.72 ^{ACb}	112.85 ^{ACa}	0.81	**
PHE+ TYR	7.99 ^A	6.37 ^{Ba}	6.25 ^{Bb}	6.22 ^{Bb}	0.12	*
ILE	5.67 ^A	3.28 ^{Bb}	3.46 ^{Ba}	3.35 ^B	0.08	*
LEU	8.61 ^A	7.78 ^{Ba}	7.67 ^B	7.52 ^{Bb}	0.10	*
LYS	9.59 ^a	9.07 ^b	9.09 ^b	9.11 ^b	0.09	ns
MET+CYS	3.31 ^b	3.45 ^b	3.88 ^{ac}	3.66 ^{ad}	0.21	ns
THR	5.37 ^A	4.23 ^{Bb}	4.49 ^{Ba}	4.37 ^B	0.11	ns
TRP	0.77 ^B	1.19 ^{Aa}	0.98 ^{Bb}	0.99 ^{Bb}	0.02	*
VAL	6.47 ^A	3.61 ^{Bb}	3.67 ^B	3.77 ^{Ba}	0.29	**

The data are average values of 6 tests: $\bar{x} \pm \text{SEM}$, ^{A, B, C, D}Values with different letters at the same line are significantly different at $P \leq 0.01$, ^{a, b, c, d}Values with different letters at the same line are significantly different at $P \leq 0.05$; ns=not significant, * $P \leq 0.05$, ** $P \leq 0.01$

The data given in Table 4 show that the leg muscles of investigated ducks contained all essential amino acids like other kinds of meat. The amino acid proportion of meat proteins depended on ducks' flocks, and significant differences were found. The leg muscles from P66 breeding strain comprised more PHE+TYR, ILE, LEU, THR, VAL, and less TRP as compared to muscles of P8, K2 and SB conservative flocks. The proteins of K2 were characterized by the highest content of TRP and lowest of THR in comparison with the muscles of the other ducks. According to the FAO/WHO/UNU (2007) standard, the VAL was amino acid limiting the biological value of meat proteins of K2, SB and P8 (Table 5). Except of VAL, the meat proteins of the investigated raw materials contained more essential amino acids than the standard. The MET+CYS (206.9–242.5) and LYS (201.6–213.1) were characterized by the higher value of index R and thereby possessed the highest biological value among essential amino acids. The leg muscles of P66 contained more of all essential amino acids than the standard, and taking into consideration the biological value of proteins, they appeared to be the most favourable.

Table 5
Coefficients of essential amino acids (R %)

Amino acid	P66	K2	SB	P8
PHE+TYR	210.3	167.6	164.5	163.7
ILE	189.00	109.3	115.3	111.7
LEU	162.4	146.8	144.7	141.9
LYS	213.1	201.6	202.0	202.4
MET+CYS	206.9	215.6	242.5	227.5
THR	233.5	183.9	195.2	190.0
TRP	128.3	198.3	163.3	165.0
VAL	165.9	92.6	94.1	96.7

The genotype of ducks affected the profile of fatty acids (Table 6). The unsaturated fatty acids (UFA) were predominant (60.14-64.04 %) in fatty acids composition of intramuscular fat for all flocks. The lipids of P66 breeding strain comprised the most of UFA especially monounsaturated fatty acids (MUFA) and n-3 polyunsaturated fatty acids (n-3 PUFA).

Table 6
Fatty acids in leg muscles

Parameter	P66	K2	Flock SB	P8	SEM	Effect of flock
SFA, %	30.57 ^B	32.84 ^{ACb}	31.55 ^{AD}	33.17 ^{ACa}	0.98	ns
MUFA, %	38.97 ^{AC}	30.01 ^B	36.88 ^{AD}	32.96 ^{BC}	0.87	**
PUFA, %	25.07 ^B	30.13 ^{AC}	25.12 ^B	27.93 ^{AD}	0.39	*
UFA, %	64.04 ^{AC}	60.14 ^{Bb}	62.00 ^{AD}	60.89 ^{Ba}	0.81	**
n-6 PUFA, %	24.16 ^{Ab}	24.85 ^{ACa}	23.85 ^{AD}	21.33 ^B	0.63	ns
n-3 PUFA, %	6.02 ^{Aa}	4.25 ^B	5.69 ^{Bb}	5.52 ^{Bb}	0.15	**
UFA/SFA	2.09 ^{Aa}	1.83 ^b	1.98 ^b	1.73 ^B	0.19	ns
PUFA/SFA	0.82	0.91	0.81	0.85	0.07	**
n-6/n-3	4.01 ^B	5.84 ^A	4.17 ^{Ba}	3.86 ^{Bb}	0.28	*

The data are average values of 6 tests: $\bar{x} \pm \text{SEM}$, ^{A,B,C,D}Values with different letters at the same line are significantly different at $P \leq 0.01$, ^{a,b,c,d}Values with different letters at the same line are significantly different at $P \leq 0.05$, ns: not significant, * $P \leq 0.05$, ** $P \leq 0.01$

This is very important because preference in human diets is given to the high level of the n-3 PUFA, which is the most valuable fatty acid in the UFA group from the nutritional and physiological points of view. The muscles of P66 contained less saturated fatty acids (SFA) compared to the conservative flocks, too. The highest content of PUFA was detected in fat of K2 muscles (30.13 %). The UFA:SFA ratio was more favourable (1.98-2.09) for P66 and SB than for the K2 and P8 muscles. The PUFA:SFA ratios ranged to 0.81-0.91 and were on the higher level for all muscles than recommended (0.4). The n-6:n-3 PUFA ratios were 3.86-5.84 and they were close to recommended (4-5). The lipids from leg muscles of P66 selected breeding strain were characterized by the most favourable fatty acid profile among the investigated birds.

The functional properties of the leg muscles were presented in Table 7. Comparing the colour parameters, significant differences were found. The origin of ducks influenced the L* ($P \leq 0.01$) and b* ($P \leq 0.5$) values. The K2 muscles were significantly lower in L* and b* and

higher in a^* values than SB, P8 and P66 ones (Table 7). The highest values in L^* and intensity of yellowness were observed for the SB muscles. There were no significant differences in L^* , a^* and b^* parameters for P66 and P8 muscles. The ΔE values (Table 8) indicate that pairs of P8, P66 ($\Delta E=0.25$) and P8, SB ($\Delta E=1.45$) were the most similar as regards colour parameters. The K2 muscles were the most distinct from the P8, P66 and SB flocks ($\Delta E=5.33$ -6.09). The results obtained in our experiments indicate the large total colour variation of the samples taken from different breeds.

Table 7
Functional properties of leg muscles

Parameter	P66	K2	Flock SB	P8	SEM	Effect of flock
L^*	45.62 ^{BC}	41.51 ^{BD}	47.63 ^A	45.81 ^{BC}	0.38	**
a^*	16.03 ^{Ba}	18.70 ^A	15.72 ^{Bb}	16.11 ^{Ba}	0.20	ns
b^*	5.42 ^B	3.31 ^B	6.82 ^{AC}	5.54 ^{AD}	0.13	*
THP, mg/g	2.89 ^{Ba}	3.96 ^A	2.55 ^{Bb}	2.75 ^B	0.11	*
SE (CU)	6.53 ^{Ba}	7.50 ^A	6.16 ^{Bb}	6.25 ^{Bb}	0.22	*
pH ₂₄	6.13 ^a	6.29 ^b	6.17 ^a	6.19 ^a	0.16	ns
WHC, %	64.60 ^B	71.30 ^A	63.80 ^{BDb}	65.60 ^{BCa}	0.91	*
CL, %	26.30 ^{AC}	22.50 ^{BD}	27.50 ^A	26.10 ^{BC}	0.24	*
SF (N/m ²)	39.10 ^{AC}	34.50 ^{Bb}	37.50 ^{ADa}	36.80 ^{BC}	0.31	*

The data are average values of 6 tests: $\bar{x} \pm \text{SEM}$, ^{A,B,C,D}Values with different letters at the same line are significantly different at $P \leq 0.01$, ^{a,b}Values with different letters at the same line are significantly different at $P \leq 0.05$, ns=not significant, * $P \leq 0.05$, ** $P \leq 0.01$, THP: total haem pigments content, WHC: water holding capacity, CL: cooking loss, SF: shear force, SE: sensory evaluation, CU: conventional unit (red-pink intensity)

Table 8
Colour (L^* , a^* , b^*) differences (ΔE) between individual flocks

Flock	P66	K2	SB	P8
P66	-	5.33	2.95	0.25
K2	5.33	-	6.09	5.48
SB	2.95	6.09	-	1.45
P8	0.25	5.48	1.45	-

The total haem pigments' content in analysed muscles depended on ducks' origin, too (Table 7). The differences between values of THP ranged from 2.55 mg/g – SB up to 3.96 mg/g – K2 and were statistically significant. The P66, P8, and SB leg muscles belong to a group with THP level comprised between 2.55 and 2.89 mg/g and the K2 had the highest THP content (3.96 mg/g). The results obtained for L^* , a^* and b^* parameters were in agreement with data established for the total haem pigment content. The muscles with the highest content of haem pigments (K2) were characterized by the lowest value in L^* and b^* parameters and the highest intensity of redness.

The colour of all investigated muscles was defined by the sensory panel as pink-red, with intensity in interval from 6.16 to 7.50 CU (Table 7). The leg muscles of K2 were characterized by the highest intensity of red- pink colour, however the differences between P66, P8 and SB were not significant. These results of sensory evaluation were similar to those obtained for colour parameters, and THP content. Generally, the K2 muscles were the most distinct

from remaining flocks in L^* , a^* , b^* , THP and SE parameters. No significant differences were observed in pH_{24} , WHC, CL, SF values for P66, P8 and SB muscles. However the K2 muscles were characterized by higher pH_{24} , WHC and lower CL and SF values (Table 7), it proves that they had the best analysed functional properties.

Discussion

Higher contents of lipids (1.9-6 %) was found in leg muscles of different Pekin type and their crossbreds (Knust 1995, Leskanich & Noble 1997, Mazanowski & Książkiewicz 2004, Chartrin *et al.* 2005) in comparison with our results. In the previous investigation we stated for Pekin type conservative flocks P33 and A3 similar content of lipids (1.73, 1.85 % respectively) in leg muscles (Wołoszyn *et al.* 2007). The protein content in the investigated muscles was higher than that determined by Mazanowski & Książkiewicz (2004) for meat type ducks from two sire strains A44, A55 (18.6-18.8 %) and by Górska & Górski (1997) for three and four-breed crosses of Pekin ducks (19.4 %). In comparison with our results obtained for conservative flocks, considerably lower cholesterol content was reported for Pekin (68.5 mg/100g) and force fed Mulard (74.1 mg/100g) (Honikel & Arneth 1996, Wołoszyn 2002). In previous work we observed a similar content of cholesterol in leg muscles of A3 (117 mg/100g) and P33 (112 mg/100g) ducks (Wołoszyn *et al.* 2007). The profile of essential amino acid for the investigated leg muscles protein was similar to that obtained for P33 and A3 ducks (Wołoszyn *et al.* 2005). The coefficients of R for MET+CYS and LYS were characterized by a higher value than the other essential amino acids and it was in agreement with results obtained for Mulard and the conservative Pekin type A33 and A3 ducks (Wołoszyn 2002, Wołoszyn *et al.* 2005).

According to our findings with regard to the fatty acids composition it was stated that the UFA were predominant as for Muscovy, Pekin and Mulard ducks (Wołoszyn 2002, Chartrin *et al.* 2003). The UFA and the MUFA contents in fat of all investigated muscles were lower than those published by Chartrin *et al.* (2003) for Muscovy (64.6, 45.5 %), Hinny (66.5, 47.7 %), Mulard (67.2, 48.4 %) and Pekin (71.2, 54.7 %) ducks. These genotypes contained more PUFA than Muscovy (18.1 %), Hinny (18.8 %), Mulard (18.7 %) and Pekin (16.5 %) and less SFA than Muscovy (36.4 %) ducks. The profile of fatty acids was similar to A3 Pekin type leg muscles. However, in spite of the same environmental conditions, the leg muscles of all investigated strains contained more UFA (≈ 6.1 -8.02 %) and less SFA (≈ 1.5 -4.5 %) than P33 flock (Wołoszyn *et al.* 2005). The higher UFA (≈ 1.5 -4.8 %) and MUFA (≈ 14.5 -24.5 %) content was observed in lipids of force fed Mulard ducks (Wołoszyn 2002) in comparison to our results. Leskanich & Noble (1997) reported more SFA and less UFA in fat of muscles of commercial Pekin ducks. The PUFA:SFA and the n-6:n-3 PUFA ratios were significantly more favourable for investigated muscles than results obtained for Pekin, Muscovy, force fed Mulard (Wołoszyn 2002, Chartrin *et al.* 2003, 2005) and similar to A3 and P33 ducks (Wołoszyn *et al.* 2005). However, comparing all investigated parameters it should be mentioned that Pekin and Muscovy originate from two species genetically very distinct from each other. Moreover the diet composition used in the studies, the housing condition and age of the ducks were not the same, what can lead to the differences.

The data obtained by Skrabka-Błotnicka *et al.* (2002) for male leg muscles of Muscovy ducks were similar in L^* , a^* , b^* and THP values to results for K2 muscles. The results presented by Wołoszyn (2002) for Mulard (force fed) leg muscles were similar in L^* , b^* and THP and higher

in a^* (21.30) than for P66, SB, and P8 flocks. The Mulard leg muscles were characterized by higher differentiation in the colour parameters, too. The colour parameters L^* , a^* and b^* stated by Skrabka-Blotnicka *et al.* (2003) for leg muscles of P33 and A3 Pekin type were comparable to the examined P66, SB and P8 flocks.

The total haem pigment content in leg muscles was similar to data established by Pikul *et al.* (1982, 1987) and Niewiarowicz *et al.* (1986) for different kinds of Pekin (2.97-3.63 mg/g). The values of L^* , a^* , b^* , ΔE parameters as well as THP, pH_{24} , WHC, CL, SF were in the same range of those presented in the literature for the duck muscles. The slight differences between our results and other investigations were caused by different genotype of animals (Pikul *et al.* 1982, 1987, Niewiarowicz *et al.* 1986, Knust 1995, Işguar *et al.* 2002, Wołoszyn 2002, Chartrin *et al.* 2003, 2005), their age, sex, feeding, housing condition (Pingel 1988, Pingel & Knust 1993, Baéza *et al.* 1999, Skrabka-Blotnicka *et al.* 2002, Kisiel & Książkiewicz 2004, Wawro *et al.* 2004) and slaughtering condition (Chen *et al.* 1991, Romboli 1995). Moreover the methods of measurements or equipment used in the studies are not always the same, which can explain different values.

Taking into consideration the analysed functional traits of the leg muscles they can be divided into two groups: 1st group – K2 and 2nd – P66, P8 and SB. The K2 duck seems to have distinct muscle characteristics than the other ones. The body weight of K2 was the lowest (it represented Miniducks type) and it is the result of a crossbreed between Mallard and Pekin ducks, where P66, P8 and SB genotype is only Pekin. According to Kisiel & Książkiewicz (2004), the K2 *m. biceps femoris* was characterized by significantly lower diameters of αW (white) and βR (red) fibres than Pekin type P33 flock. Biesiada-Drzazga *et al.* (2000) based on microstructural analysis of the *m. biceps femoris* found in A44 pedigree ducks greater diameter of the αW and βR fibres than those shown by Kisiel & Książkiewicz (2004) for K2 ducks. Probably the fibre typology – more red fibres in K2 (Książkiewicz 1982) and the fibre size are not the same, and K2 breed finally varied in values for colour parameters, THP content, pH_{24} , WHC, CL and SF.

Comparing the basic chemical, amino acid composition, cholesterol content and profile of fatty acids, it could be concluded, that the P66 leg muscles coming from a selected breeding strain, are the most favourable from the nutritional point of view. It is evident too, that muscles from all the examined flocks have been characterized by a high nutritional value. In spite of the same feeding, housing condition and age the differences in chemical composition of leg muscles coming from examined ducks were observed. Probably different physiological mechanisms in the investigated ducks resulted in the differences in chemical composition.

Taking into consideration the functional properties, it was concluded that the muscles from investigated flocks varied in colour and analysed traits. The ducks of K2 are completely different in all functional properties. The advantages of K2 in comparing to P8, SB and P66 ducks are: darker colour typical of waterfowl meat, lower cooking loss, higher water holding capacity, lower shear force. The lower value of shear force can show that their meat is characterized by more suitable tenderness. For the consumers, disadvantage of the K2 ducks can be a relatively small body weight.

In the future the studies on the sensory evaluation of roasted meat are recommended as this is the most popular and required kind of product by consumers.

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