South African Journal of Animal Science 2023, 53 (No. 4)

The effect of crossbreeding with different breeds on slaughter and carcass characteristics and meat quality in Leghorn hens

E. Arslan[1*], Hasan Keskin[2], Mustafa Garip[1], Cahit Özcan[1]

[1] Selçuk University, Veterinary Faculty, Konya, Türkiye

[2] Konya İl Tarım ve Orman Müdürlüğü, Hayvan Sağlığı ve Yetiştiriciliği Şubesi

(Submitted 27 June 2022; Accepted 6 June 2023; Published 22 September 2023)

Abstract

This study reports slaughter and carcass characteristics and meat quality as a result of crossing Leghorn chickens and five different genotypes. The experiment was carried out in the Prof. Dr. Hümeyra Özgen Research and Application Farm in Selcuk University. The material consisted of 20 leghorn crosses (F2) of each genotype reared under the same feeding and care conditions. The animals were slaughtered at 84 d. In this study, the highest value was determined in the Brahma × Leghorn (BL) genotype, followed by the Cornish × Leghorn (CL), Denizli × Leghorn (DL), and Aracuana × Leghorn (AL) genotypes, respectively, according to slaughter weight and hot and cold carcass performance values. The lowest value was calculated in the Leghorn × Leghorn (LL) genotype, as expected. Slaughter, cold, and carcass weights were found to be similar. A difference was found in colour characteristics (L*,a*,b*) of thigh (b), breast (l), and breast (a) meats of F2 groups. A difference was found in the DM and pH values of the genotypes. CL came into prominence when rearing specific genotypes as free-range broilers. In evaluating the parts of the carcass, it was found that two genotypes were superior to other genotypes in terms of thigh, breast, wing, and back weights. New three-unit and four-unit crossbreeding studies have a potential to add new local commercial genotypes to national economies.

Keywords: Leghorn, crossbreeding, slaughter, carcass, meat quality

Introduction

Stock performance and carcass quality in broilers may vary depending on several factors, such as breed, sex, age, and the rearing method employed (Santos *et al*., 2005; Połtowicz and Doktor, 2012). Stock rearing and animal health have grown into a substantial industry, contributing to the budgets of most countries (Almeida *et al*., 2015). In the 1950s, it took twelve weeks for birds to reach 1.8–2 kg slaughter weight. However, this has been reduced to 40 d by virtue of improvements in animal selection and breeding over the years. Advances in animal rearing techniques taking place in the poultry sector have added to the genetic potential of animals, while positively affecting their capacity of reaching higher live weights (Rémignon *et al*., 1994). Cross-breeding local chicken populations can augment efficiency in poultry farming (Harikrishnan *et al*., 2019). By crossing genotypes with a higher capacity for efficiency with local chicken species, the genetic structure of animals can develop, making it possible to create slower-growing lines for poultry farming (Połtowicz and Doktor, 2012). For example, Denizli breed chickens, constituting our local gene pools, may be used in crossbreeding with improved broiler or layer chicken breeds (Garip *et al*., 2011).

Since local chicken populations are resistant to diseases, thrive on poor quality food, and are preferrred by consumers, they have a potential to constitute one of the alternative sources of income for rural populations (Mengesha, 2012). Organic production supports eco-friendly food production, which can produce quality products by enhancing animal welfare conditions (Sundrum, 2001). Current

URL: http://www.sasas.co.za
ISSN 0375-1589 (print), ISSN 2221-4062 (online)
Publisher: South African Society for Animal Science
http://dx.doi.org/10.4314/sajas.v53i4.11

rearing methods for broilers enable chickens to grow more thigh and breast meat and less abdominal fat in comparison to traditional rearing systems (Castellini *et al*., 2002). Due to more health-conscious consumers and an increase in demand for alternative products, alternative poultry breeders may be encouraged to rear breeding animals (Franzoni *et al*., 2021). For that purpose, most researchers seek new genotypes by combining fast-growing commercial hybrids and slow-growing local animals (Rizzi *et al*., 2013; Cassandro *et al*., 2015; Wolde *et al*., 2021).

The Denizli breed represents a substantial local gene pool worthy of preservation because of their peculiar ability to sing for a long time, their feather colour, foot skin colour, and peculiar racial morphological structure (Aksoy *et al*., 2002). In addition, Atasoy and Gürcan (2000) reported that the Denizli breed chicken had higher live weights than other local Turkish chicken breeds. In the Denizli × Leghorn F2 population, live weights are reported to range from 1814.60–1900.0 g in females and males at 32 week (Garip *et al*., 2011).

In poultry eggs, eggshell colour is an external quality characteristic that affects the shell quality, as well as the egg quality characteristics (Kırıkçı *et al*., 2005; Drabik *et al*., 2021). Therefore, chicken breeds like Araucanas which have different eggshell colours draw the attention of breeders and consumers. Researchers have reported on the Araucana, which has different eggshell colours like pheasants, owing to their blue eggshell, which is a dominant character (Punnett 1933; Keneddy and Vevers, 1973).

It is reported that more studies are needed in this context to bring new species from local breeds to future generations and to contribute to the protection of the gene resources of the countries (Keskin *et al*., 2022). Crossbreeding studies cause some morphological and physiological changes in living things. The hypothesis that there may be a potential for the formation of new, combined, productive breeds by crossing different genotypes with Leghorn females, a commercial layer breed with high yielding characteristics, motivated us to conduct this study. The purpose of this study was to obtain new lines by crossbreeding the Leghorn layer and specific genotype groups from our local chicken breeds with peculiar characteristics, primarily the Denizli breed. In addition, the study examined the evolution of these new genotypes in the genetic potential of F2 crosses and their effects on carcass and meat quality.

Materials and Methods

The eggs from each genotype, including five different chicken breeds of broilers (Brahma, Denizli, Araucana, Leghorn, Cornish) and 20 Leghorn hens produced for crossbreeding were kept in a waiting room at 15 ^{o}C and 70% moisture for one week. All daily-collected eggs contained defining information (parent stock, date, group). After seven days of storage, hatching quality eggs were weighed and fumigated. Applying fumigation (14 g formaldehyde, 7 g potassium permanganate, v/w) for 10 mins, the eggs were set into an incubator. Brooder machine was set at 37.7 ^{o}C and 65% moisture for incubation and in a hatching machine at 37.2 ^{o}C and 70% proportional moisture. The new chicks were recorded by writing down their mother and father record numbers and wing numbers. As a result, the Brahma (B×L), Denizli (D×L), Araucana (A×L), Leghorn (L×L), and Cornish (C×L) crossbreed genotypes were obtained with the Leghorn breed in the female line, respectively. The crossbreed genotypes thus obtained were grown individually in the brooder catch machine where they were kept for one week.

The genotypes were administered 2.5% sugared water solution to reduce their risk of not accessing the feed and reduce the mortality rate and then fed after three to four hours of hunger (McNaughton *et al*., 1978). A vaccination program (Marek's, Gumboro, Newcastle) aimed at poultry was applied, similar to the one applied at Hümeyra Özgen Research and Application Center Farm Poultry Unit. The animals were revaccinated at appropriate times.

The animals were administered broiler chick mash, which had been previously prepared and weighed, nearly two hours later, *ad libitum,* using chick feeders. The genotype groups were created with four animals each and five repetitions in such a way that the groups were to have similar environmental conditions. The chick genotypes were individually fed chick starter (I) feed in the brooder catch machine for 0–7 d. Then chick grower feed (II) was used from 8–14 d. In the floor system, sections contained 10–12 birds per square metre, had at least two nipple drinkers, and chicks could not mix. A sawdust material of at least 2.5 cm was used on the floor of the sections as a base. At the end of day 14, the broiler onset feed (III) was used. From days 14–28, all groups were fed under equal conditions. On day 28, the broilers were weighed. After day 28, broiler finishing feed (IV) was administered in the same way and the feed and live weight measurements continued to be done bi-weekly. The broiler groups were fed in the coop sections until day 84.

Five animals from each group, one in each subgroup (repetition), were removed for slaughter. After slaughtering and dressing, the hot carcasses were chilled for 2 h at 4 °C. The carcasses were weighed and refrigerated for 24 h. Carcass weight and proportions were calculated on the basis of the breast (skinless), thighs, wings, back, and neck parts according to a standard procedure (Uijttenboogaart & Gerrits, 1982). In addition, gizzard, liver, and heart weights were calculated using edible parts with economic value. The inedible parts consisted of feathers, feet, head, intestines, kidneys, and urogenital organs. Although the internal organs are not considered as "carcass" in the poultry industry, protein is an essential nutrient source in them (Romero-Garay *et al*., 2022).

The animals were regularly watered using automatic nipple drinking bowls that were easily accessible. For all experimental stages, a continuous lighting programme was used (23 h of light and one hour of darkness). Nutritional values of the feed supply were determined in a private enterprise and nutritional value analysis of the feed was performed at the Selcuk University, Faculty of Veterinary Science, Animal Feeding and Nutrition Diseases Laboratory (Table 1).

Table 1 Nutrient content of the phase feeds used in feeding of the genotypes

	I	II	III	IV
Energy kCal/kg	3000	3100	3100	3100
Protein raw %	23	22	21	18
Cellulose raw %	4.0	4.0	4.0	6.0
Ash raw %	5.0	5.0	5.0	5.0
Ca %	1.0	0.95	0.80	0.80
P %	0.50	0.50	0.45	0.60
Methionine %	1.00	0.45	0.40	0.40
Lysine %	1.35	1.20	1.10	1.00

I: Chick starter feed days 1–7, II: Chick grower feed for days 8–28, III: Chick starter feed for days 8–28, IV: Broiler finisher feed for day 28 onward

For the carcass preparation procedure, wing, thigh, and breast pieces were taken by cutting one bird (five from each group) from each repetition and the pieces were weighed using a balance scale. Feeders were removed eight hours before and birds were weighed prior to slaughter and slaughter weights were determined. After the slaughter, the head and foot weights, as well as consumable (heart, liver, and gizzard) and inedible offal weights of the broilers, which had been defeathered using a wet defeathering method, were individually determined using a balance scale.

The hot performance was determined as the proportion of the weight of hot carcass, which was washed and dried for 10 min, to the slaughter weight.

Hot performance (%) = (hot carcass weight (g) / slaughter weight (g)) × 100 (1)

The cold performance was determined from the proportion of the carcass after cold storage room at +4 °C for 24 h to slaughter weight.

Cold performance (%) = ((cold carcass weight (g) / slaughter weight (g)) × 100 (2)

Dry matter, pH, water retention capacity, cooking loss, and colour values (L*, a*, b*) of thigh and breast portions of five samples taken from each genotype group were individually determined. Meat colour was measured on the external surface of the breast and thigh muscle after skin removal using a portable colour difference meter based on the lightness (L*), redness (a*), yellowness (b*) system and the external of the removed skin was measured for colour (CIE, 1976). Three measurements were performed per sample and an average value was obtained. Meat pH was measured 24 h after cooling the carcasses. Analysis of the samples was performed at Selçuk University, Faculty of Veterinary Science, Department of Nutritional Hygiene and Technology Laboratory.

The data of the study were evaluated using the IBM SPSS 25 package program licensed by Selcuk University. The normal distribution of the data was analysed using the Shapiro–Wilk test. Multiple analysis of variance (ANOVA) was used for parametric tests and Duncan's test was used for comparisons between groups. In addition, the Kruskal–Wallis-H test was used for non-parametric tests. Intergroup significance was evaluated on the basis of $P < 0.05$.

Results

Table 2 demonstrates the slaughter, hot, and cold carcass performance values of different genotypes. Of the characteristics examined in Table 2, the highest value was in the BL genotype, followed by the CL, DL, and AL genotypes. The lowest value was in the LL genotype, which was expected. Slaughter, cold, and carcass weights were similar. However, the weights were higher in one of the local genotype resources, the DL genotype (related to the CL group, which was crossbred with Brahma, a broiler breed) and in the AL group. Evaluating all slaughter and carcass characteristics, this value was found to be the lowest in the LL group, which is known as a layer genotype (P <0.01).

Table 2 Slaughter, hot carcass, and cold carcass weights of different genotypes (day 84)

Genotype	N	Slaughter Weight (Mean ± SD)	Hot Carcass Weight (Mean ± SD)	Cold Carcass Weight (Mean ± SD)
BL	20	1290.4 ± 43.1^{a}	1085.5 ± 36.5^{a}	1075.7 ± 35.9^{a}
DL	20	1155.5 ± 58.3^{b}	950.5 ± 56.3^{b}	915.5 ± 55.37^{b}
AL	20	1111.9 ± 20.4^{b}	924.3 ± 19.2^{b}	875.3 ± 35.59^{b}
LL	20	983.3 ± 49.6^{c}	803.8 ± 41.6^{c}	757.9 ± 50.94^{c}
CL	20	1221.9 ± 36.2^{ab}	1018.4 ± 33.9^{ab}	1010.3 ± 37.63^{ab}
Overall	100	1152.6 ± 27.7	956.5 ± 25.1	924.9 ± 29.86
P-value		0.001	0.001	0.003

Genotypes: BL: Broiler x Leghorn, DL: Denizli x Leghorn, AL: Aracuana x Leghorn, LL: Leghorn x Leghorn, CL: Cornish x Leghorn.
^{a,b,c}: The difference between the groups with different letters in the same column is significant (P <0.05)

Table 3 demonstrates the weights of consumable carcass parts related to the F2 genotypes. Accordingly, a difference was found in terms of thigh and wing weights (P <0.001) breast and back weights (P <0.05).

Table 4 demonstrates the weights of inedible carcass parts related to the F2 genotypes. Differences were found in terms of offal and foot weights (P <0.01) and head weight (P <0.05). Evaluating the inedible carcass portion weights in the genotype groups, the highest value was determined in the head and inedible offal in the CL group (P <0.01) and in the head in the Brahma breed. The lowest inedible offal weight was determined in the LL group and the lowest head weight was in the BL group (P <0.05).

Table 3 Weights of carcass parts related to different genotype groups at 84 weeks of age

	BL (Mean±SD)	DL (Mean±SD)	AL (Mean±SD)	LL (Mean±SD)	CL (Mean±SD)	Overall (Mean±SD)	*P*-value
Thigh	332.3±21.9^{a}	271.7±17.5^{b}	275.5±8.8^{b}	217.5±12.6^{c}	288.5±11.6^{ab}	277.1±9.7	0.001
Breast	360.1±34.2^{a}	310.8±18.4^{ab}	289.8±18.0^{c}	273.0±16.8^{c}	362.7±18.6^{a}	319.3±11.7	0.029
Wing	134.8±5.1^{ab}	118.7±5.8^{c}	125.1±4.2^{bc}	100.0±3.4^{d}	142.4±4.1^{a}	124.2±3.5	0.001
Back	171.3±9.8^{a}	144.7±18.2^{ab}	119.3±7.3^{b}	101.1±23.1^{d}	142.5±2.7^{ab}	135.8±7.6	0.025
Neck	67.2±5.0	69.7±6.5	65.6±6.5	66.3±2.1	74.2±8.8	68.6±2.6	0.864
Gizzard	29.2±1.9	38.8±11.2	25.3±2.6	27.1±5.4	22.9±0.8	28.6±2.6	0.368
Liver	39.2±1.5	38.6±2.4	31.3±4.2	34.7±5.7	37.3±2.0	36.2±1.6	0.509
Heart	9.9±0.6	8.7±0.4	8.7±0.8	11.0±2.6	9.7±0.9	9.6±0.6	0.707

Genotypes: BL: Broiler x Leghorn, DL: Denizli x Leghorn, AL: Aracuana x Leghorn, LL: Leghorn x Leghorn, CL: Cornish x Leghorn. ^{a,b,c}: The difference between the groups with different letters in the same column is significant (P <0.05)

Table 5 demonstrates the quality characteristics (L*,a*,b*) defining thigh and breast meats related to the F2 groups. A difference was found in thigh (b) and breast (l) (P <0.01) and breast (a) (P <0.05).

Table 4 Weights (g) of inedible carcass parts in the genotype groups

	BL (Mean±SD)	DL (Mean±SD)	AL (Mean±SD)	LL (Mean±SD)	CL (Mean±SD)	Overall (Mean±SD)	*P*-value
Inedible Offal	118.1±2.8^{bc}	134.7±6.1^{ab}	107.6±4.5^{c}	108.8±10.3^{b}	139.5±4.8^{a}	121.7±3.7	0.004
Head	46.5±1.7^{b}	56.3±3.1^{ab}	58.1±3.6^{a}	54.6±3.9^{ab}	64.3±4.3^{a}	56.0±1.8	0.027
Foot*	80.1±3.4^{a}	62.7±2.3^{b}	64.2±4.1^{b}	52.0±1.7^{c}	69.5±2.0^{b}	65.7±2.2	0.001

Genotypes: BL: Broiler x Leghorn, DL: Denizli x Leghorn, AL: Aracuana x Leghorn, LL: Leghorn x Leghorn, CL: Cornish x Leghorn; the difference between the groups with different letters in the same column is significant (*P* <0.05); *: consumable portion in specific countries

Table 5 Evaluating specific carcass quality characteristics related to thighs and breasts in the genotype groups

Genotype	Thigh L*	Thigh a*	Thigh b*	Breast L*	Breast a*	Breast b*
DL	45.70±0.94	3.87±0.51	2.79±0.43^{b}	43.99±1.23^{ab}	1.62±0.19^{a}	3.51±0.53
BL	44.06±0.94	4.00±0.37	3.46±0.55^{b}	44.93±0.60^{a}	0.87±0.20^{b}	4.4±0.39
AL	42.76±1.10	3.81±0.22	4.95±0.30^{a}	41.27±0.62^{c}	0.92±0.14^{b}	3.17±0.31
LL	44.94±0.90	3.81±0.39	2.35±0.41^{b}	46.45±1.06^{a}	0.64±0.23^{b}	2.98±0.31
CL	45.64±0.89	3.07±0.34	2.78±0.65^{b}	42.24±0.68^{bc}	1.14±0.25^{ab}	3.08±0.37
Overall	44.62±0.44	3.71±0.17	3.27±0.24	43.78±0.45	1.04±0.1	3.43±0.18
N=12	*P*=0.170	*P*=0.441	*P*=0.004	*P*=0.001	*P*=0.018	*P*=0.082

Genotypes: BL: Broiler x Leghorn, DL: Denizli x Leghorn, AL: Aracuana x Leghorn, LL: Leghorn x Leghorn, CL: Cornish x Leghorn
L*: Lightness, a*: Redness, b*: Yellowness. The difference between the groups with different letters in the same column is significant (*P* <0.05)

Table 6 Specific carcass quality characteristics related to thighs in the genotype groups

	Thigh DM	Thigh ASH	Thigh pH	Thigh WA	Thigh WHC	Thigh drip loss	Thigh cooking loss
DL	22.53±0.47	4.45±0.13	5.90±0.04	0.98±0.002	13.71±1.19	21.31±1.34	33.17±1.28
BL	22.82±0.24	4.40±0.06	5.88±0.06	0.98±0.002	11.82±1.25	18.39±1.03	35.82±1.06
AL	22.91±0.26	4.51±0.09	5.91±0.04	0.98±0.002	12.48±1.44	19.86±1.37	34.5±1.09
LL	22.95±0.57	4.42±0.04	5.9±0.05	0.98±0.001	14.66±2.00	21.47±0.97	34.36±0.99
CL	24.42±0.92	4.49±0.10	5.83±0.05	0.98±0.003	10.24±1.03	20.45±1.2	34.54±0.97
Overall	23.13±0.26	4.45±0.04	5.89±0.02	0.98±0.001	12.58±0.65	20.3±0.54	34.48±0.48
N=8	*P*=0.147	*P*=0.897	*P*=0.755	*P*=0.437	*P*=0.240	*P*=0.375	*P*=0.563

Genotypes: BL: Broiler x Leghorn, DL: Denizli x Leghorn, AL: Aracuana x Leghorn, LL: Leghorn x Leghorn, CL: Cornish x Leghorn
DM: dry matter, WA: water activity, WHC: water holding capacity. The difference between the groups with different letters in the same column is significant (*P* <0.05)

Table 7 demonstrates the findings related to dry matter (DM), ash, pH, and water retention in breasts obtained from the F2 genotypes. In the study groups, a difference was found in the DM (*P* <0.013) and pH values (*P* <0.003).

Table 7 Carcass quality characteristics related to breast in the genotype groups

	Breast DM	Breast ASH	Breast pH	Breast WA	Breast WHC	Breast drip loss	Breast cooking loss
DL	24.7±0.43^{ab}	4.38±0.22	5.71±0.02^{a}	0.98±0.002	14.71±1.3	24.23±1.42	31.1±1.75
BL	25.7±0.63^{ab}	4.61±0.32	5.51±0.03^{b}	0.98±0.002	13.69±1.19	23.81±1.39	30.83±0.67
AL	24.8±0.23^{ab}	4.53±0.11	5.65±0.02^{ab}	0.98±0.002	13.63±0.57	25.66±1.61	29.06±0.58
LL	23.8±0.45^{b}	4.25±0.11	5.66±0.07^{a}	0.98±0.002	17.12±2.33	26.12±0.88	30.01±1.26
CL	26.8±0.94^{a}	4.07±0.21	5.71±0.02^{a}	0.98±0.002	18.22±2.95	23.62±1.10	30.27±2.55
Overall	25.2±0.30	4.37±0.09	5.65±0.02	0.98±0.001	15.47±0.85	24.69±0.58	30.25±0.66
N=8	*P*=0.013	*P*=0.370	*P*=0.003	*P*=0.628	*P*=0.312	*P*=0.566	*P*=0.899

Genotypes: BL: Broiler x Leghorn, DL: Denizli x Leghorn, AL: Aracuana x Leghorn, LL: Leghorn x Leghorn, CL: Cornish x Leghorn. DM: Dry matter, WA: Water activity, WHC: Water holding capacity; the difference between the groups with different letters in the same column is significant (*P*<0.05)

Tables 5, 6, and 7 demonstrate the findings related to dry matter, pH, water retention capacity, cooking loss, and colour values (L*, a*, b*) in thigh and breast portions. Statistically significant differences were found in the L*, dry matter, and pH values in the breast portions. Differences were found in the b* values of thigh portions of the broilers obtained by crossbreeding (*P* <0.05).

Discussion

Table 2 demonstrates the preslaughter live, hot carcass, and cold carcass weights related to the Leghorn crossbreeds. Garip *et al*. (2011) calculated the F1 and F2 crossbreeds of the DL genotypes, respectively, to be 2132.62 g and 1856.17 g live weight at weeks three to 32 in terms of specific efficiency characteristics (*P* <0.01). Garip *et al*. (2011) reported the live weight to be 1814.60 ± 6.58 g in the female Denizli x Leghorn crossbreeds and 1900.0 ± 5.74 g in the males at week 32. Atasoy and Gürcan (2000) reported the live weight of Denizli chicken breeds to be 2597.26 g at week 35. However, in the present study, the slaughter weight of the DL genotype was calculated to be 1155.50 g on day 84. A study conducted by Castellini *et al*. (2002) which examined the effect of rearing broiler breed chicken in organic production systems up to 81 days of age on carcass meat quality characteristics reported the live weight, hot carcass, and cold carcass weights to be 4368 g, 3529 g, and 3485 g, respectively. Zanetti *et al*. (2010) examined the slow-growing, Italian-origin genotypes in terms of carcass and meat efficiency and reported the mean live weight to be 1434–2718 g and the carcass weight to be 879–1726 g. Another study which investigated the Padovana breed chicken obtained 1992, 2571, and 2717 g live weights on days 131, 180, and 201, respectively. It was reported that it was possible to develop the Padovana chicken, a local breed, by crossbreeding (Cassandro *et al*., 2015). In the slow-growing, Italian-origin chickens, live weight was 1854 g in the Saluzzo breed and 1819 g in the Piemontese breed at the age of 32 weeks (Soglia *et al*., 2020). In the 18-week Sasso-RIR (SRSR), Sasso crossbreed (LSR), and normal-feathered local chicken breed (LL), the live weights were 1877, 1379, and 1070 g, respectively. The effect of genotype was significant (*P* <0.05) in this parameter and crossbreeding enhanced the local genotypes in terms of weight. In the present study, the live weights were measured to be 1111.9, 1221.9, 1290.4, 983.3, and 1155.5 g in AL, CL, BL, LL, and DL, respectively (*P* <0.05). The discrepancy in values reported by the researchers may be because of the breed, genotype, slaughter age, purpose of rearing, geographical region, and ration content differences.

Table 3 demonstrates the weights of carcass meat portions in relation to the genotype groups. The proportion of the carcass thigh weight to the wing and liver weights was similar, whereas the carcass weight (*P* <0.001), carcass performance (*P* =0.029), and breast proportion (*P* <0.001) were found to be different (Choo *et al*., 2014). In the present study, it was found that the effect of the genotype on thigh weight (*P* =0.001), breast weight (*P* =0.029), and wing weight (*P* =0.001) was substantial, whereas the effect on the liver weight was not (*P* =0.509). De Marchi *et al*. (2005) reported 1084 g hot carcass and 213 g breast weight from the Padovana chicken at 150 days of age. In the present study, higher breast weights were obtained from all Leghorn crossbreeds than the Padovana breed chicken. Evaluating the 306.3, 373.6, and 390.5 g breast weights obtained by Cassandro *et al*. (2015) from local chicken at 131, 180, and 201 days of age, it was determined that the DL obtained a similar breast efficiency in a shorter period of time.

In addition to an increased population, there has been an increase in the demand for animal products obtained from poultry reared in open-access systems. Considering the environmental

adaptation and carcass quality of local breeds, DL can be chosen as a new line for cage-free system rearing. Zanetti *et al*. (2010) reported that the weights of breasts and thighs obtained from the Italian genotypes were 322–667 g and 140–243 g, respectively, and the genotype determined the weight of both carcass portions (P <0.05). In the present study, it was found that thigh portions were different among genotypes (P =0.001); the highest thigh weight was 332.3 g in the BL genotype, whereas the lowest value was 217.5 g in the LL genotype. This may be due to the differences in the efficiency of the parent stock. The genotypes whose thigh values were examined were superior to the slow-growing Italian-origin genotypes in terms of time and efficiency. The differences between the values reported on local chickens may have been related to the most important factors affecting the carcass, i.e., the genetic factors (breed, sex) and age, care, and feeding practices.

Table 5 demonstrates the L^*, a^*, and b^* values of thighs and breasts related to different genotypes. The L^* and a^* values of breasts were different (P <0.05), but b^* values were similar (P =0.082). The meats obtained from the AL crossbreeds had a yellower carcass content than other genotypes. Free-range production system affect the bright colour of breasts (L^*) and red colour intensity of thighs (b^*) (Sokołowicz *et al*., 2016) and even the taste of animal products (Fanatico *et al*., 2007). The AL had a higher b* value than other genotypes, which could cause darker thigh meat than this genotype in an open-access rearing system. Zanetti *et al*. (2010) reported that a difference in terms of the L^* and b^* values of slow-growing genotypes in breast meat (P <0.05), whereas the difference between the a^* values was negligible. They reported that the L^* and a^* values of breast meat in slow and fast-growing genotypes were similar, whereas there was a difference in b^* value (P <0.05); L^*, a^*, and b^* values of thigh meat were similar (Mikulski *et al*., 2011).

With increasing consumption of poultry meat and products, it is essential for consumers, retailers, and the poultry industry to achieve consistently high meat quality. The genotypic differences in WHC (water holding capacity), drip loss, and cook loss were found to be inconsequential, which is consistent with the results of Fanatico *et al.* (2007), Pereira *et al.* (2013), and Xue *et al.* (2021). Breast pH was affected by genotype, a finding similar to that of Hailemariam *et al.* (2022).

Conclusion

In order to improve local chicken breeds, which have a lower productive performance, create disease-resistant local breeds, investigate alternative feeding opportunities, introduce and protect traditional tastes and hand them down the next generations, it is believed that adding new types from local breeds can contribute to the economy, enable them to be handed down the next generation, and contribute to the protection of gene pools of countries. In evaluating the growing performance of layer types, it was concluded that BL and CL came into prominence in rearing specific genotypes as free-range broilers. In evaluating the parts of carcass, it was found that these two genotypes were superior to other genotypes in terms of thigh, breast, wing, and back portion weights. The BL genotype was noted for thigh and back portion weights and the CL genotype for breast and wing portions. No difference was found in terms of inedible weights of carcass portions, which was probably because of morphological breed characteristics.

According to the Hunter calorimetric evaluation results of breasts and thighs, it was determined that the carcass parts obtained from the AL and CL were higher than other genotypes, which could be the reason why consumers prefer them. Evaluating breasts, the LL genotype was found to be lower in terms of DM and the BL was found to be lower in terms of breast pH. Evaluating age at sexual maturity at week eight and the growth measurements including the period until week 84, it was determined that the BL genotype showed the highest performance, which was followed by the DL, CL, and AL genotypes.

In the light of crossbreeding studies between local chicken populations and commercial hybrids, it was concluded that the DL could be considered an efficient, combined breed. With effective crossbreeding between Denizli chicken breeds, which enjoy an economic value owing to their peculiar ability to sing, and commercial hybrids, which have a good adaptation capability as a local gene pool, the genetic potential of the Denizli chicken can be improved to make them more accessible for the general population. This way, it may be possible to create new sources of income for breeders in rural areas.

Since there are a limited number of studies on the crossbreeding of the Araucana breed or meat efficiency, comprehensive studies are needed on this breed. The dominant blue shells may generate a

rapid and practical alternative solution to increase the consumer demand through the crossbreeding of this breed with layer-type chicken breeds.

Considering better carcass efficiency and breast portions, the crossbreeding of local chickens with a layer breed may be economically advantageous. Crossbreeds are a good alternative for enhancing the stock and stock systems and protecting the specific meat quality of local chickens.

The findings of the study demonstrate that even dual crossbreeding might be an alternative in poultry rearing, compared to organic systems and free-range systems. Considering the carcass characteristics and organoleptic characteristics of organically-fed chickens, it was concluded that new genotypes suitable for organic production could be obtained. It is known that broilers need to meet the demands of consumers in terms of organic meat. Therefore, in order to have the best broilers to respond better to the organic and free-range feeding systems in Turkey, more and different disciplines must do research. In the light of the findings obtained from the present study, it is concluded that new three-unit and four-unit crossbreeding studies have a potential of adding new commercial local genotypes to national economies.

Acknowledgement

We would like to thank Selçuk University Scientific Research Projects Coordinatorship for their contributions to the present study, “Investigation of the fattening performance and carcass characteristics of the young generation in the Legorn breed which is hybrid with local chicken breeds,” Project No: 15401071. We also thank the administration and staff at Selçuk University, Faculty of Veterinary Science, Hümeyra Özgen Research and Application Center Farm for their contributions.

Ethics Statement

Approval was obtained from the Selcuk University Experimental Research and Application Center, Animal Experiments Ethics Committee with the decision number 2014/61 dated 29.09.2014.

Author Contributions

Garip M, Özcan C: Conducting experiment, acquisition of data. Arslan E, Garip M, Keskin H: Conducting experiment, writing manuscript. Garip M, Arslan E, Keskin H: Overall supervision, editing manuscript and final approval.

Conflict of Interests

The authors declared no conflict of interest.

References

Aksoy FT, Atasoy F, Onbaşılar EE, Apaydın S, 2002. Denizli ırkı günlük civcivlerde tüylenme özelliklerinden yararlanarak cinsiyeti belirleme olanakları. Turk. J. Vet. Anim. Sci. 26, 3, 567-75.

Almeida AMd, Bassols A, Bendixen E, Bhide M, Ceciliani F, Cristobal S, Eckersall PD, Hollung K, Lisacek F, Mazzucchelli G, 2015. Animal board invited review: Advances in proteomics for animal and food sciences. Animal. 9, 1, 1-17.

Atasoy F, Gürcan İS, 2000. Bir Denizli Tavuğu Sürüsünde Canlı Ağırlık ve Yumurta Ağırlığı Özellikleri Ankara Üniversitesi Veteriner Fakültesi Dergisi. 47, 03, 265-9.

Cassandro M, De Marchi M, Penasa M, Rizzi C, 2015. Carcass characteristics and meat quality traits of the Padovana chicken breed, a commercial line, and their cross. Ital. J. Anim. Sci. 14, 3, 3848.

Castellini C, Mugnai C, Dal Bosco A, 2002. Effect of organic production system on broiler carcass and meat quality. Meat Sci. 60, 3, 219-25.

Choo Y, Kwon H, Oh S, Um J, Kim B, Kang C, Lee S, An B, 2014. Comparison of growth performance, carcass characteristics and meat quality of Korean local chickens and silky fowl. Asian-australas. J. Anim. Sci. 27, 3, 398.

De Marchi M, Cassandro M, Lunardi E, Baldan G, Siegel P, 2005. Carcass characteristics and qualitative meat traits of the Padovana breed of chicken. Int. J. Poult. Sci. 4, 4, 233-8.

Drabik K, Karwowska M, Wengerska K, Próchniak T, Adamczuk A, Batkowska J, 2021. The variability of quality traits of table eggs and eggshell mineral composition depending on hens’ breed and eggshell colour. Animals. 11, 5, 1204.

Fanatico A, Pillai P, Emmert J, Gbur E, Meullenet J, Owens C, 2007. Sensory attributes of slow-and fast-growing chicken genotypes raised indoors or with outdoor access. Poult. Sci. 86, 11, 2441-9.

Franzoni A, Gariglio M, Castillo A, Soglia D, Sartore S, Buccioni A, Mannelli F, Cassandro M, Cendron F, Castellini C, 2021. Overview of local chicken breeds in Italy: Small scale production and marketing. Animals. 11, 3, 629.

Garip M, Nizamlioglu M, Kurar E, Yilmaz A, Çağlayan T, Dere S, Bulut Z, Ozsensoy Y, Kurtoglu V, 2011. Growth and some period yield characteristics of Denizli x Leghorn crosses (F2). Eurasian J. Vet. Sci. 27, 3, 177-82.

Harikrishnan S, Chacko B, Anitha P, Jospeh BC, Anilkumar K, Mathew J, 2019. Performance of the Production characteristics of the reciprocal crosses of local chicken of Kerala and N strain (IWN) of White Leghorn. Int. J. Curr. Microbiol. App. Sci. 8, 12, 1562-7.

Keneddy G, Vevers H, 1973. Eggshell pigments of the Araucano fowl. Comp. Biochem. Physiol. B, Biochem. Mol. Biol. 44, 1, 11-25.

Keskin H, Arslan E, Garip M, Özcan C, 2022. Some egg quality characteristics and hatching performances of Leghorn hybrids. Kocatepe Vet J. 15(4): 500-506

Kırıkçı K, Günlü A, Garip M, 2005. Some quality characteristics of pheasant (*Phasianus colchicus*) eggs with different shell colours. Turkish J. Vet. Anim. Sci. 29, 2, 315-8.

Romero-Garay MG, Montalvo-González E, Hernández-González C, Soto-Domínguez A, Becerra-Verdín EM, García-Magaña MDL, 2022. Bioactivity of peptides obtained from poultry by-products: A review. Food Chem. X, 13, 100181.

McNaughton JL, Deaton JW, Reece FN, Haynes RL, 1978. Effect of age of parents and hatching egg weight on broiler chick mortality. Poult. Sci. 57(1), 38-44.

Mengesha M, 2012. Indigenous chicken production and the innate characteristics. Asian J. Poult. Sci. 6, 2, 56-64.

Mikulski D, Celej J, Jankowski J, Majewska T, Mikulska M, 2011. Growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access. Asian-Australas. J. Anim. Sci. 24, 10, 1407-16.

Połtowicz K, Doktor J, 2012. Effect of slaughter age on performance and meat quality of slow-growing broiler chickens. Ann. Anim. Sci. 12, 4, 621-31.

Punnett C, 1933. Genetic studies in poultry. J. Genetics. 27, 3, 465-70.

Rémignon H, Lefaucheur L, Blum J, Ricard F, 1994. Effects of divergent selection for body weight on three skeletal muscles characteristics in the chicken. Br. Poult. Sci. 35, 1, 65-76.

Rizzi C, Contiero B, Cassandro M, 2013. Growth patterns of Italian local chicken populations. Poult. Sci. 92, 8, 2226-35.

Santos A, Sakomura N, Freitas E, Fortes C, Carrilho E, 2005. Comparison of free range broiler chicken strains raised in confined or semi-confined systems. Braz. J. Poult. Sci. 7, 85-92.

Soglia D, Sartore S, Maione S, Schiavone A, Dabbou S, Nery J, Zaniboni L, Marelli S, Sacchi P, Rasero R, 2020. Growth performance analysis of two Italian slow-growing chicken breeds: Bianca di Saluzzo and Bionda Piemontese. Animals. 10, 6, 969.

Sokołowicz Z, Krawczyk J, Świątkiewicz S, 2016. 4. Quality of Poultry meat from local chicken breeds–A review. Ann. Anim. Sci. 16, 2, 347-68.

Sundrum A, 2001. Organic livestock farming: a critical review. Livest. Prod. Sci. 67, 3, 207-15.

Uijttenboogaart TG, Gerrits AR, 1982. Method of dissection of broiler carcasses and description of parts (No. 370). Centrum voor Onderzoek en Voorlichting voor de Pluimveehouderij.

Wolde S, Mirkena T, Melesse A, Dessie T, Abegaz S, 2021. Hatchability and growth performances of normal feathered local, Sasso-RIR and their F1-cross chickens managed under on-station condition in southern Ethiopia. Trop. Anim. Health Prod. 53, 5, 1-8.

Zanetti E, De Marchi M, Dalvit C, Molette C, Rémignon H, Cassandro M, 2010. Carcase characteristics and qualitative meat traits of three Italian local chicken breeds. Br. Poult. Sci. 51, 5, 629-34.