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Development of selected performance, dressing and meat quality traits of Pekin ducks in relation to genotype and phytogenic feed additives

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The aim of this study was to determine the effect of the genetic origin of ducks and the use of phytogenic additives in their feeding on performance indices, slaughter value and dressing percentage, as well as meat quality. The experimental material consisted of three genetic groups of Pekin ducks: Polish Pekin P-33 (P), Dworka D-11 (D) and Star 53 H.Y. (S). A 7-week experimental rearing of 216 commercial hybrids (3 × 72 animals) was carried out. Within each genetic line, three feeding groups were established, differing in the use of plant-based additives in the feed mixture (5% herb mixture or 5% black cumin seed). To assess slaughter value and meat quality of the ducks, 18 birds from each group were selected, including 9 males and 9 females. It was shown that the basic performance and slaughter value traits of Pekin ducks depend ($p \leq 0.05$) on their genetic origin. The most favourable ($p \leq 0.05$) rearing efficiency and slaughter value (body, carcass and meat weight) were found for commercial Star 53 HY ducks. Their breast muscles were characterized by higher ($p \leq 0.05$) cooking loss and lower ($p \leq 0.05$) collagen content. The genetic origin of the ducks was shown to influence ($p \leq 0.05$) economic efficiency of rearing, dressing percentage and chemical

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indicators of meat (except for water content in breast muscles) and some physical characteristics (pH_{24}, cooking loss, colour lightness of leg muscles and electrical conductivity in breast muscles). Supplementation of the standard diet of ducks with phytogenic additives (mixture of herbs, black cumin seeds) at a level of 5% had ($p \leq 0.05$) a negative effect on body, carcass and meat weight, and a positive effect on the physical characteristics of meat related to water loss (pH24 and cooking loss).

KEY WORDS: duck / meat quality / genotype / phytogenic feed additives

The duck meat market has grown rapidly worldwide in recent years. Global meat production of this waterfowl species increased from 2.9 million tonnes in 2000 to almost 4.4 million tonnes in 2013. While Asia is the leading producer, it is estimated that production in Europe has averaged 500,000 tonnes per year since 2009. Pekin ducks are the predominant breeding stock used for meat production, in addition to a smaller proportion of Muscovy ducks and their hybrids [Chen *et al.* 2021]. The premise for proper rearing of fattening ducks is to obtain body weight and economic indicators at a level that satisfies the producer, but also to produce well-formed carcasses that meet consumer expectations [Pingel 2011, Biesiada-Drzazga *et al*. 2012, Baéza *et al.* 2022]. With the development of duck breeding and rearing, interest in scientific research on this species has increased. Genetic origin [Xu *et al*. 2011, Mucha *et al.* 2014, Stęczny *et al.* 2015], sex [Omojola 2007, Farhat 2009] and nutrition [Kokoszyński *et al.* 2017, Gunawan *et al.* 2023] have been shown to be the main factors modifying body weight of fattening ducks. Current trends in ongoing research focus on issues of behaviour, welfare and quality of duck meat [Graczyk *et al.* 2016, Kim *et al.* 2018, Abo Ghanima *et al.* 2020, Makagon and Riber 2022]. Poultry breast and leg muscles are analysed to determine their processability, sensory attributes and nutritional value [Gornowicz *et al.* 2015, Smith *et al.* 2015, Barbut and Leishman 2022]. An important indicator for this evaluation is the hydrogen ion concentration, which being correlated with the colour lightness (L*), water holding capacity, cooking loss and electrical conductivity, determines meat properties [Baéza *et al.* 2022]. Previous studies have shown that duck meat is more abundant in fat compared to meat of landfowl. Namely, breast muscles of Pekin ducks contain an average of 1.81% fat, while in broiler chickens it is 1.25% [Mazanowski *et al*. 2003, Ismoyowati and Sumarmono 2019]. Furthermore, fat in waterfowl is also deposited in the form of abdominal and subcutaneous fat, negatively affecting overall slaughter value of these bird species [Murawska 2012, Onbasilar and Yalçin 2018].

Plants such as herbs are a source of protein, minerals (Ca, P, Mg, Zn, I) and vitamins (B_1, B_2, C, PP) and, above all, biologically active substances affecting metabolism of animals and humans [Bhagya *et al.* 2017, Paula *et al.* 2020]. The simplest form of ground dried plants is easy to administer to animals together with their feed, requiring only proper mixing to ensure even distribution throughout the feed. However, it generally contains a relatively high proportion of fibre. In addition, the content of valuable bioactive components is non-standardized and can be highly variable [Pliego *et al*. 2022]. Studies on the performance and meat traits of Pekin-type ducks receiving feeds with phytogenic additives with an increased content of biologically active compounds have been scarce [Gerzilov *et al.* 2011, Azeem *et al.* 2014].

The research hypothesis assumed that three different genetic groups of ducks have different economic rearing efficiency,; dressing percentage and meat quality, and that the use of selected phytogenic additives in bird nutrition will have a positive impact on these parameters. The aim of this study was to determine the effect of the genetic origin of ducks and the use of phytogenic additives in their feeding on performance, dressing and meat quality traits of Pekin ducks.

Material and methods

The experimental material consisted of three genetic groups of Pekin ducks: Polish Pekin P-33 (P), Dworka D-11 (D) and Star 53 H.Y. (S). A 7-week experimental rearing in a semi-intensive system with access to a run for 216 commercial hybrids (3 × 72 animals) was carried out.

Within each genetic line three feeding groups were established, differing in the use of plant-based additives in the feed mixture. Starting from the fourth week of age of the birds, a 5% herb mixture (H) or 5% black cumin seed (*Nigella sativa* L., BC) was added to the feed. In contrast, the control group (C) received only the feed mixture. The results recorded in this group (C) were used to compare values of the tested parameters in ducks differing in genetic origin (D, P and S). Birds were fed *ad libitum* with the same complete feed mixtures, initially KB-1 until the 4th week of life (20.00% crude protein, 11.93 MJ of metabolic energy) and later KB-2 (18.50% and 11.86 MJ, respectively).The herb mixture used in the birds' diet contained dried herbs, cut to pieces of max. 0.5 cm (*Calendula officinalis* L, flower, 20% ; *Hypericum perforatum* L., herb, 10%; *Matricaria chamomilla* L., inflorescence, 20%; *Mentha piperita* L., herb, 25%; *Urtica dioica* L., herb, 25%). The European Production Index (EPI) of each group was calculated based on final body weight, survival rate, feed conversion ratio and rearing length.

To assess slaughter value and meat quality of the ducks, 18 birds from each group were selected, including 9 males and 9 females, excluding birds with extreme body weights. Twenty-four hours after slaughter a simplified dissection was carried out [Ziołecki and Doruchowski 1989], after which the carcasses (CW) and giblets (G) were individually weighed. During dissection the following carcass elements were separated: breast muscles (entire *m. pectoralis superficialis* and *m. pectoralis profundus*, BM), leg muscles (thigh with shank, LM), skin with subcutaneous fat (SS), abdominal fat (AF), neck (without skin), skeleton with back muscles and inedible parts (tendons), and wings (with skin). In this study the last three components (neck, skeleton and wings) were analysed jointly as other carcass parts.

Physical characteristics of breast and leg muscles were measured 24 hours after slaughter. Hydrogen ion concentration (pH_{24}) was measured with a MP 125 DE portable pH meter by Mettler-Toledo (Switzerland), with an Inlab 427 calomel electrode. Electrical conductivity (EC_{24}) was measured with an LF-STAR by Matthäus (Germany). Instrumental colour measurement in the CIE L*a*b* colour system (CIE, 1986) was performed using a Minolta Chroma Meter C580 electronic trichromatic colorimeter (illuminant D65, observer 10º, aperture 8 mm, calibrated with a white plate: L* – 99.18). The L* colour lightness of breast and leg muscle surfaces from the side adjacent to the skeleton was measured once at three points. The water holding capacity (WHC) of meat was determined using the method of Grau and Hamm [1952], modified by Pohja and Niinivaara [1957]. Contents of fat, protein, water and collagen in duck muscles were determined by near-infrared (NIR) transmission spectrometry with calibration on artificial neural networks (ANN) using a FoodScan instrument by Foss (PN-A-82109:2010). Cooking loss (CL) was determined according to Honikel [1998].

Data were processed using Statistica 10 [StatSoft, 2006]. Mean values for all analysed parameters were calculated. A two-way analysis of variance including fixed effects of genotype (G), and feed additive (FA) and interaction of G by FA was performed. The significance of differences was verified using Duncan's test. The significance level of less than 0.05 was assumed.

Results and discussion

The European Production Index and body, carcass and giblets weights were significantly ($p \leq 0.05$) highest for the S flock (Tab. 1). This genetic group achieved an EPI score of 294. The value of this parameter for ducks of the other two genetic groups was by 36.4% D and 39.5% P lower. In an earlier study Kokoszyński [2011] compared the development of EPI in the 7-week rearing of four Pekin-type fattening duck hybrids: AP54, PP54, PP45 and Star 53 H.Y. The highest value of the studied parameter (325) was reported for Star 53 H.Y. ducks, similarly to what was recorded in this study.

No significant effect of the addition of the herb/black cumin on the EPI parameter was found in any of the investigated genetic groups of ducks. Studies [Attia 2018, Hassan and Mandour 2018] using 0.5 and 1.0% supplement of black cumin seeds in the feeding of broiler chickens showed some tendency for this supplement to have a positive effect on EPI results. On average, an improvement of between 11.5 and 13.5% in this poultry rearing index was obtained, but these differences were not statistically significant.

At the end of the rearing period ducks of groups D and P were lighter ($p \leq 0.05$) by 0.82 and 1.01 kg, respectively, than S birds. A similar pattern was shown for carcass weight and giblets weight, with the differences of 0.65 and 0.88 kg for the former parameter and 29.4 and 42.4 g for the latter, respectively. It was shown that the genotype of the ducks has a major ($p \leq 0.05$) effect on the performance traits studied. Similarly, Bernacki *et al.* [2008] found a significantly ($p \leq 0.05$) greater body weight before slaughter for Star 63 (2997 g) compared to PP54 (2645 g) and Dworka CaA15

Table 1. Basic performance and dressing parameters of ducks depending on genotype and feed additive

Genotype	Feed additive	EPI	B (kg)	CW (kg)	G (g)	BM (G)	LM (g)	SS (g)	AF (g)	R (g)
D	C	187[b]	2.84[b]	1.80[b]	190.2[b]	299[c]	232[c]	474[b]	21.4[c]	763[b]
	H	185[b]	2.51[bc]	1.68[bc]	177.2[bc]	284[c]	205[d]	413[c]	15.0[e]	751[b]
	BC	185[b]	2.72[bc]	1.79[b]	192.8[b]	298[c]	219[cd]	485[b]	24.0[a]	762[b]
P	C	178[b]	2.65[bc]	1.57[bc]	177.2[bc]	236[d]	206[d]	416[c]	17.6[d]	681[bc]
	H	176[b]	2.30[c]	1.44[c]	166.6[c]	217[d]	196[d]	358[d]	14.2[e]	645[c]
	BC	177[b]	2.56[bc]	1.49[c]	165.8[c]	223[d]	205[d]	386[cd]	14.0[e]	659[c]
S	C	294[a]	3.66[a]	2.45[a]	219.6[a]	509[a]	331[a]	566[a]	22.8[b]	1006[a]
	H	283[a]	3.34[a]	2.27[a]	212.7[a]	464[b]	303[b]	512[b]	22.5[b]	964[a]
	BC	286[a]	3.42[a]	2.29[a]	222.7[a]	439[b]	301[b]	570[a]	23.9[a]	953[a]
SEM		3.96	0.67	0.42	2.75	11.06	8.09	19.9	2.10	7.39
P value										
genotype (G)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
feed additive (FA)		0.142	<0.001	<0.001	0.307	<0.001	<0.001	<0.001	0.004	0.004
G x FA		0.313	0.098	0.459	0.116	<0.001	0.864	0.030	0.030	0.579

D – Dworka D-11 duck, P – Pekin duck P-33, S – Star 53 H.Y. duck.
C – control, H – 5% of herb mixture in feed, BC – 5% of black cumin seed in feed, EPI – economic performance indicator, B – body weight, CW – carcass weight, G – giblets weight, BM – breast muscle, LM – leg muscle, SS – skin with subcutaneous fat, AF – abdominal fat, R – other carcass parts (skeleton, wings, neck), SEM – standard error of the mean.
[ab]Values in columns bearing with different superscripts differ significantly at $p \leq 0.05$.

(2488 g). When comparing meat traits of two breeding lines for intensive use P55 (of Polish origin), F11 (of French origin) and their hybrids, Kuźniacka and Adamski [2019] showed that genotype influences body weight of ducks especially in the initial (up to week 2) and final (weeks 6 to 7-8) parts of the rearing period.

A tendency for birds to have lower body and carcass weights was observed after using a 5% herb or black cumin seed mixture in the feed (Tab. 1). In all the genetic groups, the greatest body and carcass weights were recorded in the C group, i.e. birds fed without additives. After a 7-week rearing period the mean values of body weight in the supplemented groups were lower by 7.65 S, 8.30 P and 7.75% D and carcass weight by 6.94, 6.37 and 3.33%, respectively. However, the differences were not statistically significant. Analysis of variance showed that the supplements studied had an effect on body and carcass weights of ducks. The results and conclusions from studies by other researchers regarding the use of herbs and black cumin seeds in feeding of slaughter poultry are inconsistent. They usually concern the determination of the effect of only individual herbs from the combination used in the mixture in this study. When using a 1% supplement of ground black cumin seeds in feeding of Ross 308 broiler chickens after 35 days of rearing no effect of this supplement on body weight was recorded [Nasir and Grashorn 2010, Khalaji *et al*. 2011]. In contrast, such a relationship was found by Shareef *et al.* [2017] after 35-day rearing of Hubbard chickens ($p \leq 0.05$) and Khalaji *et al.* [2011] after a longer, 42-day rearing of Ross 308 chickens ($p \leq 0.01$).

The dressing percentages carcasses, expressed by the weight of BM, LM, SS and AF differed significantly ($p \leq 0.05$) between the three genetic groups studied (Tab. 1).

The S group was characterized by the aforementioned parameters with significantly ($p \leq 0.05$) highest weights of 509, 331, 566 and 22.8 g, respectively. Lower values of 273, 125, 150 and 5.2 g, respectively, were recorded for P ducks, which in this comparison showed the lowest dressing percentage indices. Also, the highest weight of the other carcass components was characteristic of S ducks (1006 g), and this was a significant ($p \leq 0.05$) difference from the two other groups analysed, between which this indicator did not differ significantly. These results confirm that the commercial hybrids of Star 53 H.Y. are good material for intensive production of fattening ducks, selected in this direction [Biesiada-Drzazga *et al.* 2011, Michalczuk *et al.* 2016].

A tendency towards a reduction in muscle and other carcass part muscle weight was observed in all groups of ducks, in which feeding was supplemented with either black cumin seeds or a mixture of herbs (Tab. 1). However, the significance of differences ($p \leq 0.05$) was confirmed only for breast and leg muscles of S ducks, and leg muscles of D ducks. Similarly, Yesuf *et al.* [2017] when using a 1 and 2% addition of black cumin seeds in chickens' diet, recorded lower breast and leg muscle weights in both groups compared to the control. However, these differences were statistically non-significant. Ducks fed a feed mixture with 5% herbs (H) had a lower weight of SS and AF. Differences in the value of the first parameter in comparison with the control ranged from 54 (S) to 61 g (D) and were significant ($p \leq 0.05$) in all the genetic groups. On the other hand, AF was found to be lower in the H groups compared to the C groups, by 0.3 g in the S flock, by 3.4 g in P and 6.4 g in D. Statistical significance ($p \leq 0.05$) of the differences was confirmed only in the P and D ducks. Similar results indicating a tendency to reduce weight of muscles and abdominal fat in poultry fed with herbs, were observed by Loetscher *et al.* [2013]. Ross PM3 chickens reared for 35 days, fed with 2.5% dried and crushed nettle, were characterized by lower BM (139 vs. 141 g/kg carcass) and lower AF content (16.5 vs. 17.9 g/kg). The differences were not statistically confirmed. Different results, but also statistically non-significant, were obtained by Safamehr *et al*. [2012]. In their experiment the addition of common nettle (0.5, 1.0, 1.5, 2.0%) increased the percentage of breast muscle (33.43, 33.37, 32.55 and 31.68% vs. the control's 31.39%, respectively) in broiler chicken carcasses. In addition, supplementation at lower levels of 0.5, 1.0 and 1.5% increased the proportion of AF (4.43, 4.45 and 4.49 vs. 4.03%). When evaluating the effect of herbs/black cumin on the weight of individual components of poultry carcasses a certain trend may be observed in their effect, although not always confirmed statistically. Introduced phytogenic feed additives, probably contribute to diluting the value of nutrients and an increase in the level of fibre in conventional feed, result in the reduction of weight of the most desirable elements, i.e. muscle. This is especially true for high-yielding ducks, commercial strains and lines. Significant differences ($p<0.05$) were confirmed for ducks of flock S. The carcasses of birds fed only complete feed contained the most meat (BM + LM), i.e. 840 g, while the introduction of a 5% herb mixture in the feed reduced the amount of meat by 8.84%, while black cumin seeds by 13.73%, respectively. On the other hand, the addition of 5% fat-rich black cumin seeds in the feed (16.5%) contributed to an increase ($p<0.05$) in abdominal fat in D ducks (by 9.0 g vs H and by 2.6 g vs C). Analysis of variance indicated that both genotype and the feed additives used had a significant ($p\leq0.05$) effect on the studied traits of duck carcass dressing percentage values (Tab. 1). In contrast, the genotype × additive interaction had an effect on weights of BM, AF and SS.

In terms of the following physical traits: pH_{24}, EC_{24} and CL, breast muscles of S ducks differed significantly ($p<0.05$) from the values shown in the other two genetic groups (Tab. 2). Analysis of variance also indicated that these three parameters were dependent ($p\leq0.05$) on the bird's genotype. Breast muscles of S ducks had the lowest pH_{24} (5.57), and the highest EC_{24} (10.05 mS/cm) and CL (34.07%). Colour lightness (L*) of breast muscles and WHC were at a level typical of meat, and the value of these parameters did not differ significantly between either genetic or dietary groups. The results of this experiment indicate that a lower concentration of hydrogen ions in breast muscles determines an increase in the values of EC and CL. A similar relationship was shown by Onk *et al*. [2019] when studying the effect of genotype on technological properties of meat from Pekin and native ducks reared for 10 weeks. Those authors confirmed a significant effect ($p\leq0.05$) of genotype on pH_{24} and CL of BM. In contrast, Kokoszyński *et al.* [2019] showed significantly lower values for BM of P-33 domestic ducks for pH_{24} ($p=0.001$), EC_{24} ($p=0.012$) and CL ($p<0.001$), and higher values for L* colour lightness ($p=0.002$) compared to commercial Star 53 H.Y hybrids. These data indicate some influence of genotype on breast muscle colour lightness.

Table 2. Physical characteristics of breast and leg muscles depending on genotype and feed additive

Genotype	Feed additive	pH_{24}		L*		EC_{24} (mS/cm)		WHC (mg%)		CL (%)	
		BM	LM	BM	LM	BM	LM	BM	LM	BM	LM
D	C	5.76^{a}	5.80^{b}	41.41	47.45^{ab}	8.49^{b}	5.94^{b}	32.28	29.37^{a}	32.46^{b}	33.90^{a}
	H	5.83^{a}	6.18^{a}	41.43	51.15^{a}	8.46^{b}	6.12^{ab}	31.11	26.00^{c}	31.33^{bc}	30.54^{c}
	BC	5.78^{a}	6.00^{ab}	40.92	48.50^{ab}	9.16^{ab}	7.08^{a}	31.06	26.90^{bc}	30.28^{c}	31.48^{c}
P	C	5.77^{a}	5.85^{b}	42.44	52.86^{a}	8.10^{b}	4.95^{c}	31.33	29.54^{a}	31.43^{bc}	32.35^{ab}
	H	5.89^{a}	6.13^{a}	43.88	50.56^{a}	8.43^{b}	4.61^{c}	31.62	26.28^{c}	31.96^{b}	30.13^{c}
	BC	5.79^{a}	5.96^{ab}	42.91	51.84^{a}	8.60^{ab}	5.96^{b}	32.12	28.86^{ab}	32.48^{b}	33.29^{a}
S	C	5.57^{b}	5.78^{bc}	42.55	45.82^{b}	10.05^{a}	6.89^{ab}	32.86	28.33^{b}	34.07^{a}	33.66^{a}
	H	5.63^{b}	5.98^{ab}	43.14	45.73^{b}	8.98^{ab}	7.08^{a}	31.68	25.49^{c}	32.26^{b}	31.89^{bc}
	BC	5.59^{b}	5.63^{c}	40.77	45.41^{b}	9.25^{ab}	6.07^{b}	30.71	28.01^{b}	33.65^{a}	32.97^{ab}
SEM		0.05	0.07	1.02	2.34	0.53	0.61	0.77	0.86	0.56	0.73
P value											
genotype (G)		<0.001	0.004	0.442	0.010	<0.001	0.584	0.389	0.330	<0.001	<0.001
feed additive (FA)		0.016	0.020	0.625	0.971	0.140	0.002	0.528	0.322	0.030	0.007
G x FA		0.326	0.103	0.454	0.933	0.155	0.388	0.240	0.553	0.305	0.426

D – Dworka D-11 duck, P – Pekin duck P-33, S - Star 53 H.Y. duck, BM – breast muscle, LM – leg muscle.
C – control, H – 5% of herb mixture in feed, BC– 5% of black cumin seed in feed, L* - colour lightness, EC – electrical conductivity, WHC – water holding capacity, CL – cooking loss
[ab]Values in columns bearing different superscripts differ significantly at $p\leq0.05$.

The second experimental factor of feed additives significantly ($p\leq0.05$) influenced pH_{24} and breast muscle cooking loss. There was a significant ($p<0.05$) reduction in breast muscle CL in D ducks when black cumin seeds were used (32.46 vs. 30.28%), and in S ducks for a mixture of herbs (34.07 vs. 32.26%). A different effect in broiler chickens fed with the addition of 1% black cumin was observed by Nasir and Grashorn [2010], who found significantly ($p<0.05$) higher CL of BM (25.0 vs. 23% in the control). On the other hand, a tendency towards an increase in pH_{24} of BM was observed in groups of ducks receiving feed supplemented with either black cumin seeds or herbs. A similar relationship for meat (BM + LM) of broiler chickens was demonstrated by Hassan and Mandour [2018]. The addition of 0.5, 1.0 and 1.5% of black cumin seeds non-significantly increased pH_{24} value (5.69, 5.72 and 5.68, respectively) compared to 5.68 in the control. In addition, those authors showed no effect of the supplement used on meat colour and WHC, which was consistent with the results of this study.

Our study and the paper of Onk *et al*. [2019] showed no significant differences in pH_{24} and CL of LM in ducks of different genetic backgrounds. Significantly ($p<0.05$) the lowest WHC values (28.33 mg%) were characteristic of LM in S ducks. In contrast, P birds were characterized by leg muscles with lowest EC (4.95 mS/cm), significantly ($p\leq0.05$) different from the S group. Wołoszyn *et al.* [2011], when studying four genetic groups of Pekin ducks (P8, SB, K2 and P66), showed the effect of duck genotype on the L* colour lightness ($p\leq0.01$), WHC ($p\leq0.05$) and CL ($p\leq0.05$) in LM. Also in this study (Tab. 3) the effect of genotype on pH_{24}, L* colour lightness and CL of LM was confirmed by analysis of variance.

The 5% herb mixture supplementation to the feed contributed to a significant ($p\leq0.05$) increase in the LM pH_{24} of D (5.80 vs. 6.18) and P (5.85 vs. 6.13) ducks, as well as a decrease in WHC and CL in all three genetic groups analysed. On the other hand, the addition of 5% black cumin seeds in duck diets reduced ($p<0.05$) WHC and CL parameters in D leg muscles (29.37 vs. 26.90 mg%, and 33.92 vs. 31.48%, respectively), and increased ($p<0.05$) EC in D (5.94 vs. 7.08 mS/cm) and P (4.95 vs 5.96 mS/cm) groups. In turn, Rahman and Kim [2016] showed that the addition of 1.0 and 2.0% black cumin to the feed of broiler chickens increases pH_{24} ($p\leq0.01$) and WHC ($p\leq0.05$) in thigh muscles. Analysis of variance showed (Tab. 2) the effect ($p\leq0.05$) of the feed additive on pH_{24}, EC_{24} and CL. Similarly, Azeem *et al.* [2014] indicated that supplementation of poultry diets with black cumin seeds increased CL. On the other hand, they showed no significant changes in pH of poultry meat.

When analysing the chemical composition of meat (Tab. 3), significant ($p\leq0.05$) differences were found only in the proportion of crude protein and collagen, with their highest content being characteristic of BM in P ducks. For the former parameter a significant difference ($p<0.05$) was shown between P and D (23.04 vs. 22.20%), while for the latter trait it was between P and S (1.39 vs. 1.24%). In turn, Kokoszyński *et al.* [2019] compared meat quality of ducks from two genetic groups P-33 and Star 53 H.Y., which were also the subject of this own study. Those authors also showed significant ($p\leq0.05$) differences both in protein and fat contents in BM of ducks. The latter relationship was also indicated by Wołoszyn *et al*. [2008]. As mentioned above, there is a small amount of collagen in BM tissue; however, it should be noted that it

Table 3. Chemical characteristics of breast and leg muscles depending on genotype and feed additive

Genotype	Feed additive	Water (%)		Fat (%)		Protein (%)		Collagen (%)	
		BM	LM	BM	LM	BM	LM	BM	LM
D	C	75.11	70.83[b]	2.50	3.87[a]	22.20[b]	22.25[bc]	1.37[ab]	1.99[ab]
	H	75.76	72.40[a]	2.45	2.65[bc]	22.64[ab]	22.04[bc]	1.39[a]	1.92[b]
	BC	75.36	71.26[b]	2.54	4.07[a]	22.48[ab]	21.74[c]	1.37[ab]	2.01[ab]
P	C	75.49	71.09[b]	2.23	3.20[b]	23.04[a]	22.37[b]	1.39[a]	1.94[b]
	H	76.04	71.82[ab]	2.39	3.24[b]	22.57[ab]	21.98[bc]	1.35[ab]	1.86[b]
	BC	75.66	71.61[ab]	2.49	3.32[b]	22.40[b]	22.17[b]	1.42[a]	1.95[b]
S	C	75.22	71.52[ab]	2.23	3.16[bc]	22.54[ab]	22.50[b]	1.24[b]	2.22[a]
	H	75.79	72.19[a]	2.61	3.05[bc]	22.34[b]	23.14[a]	1.26[b]	2.16[a]
	BC	75.51	71.64[ab]	2.26	3.14[bc]	22.38[b]	23.12[a]	1.28[b]	2.16[a]
SEM		0.21	0.28	0.28	0.28	0.19	0.29	0.31	0.22
P value									
genotype (G)		0.378	0.049	0.050	0.001	0.020	<0.001	0.019	0.010
feed additive (FA)		0.019	0.002	0.046	0.007	0.242	0.523	0.488	0.779
G x FA		0.756	0.508	0.584	0.267	0.220	0.147	0.545	0.921

D – Dworka D-11 duck, P – Pekin duck P-33, S - Star 53 H.Y. duck, BM – breast muscle, LM – leg muscle.
C – control, H – 5% of herb mixture in feed, BC – 5% of black cumin seed in feed.

has a significant effect on meat tenderness. Analysis of variance confirmed the effect ($p \leq 0.05$) of genotype on contents of both collagen (protein) and crude protein. Also Witkiewicz *et al.* [2006] found significant ($p \leq 0.05$) differences in collagen content between genetic groups of Pekin ducks after conventional seven-week rearing. It is difficult to state unequivocally that the chemical composition of BM is determined by the genetic background of ducks, since many studies have not confirmed any such relationship [Bernacki *et al.* 2006, Voutila *et al.* 2009, Kokoszyński 2011].

In all the genetic groups of ducks a trend was observed towards an increase in the proportion of water in BM of birds fed with a mixture of herbs and the analysis of variance showed an effect ($p \leq 0.05$) of experimental plant additives on breast muscle water content. Also, significantly ($p \leq 0.05$) a greater water content (75.9 vs. 75.5%) in BM of chickens consuming feed supplemented with black cumin (1%) was shown by Nasir and Grashorn [2010]. Nevertheless, the results of our experiment, as well as reports by other authors indicate that using plant additives in poultry nutrition, even at the level of 5%, it is difficult to modify the chemical composition of BM.

Evaluation of the other type of duck muscles, i.e. leg muscles, showed (Tab. 3, $p<0.05$) that they contained more fat (3.87%) in the D group compared to the groups P (3.20%) and S (3.16%). In contrast, LM of S versus P ducks contained significantly ($p \leq 0.05$) more collagen (2.22 vs. 1.94%). As in the case of BM, literature data on the chemical composition of duck LM are inconsistent. A lower fat content in LM of intensively growing Star 53 H.Y. ducks, compared to that type of muscle in ducks with slower growth rates, was reported by Kokoszyński [2011]. Namely, LM of Star 53 H.Y contained an average of 4.85% fat compared to amounts ranging from 5.70 to

6.05% in the other three groups of Pekin ducks (AP54, PP54 and PP45). A study by Wołoszyn *et al.* [2011] also showed that fat percentage (1.82, 1.47, 1.79 and 1.69%) depended significantly ($p \leq 0.05$) on genotype (P66, K2, SB and P8), but no significant effect of this factor on protein and water contents was confirmed. A different result was reported by Mazanowski and Gornowicz [2003], who confirmed the effect of the genetic origin of eight-week-old ducks on the chemical composition of LM. Namely, there was significantly ($p \leq 0.05$) the most water (78.1%) in LM of P77 birds, the least protein (18.7%) in P66 ducks and the least fat (2.3%) in K11 ducks.

The phytogenic additives used in duck feed can contribute to an increase in the water content of LM (Table 3). However, a significant ($p < 0.05$) difference in the value of this parameter was shown only among ducks of the D flock compared to the C group (70.83%) and H group (72.40%). Furthermore, a decrease ($p < 0.05$) in the proportion of fat in LM of ducks fed with herbal supplements (H 2.65 vs. C 3.87%) was observed for this genetic group. In LM of S birds the protein content increased ($p < 0.05$) after the administration of both phytogenic additives (C 22.50 vs. H 23.14 and BC 23.12%). The effect of reducing fat content in LM due to the use of black cumin seeds was reported in an experiment of Rahman and Kim [2016], where in thigh muscles of chickens fed diets supplemented with 1 and 2% black cumin seeds fat levels decreased significantly, being 2.76% ($p \leq 0.05$) and 2.38% ($p \leq 0.01$), respectively, compared to the control (3.72%). Those authors also showed an increase in the protein content of thigh muscles in chickens consuming feed with black cumin – it was 22.31% ($p \leq 0.05$) and 22.68% ($p \leq 0.01$), respectively, compared to the control (21.55%). A study by Hassan and Mandour [2018] showed no effect of 0.5, 1.0 and 1.5% black cumin addition to broiler chicken feed on individual parameters of basic muscle chemical composition, analysed together in 50% BM and 50% LM samples. In contrast, highly variable results in the chemical composition of LM in chickens fed with crushed and whole black cumin seeds supplemented at four levels ranging from 1.5 to 3.0% were recorded by Al-Beitawi and El-Ghousein [2008]. The fat content significantly ($p < 0.05$) decreased at 1.5 and 2.0% of crushed seeds (4.95 and 4.86% vs. the control's 5.22%), whereas at 2.5 and 3.0% of seeds, both crushed and whole, this parameter increased and it was 5.34 and 5.98%, and 6.14 and 5.92%, respectively. An opposite pattern of values was observed for the proportion of protein for these experimental groups, and these differences were statistically significant ($p < 0.05$). In this study the genotype of ducks was a factor affecting (at $p \leq 0.05$) the content of the four studied chemical components of LM (Table 3). On the other hand, feed additive influenced fat and water levels.

Conclusions

The three studied genetic groups of ducks (Star 53 HY, Dworka D-11 and Pekin duck P-33) differed ($p \leq 0.05$) in weight of breast muscles, legs and skin with subcutaneous fat. Differences ($p \leq 0.05$) were found in the economic rearing efficiency, slaughter value (body, carcass, giblets weight and weight of other carcass components, i.e. total skeleton, wings and neck), as well as some physical characteristics of breast muscles (pH24, EC24 and CL) and legs (WHC) between Star 53 HY ducks and the other two groups.

The most favourable ($p \leq 0.05$) rearing efficiency and slaughter value (body, carcass and meat weight) were recorded for commercial Star 53 HY ducks. Their breast muscles were characterized by higher ($p \leq 0.05$) cooking loss and lower ($p \leq 0.05$) collagen content.

The genetic origin of the ducks was shown to influence ($p \leq 0.05$) economic rearing efficiency, dressing percentage and chemical meat indexes (except for water content in breast muscles) and some physical characteristics (pH_{24}, cooking loss, colour lightness of leg muscles and electrical conductivity in breast muscles).

Supplementation of the standard diet of ducks with phytogenic additives (mixture of herbs, black cumin seeds) at a level of 5% had ($p \leq 0.05$) a negative effect on body, carcass and meat weight and a positive effect on the physical characteristics of meat related to water loss (pH24 and cooking loss).

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