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Effects of two protein levels on the performance of chicken males with different growth intensities

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Abstract: At present, genetic selection programs produce chicken genotypes with different growth intensities, which might have variable requirements for dietary protein. The objective of this study was to compare the response of three different genotypes to two levels of crude protein in feed mixtures. Cockerels of fast-growing Ross 308, medium-growing Hubbard JA 757 and slow-growing ISA Dual chickens were used in the study. Each genotype was fed diets that differed in protein level: the control group (C) received commercial feed, and the experimental group was fed a diet with a 6% lower protein content (LP). The daily weight gain (DWG) and feed conversion ratio (FCR) were significantly affected by the interaction of genotype and feed protein level. A greater percentage of DWG depression was observed in fast-growing cockerels than in medium-growing cockerels (10% and 6%, respectively), whereas the percentage of slow-growing cockerels negligibly increased (2%). A low-protein diet impaired the FCR only in fast-growing birds (–5%), whereas in the medium- (–2%) and slow-growing groups (+2%), the differences were not significant. Carcass composition significantly influenced only genotype and thigh meat pH. In terms of meat colour, significant interactions revealed that in fast-growing Ross 308 chickens, redness and yellowness did not differ according to diet group; however, in both genotypes with slower growth, significantly greater redness and yellowness were detected in the low-protein diet group than in the control group. The results indicate that genotypes with slower growth have lower protein requirements for growth performance, but lower diet protein has an effect on physical meat quality parameters in these genotypes.

Keywords: carcass composition; cockerels; feed protein; physical meat quality; strain

Chicken meat production is one of the growing sectors of animal protein production because it is considered the most cost-effective and sustainable protein source (Choi et al. 2023). Attention is given not only to the quantity of food but also to its quality and nutrition, including the influence of the economy (Strakova et al. 2024). At present, consumers are interested in meat quality, safety and welfare. To improve profitability, various strategies, including innovative feed supplements, nutrition and management feed systems and grazing, have been used (Tyl et al. 2024). Tumova et al. (2024) reported that fast-growing chickens do not forage actively; therefore, it is necessary to use genotypes with slower growth. Recently, genetic selection programs have allowed the production of chicken genotypes with different growth intensities in intensive and extensive production systems. Based

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on growth intensity, Dal Bosco et al. (2012) described fast-growing chickens as birds with a daily weight gain (DWG) of up to 35 g, medium-growing chickens with a DWG ranging from 20–35 g and slow-growing genotypes with a DWG below 20 g. Differences in growth affect the length of the fattening period. Devatkal et al. (2019) reported that a targeted weight of approximately 2.0 kg resulted in medium-growing chickens at 50 days and fast-growing chickens at 36 days. Singh et al. (2021) reported that the length of the fattening period was similar in medium-growing chickens at 55 days of age and in fast-growing chickens at 32 days. Chodova et al. (2021) used fast-, medium- and slow-growing genotypes, and their fattening periods lasted for 35, 56 and 70 days. Genotypes with different growth intensities also vary in carcass composition. Compared with medium- and slow-growing chickens, fast-growing genotypes present greater dressing percentages and breast meat percentages (Devatkal et al. 2019; Chodova et al. 2021; Hassan et al. 2021). Fast- and medium-growing chickens have similar thigh percentages (Devatkal et al. 2019; Hassan et al. 2021), whereas Singh et al. (2021) reported a higher thigh percentage in medium-growing chickens than in fast-growing chickens. On the other hand, the highest thigh percentage is described in slow-growing dual-purpose chickens (Mueller et al. 2020; Chodova et al. 2021). With respect to meat quality, Marchewka et al. (2023) reported that bird growth types also differ in meat pH, water holding capacity and cooking loss; Chodova et al. (2021) and Singh et al. (2021) reported differences in meat colour.

The feed protein and energy level are crucial factors for achieving high growth rates and a high carcass composition. Broiler chickens have high requirements for protein in feed; however, its reduction leads to economic and environmental benefits. Benahmed et al. (2023) reported that reducing protein by 3% can have no detrimental effect on performance or meat quality in fast-growing chickens. On the other hand, slow-growing chickens have lower protein requirements, and according to Kreuzer et al. (2020), dual-purpose chickens perform well on a lower-quality diet. It is hypothesised that chickens might interact with crude protein levels depending on growth intensity. The aim of the present study was to compare the response of three different genotypes to two levels of crude protein in feed mixtures.

MATERIAL AND METHODS

The experimental procedures were approved by the Central Commission for Animal Welfare at the Ministry of Agriculture of the Czech Republic and performed at the International Poultry Testing Station Ústrašice.

Animal husbandry

In the experiment, 1 260 one-day-old cockerels were placed into 18 floor pens with 11.3 birds per m^2. The birds were split into three groups according to genotype: fast-growing Ross 308, medium-growing Hubbard JA 757 and slow-growing ISA Dual. Each genotype was fed diets that differed in protein level: the control group (C) received commercial feed, and the experimental group was fed a diet with a 6% lower protein content (LP). There were three replications per group (3 genotypes × 2 diets × 3 replications). The composition of the diets is given in Table 1. Feed mixtures were ana-

Table 1. Analysed composition of experimental diets (g/kg)

Nutrient	Starter		Grower		Finisher	
	C	LP	C	LP	C	LP
Dry matter	879	884	872	877	879	881
Crude protein	223	210	207	194	192	181
Ether extract	35.2	28.1	43.9	30.1	45.2	28.4
Crude fibre	34.1	33.9	31.2	32.4	29.3	29.6
Ash	59.1	58.2	47.1	47.9	43.3	42.8
Metabolisable energy (MJ)*	12.5	11.9	12.9	12.0	13.5	12.5

*Calculated

C = control group; LP = low protein diet

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lysed according to the methods of the Association of Official Analytical Chemists (AOAC 1995). Chicken feeding was divided into three phases. The starter was fed to fast- and medium-growing chickens until 14 days and to slow-growing chickens until 21 days of age; the fast-growing chickens were fed until 28 days of age, the medium-growing chickens were fed until 35 days of age, the slow-growing chickens were fed until 28 days of age. The finisher chickens were fed until the end of the experiment at a 2 kg slaughter weight. For fast-growing chickens, the experiment ended at 35 days of age, medium-growing at 56 days of age and slow-growing at 70 days of age. Feed and water were available *ad libitum* throughout the entire experiment. The experimental conditions were in accordance with the chicken requirements: the lighting regime included 23 h of light from 1 to 7 days of age and 18 h of light from 8 days of age until the end of the experiment.

Performance measurements

The final weight was determined by individual weighing at the end of the experiment. Daily weight gain (DWG) was calculated on the basis of chicken weight, and the feed conversion ratio (FCR) was calculated from weekly feed consumption records. Mortality was recorded daily. The European performance efficiency factor (EPEF) was calculated on the basis of data on final weight, feed consumption and mortality (Tyl et al. 2024).

Carcass and meat quality characteristics

Chickens were slaughtered when each genetic group reached a slaughter weight of 2 kg. Ten birds were selected from each genotype and diet (a total of 60 males). Chickens were slaughtered in the experimental slaughterhouse of the International Poultry Testing Station Ústrašice by electrical stunning followed by bleeding from the jugular vein, plucking and evisceration. The carcasses were subsequently chilled for 24 h at 4 °C. Eviscerated cold carcasses were weighed, after which the legs were removed, and the bones were weighed. In the following procedure, the legs were deboned, and the skin was removed to determine the thigh weight, thigh percentage from the cold carcass weight, thigh meat percentage and thigh skin percentage. Abdominal fat weight was determined and used to calculate the percentage of abdominal fat relative to the cold carcass weight. For the internal organs, the liver weight was used to determine the liver percentage.

Physical meat quality parameters, pH and colour were measured in the left *biceps femoris*. The pH value was determined 24 h *post mortem* using a Jenway 3510 pH meter (Jenway, Essex, England) with a glass injection probe attached 1 cm deep into the muscle. Meat colour was measured 24 h *post mortem* on transverse sections of the BF using a Minolta Spectra Magic™ NX analyser (Konica Minolta Sensing, Inc., Osaka, Japan) with the CIElab 1976 system.

Statistical analysis

The results were processed via SAS v9.4 software (SAS Institute Inc., Cary, USA; 2013) by two-way analysis of variance (ANOVA) with the interaction of genotype and diet. Genotype and diet were considered fixed effects. The statistically significant differences between means with $P \leq 0.05$ are indicated by different superscripts.

RESULTS AND DISCUSSION

Growth performance

The performance results (Table 2) revealed that all the evaluated measurements were significantly affected not only by individual factors and genotype and feed protein levels but also by two-way interactions. The DWG was significantly reduced in fast- and medium-growing birds, whereas it was not affected by lower protein levels in slow-growing birds. A greater percentage of DWG depression was observed in fast-growing cockerels than in medium-growing cockerels (10% and 6%, respectively), whereas the percentage of slow-growing cockerels negligibly increased (2%). With respect to genotype, all the groups differed from each other ($P \leq 0.001$). Low protein levels significantly decreased DWG. The data of the present study confirmed previous findings of the effects of interactions between genotype and diet protein level on growth (Chodova et al. 2021); however,

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Table 2. Chicken performance

Genotype	Diet	Final weight (g)	DWG (g)	FCR (kg)	Mortality (%)	EPEF
Ross 308	C	2 183^{c}	61.3^{a}	1.57^{d}	5.00	378^{a}
	LP	1 970^{d}	55.2^{c}	1.65^{c}	3.57	329^{b}
JA757	C	3 293^{a}	58.1^{b}	2.12^{b}	2.86	270^{c}
	LP	3 097^{b}	54.6^{c}	2.18^{b}	4.76	242^{d}
Isa Dual	C	1 850^{c}	25.9^{d}	2.70^{a}	0	98^{d}
	LP	1 883^{c}	26.3^{d}	2.66^{a}	0	101^{b}
RMSE	–	290	6.01	0.01	–	31.3
Significance						
Genotype	–	0.001	0.001	0.001	–	0.001
Diet	–	0.001	0.001	0.001	–	0.001
G × D	–	0.001	0.001	0.001	–	0.001

C = control group; D = diet; DWG = daily weight gain; EPEF – the European performance efficiency factor; FCR – feed conversion ratio; G = genotype; LP = low protein diet; RMSE = root mean square error

$^{a–d}$Values within a column differ ($P \leq 0.05$)

in the present study, a low-protein diet decreased the DWG of fast-growing cockerels (–10% vs 8%) and medium-growing males (6% vs 4%). The growth decrease in the present study was greater than the reduction in feed protein. Therefore, we can assume that decreasing feed protein has a greater negative effect on growth in fast-growing males than in unsexed chickens or females. The lack of effect of a low-protein diet on DWG in slow-growing chickens corresponded with the results of Kreuzer et al. (2020) and Chodova et al. (2021). These data show that slow-growing chickens have lower protein requirements for growth.

Like growth, the FCR was affected by the interaction of genotype and protein level ($P \leq 0.001$); however, a low-protein diet impaired the FCR only in fast-growing birds (–5%), whereas in the medium- (–2%) and slow-growing groups (+2%), the differences were not significant. An effect of genotype ($P \leq 0.001$) and protein level ($P \leq 0.001$) was observed. The trends of the FCR corroborated those of growth and previous experiments (Chodova et al. 2021). Benahmed et al. (2023) reported that a 3% reduction in protein content in a chicken diet had no effect on the FCR or DWG of fast-growing chickens. The results of the present study indicated that a reduction of 6% negatively affected not only fast- but also medium-growing chickens.

The effects of genotype and protein level on the mortality of cockerels were inconsistent. In fast-growing birds, the protein level decreased, whereas in medium-growing birds, it increased mortality. In slow-growing birds, mortality was not detected in either group. A reduction in mortality in fast-growing cockerels fed a low-protein diet can be related to lower growth intensity and therefore to decreasing health problems, such as sudden death syndrome or ascites, which are observed in restricted chickens (Tumova and Chodova 2018; Tyl et al. 2024). The higher mortality of the medium-growing cockerels fed a low-protein diet corresponds with the findings of Usturoi et al. (2023), who reported that protein supplementation in Hubbard chickens ensured a better immune response and therefore better resilience to morbidities.

DWG, FCR and mortality are important characteristics affecting the economic efficiency of meat production. The EPEF was significantly affected by interactions as well as individual factors. The significantly highest EPEF was detected in fast-growing birds fed a low-protein diet ($P \leq 0.001$), and the EPEF was significantly lower in medium-growing birds, which also presented a decrease in low protein content ($P \leq 0.001$). The lowest EPEF ($P \leq 0.001$) was detected in slow-growing birds was not affected by protein level. A negative effect of a low-protein diet on fast-growing chickens was reported by Delezie et al. (2010) and Chodova et al. (2021), and a negative effect on medium-growing birds was reported by Chodova et al. (2021) and Usturoi et al. (2023); these effects are associated with deterioration of growth and FCR.

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Carcass composition and meat quality

Carcass structure was significantly affected only by chicken genotype (Table 3). The carcass weight ($P \leq 0.001$) and thigh weight ($P \leq 0.001$) were highest in the medium-growing birds, and the lowest thigh percentage ($P \leq 0.001$) and thigh meat percentage ($P \leq 0.001$) were observed in the fast-growing birds. The results concerning the effects of genotype on carcass composition correspond to those of Devatkal et al. (2019), Kreuzer et al. (2020) and Chodova et al. (2021). Devatkal et al. (2019) and Chodova et al. (2021) also described a higher thigh percentage in medium-growing chickens.

In the present study, the carcass fat content was evaluated by the abdominal fat percentage and thigh skin percentage because abdominal fat and subcutaneous fat are the main fat depot centres, and the liver percentage is related to lipogenesis (Table 4). All three fat characteristics were significantly affected only by genotype. The lowest abdominal fat percentage ($P \leq 0.001$) and thigh skin percentage ($P \leq 0.001$) were detected in fast-growing chickens. The results agree with those of Kreuzer et al. 2020), Chodova et al. (2021), and Valenta et al. (2022).

Table 3. Carcass composition

Genotype	Diet	Slaughter weight (g)	Carcass weight (g)	Thigh weight (g)	Thigh percentage (%)	Thigh meat percentage (%)
Ross 308	C	2 058	1 566	389	24.9	17.2
	LP	2 034	1 543	394	25.6	17.7
JA757	C	2 906	2 178	614	28.2	19.1
	LP	2 958	2 225	646	29.0	19.4
Isa Dual	C	1 945	1 321	386	29.3	18.6
	LP	1 985	1 369	406	29.7	19.2
RMSE	–	87.7	74.2	32.3	1.58	1.46
Significance						
Genotype	–	0.001	0.001	0.001	0.001	0.001
Diet	–	0.311	0.219	0.027	0.127	0.197
G × D	–	0.348	0.236	0.415	0.917	0.962

C = control group; D = diet; G = genotype; LP = low protein diet; RMSE = root mean square error

Table 4. Measurements of carcass fat

Genotype	Diet	Abdominal fat weight (g)	Abdominal fat percentage (%)	Thigh skin percentage (%)	Liver percentage (%)
Ross 308	C	15.7	1.01	1.82	2.61
	LP	16.6	1.08	1.77	2.83
JA757	C	58.1	2.66	2.79	2.10
	LP	47.8	2.16	2.69	2.10
Isa Dual	C	36.6	2.76	2.49	2.38
	LP	36.7	2.68	2.76	2.38
RMSE	–	10.6	0.59	0.34	0.36
Significance					
Genotype	–	0.001	0.001	0.001	0.001
Diet	–	0.265	0.267	0.328	0.428
G × D	–	0.187	0.287	0.187	0.537

C = control group; D = diet; G = genotype; LP = low protein diet; RMSE = root mean square error

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Table 5. Physical meat quality

Genotype	Diet	pH 24	L^*	a^*	b^*
Ross 308	C	6.36	47.9	3.70[a]	11.2[a]
	LP	6.40	48.7	3.57[a]	14.1[a]
JA757	C	6.46	52.0	0.39[c]	9.69[b]
	LP	6.47	48.1	2.17[b]	14.1[a]
Isa Dual	C	6.26	56.3	–0.27[d]	7.67[b]
	LP	6.24	51.2	2.24[b]	16.0[a]
RMSE	–	0.19	4.40	2.20	2.81
Significance					
Genotype	–	0.001	0.001	0.001	0.593
Diet	–	0.936	0.018	0.017	0.001
G × D	–	0.883	0.091	0.015	0.010

a^* = redness; b^* = yellowness; C = control group; D = diet; G = genotype; L^* = lightness; LP = low protein diet; RMSE = root mean square error

[a–d]Values within a column differ ($P \leq 0.05$)

A greater deposition of carcass fat in genotypes with slower growth might be related to the age of slaughter because fat accumulation increases with age as a tissue with late development (Tumova and Chodova 2018). The liver percentage was the highest in fast-growing chickens ($P \leq 0.001$). Tumova and Chodova (2018) reported that the liver plays an important role in lipogenesis, and a greater weight may indicate greater fat deposition, which contrasts with the present results. This discrepancy might be related to liver allometry growth. The liver is early developing tissue compared to fat tissues and therefore early slaughtered birds might have a higher proportion of liver compared to late slaughtered ones. Negligible effect of reduction of feed protein (between 1% to 7%) on carcass composition is described by Urban et al. (2018). The negligible effects of reducing feed protein (between 1% and 7%) on carcass composition have been described by Urban et al. (2018), Kreuzer et al. (2020), Chodova et al. (2021) and Benahmed et al. (2023); however, Marchewka et al. (2023) reported that lowering dietary protein from 22.5% to 16.5% had a negative effect on breast weight and fat pad weight.

The physical measurements were performed on thigh meat (*biceps femoris*). pH was significantly affected by genotype, with the lowest values in slow-growing cockerels (Table 5).

This result corresponds with the findings of Chodova et al. (2021), Valenta et al. (2022), and Marchewka et al. (2023). The thigh meat colour measurements revealed the interaction effects of genotype and protein level on redness and yellowness (Table 3). In fast-growing Ross 308, redness and yellowness did not differ according to diet group; however, in both genotypes with slower growth, significantly greater redness and yellowness were detected in the low-protein diet group than in the control group, which is consistent with the findings of Chodova et al. (2021). In terms of genotype, the darkest meat was produced by slow-growing birds ($P \leq 0.001$), which presented lower redness ($P \leq 0.001$) but greater yellowness ($P \leq 0.001$). Akyuz and Onbasilar (2023) noted that meat colour is affected by the genetics and darker meat of slow-growing chickens, as detected by Devatkal et al. (2019), Mueller et al. (2020), Hassan et al. (2021), Chodova et al. (2021), and Valenta et al. (2022). With respect to diet protein content, a reduction in protein resulted in darker meat ($P \leq 0.018$) with greater redness ($P \leq 0.017$) and yellowness ($P \leq 0.001$); similar trends were described by Jlali et al. (2012).

CONCLUSION

This study revealed significant interactions between genotype and feed protein level on performance. A lower protein level (6%) caused greater growth depression in the fast-growing genotype (10%), whereas in the medium-growing geno-

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type, growth decreased to the same level, and in the slow-growing genotype growth negligibly increased. Similarly, feed conversion was impaired mainly in the fast-growing genotype, and the results indicate lower protein requirements of genotypes with slower growth intensity. Carcass composition measurements were affected only by genotype. In terms of the physical parameters of the meat, the pH of the *biceps femoris* was affected by the genotype with the lowest values in slow-growing cockerels, whereas in the meat colour significant interactions of genotype and feed protein level were observed in redness and yellowness when higher redness and yellowness were detected in slower-growing cockerels. The results indicate that genotypes with slower growth have lower protein requirements for growth; however, lower dietary protein might affect physical meat quality parameters in these genotypes.

Conflict of interest

The authors declare no conflict of interest.

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