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The response of fast-, medium- and slow-growing chickens to a low protein diet

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Abstract: The aim of the present study was to evaluate the effect of two dietary protein levels on performance, carcass characteristics, and meat quality parameters in fast- (Ross 308), medium- (JA757), and slow-growing (ISA Dual) chickens to assess the interaction of the two factors. Each genotype was divided into a control group fed a commercial type of feed mixture and an experimental group fed a low-protein diet (LP). The trial was terminated after a common period of fattening of each genotype, and 20 chickens per group (sex ratio 1 : 1) were selected for the carcass and meat analysis. The results indicated that the LP diet decreased growth ($P < 0.001$) and increased feed consumption ($P < 0.001$) more in the fast-growing than in the slow-growing genotypes; however, reduced mortality was detected in fast-growing chickens. The LP diet had a negative effect on the European performance efficiency factor ($P < 0.001$) in fast- (–10%) and medium-growing (–6%) but not in slow-growing chickens. The main effect of the genotype on the carcass characteristics included the highest ($P < 0.001$) dressing out and breast percentage in fast-growing chickens and the highest ($P < 0.001$) percentage of thigh and abdominal fat in the slow-growing genotype. The LP diet had only a minor effect on the carcass traits. Regarding meat quality characteristics, slow-growing chickens were characterized by higher contents of dry matter ($P < 0.001$) and crude protein ($P < 0.001$) and lower contents of ether extract ($P < 0.001$) and cholesterol ($P < 0.001$) compared to medium- and fast-growing chickens. The individual effects of the genotypes were manifested by the largest cross-sectional area of the muscle fibres of *pectoralis major* in fast-growing chickens ($P < 0.001$). The results of the present study indicate a significant interaction of the dietary protein levels and genotypes in growth performance and a negligible effect on the carcass composition and physical and chemical quality of meat.

Keywords: poultry; nutrition; performance; carcass yield; meat quality

Currently, animal husbandry is a result of environmental and nutritional interactions (Migdal et al. 2019), which play an important role in poultry and chicken meat production. In chickens, genetic differences influence the response of broilers to dietary protein concentration (Yalcin et al. 2010). Saxena et al. (2020) observed significantly better growth performance of broiler chickens fed high protein feed. However, protein is the most expensive component of feed mixtures; therefore, special attention has been paid to protein restriction. Restriction of protein is applicable in practice and may reduce some welfare problems, such as chronic stress and hunger associated with quantitative feed restriction (Delezie et al. 2010). The authors pointed out that different genotypes respond differently to changes in the diet composition. In the study, the Cobb 500 hybrid was more negatively

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affected by a low protein diet than Ross 308. Dietary protein may influence the carcass composition and meat quality. Yalcin et al. (2010) observed that broiler chickens on a low protein diet had the highest carcass fat and the lowest pH_{24} and lightness. Compared to broiler chickens, slowly growing genotypes can better respond to a low protein diet. Kreuzer et al. (2020) compared medium-growing JA 957, dual-purpose Lohmann Dual and male layer Lohmann Brown. A low protein diet caused the highest growth depression in medium-growing chickens; the effect on Lohmann Dual was half of that on JA 957, and no effect was observed in Lohmann Brown. A negative effect of a low-protein diet on carcass composition was detected mainly in the medium-growing hybrids. Urban et al. (2018) evaluated the effect of protein level on dual-purpose chickens Lohmann Dual and suggested that a reduction in protein may result in economic and environmental benefits without negative impact on the performance and carcass quality. Studies describing the effect of protein diet on various genotypes were performed mainly within a group of similarly growing hybrids; however, there are no studies comparing the responses of fast-, medium- and slow-growing chickens to the protein level in feed mixtures. Therefore, the objective of the study was to evaluate the effect of two protein levels on the performance, carcass composition and meat quality in fast-, medium- and slow-growing chickens, including interactions of both factors.

MATERIAL AND METHODS

The experiment was conducted at the International Poultry Testing Station Ústrašice and was approved by the Ethics Committee of the Czech University of Life Sciences Prague and the Central Commission for Animal Welfare of the Ministry of Agriculture of the Czech Republic.

Animals and experimental design

The fattening experiment was carried out in three different genotypes of chickens: Ross 308 as fast-growing, JA 757 as medium-growing and dual-purpose ISA Dual as slow-growing. The experiment included 2 520 one-day-old chickens at a sex ratio of 1 : 1 divided into six groups according to the genotype and diet. Each genotype was fed two types of feed mixtures: the control group received a commercial type of feed mixture and the experimental group received a low protein diet (LP). Chickens were placed into 24 littered pens (three genotypes × two diets × four replications). During the experiment, three-phase feeding was applied. The starter was fed to fast- and medium-growing chickens until 14 days of age and to slow-growing chickens until 21 days of age. The grower was fed to fast-growing chickens until 28 days of age, to medium-growing chickens until 35 days of age and to slow-growing chickens until 42 days of age. The finisher was consumed by chickens until the end of the experiment. The low protein diet for the experimental groups was calculated to be 6% lower than that of the control diet; analytically, the crude protein content was approximately 7% lower. The composition of feed mixtures is listed in Table 1. The light cycle regime consisted of 23 h of light on days 1 to 7 and 18 h of light from day 8 until the end of the experiment. The experiment was terminated after a common period of fattening of each genotype: at 35 days of age in fast-growing chickens, at 56 days of age in medium-growing chickens and at 70 days of age in slow-growing chickens. Environmental conditions were maintained according to the chicken requirements.

During the entire experiment, chickens were individually weighed on the first day and at the end of the experiment, and the data were used for determination of daily weight gain (DWG). Feed consumption was registered in weekly intervals for calculation of the feed conversion ratio (FCR) over the whole experiment. Mortality was recorded daily. Based on the data of the final weight, feed consumption and mortality, the European performance efficiency factor (EPEF) was calculated:

$$EPEF = [(FLW \times CB)/(LFP \times FCR)] \times 100 \quad (1)$$

where:
EPEF – European performance efficiency factor;
FLW – final live weight (kg);
CB – culling birds (%);
LFP – length of fattening period (days);
FCR – feed conversion ratio (kg).

Carcass composition

At the end of the fattening period of each genotype, five birds per replication (20 chickens per

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Table 1. Feed composition of the experimental diets (%)

Item	Starter		Grower		Finisher	
	C	LP	C	LP	C	LP
Wheat	45.16	49.15	57.63	57.57	63.99	62.59
Maize	15.00	17.00	8.00	15.00	5.00	15.00
Soybean meal	31.05	28.75	26.86	22.95	22.35	18.60
Fish meal	1.00	–	–	–	–	–
Soybean oil	3.41	1.2	3.93	1.00	5.58	1.20
Monocalcium phosphate	0.88	1.01	0.63	0.61	0.57	0.44
Calcium carbonate	1.44	1.52	1.12	1.24	1.08	0.84
NaCl	0.28	0.27	0.25	0.29	0.28	0.28
Na_2SO_4	0.11	0.12	0.12	0.08	0.08	0.08
Vitamin-mineral premix[1]	1.68	0.99	1.47	1.26	1.07	0.97
Calculated nutrient content per kg diet (g/kg)						
Crude protein	215	203	197	185	180	170
Metabolizable energy (MJ)	12.5	11.8	12.9	12.1	13.5	12.4
Methionine	6.00	5.30	5.20	4.90	4.60	4.10
Lysine	12.9	11.8	11.6	11.2	10.3	9.70
Calcium	9.40	8.40	7.70	6.40	7.00	6.40
Phosphorus	4.50	6.20	3.90	5.10	3.50	4.60
Analysed nutrient content (g/kg)						
Dry matter	875	879	874	876	881	881
Crude protein	232	216	216	201	205	190
Ether extract	35.3	28.2	44.5	30.7	47.1	26.2
Crude fiber	34.2	29.4	28.2	29.7	26.2	26.1
Ash	59.5	55.5	45.7	46.5	43.1	42.3
Calcium	10.1	10.4	8.41	8.27	6.49	6.79
Phosphorus	5.98	5.53	4.02	4.66	4.41	4.09

C = control group fed conventional diet for growing chickens; LP = chickens fed low protein diet

[1]Vitamin-mineral premix provided per kg of diet: retinyl acetate 3.6 mg, cholecalciferol 13 µg, α-tocopherol acetate 30 mg, menadione 3 mg, thiamine 3 mg, riboflavin 5 mg, pyridoxine 4 mg, cyanocobalamin 40 µg, niacin 25 mg, calcium pantothenate 12 mg, biotin 0.15 mg, folic acid 1.5 mg, choline chloride 250 mg, copper 12 mg, iron 50 mg, iodine 1 mg, manganese 80 mg, zinc 60 mg, selenium 0.3 mg

group at a sex ratio of 1 : 1) were selected for carcass analysis. Chickens were slaughtered in an experimental slaughterhouse of the International Poultry Testing Station Ústrašice by electrical stunning and bleeding from the jugular vein. Afterwards, chickens were plucked and eviscerated. Then, the carcasses were chilled for 24 h at 4 °C. After 24 h, carcass weight, breast weight without bone, thigh weight with bone and abdominal fat (AF) weight were recorded. The weight of the carcass and carcass cuts was used for the calculation of proportions in the whole carcass. The dressing out percentage (DoP) was calculated using the equation:

$$DoP = [(\text{carcass weight} + \text{heart} + \text{liver} + \text{gizzard})/\text{slaughter weight}] \times 100 \quad (2)$$

Physical characteristics of meat

Meat colour was measured 24 h *post mortem* on the transverse section of the *biceps femoris* (BF) muscle using a Minolta Spectra Magic^{TM} NX analyser (Konica Minolta Sensing, Inc., Osaka, Japan) coupled to a CIElab 1976 system. The pH value was detected 24 h *post mortem* using a Jenway 3510 pH metre (Jenway, Essex, UK). A glass in-

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jection probe of the pH metre was inserted 1 cm deep into the BF muscle.

Chemical composition of meat

To determine the chemical composition of meat, the *pectoralis major* (PM) muscle samples were collected, mixed and frozen at –20 °C until analysis. The dry matter, crude protein, ether extract and ash analyses were performed according to the methods of the Association of Official Analytical Chemists (AOAC 1995). Dry matter was obtained by drying the samples at 105 °C to a constant weight. The Kjeldahl method (with a factor of 6.25) for detection of crude protein and the Soxhlet method for ether extract assay were used. Ash content was determined based on the weight of raw and ashed samples (at 550 °C in a muffle furnace). Cholesterol content was analysed using a validated gas chromatographic method (Model 5000; PerkinElmer, Inc., Waltham, MA, USA) after saponification of the samples with potassium hydroxide in ethanolic solution and extraction of cholesterol with *n*-hexane. The total cholesterol content was calculated based on the external standard technique and a standard curve of peak area versus concentration, and the results were expressed as mg of cholesterol per 100 g of meat.

Muscle fibre analysis

For histological analysis of muscle fibres, samples from PM were acquired immediately after slaughter, frozen in 2-methylbutane cooled with liquid nitrogen (–156 °C) and stored at –80 °C until analysis. Cross-sections (12 µm thickness) of each sample were prepared using a Leica CM 1850 cryostat (Leica Microsystems GmbH, Nussloch, Germany) at –20 °C. The haematoxylin and eosin standard method of staining was used for basic histochemical characterisation. The muscle fibre density (number of muscle fibres per 1 mm^2) and fibre cross-sectional area (CSA) were detected with NIS Elements AR v3.1 software (Nikon, Tokyo, Japan).

Statistical analysis

The results were processed with SAS v9.4 software (SAS Institute, Inc., Cary, NC, USA) by two-way analysis of variance ANOVA with the interaction of the genotype and diet (general linear model procedure). Genotype and diet were considered fixed effects. The statistically significant differences between the mean values with $P < 0.05$ are indicated by different superscript characters.

RESULTS AND DISCUSSION

The growth performance was significantly influenced by individual factors and their interactions (Table 2). As expected, the final weight was the lowest in slow-growing chickens ($P < 0.001$), and the low protein diet decreased the final weight compared to that in the control. However, a significant interaction of both factors indicated a negative effect of the LP diet in fast-growing (–8%) and medium-growing chickens (–4%), whereas there was no effect in slow-growing chickens. Trends in the final weight were confirmed by DWG. Similarly, Kreuzer et al. (2020) observed a decrease in DWG in medium-growing chickens and no differences between the control and LP diets in dual-purpose chickens. In Lohmann Dual, Urban et al. (2018) did not detect any differences in growth in the groups with normal and lower LP diets. In the present study, the protein content in the LP group was 7% lower than that in control group; however, in fast-growing chickens, DWG and final weight were decreased to a higher extent than the extent of protein reduction in the feed. On the other hand, medium-growing chickens showed a growth reduction that was lower than the corresponding reduction in the feed protein content. Feed conversion correlated with growth and was influenced by genotype ($P < 0.001$), diet ($P < 0.001$) and their interaction ($P < 0.001$). Fast- and medium-growing chickens compensated for LP content in the feed by higher feed consumption (+3% and +2%, respectively). The results indicated that a low protein diet decreases growth more and increases feed consumption in faster-growing chickens than those in the slowly growing genotypes indicating that slow-growing chickens have lower protein requirements compared to that in fast- or medium-growing chickens. Fast-growing chickens are less resistant to the diseases and show higher mortality (Sirri et al. 2011), and quantitative feed restriction reduces mortality (Tumova and Chodova 2018). In the present study, the LP diet significantly reduced mortality in fast-growing

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Table 2. Chicken performance

Genotype	Diet	Live weight at 1 day (g)	Final weight (g)	DWG (g)	FCR (kg)	Mortality (%)	EPEF
Ross 308	C	38.5	2 051^{c}	57.5^{a}	1.57^{e}	10	355^{a}
	LP	38.2	1 880^{d}	52.6^{b}	1.62^{d}	7.14	319^{b}
JA 757	C	41.4	3 013^{a}	53.1^{b}	2.24^{c}	5.71	235^{c}
	LP	41.1	2 895^{b}	51.1^{c}	2.27^{b}	9.52	218^{d}
Isa Dual	C	40.7	1 655^{e}	23.1^{d}	2.81^{a}	0	84.6^{e}
	LP	41.1	1 629^{e}	22.7^{d}	2.79^{a}	0	84.1^{e}
RMSE		0.37	320	6.37	0.09	–	35
Significance							
Genotype (G)		< 0.001	< 0.001	< 0.001	< 0.001	–	< 0.001
Diet (D)		0.178	< 0.001	< 0.001	< 0.001	–	< 0.001
G × D		0.232	< 0.001	< 0.001	< 0.001	–	< 0.001

C = control group fed conventional diet for growing chickens; DWG = daily weight gain; EPEF = European performance efficiency factor; FCR = feed conversion ratio; LP = chickens fed low protein diet; RMSE = root mean square error

$^{a–e}$Values in the same subgroup of variables with different supercripts differ ($P \leq 0.05$)

chickens but increased mortality in medium-growing chickens. No mortality was detected in slow-growing chickens. The economic effect (EPEF) of the LP diet was significantly influenced by interaction, individual factors, genotype and diet. The results indicate that the LP diet decreased EPEF by 10% in fast-growing chickens and by 6% in medium-growing chickens but it did not influence EPEF in slow-growing chickens. The negative effect of the LP diet on the final economic response was also observed by Delezie et al. (2010). Comparison of genotypes indicated that the highest EPEF was in the fast-growing genotype, intermediate EPEF was in the medium-growing genotype, and the lowest EPEF was found out in the slow-growing chickens that reached only 25% of EPEF of fast-growing chickens. On the other hand, the low effectiveness of slow-growing chickens is compensated by a higher market price (Lambertz et al. 2018).

The results of the carcass composition estimation (Table 3) indicated the main effect of the genotype, minor impact of the crude protein level and no influence by the interactions; these data correspond to the results of Kreuzer et al. (2020). The effect of the genotype on the carcass traits was antici-

Table 3. Slaughter weight and selected carcass characteristics

Genotype	Diet	Slaughter weight (g)	Carcass (g)	DoP (%)	Breast (%)	Thighs (%)	AF (%)
Ross	C	2 050	1 561	76.13	27.83	24.96	0.97
	LP	2 041	1 561	76.49	28.15	25.24	0.97
JA757	C	2 708	2 023	74.66	21.67	27.77	2.90
	LP	2 647	1 984	74.89	22.43	27.26	2.34
ISA Dual	C	1 703	1 167	68.60	13.76	28.19	3.02
	LP	1 673	1 153	68.89	13.56	28.05	2.66
RMSE		237	177	1.46	2.10	2.35	0.68
Significance							
Genotype (G)		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Diet (D)		0.441	0.587	0.267	0.441	0.773	0.016
G × D		0.885	0.881	0.982	0.593	0.751	0.179

AF = abdominal fat; C = control group fed conventional diet for growing chickens; DoP = dressing out percentage; LP = chickens fed low protein diet; RMSE = root mean square error

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Table 4. Ultimate pH and meat color of *biceps femoris*

Genotype	Diet	L*	a*	b*	pH
Ross	C	49.06	3.82^{a}	11.49^{b}	6.37
	LP	48.67	3.31^{ab}	14.35^{a}	6.40
JA757	C	52.23	1.33^{cd}	10.09^{b}	6.45
	LP	49.66	2.07^{bc}	14.26^{a}	6.47
ISA Dual	C	54.17	0.38^{d}	7.93^{c}	6.26
	LP	51.07	2.64^{b}	15.56^{a}	6.25
RMSE		4.95	2.43	2.90	0.17
Significance					
Genotype (G)		0.004	< 0.001	0.191	< 0.001
Diet (D)		0.027	0.064	< 0.001	0.639
G × D		0.434	0.044	0.001	0.876

a* = redness; b* = yellowness; C = control group fed conventional diet for growing chickens; L* = lightness; LP = chickens fed low protein diet; RMSE = root mean square error
$^{a–d}$Values in the same subgroup of variables with different supercripts differ ($P \leq 0.05$)

pated due to the selection criteria for each hybrid. Fast-growing chickens had the highest DoP and breast percentage and the slow-growing genotype had the highest thigh and AF percentage. Medium-growing chickens were in the middle. Similar findings were observed by Sirri et al. (2011); Dal Bosco et al. (2014); and Kreuzer et al. (2020). In contrast with the results of Dal Bosco et al. (2014), AF was significantly higher in slow-growing chickens than in medium- and fast-growing chickens. The discrepancy between these studies may be due to the genotypes and length of the experiments because in the present study the length of fattening was determined by the common age of each genotype, whereas Dal Bosco et al. (2014) finished their trial at 81 days of age. However, Kreuzer et al. (2020) observed lower AF in medium-growing chickens than in dual-purpose chickens, which is in agreement with our results. Comparison of the effect of the genotype on AF content is related to growth allometry of the tissue, which is developing late (Tumova and Chodova 2018) and increases with age. A minor effect of the protein level on the carcass composition is in agreement with the observations of Urban et al. (2018) and Ndazigaruye et al. (2019). Similarly, Kreuzer et al. (2020) found that the reduced feed protein level significantly decreased the AF content. The results of both studies are presumably related to the feed composition of the low protein diet with lower fat content.

Physical characteristics of the meat indicate that significant interactions of the genotype and diet influence redness (a*) and yellowness (b*) measured in BF (Table 4). ISA Dual chickens fed the diet with lower protein level had the highest a* ($P = 0.044$) and b* ($P = 0.001$), and the same genotype fed the control diet had the lowest values of these colour characteristics. The individual genotype effect on lightness (L*; $P = 0.004$) and a* values ($P < 0.001$) was manifested as darker and redder meat in fast-growing Ross chickens followed by medium-growing JA757, and the lightest meat was present in slow-growing ISA Dual chickens. Similarly to our results, slow-growing

Table 5. Chemical composition of the *pectoralis major* muscle

Genotype	Diet	Dry matter (%)	Crude protein (%)	Ether extract (%)	Ash (%)	Cholesterol (mg/kg)
Ross	C	24.91	21.41	1.15	1.15	417.5
	LP	25.16	21.80	0.99	1.18	417.2
JA757	C	25.00	22.41	0.49	1.16	332.4
	LP	25.26	22.74	0.42	1.15	328.1
ISA Dual	C	26.46	23.85	0.30	1.14	294.4
	LP	26.73	24.00	0.35	1.17	371.5
RMSE		7.83	7.12	1.93	0.63	89.1
Significance						
Genotype (G)		< 0.001	< 0.001	< 0.001	0.658	< 0.001
Diet (D)		0.878	0.039	0.101	0.251	0.162
G × D		0.998	0.743	0.066	0.463	0.085

C = control group fed a conventional diet for growing chickens; LP = chickens fed a low protein diet; RMSE = root mean square error

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chickens in the experiment of Ozbek et al. (2020) had lighter meat than the fast-growing genotypes. The differences in meat colour can be caused by the differences in the slaughter age of chickens. Similarly, Dogan et al. (2019) reported higher lightness and yellowness in slow-growing chickens; however, in this case, the differences were not significant. On the other hand, Grashorn (2006) and Devatkal et al. (2019) showed that the colour parameters of different genotypes did not correspond to significant variations in fresh thigh meat. Chickens fed a low-protein diet had darker ($P = 0.027$) meat with higher yellowness ($P < 0.001$) compared to that in the control groups. Similarly, a lower L* value and an increase in a* of the breast meat in chickens fed a diet with decreased crude protein were demonstrated by Jlali et al. (2012). Higher yellowness of the thigh meat in chickens fed a low-protein diet can be due to the higher amount of maize in the diet. The ultimate pH value of BF was influenced only by the genotype ($P < 0.001$); the highest values were detected in medium-growing JA757 and the lowest values were detected in slow-growing ISA Dual chickens. Similarly, Fanatico et al. (2007) and N'Dri et al. (2007) detected lower pH 24 of the breast meat in slow-growing chickens compared to that in the fast-growing genotypes. The cause of the differences in pH may be related to the variations in the slaughter age. Baeza et al. (2012) reported that the pH value is increased concomitantly to an increase in the age of chickens. Moreover, Lonergan et al. (2003) did not observe any effects of the genotype when chickens were slaughtered at the same age. In agreement with our results, Berri et al. (2008) observed only a small effect of the dietary crude protein level on the ultimate pH value.

There was no significant effect of the genotype by diet interaction on the chemical meat composition of *pectoralis major* (Table 5). The fixed effect of the genotype was more important in the case of dry matter ($P < 0.001$), crude protein ($P < 0.001$), ether extract ($P < 0.001$) and cholesterol ($P < 0.001$). Slow-growing ISA Dual chickens were characterized by the higher contents of dry matter and crude protein and lower contents of ether extract and cholesterol compared to those in medium-growing JA757 and fast-growing Ross chickens. The protein content results are probably related to the slaughter age, because the protein content increases concomitantly to an increase in the age of animals (Fanatico et al. 2007; Metzger et al. 2011; Mosca et al. 2016). In our experiment, fast-growing chickens with lower meat protein content were slaughtered at 35 days of age, while the slaughter age of the slow-growing genotype resulted in a higher crude protein content in PM at 70 days. The higher level of ether extract in the fast-growing genotype is in agreement with the results of Fanatico et al. (2007) and Mueller et al. (2018), and these results may be due to the incorporation of fat into the cells instead of water in the animals with a higher growth rate (Metzger et al. 2011). The diet significantly influenced only crude protein content. Chickens fed a diet with the low protein level had a higher crude protein content in the meat ($P = 0.039$) than chickens fed a control diet. The opposite results were obtained by Wang et al. (2013), who demonstrated that a low protein diet resulted in lower protein content in meat, which may be related to different conditions of the trials and different experimental diet compositions. Changes in the dietary cholesterol levels have an impact on *de novo* cholesterol synthesis suggesting that dietary changes have only a moderate influence on the cholesterol content (Cullere et al. 2019) similar to the results of our experiment.

Muscle mass is determined by the number of muscle fibres formed before hatching and their cross-sectional area after hatching (Rehfeldt et al.

Table 6. Muscle fibre characteristics of the *pectoralis major* muscle

Genotype	Diet	Number of muscle fibres per 1 mm^2	Cross-sectional area (μm^2)
Ross	C	241.7	3 297^a
	LP	233.7	3 215^a
JA757	C	262.7	2 851^b
	LP	256.5	2 982^b
ISA Dual	C	438.0	1 518^d
	LP	441.3	1 700^c
RMSE		57.9	1 410
Significance			
Genotype		< 0.001	< 0.001
Diet		0.789	0.045
G×D		0.936	0.015

C = control group fed a conventional diet for growing chickens; LP = chickens fed a low protein diet; RMSE = root mean square error

$^{a–d}$Values in the same subgroup of variables with different superscripts differ ($P \leq 0.05$)

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2008). The selection of chickens resulting in increased muscle mass depends on the changes in the number and size of muscle fibres. The total number of fibres and CSA are the most important characteristics of muscle fibres. In the present study, the number of muscle fibres was influenced only by the genotype ($P < 0.001$); the highest number of fibres was detected in slow-growing chickens compared to medium- and fast-growing chickens (Table 6). The size of muscle fibres is known to be negatively correlated with the number of muscle fibres. The CSA was significantly influenced by the genotype and diet interactions ($P = 0.015$). The largest CSA was detected in fast-growing chickens fed the control diet, whereas the smallest CSA was detected in slow-growing ISA Dual receiving the control diet.

The individual effect of the genotype was manifested by the largest CSA ($P < 0.001$) in fast-growing chickens followed by medium-growing chickens, and the smallest area of muscle fibres was detected in the slow-growing genotype; these results are consistent with the data of Devatkal et al. (2019). This distribution of size according to the genotype is probably due to the selection for growth and is also reflected in breast percentage in the genotypes with different growth in our experiment. The nutrient balance in the diet plays an important role in the growth rate. However, PM is composed of IIB muscle fibres (Verdiglione and Cassandro 2013) and is less sensitive to changes in the nutritional status (Tesseraud et al. 1996), which is also evidenced by the minor effect of a low protein diet on the muscle fibre characteristics in the present experiment.

CONCLUSION

The results of the present study indicate a significant effect of the interactions of the diet protein levels and genotypes on growth performance and a negligible effect on the carcass composition and physical and chemical quality of meat. A decrease in the protein level by approximately 7% decreased the growth of fast-growing chickens to a larger extent, whereas in medium- and slow-growing chickens the effect was less negative. This finding may be related to the lower protein requirement of these chickens. However, the European performance efficiency factor was not influenced by low protein in slow-growing chickens, and it decreased more in the case of chickens with higher growth intensity. On the other hand, the genotype by low protein diet interaction significantly affected meat redness and yellowness but the colour parameters could be influenced also by different level of maize in the diet. In slow-growing chickens, the low protein diet insignificantly increased the contents of ether extract and cholesterol in meat. Nutritional value and physical measurements in fast- and medium-growing chickens were negligibly influenced by the low protein diet.

Conflict of interest

The authors declare no conflict of interest.

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