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Growth, Welfare and Leg Soundness Traits in Genetically Different ANADOLU-T Broiler Pure Lines and Hybrids

ABSTRACT

Objective: This study aimed to investigate the growth, welfare and walking ability in broiler chickens from different genetic pure lines and hybrids.

Materials and Methods: A total of 112 broilers from each of the seven genotypes (A1, A2, A3, B1, B2, ANADOLU-T, ROSS-308) and both sexes were monitored from 0 to 42 days. Weekly body weight (BW), body length, shank length and diameter, welfare traits (foot pad dermatitis (FPD), hock burn (HB), breast burn (BB), finger crookedness (FC)), valgus-varus deformation (VVD), and gait score (GS) were measured.

Results: A1, A2, and A3 lines had lighter BW compared to the other genotypes, with ROSS-308 being heavier at 35 and 42 days. Welfare indicators showed significant genotype and sex effects, with males exhibiting higher levels of HB, BB, and FC compared to females. VV angulation increased with age, with ROSS-308 showing the highest angulation at 42 days. Gait scores were better in the A1 line at 28 days and A3 line at 35 and 42 days.

Conclusion: ANADOLU-T sire lines and hybrids had higher BW than dam lines from 21 days onwards. Overall poorer welfare and impaired walking ability were observed in sire lines and hybrids. On the other hand, VVD and gait score in ANADOLU-T sire lines could be used as selection criteria since they were not associated with BW.

Keywords: Body weight, performance, valgus, varus, foot-pad dermatitis, walking ability

Genetik Olarak Farklı ANADOLU-T Etlik Piliç Saf Hatları ve Hibritlerde Büyüme, Refah ve Bacak Sağlamlığı Özellikleri

ÖZ

Amaç: Bu çalışmada, genetik olarak farklı saf hat ve hibrit etlik piliçlerde büyüme, refah ve yürüme yeteneği özelliklerinin ortaya koyulması amaçlanmıştır.

Materyal ve Metot: Çalışmada yedi genotipin (A1, A2, A3, B1, B2, ANADOLU-T, ROSS-308) her birinden toplam 112 piliç 42 gün boyunca yetiştirilmiştir. Haftalık canlı ağırlık (CA), vücut uzunluğu, incik uzunluğu ve çapı, refah özellikleri (ayak tabanı dermatiti (FPD), diz yanığı (DY), göğüs yanığı (GY), parmak çarpıklığı (PÇ)), valgus-varus deformasyonu (VVD) ve yürüyüş skoru (YS) özellikleri incelenmiştir.

Bulgular: Kesim yaşında A1, A2 ve A3 hatları diğer genotiplere kıyasla daha düşük CA'ya sahipken, ROSS-308 en ağır olmuştur. Refah göstergeleri genotip ve cinsiyetten önemli düzeyde etkilenmiş, erkekler dişilere kıyasla daha yüksek DY, GY ve PÇ'ye sahip olmuştur. VVD yaşla birlikte artmış, 42. günde ROSS-308 en yüksek angulasyonu göstermiştir.

Yürüyüş skorları A1 hattında 28. günde, A3 hattında ise 35 ve 42 günlerde daha iyi bulunmuştur.

Sonuç: ANADOLU-T baba hatları ve hibritler 21. günden itibaren ana hatlarından daha yüksek CA'ya sahip olmuştur. Genel olarak baba hatları ve hibritlerde daha kötü refah ve yürüme kabiliyeti gözlenmiştir. Diğer yandan, ANADOLU-T baba hatlarında VVD ve yürüyüş skoru CA ile ilişkili olmadığından seleksiyon kriteri olarak kullanılabilir.

Anahtar Kelime: Canlı ağırlık, performans, valgus, varus, ayak tabanı dermatiti, yürüme yeteneği

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INTRODUCTION

Genetic selection of broilers has led to significant improvements in production traits such as growth rate and feed efficiency over the last few decades. However, intensive selection focused on growth performance has resulted on several welfare issues, particularly related to leg health and general welfare (Knowles et al. 2008; Kapell et al. 2012; Hartcher and Lum, 2019). Leg disorders such as tibial dyschondroplasia, valgus-varus deformity (VVD), foot-pad dermatitis and hock burn are common in modern broilers and the presence of genetic variation for these traits suggests that there is a genetic basis for these defects (Sanotra et al. 2001; Knowles et al. 2008; Akbas et al. 2009; Kapell et al. 2012; González-Cerón et al. 2015). Studies have shown that the associations between growth traits and leg health are commonly negative, suggesting that improvement in growth performance often occurs at the expense of leg health (Kapell et al. 2012; González-Cerón et al. 2015; Averós and Estevez, 2018). Faster growing broilers were more prone to valgus and tibial dyschondroplasia compared to their slower growing counterparts (Shim et al. 2012). Risk factors for poor locomotor activity include bird age, genotype, feeding practices, lighting regimes and stocking density (Knowles et al. 2008). Although genetic improvement and management practices can potentially reduce leg problems, implementation of these changes can reduce growth rates and production (Knowles et al. 2008; González-Cerón et al. 2015). These findings emphasize the need for a balanced approach to address leg health issues in broiler production.

Fast-growing broilers generally exhibit less locomotor activity, spend more time sitting and less time engaging in behaviors such as walking and standing. This inactivity is a major contributing factor to leg disorders and poor overall physical condition. Studies have shown that slower growing broilers tend to be more active and exhibit fewer leg problems, suggesting that reducing growth rates may improve welfare outcomes (Bessei, 2006; Dixon, 2020; Dawson et al. 2021).

The VVD may occur unilaterally or bilaterally and valgus cases are more common than varus in broilers (Leterrier and Nys, 1992; Shim et al. 2012; González-Cerón et al. 2015). The incidence of VVD varies significantly across studies, ranging from 1.75% to 66.0% (Leterrier and Nys, 1992; Shim et al. 2012, Paz et al. 2013, González-Cerón et al. 2015; Guo et al. 2019; Güz et al. 2019). Possible reasons for differences in the incidence of VVD between studies may be related to differences in growth rate, genetics, production system, lighting program, age, litter quality and diet composition (Bradshaw et al. 2002), but another important factor is the method of measuring VVD (van den Brand et al. 2022).

Walking ability in broiler chickens is closely linked to hock burns and footpad dermatitis. These are forms of contact dermatitis, often caused by poor litter quality, which can also lead to breast burns (de Jong et al., 2016; Granquist et al., 2019). Contact dermatitis are important welfare issues as they affect the overall health and productivity of poultry by causing pain and discomfort. The prevalence of these problems can vary depending on factors such as litter quality, stocking density and genetic background, with some genotypes being more susceptible to these conditions (Haslam et al., 2007; Saraiva et al., 2016; Kaukonen et al., 2016). Effective management practices, including maintaining optimum litter conditions and monitoring broiler health, are essential to reduce these welfare problems and improve broiler quality of life.

In fast-growing broiler chickens, lower activity levels are observed from the first week onwards, with a particularly sharp decline in walking distances by the third week (Reiter and Bessei, 2009). In this study, it was aimed to determine the changes in growth during 42 days, foot-leg problems and general welfare characteristics starting from the 4th week in relation to different growth levels in both pure lines and hybrid genotypes.

MATERIAL and METHODS

This study was carried out at Ondokuz Mayıs University, Faculty of Agriculture, Livestock Research and Application Farm. The broiler house was 9x40 m in size, environmentally controlled and consisted of 28 pens of 1.8x2.2 m in size. Seven different genotypes were used in the experiment. Five of them were ANADOLU-T pure lines (3 dam lines: A1 (58.3 g/d), A2 (57.8 g/d), A3 (56.5 g/d); 2 sire lines: B1 (67.1 g/d), B2 (66.9 g/d)), ANADOLU-T hybrid [(B2xB1)♂x(A2xA1)♀] (65.3 g/d) and ROSS-308 hybrid (72.6 g/d). The ANADOLU-T pure lines used in the study were obtained as the 8th generation (in 2022) progeny of elite flocks in Eskişehir Transitional Zone Agricultural Research Institute.

A total of 112 mixed sex chicks at day-old age of each genotype were tagged with a neck band and randomly allocated to 4 different pens (7 birds/m2). Each individual bird was considered as a replicate. In the pens, 8-10 cm wood shavings were used as litter and a feeder and 5 nipples were provided for each pen. All birds were subjected to standard broiler rearing procedure. The temperature was 33-34 oC at the day-old age and this was gradually reduced to 21oC until 4 weeks of age and maintained until 42 days. The lighting schedule was 24 hours for the first 3 days and gradually decreased by 1 hour each week to 18 hours at 6 weeks of age. All birds had free access to water and feed. The feeds were purchased from a commercial feed mill. All birds were fed with chick starter crumbs (3,000 kcal/kg ME; 23.0% CP; 1.35% dig. Lys; 1.00% dig. Met; 1.00% Ca; 0.50% aP for the first 10 days, and chick feed between 11 and 28 days (3,100 kcal/kg ME; 22.0% CP; 1.20% dig. Lys; 0.45% dig. Met; 0.95% Ca; 0.50% aP) and chicken feed between 29 and 35 days (3,100 kcal/kg ME; 21.0% CP; 1.10% dig. Lys; 0.40% dig. Met; 0.80% Ca; 0.45% aP) and finisher diet between 36 and 42 days (3,100 kcal/kg ME; 78.0% CP; 1.00% dig. Lys; 0.40% dig. Met; 0.80% Ca; 0.60% aP). All birds were vaccinated against New Castle-Infectious bronchitis and Gumboro diseases via drinking water at 10 and 16 days of the experiment, respectively.

Data collection. All chicks were individually weighed at day-old (using a 0.1 g scale, Shimadzu Corporation, Tokyo, Japan) and each subsequent week (using a 1 g scale, Jadever, JWQ-6 Digital Precision Scale, Northspring BizHub Industrial Building, Singapore). Shank length and diameter were measured at 28 and 42 days of age and chicken length was measured at 42 days. As described by Pishnamazi et al. (2008) and Galal et al. (2007), shank length (mm) was measured from the bottom of the foot pad to the top of the hock joint and shank diameter (mm) was measured from the middle part of the metatarsus with a digital caliper. Chicken length (cm) was measured with a tape meter as the length of the chicken from the tip of the beak to the tip of the middle finger by stretching the chicken lengthwise on a table.

For valgus-varus deformity (VVD) and gait score (GS), 56 birds of each genotype were used at 28, 35 and 42 days. The angulation (in degrees) of the tibiotarsal-tarsometatarsal joint was measured separately in both legs using a digital goniometer to determine VVD. One end of the goniometer was placed parallel along the tibio-tarsus, while the other end was placed parallel along the tarso-metatarsus (van den Brand et al. 2022). All measurements were performed by a single person. Illustrations of healthy leg and valgus and varus deformities are shown in Figure 1.

Healthy legs **Valgus deformity** **Varus deformity**

Figure 1. Healthy leg, valgus and varus deformities in broilers
Şekil 1. Broylerlerde sağlıklı bacak, valgus ve varus deformiteleri

Gait scoring was carried out for each individual bird according to a 5-point scoring system as described by Kestin et al. (1992) (0: normal gait with no abnormality, 1: slightly abnormal gait that is difficult to define, 2: obvious and identifiable lameness that does not hinder the movement of the bird, 3: obvious lameness that affects the speed and maneuverability of the birds, 4: severe lameness that makes the bird reluctant to walk, 5: complete lameness in one or both legs, unable to walk).

Welfare traits were evaluated by the same observer in 56 birds of each genotype at 42 days of age according to a 4-point scoring system. Foot pad dermatitis (FPD), hock burn (HB) and breast burn (BB) were scored with the score 0 indicating no lesions and discoloration, 1 indicating mild lesions and discoloration, 2 indicating moderate lesions and discoloration, 3 indicating severe lesions and discoloration, and 4 indicating excessive burns and discoloration. For finger crookedness (FC), a score of 0 indicated that all fingers were intact, while scores of 1, 2, 3 and 4 indicated crookedness of 1-2, 3-4, 5-6 and 7-8 fingers, respectively (Sarıca et al. 2022; Erensoy and Sarıca, 2023).

The litter moisture content was determined by collecting samples from 3 different places in each pen at 42 days. From the homogeneous mixture of these samples, 100 g of the content was dried at 60°C for 48 hours and the moisture content (%) was calculated (Erensoy and Sarıca, 2023).

Statistical analysis. The study was designed according to a random plots experimental design. All statistical analyses were performed using SPSS 21.0 software (SPSS Inc., Chicago, IL). Each individual bird was used as the experimental unit. Weekly BW, chicken length, metatarsus traits and valgus-varus angulations were analyzed using General Linear Model (GLM) by including the main effects of genotype and sex in the model for each week. Litter moisture was also tested according to the one-way ANOVA procedure. Welfare traits (FPD, HB, BB, FC) and GS were analyzed in the Generalized Linear Model using the multinomial logit-link function with binomial distribution in a model including genotype and sex main effects. In addition, in the analysis of GS, BW for each week was included as a covariate in the model. When the significance value of the effects was P≤0.05, the means were compared using Tukey's HSD test. Pearson correlation test was used for the relationships between continuous characteristics and Spearman Rank correlation test for discrete or scored data. For the ease of discussion, the following identifiers were used to describe the relative strength of the correlations among observed traits: very weak (r < 0.20), weak (r = 0.20-0.39), moderate (r = 0.40-0.59), strong (r = 0.60-0.79), and very strong (r = 0.80-0.99) (Ith, 2014).

RESULTS

The weekly BW of broiler chicks from day 0 to day 42 are given in Table 1. At day-old age, A3 line and ROSS-308 chicks were the heaviest (P<0.001), however ANADOLU-T and B2 line were heavier at 7 and 14 days (P<0.01). The A1, A2 and A3 dam lines had lighter BW than the other genotypes from day 21 onwards (P<0.001). The ROSS-308 hybrid was also heavier than the others at 35 and 42 days of age (P<0.001). Male broilers were heavier than females in all weeks except day-old age (P<0.01).

Table 1. Weekly body weight of broilers (g)
Tablo 1. Piliçlerin haftalık canlı ağırlığı (g)

Genotype	**Sex**	**0-d**	**7-d**	**14-d**	**21-d**	**28-d**	**35-d**	**42-d**
A1	F	41.8	139.6	375.3	745.4	1199.6	1693.7	2197.9
	M	41.8	144.9	405.4	835.6	1402.3	2058.3	2738.7
A2	F	37.1	128.8	347.5	701.0	1166.0	1686.0	2205.2
	M	37.9	131.0	366.8	745.7	1284.8	1941.1	2642.1
A3	F	43.3	123.5	332.6	671.8	1118.3	1596.5	2084.3
	M	42.7	132.2	364.4	762.4	1318.7	1949.5	2609.1
B1	F	40.8	145.1	403.0	814.0	1352.5	1963.8	2577.6
	M	41.1	146.1	416.4	893.0	1545.9	2362.6	3140.1
B2	F	42.3	155.1	417.0	849.1	1396.4	2022.6	2589.0
	M	42.4	154.1	432.5	891.6	1568.3	2307.7	3067.7
ANADOLU-T	F	40.9	155.4	418.5	828.9	1365.8	1935.0	2499.3
	M	41.3	159.9	444.0	922.9	1575.8	2316.8	3029.6
ROSS-308	F	42.1	125.8	363.1	787.1	1366.2	2077.5	2760.8
	M	43.6	140.7	433.9	927.3	1614.0	2524.1	3411.1
SEM		0.119	0.533	1.515	2.766	5.074	7.506	10.239
Effects								
Genotype		*<0.001*	*0.006*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
A1		41.8^{abc}	142.1^{b}	389.2^{c}	787.1^{b}	1293.3^{b}	1862.3^{c}	2448.0^{c}
A2		37.5^{d}	129.9^{c}	357.2^{d}	723.6^{c}	1226.1^{c}	1815.0^{c}	2426.1^{c}
A3		43.0^{a}	128.3^{c}	350.1^{d}	721.6^{c}	1228.4^{c}	1790.5^{c}	2372.7^{c}
B1		40.9^{c}	145.5^{b}	408.7^{bc}	847.8^{a}	1435.4^{a}	2134.7^{b}	2818.7^{b}
B2		42.3^{ab}	154.6^{a}	424.1^{ab}	868.6^{a}	1475.3^{a}	2153.4^{b}	2808.7^{b}
ANADOLU-T		41.1^{bc}	157.4^{a}	430.2^{a}	872.0^{a}	1462.2^{a}	2110.2^{b}	2742.6^{b}
ROSS-308		42.7^{a}	132.5^{c}	394.6^{c}	849.6^{a}	1476.7^{a}	2276.5^{a}	3050.6^{a}
Sex		*0.383*	*0.002*	*0.005*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
Female		41.2	139.2	380.0	772.7	1283.8	1859.4	2424.4
Male		41.5	143.3	406.4	847.8	1461.6	2190.1	2925.5

F: Female, M: Male.

a–c: The differences between the means shown with different letters in the same column differ significantly according to Tukey's test (P < 0.05).

The length of broilers, shank length and diameter are given in Table 2. At 42 days, broiler length was not different among genotypes, but male broilers were longer than females (P<0.001). The shank length and diameter were significantly different among genotypes at 28 and 42 days (P<0.001). The B1 and ROSS-308 genotypes had the longest shank at 28 days, while ANADOLU-T and ROSS-308 had the longest shank at 42 days (P<0.001). ROSS-308 genotype had thicker shank at 28 and 42 days (P<0.001).

Table 2. Chicken length, shank length and diameter

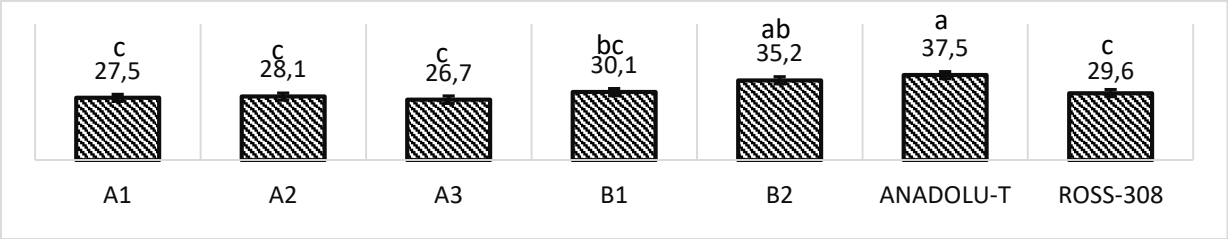
Tablo 2. Tavuk boyu, incik uzunluğu ve çapı

Genotype	Sex	Chicken length at 42-d (cm)	Shank length (mm)		Shank diameter (mm)	
			28-d	42-d	28-d	42-d
A1	F	57.1	66.0	76.9	9.9	11.6
	M	60.1	69.7	81.9	10.8	12.9
A2	F	58.0	65.6	75.5	9.5	10.7
	M	60.7	68.3	80.7	10.3	12.1
A3	F	57.1	63.5	76.2	10.1	11.1
	M	60.8	66.8	80.8	11.4	12.9
B1	F	53.6	68.5	78.5	10.3	11.3
	M	61.5	72.7	84.2	11.5	13.1
B2	F	58.5	66.1	78.4	10.3	11.1
	M	61.9	70.3	84.9	11.5	12.9
ANADOLU-T	F	54.8	68.3	79.6	10.3	11.3
	M	58.9	72.6	88.4	11.6	12.9
ROSS-308	F	56.3	69.5	80.4	10.9	12.2
	M	61.3	71.2	85.2	11.9	13.7
SEM		0.509	0.204	0.227	0.046	0.039
Effects						
Genotype		*0.677*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
A1		58.5	67.8^{bcd}	79.3^{bc}	10.3^{cd}	12.2^{b}
A2		59.2	66.8^{cd}	78.0^{c}	9.9^{d}	11.4^{c}
A3		59.7	65.8^{d}	79.4^{bc}	11.0^{ab}	12.4^{b}
B1		56.8	70.8^{a}	80.7^{ab}	10.9^{ab}	12.0^{b}
B2		60.1	68.0^{bc}	81.5^{ab}	10.9^{b}	12.0^{b}
ANADOLU-T		56.3	69.9^{ab}	83.0^{a}	10.8^{bc}	11.9^{b}
ROSS-308		59.1	70.4^{a}	83.1^{a}	11.4^{a}	13.1^{a}
Sex		*<0.001*	*0.007*	*<0.001*	*<0.001*	*<0.001*
Female		56.4	66.8	78.0	10.2	11.3
Male		60.8	69.8	83.4	11.3	12.9

F: Female, M: Male.

a–d: The differences between the means shown with different letters in the same column differ significantly according to Tukey's test (P < 0.05).

Welfare characteristics of broiler chickens are given in Table 3. Neither genotype nor sex had a significant effect on FPD, but genotype and sex effects were significant for HB, BB and FC (P<0.001). HB, BB and FC were higher in B2, B1 and ANADOLU-T lines, respectively (P<0.001). Males also had higher HB, BB and FC values than females (P<0.001). Litter moisture content differed significantly among genotypes and the litter of ANADOLU-T hybrids had higher moisture content than the others (P<0.001, Figure 2).



a-c Means shown with different letters in bar columns are significantly different according to Tukey's test (P < 0.05).

Figure 2. Litter moisture content (%)

Şekil 2. Altlık nem içeriği (%)

Table 3. Welfare traits of broilers

Tablo 3. Broylerlerin refah özellikleri

Genotype	Sex	FPD	Hock burn	Breast burn	Finger crookedness
A1	F	0.00	0.54	0.50	0.00
	M	0.00	0.88	0.77	0.00
A2	F	0.00	0.59	0.61	0.00
	M	0.00	1.00	1.07	0.00
A3	F	0.00	0.78	0.61	0.00
	M	0.00	1.06	0.80	0.00
B1	F	0.00	1.21	0.96	0.00
	M	0.00	1.85	1.12	0.00
B2	F	0.07	1.15	0.78	0.04
	M	0.13	1.90	0.95	0.21
ANADOLU-T	F	0.09	0.94	0.63	0.04
	M	0.03	1.56	0.72	0.28
ROSS-308	F	0.00	0.84	0.80	0.00
	M	0.00	1.10	0.88	0.07
SEM		0.006	0.024	0.025	0.009
Effects					
Genotype		*0.994*	*<0,001*	*<0,001*	*<0,001*
A1		0.00	0.70c	0.62b	0.00c
A2		0.00	0.80c	0.84ab	0.00c
A3		0.00	0.93c	0.71b	0.00c
B1		0.00	1.48ab	1.03a	0.00c
B2		0.10	1.49a	0.86ab	0.12ab
ANADOLU-T		0.06	1.22b	0.67b	0.15a
ROSS-308		0.00	0.96c	0.84ab	0.03bc
Sex		*0,984*	*<0,001*	*<0,001*	*<0,001*
Female		0.02	0.86	0.70	0.01
Male		0.02	1.30	0.89	0.08

F: Female, M: Male.

a–c: The differences between the means shown with different letters in the same column differ significantly according to Tukey's test (P < 0.05).

Valgus-varus angulation of the tibiotarsal-tarsometatarsal joint in broilers at different ages is given in Table 4. Valgus-varus angulation at 28 days was higher in ANADOLU-T hybrid (41.3o) and A3 line (41.1o) (P<0.001). Sum of the angulation at 35 days was similar among genotypes. ROSS-308 hybrid had the highest angulation at 42 days (56.6o) (P<0.001). Male broilers had more valgus-varus angulation for both leg than female at 28, 35 and 42 day (P<0.001). Valgus-vars angulation in broilers increased with advancing age (Figure 3).

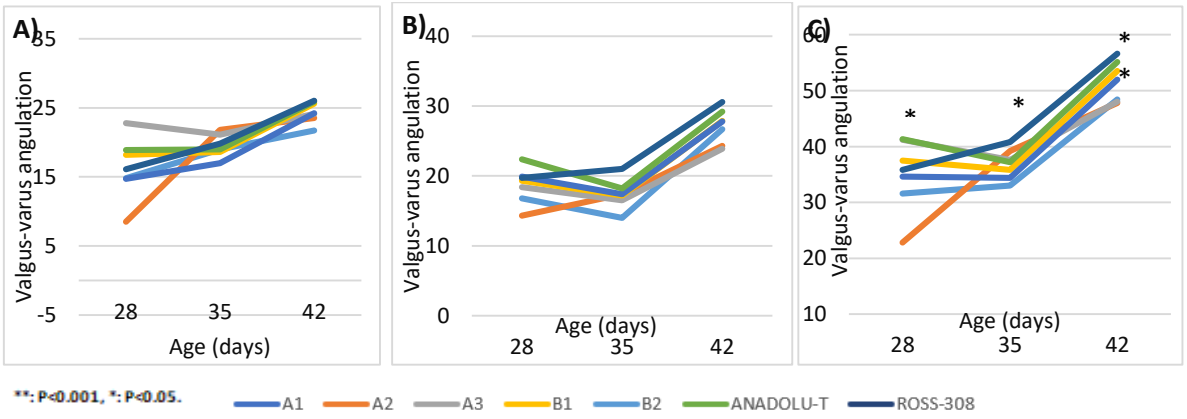


Figure 3. Changes in the valgus-varus angulation (in degrees) in left (A), right (B) and sum of both leg (C) in broilers with advancing age

Şekil 3. Broylerlerde yaş ilerledikçe sol (A), sağ (B) ve her iki bacağın toplamında (C) valgus-varus açılanmasının (derece cinsinden) değişimi

Table 4. Sum of the valgus-varus angulation (in degrees) of the tibiotarsal-tarsometatarsal joint in broilers at different ages

Tablo 4. Farklı yaşlardaki piliçlerde tibiotarsal-tarsometatarsal eklemin valgus-varus açılanmasının (derece cinsinden) toplamı

Genotype	**Sex**	**28-d**	**35-d**	**42-d**
A1	F	26.3	26.3	46.3
	M	37.3	40.3	50.6
A2	F	23.1	35.8	46.9
	M	22.4	43.1	48.8
A3	F	38.7	32.6	45.2
	M	42.2	39.8	49.2
B1	F	37.0	35.0	53.6
	M	38.2	36.9	53.5
B2	F	33.1	32.6	49.0
	M	36.3	36.5	55.2
ANADOLU-T	F	35.8	35.6	52.3
	M	50.5	40.0	59.6
ROSS-308	F	31.3	34.7	49.6
	M	39.5	45.3	62.2
SEM		0.722	0.719	0.678
Effects				
Genotype		*<0.001*	*0.095*	*<0.001*
A1		31.5^{b}	33.0	48.4^{b}
A2		22.8^{c}	39.2	47.8^{b}
A3		41.1^{a}	37.6	48.0^{b}
B1		37.5^{ab}	35.8	53.6^{ab}
B2		34.6^{ab}	34.4	52.0^{ab}
ANADOLU-T		41.3^{a}	37.3	55.1^{ab}
ROSS-308		35.9^{ab}	40.7	56.6^{a}
Sex		*<0.001*	*<0.001*	*<0.001*
Female		31.8	33.2	49.2
Male		37.9	40.5	53.9

F: Female, M: Male.

a–c: The differences between the means shown with different letters in the same column differ significantly according to Tukey's test (P < 0.05).

The gait scores of broiler chickens are given in Table 5. The A1 line at 28 days and A3 line at 35 and 42 days showed the better walking ability than other genotypes (P<0.001). Male broilers had lower walking ability than females at all ages.

The correlations between VVD deformity and body and production characteristics of broiler chickens at different ages are given in Table 6. There was a positive correlation between VVD and BW ranging from 0.43-0.57 at 28 and 35 days and a correlation with gait score at 0.30, 0.66 and 0.32 at 28, 35 and 42 days, respectively. The VDD at 35 days was positively correlated with BW (0.39) and GS (0.43) in the A2 line. In the A3 line, there was a significant but weak correlation between VVD and GS at 35 days. There were no significant correlations between VVD and other traits in line B1. In B2 line, VVD and shank length were correlated at 0.38. In ANADOLU-T hybrid, VVD was weakly positively correlated with BW and chicken length (0.34 to 0.39) and moderately positively correlated with shank diameter (0.46). ROSS-308 was moderate to weak associated with BW at 35 and 42 days and shank length at 28 and 42 days.

Table 5. Gait scores of broilers at different ages

Tablo 5. Farklı yaşlardaki piliçlerin yürüyüş puanları

Genotype	Sex	28-d	35-d	42-d
A1	F	1.50	2.08	2.54
	M	1.59	2.50	2.96
A2	F	1.84	2.08	2.65
	M	2.67	2.81	2.76
A3	F	1.31	1.46	2.15
	M	2.23	2.30	2.66
B1	F	1.96	2.77	2.91
	M	2.19	2.88	3.15
B2	F	1.63	2.54	2.91
	M	2.57	3.10	3.19
ANADOLU-T	F	2.11	2.38	3.00
	M	2.31	2.53	3.13
ROSS-308	F	1.75	2.58	2.85
	M	2.12	2.88	3.04
SEM		0.043	0.036	0.034
Effects				
Genotype		*<0.001*	*<0.001*	*<0.001*
A1		1.54^{b}	2.28^{cd}	2.74^{ab}
A2		2.22^{a}	2.42^{bcd}	2.71^{ab}
A3		1.95^{ab}	2.05^{d}	2.50^{b}
B1		2.05^{a}	2.82^{a}	3.00^{a}
B2		2.07^{a}	2.80^{ab}	3.05^{a}
ANADOLU-T		2.19^{a}	2.44^{abc}	3.05^{a}
ROSS-308		1.96^{ab}	2.75^{ab}	2.96^{a}
Sex		*0.016*	*0.002*	*0.001*
Female		1.76	2.31	2.75
Male		2.23	2.69	2.95

Table 6. Relotionships between foot-leg health, welfare and body traits in broilers

Tablo 6. Etlik piliçlerde ayak-bacak sağlığı, refahı ve vücut özellikleri arasındaki ilişkiler

Genotypes	Traits	Valgus-varus deformity		
		28-d	35-d	42-d
A1	Body weight	0.432*	0.574*	0.282
	Chicken length			0.196
	Shank length	0.313*		0.033
	Shank diameter	0.255		0.270
	Gait score	0.302*	0.659*	0.317*
A2	Body weight	-0.112	0.391*	0.079
	Chicken length			0.114
	Shank length	-0.053		0.089
	Shank diameter	-0.235		-0.031
	Gait score	-0.097	0.430*	0.219
A3	Body weight	-0.049	0.297	0.181
	Chicken length			0.005
	Shank length	-0.103		0.143
	Shank diameter	0.074		0.135
	Gait score	-0.018	0.326*	0.056
B1	Body weight	0.135	0.252	0.087
	Chicken length			-0.122
	Shank length	0.385		0.006
	Shank diameter	0.303		0.164
	Gait score	-0.042	0.097	0.029
B2	Body weight	-0.007	-0.008	0.140
	Chicken length			0.210
	Shank length	-0.104		0.381*
	Shank diameter	0.252		0.278
	Gait score	0.190	0.196	0.102
ANADOLU-T	Body weight	0.386*	-0.119	0.185
	Chicken length			0.342*
	Shank length	0.328		0.134
	Shank diameter	0.464*		0.106
	Gait score	0.204	0.256	0.277
ROSS-308	Body weight	0.283	0.301*	0.401*
	Chicken length			0.207
	Shank length	0.456*		0.316*
	Shank diameter	0.198		0.420*
	Gait score	0.132	0.125	0.080

**: P<0.001, *: P<0.05.

DISCUSSION

Genetic selection in broilers has primarily focussed on improving production traits such as growth rate and feed efficiency. This intensive selection has resulted in significant improvements in body weight and overall productivity. When comparing the 1991 and 1957 broiler lines, a 420% increase in body weight was observed at 42 days of age and 85-90% of this improvement was attributed to genetic selection (Zuidhof et al. 2014). However, this fast growth has led to some unfavourable effects, especially in terms of foot-leg health and overall welfare of broilers (Bessei, 2006).

The breeding of fast growing broiler chickens started in Turkey in 2015 and the selection of 5 pure lines is currently in progress at Eskişehir Transitional Zone Agricultural Research Institute. While a balanced selection has been implemented for reproductive traits and BW in the dam lines (A1, A2, A3 lines), the sire lines (B1 and B2 lines) have focused on body weight and feed efficiency (Erensoy et al. 2020; Sarıca et al. 2021a; Erensoy and Sarıca, 2022; Erensoy and Sarıca, 2023). Crossbreeding studies in ANADOLU-T pure lines showed the possibility of over 10% heterosis for growth traits in their 4-way hybrids (Erensoy and Sarıca, 2023). In previous studies, BW at 42 days for A1, A2, A3, B1 and B2 lines, ANADOLU-T and ROSS-308 hybrids were 2557.8-2624.4 g, 2474.6-2538.6 g, 2390.7-2444.5 g, 2795.1-2828.8 g, 2724.1-2753.6 g, 2777.3 g and 3083.2 g, respectively (Sarıca et al. 2021b; Erensoy and Sarıca, 2023). In our study, 42-days BW values were consistent with the previous studies. The differences in BW between dam and sire lines are due to line-specific selection strategies (Erensoy and Sarıca, 2023). Selection for BW and feed efficiency in sire lines made them superior to dam lines. On the other hand, the fact that ROSS-308 is superior to both ANADOLU-T hybrid and pure lines in terms of BW is due to its very effective selection history for fast growth over long generations (Siegel, 2014; Zuidhof et al. 2014; Tallentire et al. 2018; Hartcher and Lum, 2020).

The main objective in the selection of broilers for BW and feed efficiency is to enhance the amount of breast meat (Zuidhof et al., 2014). The chicken lengths at 42 days were not different among the genotypes, indicating that the increase in the amount of breast meat causes enlargement in the breast area rather than the length of the bird. Erensoy et al. (2019) reported that ANADOLU-T pure sire lines had longer and thicker shank than the dam lines, but two-way hybrids were superior to both dam and sire lines with respect to shank characteristics. In our study, ROSS-308 and ANADOLU-T hybrids and sire lines had longer and thicker shank lengths than the dam lines. Since it is known that there are strong phenotypic and genetic associations between 6-week BW and shank length and diameter in broiler chickens (Singh and Jilani, 2008), this was probably related to more resilient shank traits developing in parallel with higher BW. Shank length and girth are two important traits for skeletal development in broilers (Gao et al. 2010; Guo et al. 2019), so they may be directly or indirectly related to VVD (Guo et al. 2022). Although shank length and diameter were lower in the A2 line, this was not directly related to the change in VVD at 28 and 42 days. Furthermore, in all genotypes except ROSS-308 hybrid, shank traits at 28 and 42 days were also not strongly correlated with VVD and were often negligible. This indicates that the shank traits of ANADOLU-T pure lines and their hybrids develop in harmony with BW without any increase in VVD with advancing age.

It is well known that the development of contact dermatitis is linked to genetics (Haslam et al. 2007; Kapell et al. 2012), body weight (Santos et al. 2022; Erensoy and Sarıca, 2023) and litter moisture level (over 30%) (Erensoy et al. 2021; Sarıca et al. 2022). In our study, neither genetic differences nor sex caused any difference on FPD. However, HB and BB were affected by both genetic background and sex. The higher levels of HB and BB in ANADOLU-T and sire lines (B1 and B2) were probably due to the fact that these birds were reared in pens with higher moisture content. Although all pens had the same litter characteristics (litter material, thickness and management), the reasons for the differences in moisture levels between the pens were not clear. On the other hand, as reported by Erensoy and Sarıca (2023), weak to moderate relationships between BW, HB and BB for ANADOLU-T pure lines and hybrids and ROSS-308 may also have contributed to this situation.

In broiler chickens, fast growth significantly affects the incidence and severity of VVD deformity, which is more common in fast-growing broilers than in slow-growing ones (Shim et al. 2012). The VVD was higher in male birds than in females, in agreement with Leterrier and Nys (1992). In our study, although VV angulation did not evolve in parallel with the growth rate of the genotypes at 28 days, it was higher in sire lines and hybrids than in dam lines due to heavier BW at 42 days. However, BW contributed moderately to VVD development only in A1 and ANADOLU-T hybrid at 28 days and ROSS-308 at 42 days, and the variation in VV angulation in other genotypes was independent of BW. The B1 and B2 lines have been selected for heavier BW, breast yield and feed efficiency in each generation (Sarıca et al. 2016; Erensoy et al. 2020; Erensoy and Sarıca, 2022; Erensoy and Sarıca, 2023). In these lines, the BW was not phenotypically associated with VVD at any age, which means that an increase in BW would not be accompanied by VVD and favor the sustainability of body robustness in the breeding process. We may also suggest that ANADOLU-T hybrids produced by 4-way crossing from pure lines would allow the

production of more robust birds despite increased BW, as BW is not associated with VVD at 35 and 42 days. However, these phenotypic relationships are also influenced by the environment. As a point of emphasis, previous studies have shown that leg problems are heritable. However, while genetic correlations between leg problems and growth are contradictory, the magnitude of the association is very low and ranges from slightly negative to slightly positive (Le Bihan-Duval et al. 1997; Kapell et al. 2012; Rekaya et al. 2013). In this respect, we underline the importance of exploring the genetic determinism of BW and foot-leg traits in ANADOLU-T pure lines. This would allow the monitoring of the genetic evolution trend and the degree of correlation with other traits, and contribute to the success of selection.

GS is a trait that indicates the overall fitness of the overall locomotion system and walking ability of the bird (Kapell et al. 2017), and the phenotypic expression of this trait may be the result of the complex effect of BW, VVD, FPD, HB and shank traits. Walking ability deteriorated with advancing age in all genotypes, and males were worse than females at all ages, in line with Sørensen et al. (2000) and Rasmussen et al. (2022). The higher GS at day 28 in the A2 line implies that other factors than BW are involved in the phenotypic expression of GS at earlier ages. However, the effect of increased BW on GS with advancing age seems to have become more pronounced (van der Eijk et al. 2023). This is because sire lines and hybrids that were heavier at 42 days also had higher GS. At 35 days of age, the high (r=0.66), medium (r=0.430) and low (r=0.326) correlations between GS and VVD in lines A1, A2 and A3, respectively, indicate that improvement in the phenotype of GS would contribute to reduce VV angulation. However, there was no significant correlation between VVD and GS at any age in sire lines and hybrids.

CONCLUSIONS

This study revealed the age-related changes in growth, welfare and leg soundness in ANADOLU-T pure lines and hybrid and ROSS-308 genotype and the correlations between some traits. As expected, sire lines and hybrids had higher body weight than dam lines from 21 days onwards. Overall poorer welfare and impaired walking ability were observed in sire lines and hybrids, probably due to their increased BW. On the other hand, the leg soundness traits, valgus-varus deformity and gait score in ANADOLU-T sire lines could be used as selection criteria since they were not associated with BW. However, this could be confirmed by further studies to identify the genetic determinism of the traits and the correlations between them in pure sire lines.

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