Turkish Journal of Agriculture - Food Science and Technology, 14(7): 2010-2024, 2026
DOI: https://doi.org/10.24925/turjaf.v14i7.2010-2024.8974

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

# Carcass Characteristics and Economic Performance of Reciprocal Cross Hybrids between Anadolu-T and Commercial Broiler Parent Stocks

**Beyhan Yeter[1,a,*], Hasan Eleroğlu[2,b]**

[1]*Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Animal Science, 46050, Kahramanmaraş, Türkiye.*
[2]*Sivas Cumhuriyet University, Sivas Technical Sciences Vocational School, Department of Plant and Animal Production, 58140, Sivas, Türkiye.*
[*]*Corresponding author*

ARTICLE INFO

*Research Article*

Received : 10.04.2026
Accepted : 17.07.2026

*Keywords:*
Anadolu-T
Commercial broilers
Carcass Characteristics
Economic analysis
Reciprocal Cross

ABSTRACT

In the present study, Anadolu-T chickens and reciprocal cross hybrids produced from Anadolu-T and Commercial Broiler parent stocks were evaluated for carcass characteristics, meat quality, and economic performance. Four genotypes (AA, AC, CA, and CC) were tested using 384 chicks (4 genotypes × 4 replicates × 24 chicks). Following a 12-hour feed withdrawal, 96 birds were slaughtered for carcass and meat quality analyses. Genotype and sex significantly affected absolute carcass traits. Commercial Broiler genotypes (CC and AC) had the highest hot and cold carcass weights and cut-up part weights, whereas AA birds had the lowest values. Males consistently exhibited greater carcass and cut-up part weights than females. In contrast, carcass yield percentages were largely unaffected by genotype, with only breast and thigh proportions showing significant variation. Fat deposition differed according to genotype and sex, particularly for back fat weight and abdominal fat proportion. Meat quality analysis indicated that water-holding capacity and pH were primarily influenced by genotype and carcass region, while sex had limited effects. Meat color traits, including hue angle, chroma, and total color difference, were mainly affected by carcass region and sex, with genotype exerting only minor influence. Economic evaluation showed that although feed costs per bird were similar among genotypes, total production cost, revenue, net profit, and profitability differed significantly. CC and AC genotypes generated the highest revenues and net profits, while AC achieved the lowest production cost per kilogram of live weight and the greatest overall profitability. Overall, genetic background and sex strongly influenced carcass weight, fat deposition, and selected meat quality traits, whereas proportional carcass yields remained relatively stable. Reciprocal crossbreeding, particularly the AC and CC genotypes, improved economic performance while maintaining desirable carcass and meat quality characteristics. These findings demonstrate the potential of reciprocal crossing strategies to enhance productivity, carcass composition, and profitability in commercial broiler production and provide valuable guidance for parental line selection and hybrid breeding programs.

[a] byeter@gmail.com https://orcid.org/0000-0002-1741-4635 | [b] eleroglu@cumhuriyet.edu.tr https://orcid.org/0000-0002-1032-9833

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

## Introduction

Since the mid-20th century, meat-type (broiler) chickens have undergone intensive genetic selection targeting early growth rate, feed conversion efficiency, and body composition, complemented by management practices aimed at optimizing production (Tallentire et al., 2016; Muth & Zarate, 2017; Hartcher & Lum, 2020). These breeding programs have profoundly transformed broiler production, resulting in accelerated growth, increased meat yield, reduced slaughter age, and improved feed and energy efficiency. Importantly, the persistence of additive genetic variation in modern broiler populations ensures continued responsiveness to selection, providing insights applicable to other agricultural animal species.

Hybrid breeding strategies aim to exploit heterosis by controlled crossing of genetically distinct parental lines. $F_1$ offspring often exhibit superior growth performance, carcass traits, and viability compared with their pure-line parents (Türkoğlu & Sarıca, 2018; Paril et al., 2024). These programs emphasize improving general combining ability within pure lines and evaluating specific combining ability across multiple crossbreeding schemes, facilitating the identification of optimal parental combinations for efficient hybrid production (van Grevenhof & Van der Werf, 2015; Calus et al., 2019; Peters et al., 2026).

In commercial broiler breeding, rapid growth remains a key selection objective, and males from both dam and sire lines are preferentially selected based on elevated body weight (BW), which exhibits moderate heritability (0.29–0.40) and positively correlates with progeny performance (Leeson & Summers, 2010; Chu et al., 2020; Sarıca et al., 2021; Uçar et

al., 2025). Long-term selection has significantly increased growth rate and final live weight in modern broilers compared to historical strains (Havenstein, Ferket, & Qureshi, 2003), while substantial genetic variation for BW persists, allowing continued selection response.

Although much research has focused on growth performance and physiological traits in poultry, economic considerations remain essential. The profitability of crossbreeding strategies is determined by factors such as feed efficiency, production costs, and market prices. Assessing these parameters provides producers and stakeholders with a comprehensive understanding of the potential advantages and limitations of implementing crossbreeding programs in commercial broiler production (Karaman et al., 2023; Dzungwe et al., 2024; Vanlalhmangaihsanga et al., 2025; Adaszyńska-Skwirzyńska et al., 2025).

Within this context, the present study aims to evaluate the carcass characteristics and economic performance of reciprocal cross hybrids between Anatolian-T and Commercial Broiler parent stocks. Specifically, the study investigates how different parental combinations affect growth, carcass yield, meat quality, and cost-efficiency, providing insights for optimizing hybrid breeding strategies in commercial broiler production.

## Materials and Methods

### *Research Location and Animal Material*

The Anadolu-T genotype used in this study was developed within the scope of the National Broiler Breeding Project coordinated by the General Directorate of Agricultural Research and Policies (TAGEM) and conducted at the Hamidiye Poultry Research Center (Geçit Kuşağı Agricultural Research Institute). The genotype was obtained through controlled crossbreeding and selection based on zootechnical performance traits and was officially introduced in 2017. In the present study, Anadolu-T chickens and reciprocal cross hybrids obtained from Anatolian-T and Commercial Broiler parent stocks were used as experimental material to evaluate and compare carcass characteristics and economic performance (Figure 1).

The study was conducted at the broiler research and development facility of the Animal Production Application and Research Center, of Kahramanmaraş Sütçü İmam University. The animal material consisted of broiler chicks from four distinct genotypes, all sourced from parent stock (PS) flocks of the same age. The crossbreeding combinations of the hybrids used are presented in Table 1.

### *Experimental Design and Housing Conditions*

The experiment comprised four primary treatment groups, each representing a different genotype. Each group included four replicates, with 24 chicks assigned to each replicate pen, totaling 384 chicks (4 genotypes × 4 replicates × 24 chicks). The experiment was conducted using a completely randomized design, in which replicates were randomly assigned to the experimental treatments.

Birds were housed in a fully environmentally controlled closed poultry house measuring 7 m × 19 m. They were placed in pens measuring 2 m × 1.5 m (3 m²), separated by wire mesh partitions. Stocking density was maintained at 8 birds per m² throughout the trial. The floor was covered with pine wood shavings to a depth of 7–8 cm as litter material.

Table 1. The crossbreeding combinations of the hybrids

| Genotype | Sire Line (♂) | Dam Line (♀) |
|---|---|---|
| Genotype 1 (AA) | Anadolu-T PS | Anadolu-T PS |
| Genotype 2 (CC) | Commercial PS | Commercial PS |
| Genotype 3 (AC) | Anadolu-T PS | Commercial PS |
| Genotype 4 (CA) | Commercial PS | Anadolu-T PS |

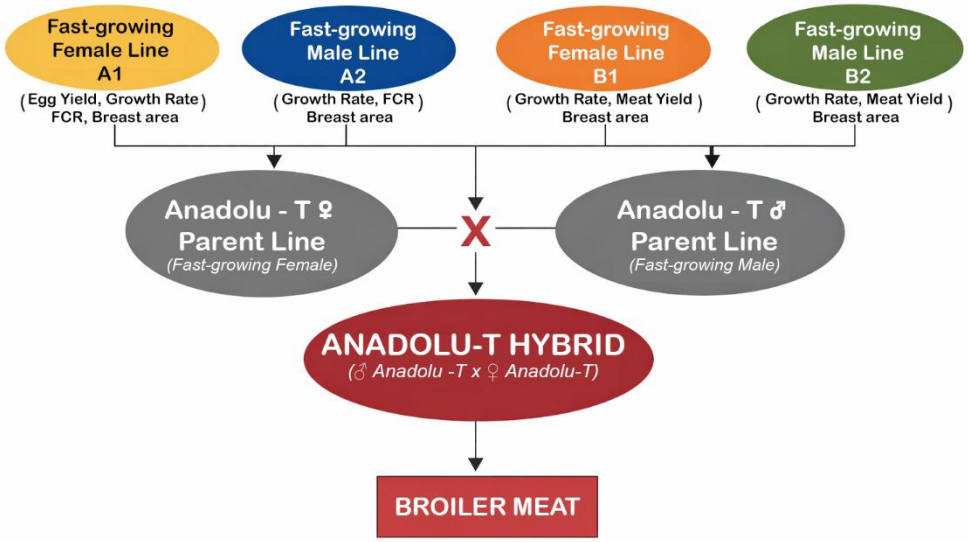



Figure 1. Anadolu – T Development and Production Scheme

Table 2. Feed types and nutrient composition provided to chicks at different ages

| Ingredients | 0-21 days | 22-35 days | 36-84 days |
|---|---|---|---|
| Metabolizable enerji MJ/kg | 12.20 | 12.56 | 13.08 |
| Crude Protein % | 22.00 | 20.50 | 19.50 |

***Environmental Conditions and Housing Management***

The indoor climate was regulated using the following equipment:

- *Heating:* Thermostat-controlled forced-air electric heaters.
- *Ventilation:* Minimum ventilation was provided by one 60-cm exhaust fan and seven air inlets.
- *Cooling:* From day 10 onwards during daytime, and from day 25 onwards during both day and night as needed, cooling was achieved using evaporative cooling pads (total area 6 m²) located on the sidewalls, in conjunction with three 90-cm tunnel fans.
- *Lighting:* A photoperiod of 23 hours light and 1 hour darkness was maintained. Lighting was supplied by 15-W daylight spectrum bulbs, with an intensity of 20 lux measured at feeder level using a Lutron LX-101 lux meter.

***Feeding and Management Program***

Birds were provided a three-phase feeding program consisting of commercial broiler starter, grower, and finisher diets obtained from a commercial feed company. The nutritional composition of the diets is presented in Table 2.

- *Feeding:* Feed was offered ad libitum from one hanging feeder per pen.
- *Watering:* Water was provided ad libitum via nipple drinkers (five nipples per pen). As supportive care, a multivitamin supplement (20 g/200 L) was administered in the drinking water once weekly.
- *Health Management:* Standard biosecurity measures were followed. A live Newcastle disease vaccine was administered via drinking water on day 6, and a live Gumboro vaccine on day 13.

***Slaughter, Defeathering, and Evisceration***

A total of 96 birds, following a 12-hour feed withdrawal period with ad libitum access to water, were processed. Slaughter was performed without stunning in accordance with standard Turkish slaughter regulations and under the approval of the institutional ethics committee (2019/07). The procedure was conducted in a local organic processing facility. All experimental birds were slaughtered under the same commercial conditions without stunning to ensure consistency of slaughter procedures across all treatment groups. Slaughter was performed manually using killing funnels by severing the throat and major cervical blood vessels. Carcasses were then scalded in water at 54°C for 30 seconds and mechanically defeathered. To minimize bacterial proliferation and ensure cleanliness, carcasses were immersed in 22°C water for 20 minutes prior to evisceration via an abdominal incision. Hot carcass weight was recorded, followed by individual weighing of edible internal organs (liver, heart, gizzard).

***Carcass Cutting Procedure***

Following evisceration, carcasses were chilled at +4°C for 24 hours. After chilling, excess surface moisture was removed. Heads, feet, and visceral organs (excluding previously weighed edible organs) were removed prior to dissection.

Carcasses were cut into standard commercial parts according to anatomical landmarks:

- *Breast:* The breast portion, including the pectoralis major and pectoralis minor muscles, was separated by cutting along the sternum.
- *Leg (Thigh-Drumstick):* The leg quarters were detached from the carcass at the hip joint.
- *Wings:* Wings were removed by cutting through the shoulder joint, including the drumette, wingette, and tip.
- *Back:* The back portion consisted of the dorsal region remaining after removal of the breast, legs, and wings.
- *Neck:* The neck was separated at the base of the cervical vertebrae.
- *Abdominal Fat:* Fat depots, including fat surrounding the cloaca and the bursa of Fabricius, were manually collected from the abdominal cavity.
- The weights of edible internal organs (heart, liver, and gizzard) in chickens were determined by weighing each organ separately.

***Weighing and Calculations***

All carcass parts and fat depots were weighed using a digital balance with 0.01 g precision. The yield of each part was calculated as a percentage of cold carcass weight using the following formula:

$$\text{Part Yield (\%)} = \frac{\text{Part Weight}}{\text{Cold Carcass Weight}} \times 100 \qquad (1)$$

Cold carcass weight was recorded after the 24-hour chilling period.

***pH and Color Measurements***

- *pH:* Muscle pH was determined using a Hanna HI2211 pH meter. The probe was inserted directly into the muscle tissue. For analytical reliability, three measurements were taken from each breast and thigh muscle.
- *Color: Meat color (L*, a*,* and *b**) was measured using a HunterLab ColorFlex EZ spectrophotometer (Hunter Associates Laboratory Inc., Reston, VA, USA), calibrated with the manufacturer's standard white calibration tile under illuminant D65 and a 10° standard observer angle. Color coordinates (*L**: lightness, *a**: redness / greenness, *b**: yellowness / blueness) were determined based on the CIE *L*, a*, b** color space system. Color difference (ΔE), chroma (C), and hue angle (h°) were calculated using the following formulas:

$$\Delta E^* = \sqrt{(\Delta L^2 + \Delta a^2 + \Delta b^{*2})} \quad (2)$$

$$C^* = \sqrt{(a^2 + b^2)} \quad (3)$$

$$h^\circ = \tan^{-1}(b^*/a^*) \quad (4)$$

During cutting, three samples (approximately 1-2 g each) were taken from the breast and thigh of the right side of each carcass for color analysis.

***Water-Holding Capacity (WHC)***

Water-holding capacity (WHC) was determined using the method proposed by Hamm (1972) and later modified by Zayas and Lin (1988, 1989). A 300 mg sample obtained from skinless breast and thigh meat was placed on Whatman filter paper and subjected to a pressure of 1 kg for 20 minutes. Subsequently, scaled images of the filter papers were captured using a Canon EOS 60D equipped with an 18–135 mm lens, mounted on a tripod at a fixed height (Figure 2a). The water spreading area (T) (Figure 2b) and meat spreading area (E) (Figure 2c) were determined using Adobe Photoshop (Eleroğlu et al., 2016).

The calculation of WHC was based on the formula developed by Hofmann (1982), which has been widely applied in previous studies (Hofmann et al., 1982; Reuter, 1982; Honikel and Hamm, 1983; Honikel and Kim, 1986; Honkavaara, 1989) and was also reported by Öztan and Vural (1983). Accordingly, WHC was calculated (Eq 5) as the ratio of meat spreading area (E) to water spreading area (T).

$$WHC = E/T \quad (5)$$

***Economic Analysis***

An economic analysis was performed to assess the financial efficiency of broiler production. The analysis included the following cost components: feed, chicks, and a contract manufacturing fee (encompassing labor, energy, veterinary services, and miscellaneous expenses).

- Feed cost per bird was calculated based on total feed intake and feed price.
- Total production cost per bird was the sum of feed cost, chick cost, and the contract manufacturing fee.
- Revenue per bird was calculated from final live body weight and the market price per kilogram of live weight.
- Net profit per bird was derived as the difference between total revenue and total production cost.
- Production cost per kilogram of live weight was calculated to evaluate economic efficiency.

The following formulas were used for the economic analysis:

$$FC = FI \times FP \quad (6)$$

FC : Feed Cost (per bird)
FI : Feed Intake (kg/bird)
FP : Feed Price (currency/kg)

$$TPC = FC + CC + OVC \quad (7)$$

TPC : Total Production Cost (per bird)
FC : Feed Cost (per bird)
CC : Chick Cost
OVC: Other Variable Costs

$$R = LBW \times MP \quad (8)$$

R : Revenue (per bird)
LBW: Live Body Weight (kg/bird)
MP : Market Price (currency/kg)

$$NP = R - TPC \quad (9)$$

NP : Net Profit (per bird)
R : Revenue (per bird)
TPC : Total Production Cost (per bird)

$$PCLW = TPC / LBW \quad (10)$$

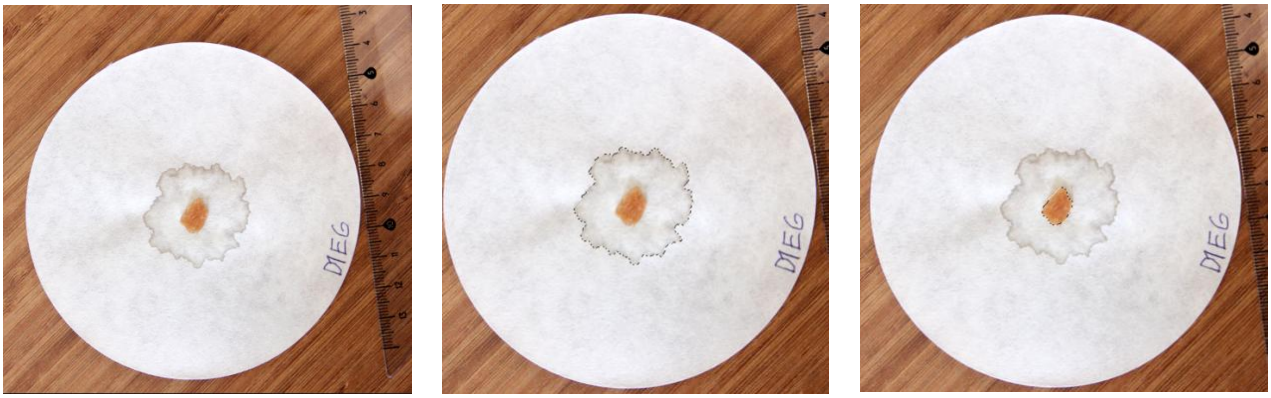
PCLW : Production Cost per kg Live Weight
TPC : Total Production Cost (per bird)
LBW : Live Body Weight (kg/bird)

$$PR = (NP / TPC) \times 100 \quad (11)$$

PR : Profitability Ratio (%):
NP : Net Profit (per bird)
TPC : Total Production Cost (per bird)

***Statistical Analysis***

Data were analyzed using univariate statistical analysis to evaluate the effects of genotype and sex on the measured traits, while carcass part was additionally included as a fixed effect for water-holding capacity (WHC) and pH. The interaction between genotype and sex was also included in the model. Following ANOVA, Duncan's multiple range test was used as a post hoc test to determine significant differences among the groups. Statistical significance was declared at $P < 0.05$. Results are presented as means ± standard error of the mean (SEM).



**a** **b** **c**

Figure 2. Measurement of water spreading area (T) and meat spreading area (E) by image analysis using Adobe Photoshop

***Statistical model***

$$Y_{ijk}=\mu+G_i+S_j+(G\times S)_{ij}+e_{ijk} \quad (12)$$

Where;
$Y_{ijk}$ = observed value,
$\mu$ = overall mean,
$G_i$ = effect of genotype,
$S_j$ = effect of sex,
$(G\times S)_{ij}$= interaction effect,
$e_{ijk}$= random error.

## Result and Discussion

The effects of genotype and sex on carcass traits and their proportions relative to cold carcass weight (%) are summarized in Table 3.

Genotype and sex had significant effects on absolute carcass traits, whereas their effects on the relative proportions of carcass parts to cold carcass weight (%) were more limited. Regarding carcass weights (g), genotype significantly affected hot carcass, cold carcass, and edible internal organ weights ($p < 0.05$). Among genotypes, the CC group exhibited the highest hot and cold carcass weights, followed by AC and CA genotypes, while the AA genotype showed the lowest values ($p < 0.05$). This pattern was consistent for both hot and cold carcass weights, indicating a strong genetic influence on growth and carcass yield. Edible internal organ weight was also significantly influenced by genotype, with CC birds presenting higher values than the other genotypes.

Sex had a significant effect on hot and cold carcass weights ($p < 0.001$), with males consistently showing higher carcass weights than females across all genotypes. However, sex did not significantly affect edible internal organ weight ($p > 0.05$). Moreover, the genotype × sex interaction was not significant for any of the evaluated carcass traits, suggesting that the effect of sex on carcass weight was consistent across genotypes.

When carcass traits were expressed as proportions of live body weight (%), genotype and sex had no significant effects on hot or cold carcass yields ($p > 0.05$). In contrast, the proportion of edible internal organs was significantly influenced by both genotype ($p < 0.01$) and sex ($p < 0.001$). Females generally exhibited a higher proportion of edible internal organs compared to males, and the CA genotype showed the highest total edible internal organ proportion, differing significantly from the other genotypes ($p < 0.05$). No significant genotype × sex interaction was observed for carcass proportions.

Table 3. Effects of genotype and sex on carcass traits and their proportions relative to cold carcass weight (%)

| Items | | Carcass values (gr) | | |
|---|---|---|---|---|
| Genotype | Sex | Hot carcass ± SEM | Cold carcass ± SEM | Edible internal organs ± SEM |
| AA | Male | 2182.5±59.69 | 2158.33±60.12 | 85.57±3.67 |
| | Female | 1746.67±60.59 | 1718.33±60.02 | 85.98±3.69 |
| | Total | **1964.58$^{c}$±61.6** | **1938.33$^{c}$±61.89** | **85.77$^{b}$±2.54** |
| CC | Male | 2740±68.52 | 2709.17±69.23 | 94.61±3.53 |
| | Female | 2149.17±62.18 | 2127.5±64.59 | 94.73±3.02 |
| | Total | **2444.58$^{a}$±76.43** | **2418.33$^{a}$±76.3** | **94.67$^{a}$±2.27** |
| AC | Male | 2482.5±61.93 | 2453.33±61.27 | 87.8±3.59 |
| | Female | 2088.33±66.73 | 2058.33±65.88 | 87.52±2.71 |
| | Total | **2285.42$^{b}$±60.59** | **2255.83$^{b}$±60.26** | **87.66$^{b}$±2.2** |
| CA | Male | 2393.33±64.99 | 2365±63.71 | 82.36±3.15 |
| | Female | 1932.5±53.43 | 1906.67±52.5 | 89.63±2.35 |
| | Total | **2162.92$^{b}$±63.25** | **2135.83$^{b}$±62.55** | **85.99$^{b}$±2.07** |
| Source of variation | | p value | p value | p value |
| Genotype (G) | | **0.001** | **0.001** | **0.023** |
| Sex (S) | | **0.001** | **0.001** | 0.416 |
| G × S | | 0.433 | 0.486 | 0.606 |
| Items | | Proportions of carcass parts to cold carcass weight (%) | | |
| Genotype | Sex | Hot carcass ± SEM | Cold carcass ± SEM | Edible internal organs ± SEM |
| AA | Male | 76.88±0.18 | 76.02±0.2 | 3.94±0.18 |
| | Female | 77.19±0.14 | 75.93±0.12 | 4.94±0.18 |
| | Total | 77.03±0.12 | 75.97±0.11 | **4.44$^{b}$±0.16** |
| CC | Male | 77.2±0.12 | 76.31±0.13 | 3.48±0.16 |
| | Female | 76.73±0.3 | 75.92±0.27 | 4.44±0.16 |
| | Total | 76.96±0.17 | 76.12±0.15 | **3.96$^{b}$±0.15** |
| AC | Male | 77.14±0.15 | 76.23±0.14 | 3.55±0.14 |
| | Female | 77.4±0.19 | 76.29±0.16 | 4.24±0.18 |
| | Total | 77.27±0.12 | 76.26±0.1 | **3.89$^{b}$±0.13** |
| CA | Male | 76.94±0.16 | 76.04±0.16 | 3.46±0.13 |
| | Female | 77.08±0.15 | 76.05±0.17 | 4.68±0.18 |
| | Total | 77.01±0.11 | 76.05±0.11 | **4.07$^{a}$±0.17** |
| Source of variation | | p value | p value | p value |
| Genotype (G) | | 0.349 | 0.403 | **0.007** |
| Sex (S) | | 0.642 | 0.405 | **0.000** |
| G × S | | 0.137 | 0.566 | 0.457 |

AA: Anadolu – T × Anadolu – T; CC: Commercial PS × Commercial PS; AC: Anadolu – T male × Commercial PS female; CA: Commercial PS male × Anadolu – T female; SEM: Standard error of the mean, Total values within the same column with different superscript letters differ significantly ($p < 0.05$).

Table 4. Effects of genotype and sex on marketed cut-up carcass traits and their proportions relative to cold carcass weight

| Items | | Carcass parts (gr) | | | |
|---|---|---|---|---|---|
| Genotype | Sex | Wing ± SEM | Thigh± SEM | Breast± SEM | Neck± SEM |
| AA | Male | 209.17±5.83 | 632.50±21.15 | 780.83±26.27 | 148.33±3.86 |
| | Female | 169.17±4.99 | 485.00±14.85 | 646.67±26.7 | 120.00±4.61 |
| | Total | **189.17$^{c}$±5.61** | **558.75$^{b}$±19.9** | **713.75$^{c}$±23.05** | **134.17$^{c}$±4.17** |
| CC | Male | 250.83±8.11 | 746.67±21.01 | 1073.33±28.61 | 171.67±6.72 |
| | Femal | 204.17±7.12 | 571.67±17.83 | 830.00±28.47 | 141.67±5.75 |
| | Total | **227.50$^{a}$±7.18** | **659.17$^{a}$±22.68** | **951.67$^{a}$±32.14** | **156.67$^{a}$±5.34** |
| AC | Male | 227.50±6.17 | 694.17±21.41 | 944.17±29.53 | 168.33±6.13 |
| | Female | 194.17±6.57 | 579.17±18.44 | 781.67±29.51 | 129.17±5.14 |
| | Total | **210.83$^{b}$±5.61** | **636.67$^{a}$±18.29** | **862.92$^{b}$±26.53** | **148.75$^{ab}$±5.66** |
| CA | Male | 225.00±5.97 | 668.33±17.53 | 908.33±28.36 | 154.17±4.68 |
| | Female | 186.67±4.49 | 519.17±14.01 | 730.00±20.71 | 126.67±4.32 |
| | Total | **205.83$^{b}$±5.41** | **593.75$^{b}$±19.03** | **819.17$^{b}$±25.31** | **140.42$^{bc}$±4.23** |
| Source of variation | | p value | p value | p value | p value |
| Genotype (G) | | **0.000** | **0.000** | **0.000** | **0.000** |
| Sex (S) | | **0.000** | **0.000** | **0.000** | **0.000** |
| G × S | | 0.762 | 0.452 | 0.241 | 0.664 |
| Items | | Proportions of carcass parts to cold carcass weight (%) | | | |
| Genotype | Sex | Wing ± SEM | Thigh± SEM | Breast± SEM | Neck± SEM |
| AA | Male | 9.71±0.17 | 29.27±0.36 | 36.15±0.51 | 6.90±0.19 |
| | Female | 9.88±0.16 | 28.29±0.27 | 37.54±0.34 | 7.00±0.21 |
| | Total | **9.79$^{a}$±0.12** | **28.78$^{a}$±0.24** | **36.85$^{c}$±0.33** | **6.95$^{a}$±0.14** |
| CC | Male | 9.25±0.14 | 27.56±0.35 | 39.62±0.32 | 6.32±0.15 |
| | Female | 9.61±0.19 | 26.90±0.37 | 38.97±0.33 | 6.65±0.16 |
| | Total | **9.43$^{ab}$±0.12** | **27.23$^{c}$±0.26** | **39.30$^{a}$±0.24** | **6.49$^{b}$±0.11** |
| AC | Male | 9.28±0.13 | 28.29±0.46 | 38.44±0.49 | 6.86±0.16 |
| | Female | 9.46±0.24 | 28.18±0.46 | 37.93±0.52 | 6.29±0.19 |
| | Total | **9.37$^{b}$±0.13** | **28.24$^{ab}$±0.32** | **38.19$^{b}$±0.36** | **6.57$^{ab}$±0.14** |
| CA | Male | 9.53±0.18 | 28.28±0.32 | 38.38±0.39 | 6.56±0.23 |
| | Female | 9.83±0.23 | 27.27±0.41 | 38.28±0.18 | 6.66±0.19 |
| | Total | **9.68$^{ab}$±0.14** | **27.78$^{bc}$±0.28** | **38.33$^{b}$±0.21** | **6.61$^{ab}$±0.14** |
| Source of variation | | p value | p value | p value | p value |
| Genotype (G) | | 0.068 | **0.001** | **0.000** | 0.069 |
| Sex (S) | | 0.053 | **0.012** | 0.901 | 0.944 |
| G × S | | 0.950 | 0.609 | **0.049** | 0.092 |

AA: Anadolu – T × Anadolu – T; CC: Commercial PS × Commercial PS; AC: Anadolu – T male × Commercial PS female; CA: Commercial PS male × Anadolu – T female; SEM: Standard error of the mean, Total values within the same column with different superscript letters differ significantly ($p < 0.05$).

Overall, these results indicate that genotype and sex primarily affect absolute carcass weights rather than carcass yield percentages, while the relative contribution of edible internal organs to live body weight appears to be more sensitive to both genetic background and sex.

The present study demonstrated that genotype significantly influenced absolute carcass weights, with the CC genotype exhibiting the highest hot and cold carcass weights, while the AA genotype showed the lowest values. This finding aligns with previous reports highlighting strong genetic effects on growth rate and carcass weight in broilers (Havenstein et al., 2003; Tallentire et al., 2016). Long-term selection for rapid growth and increased body weight in commercial lines has been shown to directly enhance carcass mass, explaining the superior weights observed in genotypes carrying Commercial Broiler genetic background. Likewise, body weight, which exhibits moderate heritability, has been reported to be positively associated with carcass weight, reinforcing the influence of genetic background on absolute carcass traits (Duenk et al., 2019; Gaya et al., 2006; Le Bihan-Duval et al., 1999).

Sex also significantly affected hot and cold carcass weights, with males consistently outperforming females across all genotypes. This observation concurs with established evidence that male broilers typically exhibit higher growth rates and heavier carcasses due to hormonal and metabolic differences (Leeson & Summers, 2001; Sarıca et al., 2021). The lack of a significant genotype × sex interaction suggests that the sex-related growth advantage was consistent across genetic backgrounds, consistent with reports indicating that sexual dimorphism in growth performance is largely independent of genotype in commercial broilers (Erensoy & Sarıca, 2023).

In contrast to absolute weights, carcass yields expressed as percentages of live body weight were not significantly affected by either genotype or sex. Similar results have been reported in studies where differences in live body weight translated proportionally into carcass weight without markedly altering carcass yield percentages (Zuidhof et al., 2014; Shim et al., 2012). This indicates that although genetic selection increases overall size, the proportional distribution between live weight and carcass weight remains relatively stable across genotypes.

Previous studies have demonstrated that organ development and body composition can differ between males and females and among genetic lines, particularly in relation to growth rate and selection intensity (Ahmadzadeh et al., 2025; Sarıca et al., 2021; Kokoszyński et al., 2017; Tallentire et al., 2016).

Overall, these results indicate that genetic background and sex have a greater effect on absolute carcass traits than on carcass yield percentages. While growth-oriented genotypes increase total carcass mass, proportional carcass yield remains relatively constant. In contrast, the relative contribution of edible internal organs to live body weight varies significantly with both genotype and sex, highlighting the importance of considering both absolute and relative measures when evaluating carcass performance in reciprocal cross hybrids.

The results related to the proportions of carcass parts relative to cold carcass weight (%) are summarized in Table 4.

Genotype and sex had significant effects on the absolute weights of marketed cut-up carcass parts (wing, thigh, breast, and neck) ($p < 0.001$), whereas their effects on the relative proportions of these parts were more limited and trait-dependent.

For carcass part weights (g), genotype significantly influenced all evaluated traits ($p < 0.001$). The CC genotype exhibited the highest wing, thigh, breast, and neck weights, followed by the AC and CA genotypes, while the AA genotype showed the lowest values ($p < 0.05$). These differences reflect the superior growth performance and muscle development associated with the CC genotype. Sex also had a significant effect on all carcass part weights, with males consistently presenting higher values than females across all genotypes ($p < 0.001$). No significant genotype × sex interaction was observed for any of the carcass part weights, indicating that the sex-related differences were consistent among genotypes.

When expressed as proportions of carcass parts (%), genotype significantly affected thigh and breast proportions ($p < 0.01$), whereas its effects on wing and neck proportions were not significant ($p > 0.05$). In particular, the CC genotype showed the highest breast proportion, differing significantly from the AA genotype ($p < 0.05$). Sex had a significant effect on thigh proportion ($p < 0.05$), with males generally exhibiting higher values, while no significant sex effect was observed for breast, wing, or neck proportions. A significant genotype × sex interaction was detected only for breast proportion ($p < 0.05$), suggesting that the effect of sex on breast yield varied depending on genotype.

Overall, these findings indicate that genotype and sex have a significant effect on the absolute weights of marketed carcass cuts, whereas their impact on relative cut proportions is less pronounced, with breast and thigh yields being the most responsive traits.

The current study demonstrated that genotype significantly affected the absolute weights of major marketed carcass parts (wing, thigh, breast, and neck), with the CC genotype consistently exhibiting the highest values and the AA genotype the lowest. These results align with previous research indicating that genetic background plays a crucial role in growth performance and muscle development in broilers (Sarıca et al., 2021; Tallentire et al., 2016; Zuidhof et al., 2014; Havenstein et al., 2003). The superior weights observed in the CC genotype likely reflect the enhanced growth potential and muscle accretion associated with commercial broiler genetic lines.

Sex also had a significant effect on the absolute weights of all carcass parts, with males outperforming females across all genotypes. This finding is consistent with well-documented sexual dimorphism in broilers, where males exhibit faster growth rates and greater muscle deposition (Erensoy & Sarıca, 2023; Türkoğlu & Sarıca, 2018; Shim et al., 2012; Leeson & Summers, 2010; López et al., 2011). The absence of a significant genotype × sex interaction for most carcass parts suggests that the sex-related weight advantage is largely independent of genotype, which is in agreement with findings reported in modern commercial broiler lines (Wegner et al., 2024).

When carcass parts were expressed relative to cold carcass weight, genotype significantly influenced thigh and breast proportions, whereas wing and neck proportions were largely unaffected. The CC genotype presented the highest breast proportion, significantly differing from the AA genotype. These results are consistent with previous findings indicating that selection for growth and breast yield disproportionately enhances pectoral muscle development without markedly affecting other carcass components (Sarıca et al., 2021; Türkoğlu & Sarıca, 2018; Zuidhof et al., 2014; Havenstein et al., 2003). Similarly, sex affected thigh proportion, with males generally exhibiting higher values, while no significant sex differences were observed for breast, wing, or neck yields. A significant genotype × sex interaction was observed for breast proportion, suggesting that the response of pectoral muscle development to sex may vary depending on genetic background (Lopez et al., 2011).

The reciprocal hybrid groups (AC and CA) generally exhibited intermediate carcass characteristics compared with the purebred AA and CC genotypes. Their carcass traits tended to fall between those of the parental lines, reflecting the combined contribution of the commercial and Anadolu-T genetic backgrounds. Although the hybrids did not consistently match the superior breast yield of the CC genotype, they generally outperformed the AA genotype for several carcass traits. These findings suggest that reciprocal crossbreeding may provide a practical compromise between carcass performance and the conservation of indigenous genetic resources. Such an approach could improve the commercial potential of locally developed broiler lines while maintaining valuable genetic diversity. Nevertheless, further studies evaluating economic efficiency, meat quality, adaptability, and long-term breeding performance are needed before these hybrids can be recommended for commercial breeding programs.

Overall, the findings suggest that absolute weights of marketed carcass cuts are strongly influenced by both genotype and sex, whereas relative proportions of these cuts are more trait-specific, with breast and thigh yields being particularly responsive. These results underscore the importance of considering both absolute and proportional measures when evaluating carcass performance, particularly in reciprocal cross hybrids where genetic background and sex may interact to influence muscle distribution and marketable yield.

Table 5. Effects of genotype and sex on back and abdominal fat and their proportions relative to cold carcass weight

| Items | | Carcass parts (gr) and relative to cold carcass weight (%) | | | |
|---|---|---|---|---|---|
| Genotype | Sex | Back (gr) ± SEM | Back (%) ± SEM | Abdominal fat (gr) ± SEM | Abdominal fat (%) ± SEM |
| AA | Male | 325.83±10.76 | 15.1±0.29 | 61.67±4.05 | 2.87±0.19 |
| | Female | 249.17±9.08 | 14.5±0.17 | 50±5.5 | 2.87±0.26 |
| | Total | **287.5$^{c}$±10.55** | 14.8±0.18 | 55.83±3.56 | **2.87$^{a}$±0.16** |
| CC | Male | 416.67±12.87 | 15.4±0.34 | 50±4.26 | 1.85±0.15 |
| | Female | 320.83±11.31 | 15.09±0.32 | 57.5±4.46 | 2.71±0.2 |
| | Total | **368.75$^{a}$±13.04** | 15.25±0.23 | 53.75±3.12 | **2.28$^{c}$±0.15** |
| AC | Male | 358.33±9.99 | 14.62±0.26 | 60.83±5.43 | 2.52±0.25 |
| | Female | 318.33±12.6 | 15.46±0.36 | 55.83±4.99 | 2.67±0.2 |
| | Total | **338.33$^{b}$±8.9** | 15.04±0.23 | 58.33±3.64 | **2.6$^{ab}$±0.16** |
| CA | Male | 354.17±14.64 | 14.93±0.29 | 55±2.89 | 2.32±0.1 |
| | Female | 292.5±12.56 | 15.3±0.38 | 51.67±5.05 | 2.66±0.22 |
| | Total | **323.33$^{b}$±11.42** | 15.11±0.24 | 53.33±2.87 | **2.49$^{ab}$±0.12** |
| Source of variation | | p value | p value | p value | p value |
| Genotype (G) | | **0.000** | 0.540 | 0.693 | **0.034** |
| Sex (S) | | **0.000** | 0.729 | 0.345 | **0.019** |
| G × S | | 0.122 | 0.089 | 0.231 | 0.166 |

AA: Anadolu – T × Anadolu – T; CC: Commercial PS × Commercial PS; AC: Anadolu – T male × Commercial PS female; CA: Commercial PS male × Anadolu – T female; SEM: Standard error of the mean, Total values within the same column with different superscript letters differ significantly ($p < 0.05$).

The effects of genotype and sex on back and abdominal fat traits, expressed both as absolute weights and as proportions relative to cold carcass weight, are presented in Table 5.

The effects of genotype and sex on abdominal fat traits expressed both as absolute weights and as proportions relative to cold carcass weight were evaluated in this study. The results indicate that absolute abdominal fat weight did not differ significantly among genotypes or between sexes, as evidenced by non-significant genotype ($p = 0.693$) and sex ($p = 0.345$) effects. This finding suggests that total fat deposition in broiler chickens may be relatively stable across genetic backgrounds and between males and females when assessed on an absolute basis, a pattern that has been observed in other broiler populations where total fat weight shows limited divergence among commercial and alternative lines (Petracci et al., 2015; Shim et al., 2012; Becker et al., 1981).

In contrast, when abdominal fat was expressed relative to cold carcass weight, both genotype ($p = 0.034$) and sex ($p = 0.019$) exhibited significant effects. The AA genotype showed the highest relative abdominal fat percentage, whereas the CC genotype displayed the lowest value, indicating genotype specific differences in fat partitioning relative to overall body size. Additionally, females tended to have higher abdominal fat percentages than males across genotypes. These results highlight that proportional measures are more sensitive than absolute weights in detecting subtle differences in fat deposition, reflecting underlying genetic and physiological variation more clearly. Similar observations have been reported in broiler studies, where relative adipose tissue measures reveal genotype and sex linked differences not evident in absolute fat weights (Moreira et al., 2018; Wang et al., 2017).

The lack of a significant genotype × sex interaction for abdominal fat traits suggests that although both genotype and sex independently influence relative abdominal fat deposition, their combined interaction does not significantly amplify or mitigate this effect. This is consistent with reports in commercial broiler research indicating that sex differences in fat distribution are generally additive and not dependent on specific genotype combinations (López et al., 2011). The higher relative abdominal fat observed in females aligns with established patterns of sexual dimorphism in poultry, where females tend to deposit a greater proportion of adipose tissue relative to carcass mass due to endocrine and metabolic differences (Xie et al., 2026; Chen et al., 2021).

The analysis of back weight indicates that absolute dorsal muscle mass is significantly affected by both genotype and sex, whereas its proportion relative to cold carcass weight remains stable. In the present study, the CC genotype exhibited the highest back weight ($368.75 \pm 13.04$ g), followed by AC ($338.33 \pm 8.9$ g) and CA ($323.33 \pm 11.42$ g), whereas the AA genotype ($287.50 \pm 10.55$ g) had the lowest back weight. Males consistently had higher back weights than females across all genotypes, reflecting the pronounced differences in growth performance and muscle development between sexes and among genetic lines. Such sexual dimorphism in carcass traits, including muscle mass, has been previously observed in broiler strains, with males generally achieving greater body and cut weights than females (Hussein et al., 2019; López et al., 2011).

The absence of a significant genotype × sex interaction suggests that sex-related advantages in back muscle mass are largely additive and independent of genetic background, indicating consistent male superiority in absolute muscle mass across genotypes. However, when back weight is expressed as a proportion of cold carcass weight, the observed differences disappear, indicating that relative distribution of dorsal muscle scales proportionally with overall carcass size. This pattern is consistent with reports that selective breeding and genotype differences primarily increase absolute muscle mass, whereas proportional carcass composition, such as relative cut weights, tends to be conserved across genotypes (Hussein et al., 2019; López et al., 2011).

The lack of a significant genotype × sex interaction suggests that the effects of sex on relative abdominal fat are additive and independent of genotype, which is consistent with earlier research demonstrating that sexual dimorphism in fat deposition is generally consistent across broiler lines (Luo et al., 2022).

Table 6. Effects of genotype and sex on water-holding capacity (WHC) and pH of carcass regions

| Genotype | Sex | Carcass region | n | WHC (mean ± SEM) | n | pH |
|---|---|---|---|---|---|---|
| AA | Male | Thigh | 12 | 0.15±0.02 | 36 | 5.29±0.02 |
| | | Breast | 12 | 0.14±0.02 | 36 | 5.37±0.03 |
| | | Total | 24 | 0.14±0.01 | 72 | 5.33±0.02 |
| | Female | Thigh | 12 | 0.14±0.01 | 36 | 5.27±0.02 |
| | | Breast | 12 | 0.15±0.02 | 36 | 5.35±0.03 |
| | | Total | 24 | 0.15±0.01 | 72 | 5.31±0.02 |
| | Total | | 48 | **0.14$^{a}$±0.01** | 144 | **5.32$^{a}$±0.01** |
| CC | Male | Thigh | 12 | 0.11±0.01 | 36 | 5.26±0.04 |
| | | Breast | 12 | 0.1±0.01 | 36 | 5.15±0.04 |
| | | Total | 24 | 0.1±0.01 | 72 | 5.21±0.03 |
| | Female | Thigh | 12 | 0.09±0.01 | 36 | 5.28±0.04 |
| | | Breast | 12 | 0.12±0.01 | 36 | 5.24±0.05 |
| | | Total | 24 | 0.11±0.01 | 72 | 5.26±0.03 |
| | Total | | 48 | **0.11$^{b}$±0.01** | 144 | **5.23$^{b}$±0.02** |
| AC | Male | Thigh | 12 | 0.09±0.01 | 36 | 5.28±0.06 |
| | | Breast | 12 | 0.11±0.01 | 36 | 5.02±0.15 |
| | | Total | 24 | 0.1±0.01 | 72 | 5.15±0.08 |
| | Female | Thigh | 12 | 0.12±0.01 | 36 | 5.23±0.06 |
| | | Breast | 12 | 0.12±0.01 | 36 | 5.21±0.04 |
| | | Total | 24 | 0.12±0.01 | 72 | 5.22±0.03 |
| | Total | | 48 | **0.11$^{b}$±0.01** | 144 | **5.18$^{b}$±0.04** |
| CA | Male | Thigh | 12 | 0.09±0.01 | 36 | 5.39±0.04 |
| | | Breast | 12 | 0.11±0.01 | 36 | 5.28±0.04 |
| | | Total | 24 | 0.1±0.01 | 72 | 5.33±0.03 |
| | Female | Thigh | 12 | 0.09±0.01 | 36 | 5.4±0.05 |
| | | Breast | 12 | 0.12±0.01 | 36 | 5.34±0.05 |
| | | Total | 24 | 0.11±0.01 | 72 | 5.37±0.03 |
| | Total | | 48 | **0.1$^{b}$±0** | 144 | **5.35$^{a}$±0.02** |

| Source of variation | p-value | |
|---|---|---|
| Genotype (G) | **0.000** | **0.000** |
| Sex (S) | 0.191 | 0.210 |
| Carcass region (CR) | 0.052 | **0.045** |
| G × S | 0.820 | 0.663 |
| G × CR | 0.474 | **0.033** |
| S × CR | 0.449 | 0.110 |
| G × S × CR | 0.431 | 0.468 |

AA: Anadolu – T × Anadolu – T; CC: Commercial PS × Commercial PS; AC: Anadolu – T male × Commercial PS female; CA: Commercial PS male × Anadolu – T female; SEM: Standard error of the mean, Total values within the same column with different superscript letters differ significantly ($p < 0.05$).

Effects of genotype and sex on water-holding capacity (WHC) and pH of carcass regions are presented in Table 6.

Analysis of water-holding capacity (WHC) and pH in thigh and breast muscles revealed significant effects of genotype, while sex had no significant influence ($p > 0.05$). The AA genotype (Anadolu-T × Anadolu-T) consistently exhibited the highest WHC values (0.14 ± 0.01), whereas CC (Commercial Broiler × Commercial Broiler) and hybrid genotypes (AC and CA) showed lower values (0.10–0.11 ± 0.01), indicating that slower-growing Anadolu-T birds maintain superior water retention in the muscle. This is consistent with previous findings demonstrating that WHC is strongly associated with growth rate and muscle fiber characteristics, with fast-growing commercial lines generally showing lower water retention due to rapid muscle accretion (Zuidhof et al., 2014; Shim et al., 2012). No significant genotype × sex interaction was observed, suggesting that WHC differences are primarily determined by genetic background rather than sex.

Regarding pH, genotype also had a significant effect ($p = 0.000$), with CC and AC birds showing lower mean pH values (5.18–5.23) compared to AA and CA birds (5.32–5.35). Lower pH in fast-growing commercial broilers is indicative of accelerated post-mortem glycolysis, which may affect meat quality attributes such as texture and WHC. Although the effect of carcass region was marginally significant ($p = 0.045$) and a genotype × region interaction was detected ($p = 0.033$), no sex effect was observed. These findings suggest that pH differences are primarily driven by genotype, with region-specific variation reflecting inherent differences between thigh and breast muscles. Overall, the results indicate that genetic selection for rapid growth influences both WHC and pH, whereas sex has limited impact, and that slower-growing Anadolu-T birds may possess more favorable meat quality traits in terms of water retention and pH stability.

The present study demonstrated that genotype significantly influenced both water-holding capacity (WHC) and pH of thigh and breast meat. Specifically, the AA genotype exhibited the highest WHC values, whereas the CC, AC, and CA genotypes showed lower and comparable WHC. Similarly, pH values differed among genotypes, with the AA and CA genotypes exhibiting

higher pH than the CC and AC groups. These findings are consistent with previous studies indicating that genetic background is a major determinant of meat quality traits, including WHC and ultimate pH, through its influence on muscle characteristics and postmortem glycolysis (Le Bihan-Duval et al., 2008; Marchewka et al., 2023). Recent studies have further demonstrated that differences between fast- and slow-growing genotypes are associated with variations in muscle metabolism and postmortem biochemical processes, which directly influence pH decline and water-holding capacity (Özbek et al., 2020; Afrin et al., 2024).

The superior WHC and higher ultimate pH observed in the Anadolu-T (AA) genotype are consistent with the physiological characteristics of slow-growing chickens. Compared with fast-growing commercial broilers, slow-growing genotypes generally possess a greater proportion of oxidative muscle fibers and a lower glycolytic potential. As a result, postmortem glycogen depletion and lactic acid accumulation occur at a slower rate, leading to a higher ultimate muscle pH. The higher pH minimizes protein denaturation and enhances the water-binding capacity of muscle proteins, thereby improving WHC. These physiological mechanisms have been widely reported in slow-growing poultry genotypes and provide a plausible explanation for the superior meat quality observed in the AA genotype (Fanatico et al., 2007; Mir et al., 2017).

In contrast, sex had no significant effect on either WHC or pH, indicating that under the present experimental conditions, male and female broilers exhibited comparable meat quality characteristics. This finding agrees with previous reports showing limited or negligible effects of sex on WHC and ultimate pH in broilers (Leeson & Summers, 2010; Erensoy & Sarıca, 2023), although differences may become evident in genotypes with pronounced sexual dimorphism or under different nutritional and management conditions.

Overall, these results suggest that genotype is the primary factor influencing WHC and pH, while sex has minimal impact, and muscle region contributes mainly to pH differences rather than WHC. These findings highlight the importance of considering both genetic background and carcass region when evaluating meat quality in reciprocal cross hybrids, particularly for traits linked to processing performance and consumer acceptability.

The effects of genotype, sex, and carcass region on meat color parameters ($L^*$, $a^*$, and $b^*$) of thigh and breast meat are presented in Table 7.

Table 7. Effects of genotype and sex on meat color parameters ($L^*$, $a^*$, $b^*$) in different carcass regions

| Genotype | Sex | Carcass region | n | $L^*$ | $a^*$ | $b^*$ |
|---|---|---|---|---|---|---|
| | | Thigh | 36 | 43.74±1.02 | 3.51±0.21 | 11.56±0.35 |
| | Male | Breast | 36 | 45.33±1.51 | 2.52±0.25 | 13.29±0.41 |
| | | Total | 72 | 44.54±0.91 | 3.01±0.17 | 12.42±0.29 |
| AA | | Thigh | 36 | 46.01±0.9 | 3.23±0.24 | 13.43±0.36 |
| | Female | Breast | 36 | 47.79±0.89 | 2.77±0.22 | 15.36±0.39 |
| | | Total | 72 | 46.9±0.64 | 3±0.16 | 14.4±0.29 |
| | Total | | 144 | 45.72±0.56 | 3.01±0.12 | 13.41±0.22 |
| | | Thigh | 36 | 45.45±1.21 | 2.84±0.32 | 11.88±0.53 |
| | Male | Breast | 36 | 50.41±1.09 | 1.5±0.24 | 13.82±0.45 |
| | | Total | 72 | 47.93±0.86 | 2.17±0.21 | 12.85±0.36 |
| CC | | Thigh | 36 | 43.63±1.5 | 4.41±1.07 | 12.56±0.49 |
| | Female | Breast | 36 | 49.58±1.05 | 2.62±0.19 | 15.01±0.5 |
| | | Total | 72 | 46.6±0.98 | 3.51±0.55 | 13.78±0.38 |
| | Total | | 144 | 47.27±0.65 | 2.84±0.3 | 13.32±0.26 |
| | | Thigh | 36 | 46.86±0.85 | 2.88±0.18 | 12.31±0.48 |
| | Male | Breast | 36 | 49.71±1.24 | 1.26±0.19 | 13.5±0.48 |
| | | Total | 72 | 48.29±0.77 | 2.07±0.16 | 12.91±0.34 |
| AC | | Thigh | 36 | 40.67±0.91 | 3.29±0.23 | 12.27±0.41 |
| | Female | Breast | 36 | 61.75±14.02 | 2.24±0.17 | 14.47±0.37 |
| | | Total | 72 | 51.21±7.09 | 2.77±0.16 | 13.37±0.3 |
| | Total | | 144 | 49.75±3.55 | 2.42±0.12 | 13.14±0.23 |
| | | Thigh | 36 | 44.87±1.31 | 2.75±0.19 | 11.72±0.52 |
| | Male | Breast | 36 | 49.02±1.01 | 2.4±0.2 | 14.46±0.47 |
| | | Total | 72 | 46.95±0.86 | 2.58±0.14 | 13.09±0.38 |
| CA | | Thigh | 36 | 43.16±1.13 | 3.12±0.23 | 12.09±0.44 |
| | Female | Breast | 36 | 48.74±0.69 | 2.71±0.2 | 14.84±0.29 |
| | | Total | 72 | 45.95±0.73 | 2.91±0.15 | 13.46±0.31 |
| | Total | | 144 | 46.45±0.56 | 2.75±0.1 | 13.28±0.25 |

| Source of variation | p-value | p-value | p-value |
|---|---|---|---|
| Genotype (G) | 0.434 | 0.100 | 0.853 |
| Sex (S) | 0.686 | **0.001** | **0.000** |
| Carcass region (CR) | **0.001** | **0.000** | **0.000** |
| G × S | 0.779 | 0.035 | 0.040 |
| G × CR | 0.247 | 0.057 | 0.332 |
| S × CR | 0.156 | 0.664 | 0.325 |
| G × S × CR | 0.240 | 0.669 | 0.867 |

Genotype had no significant effect on $L^*$, $a^*$, or $b^*$ values ($p > 0.05$), indicating that overall meat color characteristics were not markedly influenced by genetic background. In contrast, sex significantly affected $a^*$ and $b^*$ values ($p < 0.01$), whereas its effect on $L^*$ was not significant ($p > 0.05$). Females generally exhibited higher redness ($a^*$) and yellowness ($b^*$) values compared to males.

Carcass region had a significant effect on all color parameters ($p < 0.001$). Breast meat showed higher $L^*$ and $b^*$ values, indicating lighter and more yellow coloration, while thigh meat exhibited higher $a^*$ values, reflecting greater redness. These differences highlight the distinct muscle characteristics between carcass regions.

Significant genotype × sex interactions were observed for $a^*$ ($p < 0.05$) and $b^*$ ($p < 0.05$), suggesting that sex-related differences in redness and yellowness varied among genotypes. However, no significant genotype × carcass region, sex × carcass region, or three-way interactions were detected for any of the color parameters ($p > 0.05$).

The present study showed that genotype had no significant effect on meat color parameters ($L^*$, $a^*$, and $b^*$) in both thigh and breast muscles, indicating that overall meat color is largely independent of genetic background. This observation is consistent with previous reports suggesting that genetic effects on meat color are generally limited in commercial broiler populations, particularly for fast-growing lines selected primarily for growth and carcass yield rather than pigmentation traits (Le Bihan-Duval et al., 2008; Sarıca et al., 2021).

In contrast, sex significantly influenced redness (a) and yellowness ($b^*$) values, with females exhibiting higher $a^*$ and $b^*$ values than males, whereas $L^*$ was not significantly affected. These findings agree with earlier studies reporting sex-related differences in meat color (Leeson & Summers, 2010; Erensoy & Sarıca, 2023). The observed differences may be associated with physiological variations in muscle composition between males and females. Differences in intramuscular fat deposition, myoglobin concentration, and carotenoid deposition can influence meat color characteristics, thereby contributing to variations in redness and yellowness. Although these mechanisms were not directly evaluated in the present study, they provide plausible biological explanations for the observed sex effects and are consistent with previous reports on broiler meat quality (Fletcher, 2002; Petracci & Cavani, 2012; Mir et al., 2017).

Carcass region had a pronounced effect on all color parameters, with breast meat showing higher $L^*$ and $b^*$ values, reflecting lighter and more yellow coloration, whereas thigh meat exhibited higher $a^*$, indicating greater redness. This pattern is consistent with the oxidative versus glycolytic nature of thigh and breast muscles, respectively, as reported in broiler meat color studies (Le Bihan-Duval et al., 2008; Tallentire et al., 2016). The observed genotype × sex interactions for $a^*$ and $b^*$ suggest that sex-related color differences may be modulated by genotype, although the overall impact of genetic background remains minor. No significant genotype × region, sex × region, or three-way interactions were observed, indicating that regional differences dominate meat color variation in these hybrids.

Overall, these results indicate that meat color in reciprocal cross hybrids is primarily determined by carcass region and, to a lesser extent, by sex, while genotype plays a limited role. The findings emphasize the importance of considering muscle type and sex when evaluating color traits, which are critical for consumer perception and processing quality.

The effects of genotype, sex, and carcass region on meat color parameters (H° – hue angle, C – chroma, and ΔE) of thigh and breast meat are presented in Table 8.

Genotype had a significant effect on H° values ($p < 0.01$), while its effects on C* and ΔE* were not significant ($p > 0.05$), indicating that genetic background primarily influences overall color tone rather than color intensity or total color variation (Le Bihan-Duval et al., 2008; Sarıca et al., 2021). Sex significantly affected both H° and C* values ($p < 0.001$), with females generally showing higher hue angle and chroma, reflecting brighter and more vivid meat coloration, likely due to differences in muscle fiber distribution, myoglobin content, and lipid deposition (Leeson & Summers, 2010; Erensoy & Sarıca, 2023). In contrast, sex did not significantly affect ΔE*, suggesting that overall color difference is less sensitive to sex than individual color parameters.

Carcass region had a significant effect on C* ($p < 0.001$) and ΔE* ($p < 0.01$), with breast meat exhibiting higher chroma and ΔE* than thigh meat, reflecting more intense color and greater total color difference. H° was not significantly influenced by carcass region. Significant genotype × sex interactions for H° indicate that the effect of sex on hue angle varies depending on genotype. Additionally, a significant sex × carcass region interaction for H° suggests that regional differences in color tone are modulated by sex. No other two- or three-way interactions were significant for C* or ΔE*, highlighting that these traits are primarily shaped by muscle region rather than genotype or sex.

Overall, the results suggest that hue angle is the color parameter most sensitive to both genotype and sex, whereas chroma and total color difference are mainly influenced by carcass region. These findings emphasize the multifactorial nature of meat color in reciprocal cross hybrids and highlight the importance of considering genotype, sex, and muscle region simultaneously when evaluating color-related meat quality traits relevant for processing and consumer acceptability.

The economic performance parameters of broiler production according to genotype are presented in Table 9.

Genotype had no significant effect on feed cost per bird ($p > 0.05$), indicating comparable feed expenses among genotypes. However, total production cost per bird tended to differ ($p = 0.056$), with the CC genotype showing the highest cost and the AA genotype the lowest. When production cost was expressed per kilogram of live body weight, a significant genotype effect was observed ($p < 0.05$), with the AC genotype exhibiting the lowest cost, while AA and CA were less efficient.

Genotype significantly affected revenue and net profit per bird ($p < 0.01$). CC and AC genotypes generated higher returns compared to AA and CA ($p < 0.05$), with CC achieving the highest net profit, reflecting superior growth performance and marketable output. Profitability (%) also differed among genotypes ($p < 0.05$), with AC leading, followed by CC, and AA showing the lowest value. These results indicate that crossbred genotypes, particularly AC, provide economic advantages under the present production conditions.

Table 8. Effects of genotype and sex on meat color parameters (H°, C*, ΔE) in different carcass regions

| Genotype | Sex | Carcass region | n | H° | C* | ΔE |
|---|---|---|---|---|---|---|
| AA | Male | Thigh | 36 | 72.91±1.03 | 12.14±0.35 | 45.44±1.02 |
| | | Breast | 36 | 69.61±6.5 | 13.59±0.42 | 47.52±1.39 |
| | | Total | 72 | 71.26±3.27 | 12.87±0.29 | 46.48±0.87 |
| | Female | Thigh | 36 | 76.69±0.92 | 13.87±0.38 | 48.09±0.92 |
| | | Breast | 36 | 79.84±0.8 | 15.66±0.4 | 50.33±0.93 |
| | | Total | 72 | 78.26±0.63 | 14.77±0.29 | 49.21±0.66 |
| | Total | | 144 | 74.76±1.69 | 13.82±0.22 | 47.84±0.55 |
| CC | Male | Thigh | 36 | 57.19±8.79 | 12.32±0.56 | 47.16±1.25 |
| | | Breast | 36 | 54.39±10.76 | 13.95±0.47 | 52.34±1.14 |
| | | Total | 72 | 55.79±6.9 | 13.14±0.37 | 49.75±0.9 |
| | Female | Thigh | 36 | 73.28±1.9 | 13.9±0.96 | 46.29±1.36 |
| | | Breast | 36 | 79.13±1.6 | 15.34±0.45 | 51.94±1.08 |
| | | Total | 72 | 76.2±1.28 | 14.62±0.53 | 49.12±0.93 |
| | Total | | 144 | 66±3.6 | 13.88±0.33 | 49.43±0.64 |
| AC | Male | Thigh | 36 | 76.63±0.85 | 12.69±0.48 | 48.61±0.88 |
| | | Breast | 36 | 65.29±9.07 | 13.6±0.49 | 51.59±1.28 |
| | | Total | 72 | 70.96±4.57 | 13.14±0.34 | 50.1±0.79 |
| | Female | Thigh | 36 | 74.95±0.93 | 12.77±0.42 | 42.68±0.95 |
| | | Breast | 36 | 81.34±0.57 | 14.66±0.38 | 63.92±13.97 |
| | | Total | 72 | 78.15±0.66 | 13.72±0.3 | 53.3±7.06 |
| | Total | | 144 | 74.55±2.32 | 13.43±0.23 | 51.7±3.54 |
| CA | Male | Thigh | 36 | 76.74±0.88 | 12.09±0.52 | 46.54±1.34 |
| | | Breast | 36 | 75.8±4.76 | 14.69±0.49 | 51.23±1.05 |
| | | Total | 72 | 76.27±2.41 | 13.39±0.39 | 48.88±0.89 |
| | Female | Thigh | 36 | 75.7±1 | 12.54±0.45 | 45±1.16 |
| | | Breast | 36 | 79.82±0.71 | 15.12±0.31 | 51.05±0.7 |
| | | Total | 72 | 77.76±0.66 | 13.83±0.31 | 48.02±0.76 |
| | Total | | 144 | 77.01±1.24 | 13.61±0.25 | 48.45±0.59 |

| Source of variation | p-value | p-value | p-value |
|---|---|---|---|
| Genotype (G) | **0.005** | 0.555 | 0.463 |
| Sex (S) | **0.000** | **0.000** | 0.544 |
| Carcass region (CR) | 0.952 | **0.000** | **0.001** |
| G × S | 0.033 | 0.104 | 0.792 |
| G × CR | 0.920 | 0.298 | 0.269 |
| S × CR | 0.044 | 0.574 | 0.166 |
| G × S × CR | 0.776 | 0.836 | 0.226 |

Overall, the findings demonstrate that genotype is a key determinant of economic performance in broiler production. While feed costs were similar across genotypes, differences in growth, carcass yield, and market traits translated into variations in total production cost, revenue, net profit, and profitability. In particular, the superior economic performance of the AC hybrid, characterized by its lower production cost per kilogram of live weight and higher profitability, suggests that incorporating Anadolu-T genetic resources into crossbreeding programs may improve economic returns while supporting the sustainable use of indigenous poultry germplasm. The favorable performance of the AC hybrid may also reflect heterosis and maternal effects associated with reciprocal crossbreeding. However, because maternal performance, egg quality, and hatchability traits were not evaluated in the present study, these mechanisms should be considered as potential explanations requiring further investigation. This approach may be particularly valuable for alternative production systems, such as free-range and organic production, where locally adapted genotypes are increasingly preferred. However, further studies under commercial production conditions are needed to confirm these findings.

## Conclusion

This study investigated the effects of genotype and sex on carcass characteristics, meat quality, and economic performance in reciprocal crosses between Anatolian-T and Commercial Broiler parent stocks. The results indicate that genetic background is the primary determinant of absolute carcass weights and marketed cut-up parts, with Commercial Broiler genotypes (CC and AC) exhibiting superior growth, muscle development, and total carcass mass. Sex significantly influenced absolute weights, with males outperforming females, whereas relative carcass yields were largely consistent across genotypes, highlighting the importance of evaluating both absolute and proportional traits.

Fat deposition patterns were trait-specific: back fat was primarily affected by genotype and sex in absolute terms, while differences in abdominal fat were more apparent when expressed relative to carcass weight, emphasizing variation in fat partitioning among genotypes and sexes. Meat quality traits, including water-holding capacity, pH, and color parameters, were mainly influenced by genotype and muscle type, with sex having secondary effects.

Table 9. The economic performance of broiler production

| Economic Parameters | Genotype | N | Mean ±SEM | Minimum | Maximum | F | p |
|---|---|---|---|---|---|---|---|
| Feed Cost (per bird) | AA | 4 | 2.03±0.03 | 2.00 | 2.10 | | |
| | CC | 4 | 2±0.04 | 1.90 | 2.10 | | |
| | AC | 4 | 2.03±0.03 | 2.00 | 2.10 | 1.333 | 0.310 |
| | CA | 4 | 1.95±0.03 | 1.90 | 2.00 | | |
| | Total | 16 | 2±0.02 | 1.90 | 2.10 | | |
| Total Production Cost (per bird) | AA | 4 | **2.5$^{c}$±0.04** | 2.40 | 2.60 | | |
| | CC | 4 | **2.65$^{a}$±0.03** | 2.60 | 2.70 | | |
| | AC | 4 | **2.6$^{b}$±0.04** | 2.50 | 2.70 | **3.333** | **0.056** |
| | CA | 4 | **2.55$^{b}$±0.03** | 2.50 | 2.60 | | |
| | Total | 16 | 2.58±0.02 | 2.40 | 2.70 | | |
| Revenue (per bird) | AA | 4 | **4.58$^{b}$±0.05** | 4.50 | 4.70 | | |
| | CC | 4 | **5.1$^{a}$±0.06** | 5.00 | 5.20 | | |
| | AC | 4 | **5.0$^{a}$±0.08** | 4.80 | 5.20 | **14.108** | **0.000** |
| | CA | 4 | **4.7$^{b}$±0.07** | 4.50 | 4.80 | | |
| | Total | 16 | 4.84±0.06 | 4.50 | 5.20 | | |
| Net Profit (per bird) | AA | 4 | **2.13$^{b}$±0.03** | 2.10 | 2.20 | | |
| | CC | 4 | **2.45$^{a}$±0.03** | 2.40 | 2.50 | | |
| | AC | 4 | **2.4$^{a}$±0.07** | 2.30 | 2.60 | **10.000** | **0.001** |
| | CA | 4 | **2.18$^{b}$±0.06** | 2.00 | 2.30 | | |
| | Total | 16 | 2.29±0.04 | 2.00 | 2.60 | | |
| Production Cost per kg Live Weight | AA | 4 | **0.92$^{a}$±0.01** | 0.90 | 0.94 | | |
| | CC | 4 | **0.89$^{bc}$±0** | 0.88 | 0.90 | | |
| | AC | 4 | **0.88$^{c}$±0.01** | 0.85 | 0.91 | **4.364** | **0.027** |
| | CA | 4 | **0.92$^{ab}$±0.01** | 0.89 | 0.94 | | |
| | Total | 16 | 0.9±0.01 | 0.85 | 0.94 | | |
| Profitability (%) | AA | 4 | **84.25$^{c}$±1.91** | 79.95 | 89.23 | | |
| | CC | 4 | **91.55$^{ab}$±0.6** | 89.75 | 92.28 | | |
| | AC | 4 | **92.75$^{a}$±2.7** | 86.36 | 99.23 | **4.331** | **0.028** |
| | CA | 4 | **85.97$^{bc}$±2.16** | 81.35 | 91.64 | | |
| | Total | 16 | 88.63±1.29 | 79.95 | 99.23 | | |

Hue angle was particularly sensitive to genotype and sex, whereas chroma and total color difference (ΔE) were predominantly shaped by muscle region. These findings underscore the multifactorial nature of meat quality in reciprocal cross hybrids and the need to consider genetic, sexual, and regional factors simultaneously.

Economic analysis demonstrated that genotype plays a critical role in profitability and cost efficiency. CC and AC genotypes achieved higher revenues, net profits, and profitability percentages, reflecting their superior growth, carcass yield, and market performance, despite similar feed costs across genotypes. This highlights the potential economic advantages of crossbreeding strategies for optimizing both production efficiency and financial returns.

In summary, reciprocal crosses between Anatolian-T and Commercial Broiler parent stocks can enhance carcass traits, meat quality, and economic performance. The effects of genotype, sex, and carcass region differ among traits, providing valuable insights for hybrid breeding programs, parental line selection, and the improvement of overall productivity and profitability in commercial broiler production.

## Declarations

A shortened version of this manuscript has been submitted to TARGID 20026 for presentation at the congress.

### *Ethical Approval Certificate*

The experimental procedures of this study were approved by the Local Animal Care and Ethics Committee of Animal Experiments of Kahramanmaraş Sütçü İmam University (Approval date: 28 February 2025; Approval number: 2025/02)

### *Author Contribution Statement*

The authors declare that they have contributed equally to the work.

### *Conflict of Interest*

The authors declare no conflict of interest.

### *Acknowledgments*

In this study, we would like to thank TAGEM for providing the animal material we used from project number TAGEM/HAYSÜT/G/22/A4/P4/6230.

## References

Adaszyńska-Skwirzyńska, M., Konieczka, P., Bucław, M., Majewska, D., Pietruszka, A., Zych, S., & Szczerbińska, D. (2025). Analysis of the Production and Economic Indicators of Broiler Chicken Rearing in 2020–2023: A Case Study of a Polish Farm. Agriculture, 15(2), 139. https://doi.org/10.3390/agriculture15020139

Afrin, A., Ahmed, T., Lahiry, A., Rahman, S., Dey, B., Hashem, M. A., & Das, S. C. (2024). Profitability and meat quality of fast-, medium- and slow-growing meat-type chicken genotypes as affected by growth and length of rearing. Saudi Journal of Biological Sciences, 31(8), 104025. https://doi.org/10.1016/j.sjbs.2024.104025

Ahmadzadeh, R., Samadian, F., Habibizad, J., Mohagheghi-Dolatabadi, M., & Eivakpour, A. (2025). Effect of Broiler Strain, Sex, and Age on the Live Body Weight and Relative Weights of the Visceral Organs in Broiler Chickens. Journal of Poultry Sciences and Avian Diseases, 3(3), 29-39. https://doi.org/10.61838/kman.jpsad.3.3.5

Becker, W. A., Spencer, J. V., Mirosh, L. W., & Verstrate, J. A. (1981). Abdominal and carcass fat in five broiler strains. Poultry science, 60(4), 693–697. https://doi.org/10.3382/ps.0600693

Calus, M. P. L., Vandenplas, J., Hulsegge, I., Borg, R., Henshall, J. M., & Hawken, R. (2019). Assessment of sire contribution and breed-of-origin of alleles in a three-way crossbred broiler dataset. Poultry science, 98(12), 6270–6280. https://doi.org/10.3382/ps/pez458

Chen, C., Su, Z., Li, Y., Luan, P., Wang, S., Zhang, H., Xiao, F., Guo, H., Cao, Z., Li, H., & Leng, L. (2021). Estimation of the genetic parameters of traits relevant to feed efficiency: result from broiler lines divergent for high or low abdominal fat content. Poultry Science, 100(2), 461–466. https://doi.org/10.1016/j.psj.2020.10.028

Chu, T. T., Madsen, P., Norberg, E., Wang, L., Marois, D., Henshall, J., & Jensen, J. (2020). Genetic analysis on body weight at different ages in broiler chicken raised in commercial environment. Journal of animal breeding and genetics = Zeitschrift fur Tierzuchtung und Zuchtungsbiologie, 137(2), 245–259. https://doi.org/10.1111/jbg.12448

Duenk, P., Calus, M. P. L., Wientjes, Y. C. J., Breen, V. P., Henshall, J. M., Hawken, R., & Bijma, P. (2019). Estimating the purebred-crossbred genetic correlation of body weight in broiler chickens with pedigree or genomic relationships. Genetics Selection Evolution, 51, 6. https://doi.org/10.1186/s12711-019-0447-9

Dzungwe, J. T., Adjei-Mensah, B., Chrysostome, C. A. A. M., & Tozo, K. (2024). Effect of crossbreeding on growth performance, meat quality, and the economics of production of the pure and reciprocal crosses between the Sasso and Wassachie chickens. Poultry science, 103(8), 103823. https://doi.org/10.1016/j.psj.2024.103823

Eleroğlu, H., Develi Işıklı, N., Türkoğlu, M., Okur, N., Uçar, A., & Özlü, S. (2016). Effect of different rearing systems on physical and sensory characteristics of broiler chickens. Journal of Poultry Research, 13(1), 16–21.

Erensoy, K., & Sarıca, M. (2023). Fast growing broiler production from genetically different pure lines in Turkey. 2. Broiler traits: growth, feed intake, feed efficiency, livability, body defects and some heterotic effects. Tropical animal health and production, 55(1), 61. https://doi.org/10.1007/s11250-023-03461-2

Fanatico, A. C., Pillai, P. B., Emmert, J. L., & Owens, C. M. (2007). Meat quality of slow- and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or with outdoor access. Poultry science, 86(10), 2245–2255. https://doi.org/10.1093/ps/86.10.2245

Fletcher, D. L. (2002). Poultry meat quality. World's Poultry Science Journal, 58(2), 131–145. https://doi.org/10.1079/WPS20020013

Gaya, L. G., Ferraz, J. B. S., Rezende, F. M., Mourão, G. B., Mattos, E. C., Eler, J. P., & Michelan Filho, T. (2006). Heritability and genetic correlation estimates for performance and carcass and body composition traits in a male broiler line. Poultry Science, 85(5), 837–843. https://doi.org/10.1093/ps/85.5.837

Gowane GR, Kumar A, Nimbkar C (2019) Challenges and opportunities to livestock breeding programmes in India. J Anim Breed Genet 136(5):329–338

Hamm, R. 1972. Kolloidchemie des Fleisches (ed. P. Parey), Verlag, Berlin, p: 73.

Hartcher KM, Lum HK. (2020). Genetic selection of broilers and welfare consequences: a review. World's Poultry Science Journal 76(1):154-167.

Havenstein, G. B., Ferket, P. R., & Qureshi, M. A. (2003). Growth, livability, and feed conversion of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poultry science, 82(10), 1500–1508. https://doi.org/10.1093/ps/82.10.1500

Hofmann, K. 1982. Bestimmung der Wasserbindung des Fleisches: Auswertung Schnelle, der nichtplanimetrische Filterpapierpressmethode. Fleischwirtschaft, 62, issue 3, p. 346-348, ISSN 0015-363X

Hofmann, K., Hamm, R. ve Bltichel, E. 1982. Neues iiber die Bestimmung der Wasserbindung des Fleisches mit Hilfe der FilterpapierpreBmethode. Fleischwirtsch. 62, 87-92. Reuter, G. 1982 Verfahren zur Erkennung von Fleischqualitatat-sabweichungen bei Schlachttierkdrpern. Fleischwirtsch. 62: 1153-l 160.

Honikel, K.O. ve Hamm, R. 1983. Einsatz von Emulgatoren bei der Herstellung von brtihwurst. IV. Lecithine, Einfluß der Salzkonzentration und des pHWertes. Fleischwirtschaft 63, 1320.

Honikel, K.O. ve Kim, C. J. 1986. Causes of the development of PSE pork. Fleischwirtschaft, 66: 349–353.

Honkavaara, M. 1989. Effect of PSE pork on the processing properties of cooked meat products. Fleischwirtschaft, 69: 1573–1574

Hussein, E. O. S., Suliman, G. M., & Abd El-Hack, M. E. (2019). Effects of stock, sex, and muscle type on carcass characteristics and meat quality attributes of parent broiler breeders and broiler chickens. Poultry Science, 98(12), 6586–6592. https://doi.org/10.3382/ps/pez464

Hutu I, Oldenbroek K, van der Waaji L (2020) Chapter II.3 breeding goals. In: Animal breeding and husbandry textbook. Agroprint Publishing House, Timisoara

Karaman, S., Taşcıoğlu, Y., & Bulut, O. D. (2023). Profitability and Cost Analysis for Contract Broiler Production in Turkey. Animals, 13(13), 2072. https://doi.org/10.3390/ani13132072

Kokoszynski, D., Bernacki, Z., Saleh, M., Steczny, K., & Binkowska, M. (2017). Body Conformation and Internal Organs Characteristics of Different Commercial Broiler Lines. Revista Brasileira de Ciência Avícola, 19(1), 47-51, https://doi.org/10.1590/1806-9061-2016-0262

Le Bihan-Duval, E., Debut, M., Berri, C. M., Sellier, N., Santé-Lhoutellier, V., Jégo, Y., & Beaumont, C. (2008). Chicken meat quality: genetic variability and relationship with growth and muscle characteristics. BMC genetics, 9, 53. https://doi.org/10.1186/1471-2156-9-53

Le Bihan-Duval, E., Millet, N., & Remignon, H. (1999). Broiler meat quality: effect of selection for increased carcass quality and estimates of genetic parameters. Poultry science, 78(6), 822–826. https://doi.org/10.1093/ps/78.6.822

Leeson, S. & Summers, J. D. (2010). Broiler Breeder Production, Nottingham University Press, 2010, 1907284257, 9781907284250

Leeson, S. and Summers, J.D. (2001) Scott's Nutrition of the Chicken, 4th ed., University Books, Guelph, Ontario, Canada, 591 pp.

López, K. P., Schilling, M. W., & Corzo, A. (2011). Broiler genetic strain and sex effects on meat characteristics. Poultry Science, 90(5), 1105–1111. https://doi.org/10.3382/ps.2010-01154

Luo, N., Shu, J., Yuan, X., Jin, Y., Cui, H., Zhao, G., & Wen, J. (2022). Differential regulation of intramuscular fat and abdominal fat deposition in chickens. BMC genomics, 23(1), 308. https://doi.org/10.1186/s12864-022-08538-0

Marchewka, J., Sztandarski, P., Solka, M., Louton, H., Rath, K., Vogt, L., Rauch, E., Ruijter, D., de Jong, I. C., & Horbańczuk, J. O. (2023). Linking key husbandry factors to the intrinsic quality of broiler meat. Poultry science, 102(2), 102384. https://doi.org/10.1016/j.psj.2022.102384

Mebratie, W., Madsen, P., Hawken, R., & Jensen, J. (2018). Multi-trait estimation of genetic parameters for body weight in a commercial broiler chicken population. Livestock Science, 217, 15-18.

Mir, N. A., Rafiq, A., Kumar, F., Singh, V., & Shukla, V. (2017). Determinants of broiler chicken meat quality and factors affecting them: a review. Journal of food science and technology, 54(10), 2997–3009. https://doi.org/10.1007/s13197-017-2789-z

Moreira, G. C. M., Boschiero, C., Cesar, A. S. M., Reecy, J. M., Godoy, T. F., Trevisoli, P. A., Cantão, M. E., Ledur, M. C., Ibelli, A. M. G., Peixoto, J. O., Moura, A. S. A. M. T., Garrick, D., & Coutinho, L. L. (2018). A genome-wide association study reveals novel genomic regions and positional candidate genes for fat deposition in broiler chickens. BMC genomics, 19(1), 374. https://doi.org/10.1186/s12864-018-4779-6

Muth, P. C., & Valle Zárate, A. (2017). Breast meat quality of chickens with divergent growth rates and its relation to growth curve parameters. Archives animal breeding, 60(4), 427-437.

Özbek, M., Petek, M., & Ardıçlı, S. (2020). Physical quality characteristics of breast and leg meat of slow- and fast-growing broilers raised in different housing systems. Archives animal breeding, 63(2), 337–344. https://doi.org/10.5194/aab-63-337-2020

Öztan, A., Vural H. 1993. Sığır etinde su tutma kapasitesi ve serbest su oranı değişimi üzerine bir arastırma, Gıda, 18:(1) 29-33

Paril, J., Reif, J., Fournier-Level, A., & Pourkheirandish, M. (2024). Heterosis in crop improvement. The Plant journal : for cell and molecular biology, 117(1), 23–32. https://doi.org/10.1111/tpj.16488

Peters, S.O., Ozoje, M.O., Adenaike, A.S, Hako Touko, B.A., Tiambo, C.K., Adeleke, M.A., Opoola, O., Dessie, T. (2026). Defining Breeding Goals and Breeding Strategies for Chicken Production Systems in Africa. In: Ibeagha-Awemu, E.M., Peters, S.O., Djikeng, A., Rege, J.E.O. (eds) African Livestock Genetic Resources and Sustainable Breeding Strategies. Sustainable Development Goals Series. Springer, Cham. https://doi.org/10.1007/978-3-031-92076-9_18

Petracci, M., & Cavani, C. (2012). Muscle growth and poultry meat quality issues. Nutrients, 4(1), 1–12. https://doi.org/10.3390/nu4010001

Petracci, M., Mudalal, S., Soglia, F., Cavani, C. (2015). Meat quality in fast- growing broiler chickens. Worlds Poultry Science Journal; 71: 363-374. https://doi.org/10.1017/S0043933915000367

Reuter, G. 1982. Verfahren zur Erkennung von Fleischqualitatat-sabweichungen bei Schlachttierkdrpern. Fleischwirtsch. 62, 1153-l 160

Sarıca, M., Erensoy, K., Oğuzhan, E., Yeter, B., & Camcı, Ö. (2021). Effects of Male Selection for Body Weight on Performance of Offsprings in Broiler Pure-Lines. Brazilian Journal of Poultry Science, 23(3). https://doi.org/10.1590/1806-9061-2021-1464

Shim, M. Y., Karnuah, A. B., Mitchell, A. D., Anthony, N. B., Pesti, G. M., & Aggrey, S. E. (2012). The effects of growth rate on leg morphology and tibia breaking strength, mineral density, mineral content, and bone ash in broilers. Poultry science, 91(8), 1790–1795. https://doi.org/10.3382/ps.2011-01968

Shim, M. Y., Tahir, M., Karnuah, A. B., Miller, M., Pringle, T. D., Aggrey, S. E., & Pesti, G. M. (2012). Strain and sex effects on growth performance and carcass traits of contemporary commercial broiler crosses. Poultry Science, 91(11), 2942–2948. https://doi.org/10.3382/ps.2012-02414

Shim, M. Y., Tahir, M., Karnuah, A. B., Miller, M., Pringle, T. D., Aggrey, S. E., & Pesti, G. M. (2012). Strain and sex effects on growth performance and carcass traits of contemporary commercial broiler crosses. Poultry science, 91(11), 2942–2948. https://doi.org/10.3382/ps.2012-02414

Tallentire, C. W., Leinonen, I., & Kyriazakis, I. (2016). Breeding for efficiency in the broiler chicken: A review. Agronomy for Sustainable Development, 36(4), Article 66. https://doi.org/10.1007/s13593-016-0398-2

Tallentire, C.W., Leinonen, I. & Kyriazakis, I. (2016). Breeding for efficiency in the broiler chicken: A review. Agron. Sustain. Dev. 36, 66. https://doi.org/10.1007/s13593-016-0398-2

Türkoğlu M, Sarıca M. (2018). "Tavuk Genetiği ve Islahı" Tavukçuluk Bilimi, Yetiştirme, Besleme, Hastalıklar. Ankara: Editörler M.Türkoğlu, M.Sarıca; p.354-404

Uçar A, Elibol O, Türkoğlu M (2025). The Effect of Male Broiler Parent Live Weight Differences during the Growing Period on Progeny Broiler Performance. Journal of Agricultural Sciences (Tarim Bilimleri Dergisi), 31(2):332-343. DOI: 10.15832/ankutbd.1502100

van Grevenhof, I. E., & van der Werf, J. H. (2015). Design of reference populations for genomic selection in crossbreeding programs. Genetics, selection, evolution : GSE, 47(1), 14. https://doi.org/10.1186/s12711-015-0104-x

Vanlalhmangaihsanga, Roy NK, Lalrinkima, Praharaj N, Mohanty S, Majumder S. (2025). Performance and financial analysis in broiler (cobb 430 y strain): A case review on the feed conversion ratio and mortality rate. Veterinaria, 74(1), 113-23, doi.org/10.51607/22331360.2025.74.1.113

Wang, G., Kim, W. K., Cline, M. A., & Gilbert, E. R. (2017). Factors affecting adipose tissue development in chickens: A review. Poultry science, 96(10), 3687–3699. https://doi.org/10.3382/ps/pex184

Xie, C., Macelline, S., Liu, S., & Toghyani, M. (2026). Interactions of dietary nutrient density with genotype and sex in broiler chickens: implications for growth, carcass quality, and nutrient utilization. Poultry science, 105(1), 106147. https://doi.org/10.1016/j.psj.2025.106147

Zayas J.F., Lin C.S. 1988. Storage Stability of Frankfurters Containing Corn Germ Protein. Journal of Food Quality. Vol: 53, Issue: 6, P: 1587-1591.

Zayas J.F., Lin C.S. 1989. Frankfurters Supplemented with Corn Germ Protein: Sensory Characteristics, Proximate Analysis and Amino Acid Composition. Journal of Food Quality. Vol: 11, Issue: 6, P: 461-474.

Zuidhof, M. J., Schneider, B. L., Carney, V. L., Korver, D. R., & Robinson, F. E. (2014). Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005. Poultry Science, 93(12), 2970–2982. https://doi.org/10.3382/ps.2014-04291