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Development of dual-purpose cross for meat and egg production II. Meat quality of the crossbred chickens and the parent lines

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ABSTRACT

The study aimed to examine the meat quality of chickens from a dual-purpose cross and its parent lines. The trial was conducted in the experimental poultry farm of the Institute of Animal Science-Kostinbrod, Bulgaria. The dual-purpose chickens were obtained by crossing female layers (Line L) and dual-purpose cocks (BB, based on Bresse Gauloise). At the age of 9 weeks the male chickens from the parent lines and the dual-purpose cross were slaughtered. Six chickens of each genotype were subjected to breast and thigh meat quality analysis. The crossbred chickens tended to have lower pH in breast but the values of this parameter were higher in their thighs. The BB line showed the poorest water-holding capacity (WHC) in both breast and thigh meat cuts. This line and the crossbreed showed lighter meat compared to the L line. Except the ash content of the breast and thigh meat that was higher in the BB line, the proximate composition did not differ between the examined lines and their cross. The L and dual-purpose chickens tended to have higher intramuscular fat (IMF) but lower protein in thigh meat than the BB line. The correlation analysis revealed clear relationships between the meat quality traits and the proximate composition, however they differed for the breast and thigh meat.

Keywords: dual-purpose chickens, layer line, meat, quality characteristics

INTRODUCTION

Poultry products are considered as one of the most important sources of cheap protein. Both eggs and poultry meat play an important role in the human nutrition, being rich in essential amino and fatty acids, vitamins and trace elements (Lombardi-Boccia et al., 2005; Réhault-Godbert et al., 2019; El-Tarabany et al., 2022). This is the reason for the significant increase in the consumption of eggs and meat in the last decades. In order to meet the growing demand of the consumers, world poultry meat production escalated from 9 to 135 million tonnes between 1961 and 2021, while the egg production rose from 15 to 86.3 million tonnes (Statista, 2023). According to FAO, in 2020, approximately 40 % of the global meat production was represented by poultry meat, while in the last three decades, the world egg production has increased by 150 percent (FAO, 2023). Most of the chicken meat has been obtained from fast growing broilers, although in recent years the interest in slower-growing types of birds has been constantly increasing. This is due to the higher demands of the consumers for better quality of meat and meat products, since the selection for the fast growth in broilers has been associated with various abnormalities in their meat (Baldi et al., 2021). On the other hand, when raising of the layers for egg production, male chickens are also hatched. They are usually culled right after hatching and this common practice however has met the sharp criticism of the society (Reithmayer et al., 2020). In order to avoid the culling of the one-day-old layer type cockerels, the use and development of dual-purpose lines and combinations is regaining interest. According to Damme et al. (2015), the use of dual-purpose breeds was common in conventional poultry industry until 1960s before the differentiation of special breeds for eggs and meat due to genetical antagonism between the growth rate and reproduction occurred. Since the eggs and meat from the dual-purpose breeds differed in appearance from the products obtained by the commercial hybrids and are more expensive (Brümmer et al., 2018), in order to be successfully realized on market, the willingness of the consumers to pay for such products seems to the of critical importance. The survey conducted by the authors in Germany showed that most of the people were in favour of dual-purpose chickens as alternative to culling of male layers, however they had specific expectations concerning the husbandry conditions, product characteristics and labelling. In Switzerland, Gangnat et al. (2018) showed that consumers are preferring this type of production over chick culling and would be willing to pay more for such foods but linking it to organic production could be a factor needed for success in the market.

With the present study we aim to develop a dual-purpose cross based on lines from the National Gene Pool (layer L and dual-purpose BB, originating from Bresse Gauloise), that will be suitable for rearing in alternative type of

systems. In the previous part of this study (Petkov et al., 2022) when comparing the dual-purpose cross ♀L×♂BB with the parent lines we found that the chickens from the developed combination had better live weight and feed efficiency than L line, but lower than the BB line. Furthermore, the chickens displayed good carcass composition and deposited less abdominal fat, revealing good potential to be successfully realized in market.

In this part of the study, we aim to assess the meat quality traits of the chickens from the dual-purpose cross and those from the parent lines.

MATERIALS AND METHODS

The trial was carried out in the experimental poultry farm of the Institute of Animal Science - Kostinbrod, Bulgaria with chickens of line L, BB, and their cross ♀L×♂BB. The experimental protocol used in this study, was designed in compliance with the guidelines of the European and Bulgarian legislation regarding the protection of animals used for experimental and other scientific purposes (Directive 2010/63; EC, 2010 – put into law in Bulgaria with Regulation 20/2012).

Experimental bird and housing

The lines and the dual-purpose cross involved in the trial and their housing were described in details in a previous work (Petkov et al., 2022).

Slaughtering and sampling procedures

At 9 weeks of age, the males from the lines and the cross were slaughtered in a certified abattoir. After stunning, decapitation and bleeding, the carcasses were plucked, eviscerated and their feet removed. The edible by-products (neck, liver, gizzard, heart and spleen) were separated. The carcasses were then kept at 4 °C for 24 and six chickens of each genotype were selected for analysis of meat quality traits. The breasts and thighs of each cockerel were separated from the carcass. The skin and bones were removed and meat was subjected to further analysis.

Measurement of pH and colour

Muscle pH and colour were measured at the time of deboning of the breast and thigh cuts. The measurements were done using a portable pH meter equipped with a glass electrode, calibrated prior use at pH 4.0 and 7.0. The surface colour of the breast and thigh muscles was measured by Croma meter CR-410 (Konica Minolta Inc., Japan) using CIE values expressed as lightness (L*), redness (a*) and yellowness (b*). Measuring area of 50 mm, illuminant D65 and 2° standard observer were used. The instrument was calibrated using a standard white plate. The measurements of the pH and

colour were done on three locations of the muscles and the results were averaged.

Determination of water holding capacity

Water holding capacity measured as free water content (%) was determined as described by Grau and Hamm (1952).

Proximate analysis

Moisture content was determined by drying the samples at 105 °C to constant weight (AOAC, 2004); protein content was determined by the Kjeldahl method, and the fat content was determined by the Soxhlet method (AOAC, 2004); ash content was determined with a muffle furnace at 550 °C (AOAC, 2004).

Statistical evaluation

The results were statistically evaluated through one way ANOVA procedure of JMP v.7 software package. Each bird was used as experimental unit. The normality of distribution of the data and homogeneity of variances were checked by Shapiro-Wilk and Brown-Forsythe tests prior ANOVA. Whenever appropriate, differences among the means were assessed through Tukey HSD test at $P<0.05$. Pearson's r correlation coefficients were calculated to determine the correlations among variables.

RESULTS AND DISCUSSION

Meat quality parameters

The ultimate pH values were within the range of 5.71-5.85 in the breast meat, and 6.10-6.40 in the thighs (Table 1).

Table 1. Quality parameters of the breast and thigh meat of the parent lines and the dual-purpose cross

Trait	Line L	Line BB	Cross ♀L×♂BB	SEM	Sig.
Breast					
pH 24	5.80	5.85	5.71	0.10	0.0866
WHC	38.93^{b}	42.37^{a}	38.59^{b}	1.92	0.0067
L*	55.88^{b}	58.70^{a}	58.66^{a}	2.02	0.0446
a*	14.34	13.43	13.09	1.15	0.0875
b*	7.40	7.22	8.67	1.09	0.0752
Thigh					
pH 24	6.28^{ab}	6.10^{b}	6.40^{a}	0.16	0.0237
WHC	34.18^{b}	38.74^{a}	33.26^{b}	2.24	0.0016
L*	46.85^{b}	50.23^{a}	48.96^{ab}	2.16	0.0474
a*	18.79	17.71	18.94	0.98	0.0899
b*	6.44	7.01	7.36	0.65	0.0777

Means connected with different superscripts are differ significantly ($P<0.05$)

Despite the lack of significant difference between the pH 24 in the breast of the parent lines and the cross, the latter tended to display the lowest values of this parameter (P=0.0866). The opposite was observed in the thigh meat, where the genotype affected pH (P=0.0237), the highest ultimate pH being found in the dual-purpose cross, and the lowest in the BB birds. The values of the muscle pH are indicative for the presence or absence of abnormalities such as PSE or DFD, affect the quality of the meat and determine the possibilities for its further storage and processing. The rapid decline of pH during *post mortem* and its low values are associated with PSE meat, that has low WHC and pale colour. According to Zhang and Barbut (2005) pH values <5.7 and >6.1 in the breast indicate PSE and DFD respectively. In our study we did not observe such values in breast, hence, no quality abnormalities were detected. The higher values of pH measured in thigh meat are due to the muscle fibre type. While breast muscle consists of only glycolytic fibers (Huo et al., 2022) thigh muscles comprise also oxidative fibres (Mehmood and Zhang, 2019) and they were in higher percentage in the slow-growing chickens than fast growing broilers (Weng et al., 2022). These authors also determined higher pH values in legs, that is in line with our results. The range of pH that we observed in our study for breast and thighs is in agreement with the results of Bohrer (2018) in 5 unique genetic strains at 56 days age and also with Sirri et al. (2011) and Chodová et al. (2021) in fast-, medium- and slow-growing chickens.

In this study we found significant differences in WHC for breast (P=0.0067) and thighs (P=0.0016) among the examined lines and their cross. In both meat cuts the lowest WHC was observed in the BB line in comparison to the L and ♀L×♂BB.

The surface colour of the meat is an important parameter that influences the desire of the consumers to buy the meat (Mancini and Hunt, 2005). Meat colour can be affected by many factors among which significant importance has the concentration of myoglobin and its chemical state (Jeong et al., 2009; Kim et al., 2010). Both BB parent line and the crossbred cockerels had lighter colour of the breast, when compared to the L line. All three, however had lighter than normal colour according to the values set by Qiao et al. (2001). The same was observed in thighs with BB showing the highest values of L*, followed by ♀L×♂BB and L. The latter showed the darkest colour. The highest L* values in the thigh meat of BB chickens corresponded to lowest pH in these birds and also to the lowest WHC. Despite the lack of significant differences, the redness a* tended to be higher in the breast of L line (P=0.0875), and lower in the thighs of the BB chickens (P=0.0899). The yellowness on the other hand, tended to be higher in the breast (P=0.0752) and thigh (P=0.0777) of the crossbred chickens when compared to the BB and L lines.

Proximate composition

The content of the protein and intramuscular fat in breast was within the range of 20.30%-21.24% and 0.46%-0.52%, respectively (Table 2). In thighs the protein varied within 17.34-18.06%, while the percentage of lipids was within 2.44-3.23%. In thigh meat, the content of protein tended to be higher in the BB chickens (P=0.0965). The latter also had lower intramuscular fat in this meat cut (P=0.0961).

Table 2. Proximate composition of the breast and thigh meat of the parent lines and the dual-purpose cross

Trait	Line L	Line BB	Cross ♀L×♂BB	SEM	Sig.
Breast					
Protein, %	20.30	21.24	20.76	0.90	0.2289
IMF, %	0.46	0.47	0.52	0.18	0.8496
Moisture, %	76.35	75.26	75.79	0.82	0.1044
Ash, %	0.90^{b}	1.04^{a}	0.94^{b}	0.05	0.0007
Thigh					
Protein, %	17.68	18.06	17.34	0.53	0.0965
IMF, %	3.12	2.44	3.23	0.63	0.0961
Moisture, %	76.31	75.53	76.57	0.74	0.8122
Ash, %	0.94^{b}	1.02^{a}	0.92^{b}	0.03	0.0002

Means connected with different superscripts are differ significantly (P<0.05)

The values of protein and fat content in the birds in this study was lower than those reported by Sirri et al. (2011) and also by Chen et al. (2016). The latter also found significant difference in protein and fat content in breast and thigh between different breeds. Mueller et al. (2020) determined considerably lower content of fat in the thighs but higher content of protein in the breast and the thigh in dual-purpose breeds. The authors observed difference between slow-growing broilers, dual purpose and layer hybrids that were attributable also to the age of slaughter.

In both breast and thigh, the content of ash differed significantly, showing highest content in the BB cockerels. The percentage of ash was in the range of 0.90%-1.04 % in breast and thigh meat. These values are in line with the results of Souza et al. (2011) and Bogosavljevic-Boskovic et al. (2010). Chen et al. (2016) found significant differences between different genotypes of chickens (commercial broiler and crossbred chickens) in regard to the ash content in breast but not in thighs. According to Rehman et al. (2016), ash content did not differ neither in breast nor in thighs between White Fayoumi and Leghorn chickens. Later Cömert et al. (2016) reported different ash content in the meat of slow and fast-growing broilers however attributed to the rearing system and not genotype.

Relationships between meat quality characteristics and proximate components in the breast and thigh in the studied birds

Table 3 showed strong correlations among the instrumental colour parameters in the breast. It was found that a* strongly correlated to L*(r=-0.788, P=0.0001) and b*(r=-0.612; P=0.0069), indicating that the redder breast meat was darker and less yellow. This contradicts to the findings of Silva et al. (2011). According to these authors redness and yellowness of the breast meat are linked and redder meat is more yellow. The yellowness in breast showed moderate correlations to L (r=0.504, P=0.0331), however in thighs, (Table 4) strong correlations were found between these two colour coordinates (0.668, P=0.0025). In this study pH correlated strongly with b * and a*, showing that higher pH is associated with less yellow meat in breast (r=-0.613; P=0.007) and more red meat in thighs (r=0.781, P=0.0001). On the other hand, we failed to observe any significant correlation between pH and L *. This is line with the results of Haunshi et al. (2022) showing lack of significant correlation between pH 24 and L* of breast in indigenous chickens and broilers. In broilers, Fletcher (1999). found significant correlations between pH and L*, a*, and b*, indicating that lower pH was associated with lighter, more yellow and less red meat. In a study on the correlation between quality and sensory attributes in chicken breast and thigh, Bohrer (2019) found weak to moderate negative correlation of pH with L* in breast and thigh and weak negative correlation with b* in breast, partially in agreement with our results. The author also found weak to moderate negative correlation between L* and a* in breast and thigh and strong negative correlation between L* and b* in breast. In line with our results, Chen et al. (2016) found significant correlation between L* and a* in chicken meat, indicating that darker meat was more red.

Moderate to strong correlations were observed between WHC and pH (r=-0.522, P=0.0264), L* (r=0.522; P=0.0263) and a* (r=-0.593; P=0.0095) in thighs. Numerous studies confirm that the lower pH, the lower WHC in meat. Furthermore, the higher L* values also indicate higher percentage of free water, measured by WHC in this study. On the other hand, the thigh meat with higher redness was associated with higher WHC. Our results are in agreement with Chen et al. (2016) who observed higher pressing losses in meat that had higher L* values. In turkeys, Hiscock et al. (2022) observed significant positive correlations between L* and dripping loss.

Table 3. Pearson's correlation coefficients between the quality characteristics and proximate composition of breast meat

		pH	L*	a*	b*	WHC	Protein	Fat	Moisture	Ash
pH	r	1								
	P									
L*	r	-0.141	1							
	P	0.5783								
a*	r	0.224	-0.778	1						
	P	0.3713	0.0001							
b*	r	-0.613	0.504	-0.612	1					
	P	0.0067	0.0331	0.0069						
WHC	r	0.170	0.314	0.057	-0.251	1				
	P	0.4998	0.2044	0.8237	0.3143					
Protein	r	-0.045	-0.172	0.202	-0.377	0.253	1			
	P	0.8592	0.4955	0.4213	0.1235	0.3117				
Fat	r	-0.157	0.308	-0.326	0.572	-0.001	-0.576	1		
	P	0.5342	0.2144	0.1862	0.0132	0.9962	0.0124			
Moisture	r	0.054	0.116	-0.140	0.309	-0.307	-0.981	0.418	1	
	P	0.8312	0.6465	0.5807	0.2121	0.2175	0.0001	0.0844		
Ash	r	0.258	0.073	-0.127	-0.259	0.496	0.526	-0.026	-0.629	1
	P	0.3018	0.7723	0.6148	0.2999	0.0363	0.0249	0.9201	0.0052	

Table 4. Pearson's correlation coefficients between the quality characteristics and proximate composition of thigh meat

		pH	L*	a*	b*	WHC	Protein	Fat	Moisture	Ash
pH	r	1								
	P									
L*	r	-0.152	1							
	P	0.5463								
a*	r	0.781	-0.323	1						
	P	0.0001	0.1912							
b*	r	0.235	0.668	0.177	1					
	P	0.3488	0.0025	0.4829						
WHC	r	-0.522	0.522	-0.593	0.039	1				
	P	0.0264	0.0263	0.0095	0.8767					
Protein	r	-0.449	0.0003	-0.392	-0.289	0.219	1			
	P	0.0616	0.9990	0.1072	0.2437	0.3830				
Fat	r	0.358	-0.126	0.576	0.318	-0.673	-0.397	1		
	P	0.1449	0.6188	0.0124	0.1992	0.0022	0.1032			
Moisture	r	0.074	0.102	-0.188	-0.068	0.428	-0.477	-0.616	1	
	P	0.7711	0.6870	0.4539	0.7900	0.0765	0.0453	0.0065		
Ash	r	-0.678	0.250	-0.587	-0.002	0.527	-0.543	-0.259	-0.268	1
	P	0.0020	0.3171	0.0104	0.9941	0.0248	0.0198	0.2980	0.2816	

With regard to the proximate composition of the meat of L and BB lines, and their crossbred chickens, in breast we found strong positive correlation between the intramuscular fat content and b*(r=0.572, P=0.0132) as well as strong negative correlation between the fat and the protein (r=-0.576, P=0.0124). On the other hand, the higher protein content in the breast was associated with less moisture (r=-0.981, P=0.0001). In thighs, however, fat content showed strong negative correlation with WHC (r=-0.673; P=0.0022) and moisture (r=-0.616; P=0.007). Similar relationship was also observed between moisture and protein content (r=-0.477; P=0.0453). Such correlation was also observed by Chen et al. (2016) and Haunshi et al. (2022). In addition, Chen et al. (2016) reported negative correlation between intramuscular fat content and protein in breast that is in line with our results.

In breast meat, the ash content correlated positively with the percentage of free water (r=0.496; P=0.0363) and protein content (r=0.526; P=0.0249), while negative correlation was found between this parameter and moisture (r=-0.629; P=0.0052). In thighs the ash was negatively correlated with pH (r=-0.678; P=0.0020), redness (r=-0.587; P=0.0104) and protein content (r=-0.543; P=0.0198). Chen et al. (2016) found that ash content of breast correlated negatively with intramuscular fat and redness of the meat, but positively with protein, lightness and yellowness.

CONCLUSION

The results from the study demonstrated differences between the parent lines and their cross in regard to the meat quality traits. It was found that the chickens from the L line and the dual-purpose cross were superior to BB line in terms of WHC, however, layer line showed the darkest colour among the three. With exception to the ash content, exhibiting the highest values in the BB birds, no significant differences were found in regard to the proximate components of the meat. However, the L and crossbred birds tended to have higher intramuscular fat and lower protein in thighs than BB cockerels. Clear relationships between the meat quality traits and proximate composition were found depending on the type of meat. The crossbreed presented in the study was developed using parent lines adapted to rearing in alternative systems. Since there were not dramatic deviations in the examined parameters of meat of the crossbreed compared to the parent lines, we may conclude that rearing in alterative type of system is not expected to negatively affect its meat quality.

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