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Growth and Carcass Traits Comparison of Different Chicken Strains Under On-Station Conditions

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ABSTRACT

Background and Objective: Genetic improvement in poultry can be achieved through selection or crossbreeding. Understanding the factors that affect growth and carcass characteristics is crucial for poultry enterprises. The study aimed to investigate and compare the effect of genotype and sex on growth and carcass characteristics of Cosmopolitan (C), Improved Horro (H), ♂Improved Horro*Cosmopolitan♀ (HC), ♂Cosmopolitan*Improved Horro♀ (CH), Indigenous (L) and Koekoek (KK) genotypes under on station condition at Werer Agricultural Research Center in Ethiopia. **Materials and Methods:** A completely randomized design was used. A total of 720 and 114 chickens were used for the growth and carcass, respectively. Data on body weight, body weight change, weight gain feed intake, feed conversion ratio and characteristics were collected and derived. The data collected was summarized and analyzed by GLM model using SAS software. **Results:** Koekoek (KK) chickens had the highest body weight, weight gain and feed intake, with the lowest feed conversion ratio, while Indigenous chickens (L) had the lowest values. Males exhibited better growth metrics but poorer feed efficiency and mortality compared to females. Slaughter, dressed and eviscerated weights, as well as individual carcass parts, were highest in KK and lowest in L, with males outperforming females. Overall, genotype and sex significantly impact growth and carcass traits. **Conclusion:** Growth and carcass characteristics are affected by genotypes, sexes and their interactions.

KEYWORDS

Cosmopolitan, Horro, Koekoek (kk) chickens, carcass traits, genotype, genetic improvement

INTRODUCTION

The current global human population is 8.00 billion and is expected to be 9.70 billion globally by 2050, whereas the current human population of Ethiopia is 120 million and will reach 175.50 million by 2040[1]. In chicken, growth can be defined as a change in the weight of a genotype over time and has a great impact on the value of the live chicken for both breeding value and retail meat[2,3]. Genetic improvement can be made either by selection or crossbreeding[4,5]. Understanding factors that affect growth and carcass characteristics is important in poultry enterprise[6]. Additionally, growth and carcass traits are quantitative traits that depend on multiple factors such as genetic make-up, sex, age and nutrition[7-9]. The proportions and distribution of lean tissue in poultry carcass are crucial factors to consider[10]. Slow-growing birds typically exhibit a lower growth rate and require more feed per kilogram of body weight gain compared to their faster-growing counterparts[11-13].

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Edible components of poultry carcasses consist of meat, skin with subcutaneous fat and giblets (gizzard, liver and heart and may also include abdominal fat in guinea fowl[14]. The relative proportions of edible and inedible parts in carcasses vary across poultry species and are an important economic factor[15]. Muscle tissue grows more rapidly compared to internal organs and non-edible parts like feathers and blood[16].

Selection of the Horro chicken has resulted in a 95% increase in body weight by 16 weeks and a 123% increase in egg production by 45 weeks of age[17]. Cosmopolitan chickens, known for their diverse genetic backgrounds from various domestic breeds worldwide, are capable of producing up to 200 eggs per year[18]. The Koekoek genotype (KK), an exotic breed combining White Leghorn, Black Australorp and Barred Plymouth Rock, serves dual purposes with its large body size (2-3 kg at 24 weeks) suitable for meat production[19,20]. In Ethiopia, the weight of the Indigenous chicken is low when compared to exotic chicken[21]. The Indigenous chicken is characterized by low meat and egg production performance, live in low input-output productions, resistant to diseases and highly adaptive to tropical environmental conditions.

In Ethiopia effort has been made to develop and test genotypes or strains that could be tolerant to tropical environment. The country has implemented different strategies for improving the livestock sector performance such as selection in the long run and cross breeding. Crossbreeding of chickens to increase both meat and egg of the intensive and extensive system is still under way[22]. The Indigenous chicken (L) was used as a reference based on previous selection and breeding studies[23]. Since the Cosmopolitan breed is newly introduced to Ethiopia, initial research is needed to document its growth and carcass characteristics before widespread use. Furthermore, direct and reciprocal crosses between Cosmopolitan (C) and Improved Horro (H), Cosmopolitan♂*Improved Horro♀ (CH) and Improved Horro♂*Cosmopolitan♀ (HC) are being studied to explore variations in growth and carcass traits among these genotypes and sexes, with comparisons made to Indigenous (L) and Koekoek (KK) genotypes. Therefore, the objective of this study was to investigate and compare the effect of genotype and sex on growth and carcass characteristics of different chickens.

MATERIALS AND METHODS

Description of the study areas: The experiment was conducted at Werer Agricultural Research Center (WARC), Ethiopia from 2021 to 2022. The Werer Agricultural Research Center is located 280 km away from Ethiopia's capital, Addis Ababa and is also located at an Altitude of 820 m above sea level and 9°55'N Latitude and 40°40'E Longitude. The annual rainfall and average minimum and maximum temperatures for Werer Agricultural Research Center range from 400 to 600 mm and 19.3 to 45°C, respectively.

Experimental animals, managements and sampling procedures

Ethical approval and experimental chicken genotypes: This experiment was managed following the guidelines approved by the Institutional Animal Care and Use Committee (IACUC) and conducted jointly with the article reported by Choo *et al.*[24]. The experimental animals were namely: I = Improved Horro (H), II = Cosmopolitan (C), III = Koekoek (KK), IV = Indigenous (L), V= Cosmopolitan♂*Improved Horro♀(CH) and VI = Improved Horro♂*Cosmopolitan♀(HC).

Managements and sampling procedures: Experimental chickens were obtained from the Debre Zeit Agricultural Research Center. Prior to the experiment, watering and feeding troughs were cleaned, disinfected and treated for external parasites. Each pen's floor was covered with 15 cm of disinfected grass hay to absorb moisture, with replacement as needed. Chickens were allocated 0.25 m^2 of floor space each in randomly assigned pens, with 24 pens available, each measuring 7.50 m^2. All chickens received the same commercial feed, with formulations adjusted for different growth phases: Starter (20.50% crude protein, 3000 kcal/kg ME), grower (18.80% crude protein, 2950 kcal/kg ME) and finisher (16.00% crude protein, 2800 kcal/kg ME) (Alema feeds Co., Ltd., Debre Zeit, Ethiopia). Vaccinations were administered against Newcastle disease, Gumboro (Infectious Bursal Disease-IBD) and Fowl Typhoid according to guidelines from the Ethiopian National Veterinary Institute in Bishoftu, Ethiopia (Table 1). Experimental chickens were

Table 1: Vaccination schedules for all experimental genotypes

Day	Week	Name and type of vaccination	Route of administration
1	1	Marek's	Sub-cutaneous
3	1	NCDV(HB1)	Ocular (eye droplet)
9	2	Gumboro (IBDV)	Drinking water
21	3	Gumboro (IBDV)	Drinking water
27	3	NCDV(Lasota strain vaccine)	Drinking water
45	6	Fowl typhoid	Sub-cutaneous
63	8	NCDV(Lasota strain vaccine)	Drinking water
90	12	Fowl typhoid	Sub-cutaneous
70-105	10-14	Fowl pox	Wing web
112-120	16	NCDV (inactivated)	Ocular (eye droplet)

NCDV: Newcastle diseases vaccine and IBDV: Infectious bursal disease vaccine

reared as mixed-sex and subjected to similar management under on-station conditions. Health Stata were monitored during the entire trial. Feed manufactured by Alema Koudjis; Feed Co., Ltd., Debrezeit, Ethiopia was used during the entire trial period and supplements were given through drinking water. For growth study, a total of 720 genotypes and 30 chickens/pen of each genotype in a ratio of 1 to 5 male to female were considered in this study. For the carcass characteristics trial, a total of 144 chickens (72 males, 72 females) and (24/genotype; 12/sex per genotype) chickens were considered for this study.

Animal welfare, growth and slaughtering procedures: The chickens were slaughtered following the guidelines approved by the Institutional Animal Care and Use Committee (IACUC) and conducted jointly[24].

Growth characteristics of KK, CH, HC, C, H and L genotypes: Feed provided to the chickens in each pen, along with feed residual, was recorded before each weighing. Average feed intake (AFI) was determined by subtracting the residual feed from the amount given. Feed conversion ratio (FCR) was computed as the grams of AFI per unit of body weight. Average daily gain (ADG) was calculated by dividing the weight gain in grams by the number of days. Body weight change (BWC) was the difference between the final and initial body weights. The mortality rate (MR%) was calculated by dividing the number of deceased chickens by the initial number, then multiplying by 100 to express it as a percentage.

Carcass characteristics of KK, CH, HC, C, H and L genotypes: The chickens were slaughtered following the guidelines approved by the Institutional Animal Care and Use Committee (IACUC) and the chickens were fasted for 12 hrs with free access to drinking water. The chickens were weighed at 24 weeks of age. Moreover, after stunning the chickens were slaughtered and thereafter bled. The chickens were scalded at the recommended water temperature of 53°C. The scalded chickens were de-feathered. The de-feathered carcasses were eviscerated and dissected using dissector blades into various parts such as breast (with bone and skin), drumstick (with bone and skin), thigh (with bone and skin), back, wings, giblets (heart, liver and gizzard) and abdominal fat. The different parts were measured using a sensitive scale (NANBEI; NBT-A200; China) and were expressed in grams (g) and/or percentages. Then, carcasses were washed and placed in airtight plastic bags and carcasses were chilled for 24 hrs at 4°C. Finally, the corresponding percent weight of carcass parameters or traits was computed with respect to their live weight at slaughter (%SW).

Experimental design: A factorial arrangement with two factors (genotype and sex) in the CRD (Completely Randomized Design) was used for the study.

Statistical analysis: The data was recorded as per the prepared sheet and was entered into Excel regularly. The data collected was summarized and analyzed by GLM model using SAS software version 9.00. When the GLM showed a significant difference at $p<0.05$, Duncan's multiple range tests were used for mean separation[25].

The model used for the analysis was:

$$Y_{ijk} = \mu + G_i + S_j + (G_i \times S_j) + e_{ijk}$$

Where:

Y_{ijk} = Response variables
μ = Overall mean
G_i = Effect of genotype (i = 1, 2, 3, 4, 5 and 6)
S_j = Effect of sex (j = 1, 2)
$G_i \times S_j$ = Interaction between genotype and sex
e_{ik} = Random error

RESULTS AND DISCUSSION

Effect of genotype on growth traits of different chickens at different ages (unsexed age included): The result of the effect of genotypes on the growth traits of different chickens is indicated in Table 2. The body weight at hatch (BW0) was significantly ($p \leq 0.01$) the highest for KK, high for HC, CH, C and H and the lowest for L chicken genotypes. Body weight at hatch varied across genotypes[12]. The EM and WB chickens had lower body weight at hatch than the CB chickens[25]. In line with the study, the differences in hatch weight of the chickens could be attributed to variations among genotypes and egg sizes[26]. Significantly heaviest body weight and body weight change at 8 weeks of age (BW8, BWC8) were recorded in the KK genotype followed by HC and CH, whereas the lightest body weight and body weight change at 8 weeks of age were observed in the L genotype followed by H and C. Additionally, the daily weight gain at 8 weeks of age (ADG8) was significantly ($p \leq 0.001$) the highest for KK (10.43±0.52 g), higher for HC (8.85±0.45 g), high for CH (8.60±0.38 g) and C (8.44±0.25 g), low for H (8.05±0.23 g) and the lowest for L (6.56±0.29 g) chickens. The highest body weight and body weight change at 16 weeks of age (BW16, BWC16) were demonstrated in the KK chicken followed by HC and CH, whereas the lowest body weight and body weight change at 16 weeks of age were exhibited in the L chicken followed by H and C. The daily weight gain (ADG16) was significantly ($p \leq 0.001$) the highest for KK chicken followed by HC, CH, C and H, while the ADG16 was notably the lowest for L chicken. The heaviest body weight, body weight change and daily weight gain at 24 weeks of age (BW24, BWC24) were revealed in the KK chicken followed

Table 2: Effect of genotype on growth traits of KK, CH, HC, C, H and L different chickens (unsexed age included)

	Genotype (Mean±SE)						p-value
Category	Koekoek genotypes	Cosmopolitan* improved horro	Cosmopolitan	Improved horro* cosmopolitan	Improved horro	Indigenous	G
Traits (0-8 weeks)							
BW0	32.79±0.42^{a}	28.98±0.31^{b}	28.63±0.36^{b}	28.51±0.40^{b}	28.86±0.24^{b}	25.77±29^{c}	**
BW8	658.36±20.26^{a}	544.83±16.58^{b}	535.24±15.74^{cb}	560.14±17.85^{b}	511.71±13.42^{c}	419.16±11.97^{d}	***
BWC8	625.57±17.54^{a}	515.85±14.73^{b}	506.61±13.26^{cb}	531.63±15.62^{b}	482.42±12.54^{c}	393.39±11.31^{d}	***
ADG8	10.43±0.52^{a}	8.60±0.38^{cb}	8.44±0.25^{cb}	8.85±0.45^{b}	8.05±0.23^{c}	6.56±0.29^{d}	***
Traits (8-16 weeks)							
BW16	1766.44±25.06^{a}	1428.63±19.11^{c}	1288.84±15.85^{cd}	1500.34±21.19^{b}	1228.11±15.03^{d}	1013.76±13.59^{e}	***
BWC16	1108.08±24.38^{a}	883.80±18.72^{bc}	753.60±15.46^{c}	940.20±20.19^{b}	716.40±14.85^{d}	594.60±12.91^{e}	***
ADG16	18.48±0.72^{a}	14.73±0.55^{c}	12.56±0.38^{d}	15.67±0.46^{b}	11.94±0.29^{d}	9.91±0.24^{e}	***
Traits (0-24 weeks)							
BW24	2319.78±22.36^{a}	1870.59±17.64^{bc}	1665.69±15.58^{c}	1970.53±19.82^{b}	1579.54±13.65^{d}	1311.10±11.96^{e}	***
BWC24	2286.99±18.52^{a}	1841.61±15.29^{bc}	1637.06±13.65^{c}	1942.02±17.13^{b}	1550.68±12.09^{cd}	1285.33±10.11^{d}	***
ADG24	12.71±0.64^{a}	10.23±0.48^{bc}	9.09±0.36^{c}	10.79±0.41^{b}	8.61±0.33^{d}	7.14±0.19^{e}	***

[abcd]Mean under the same category bear different superscript letters are significantly different, ***p<0.001, **p<0.01, SE: Standard error, BW0, BW8, BW16 and BW24 stand for body weight(g) at hatch, 8, 16 and 24 weeks of age, BWC8, BWC16 and BWC24 stand for body weight change (g) at 0-8, 8-16 and 0-24 weeks of age, ADG8, ADG16 and ADG24 stand for daily weight gain (g) at 0-8, 8-16 and 0-24 weeks of age

by HC and CH, whereas the lightest body weight and body weight change at 24 weeks of age were confirmed in L followed by H and C. The daily weight gain at 24 weeks of age (ADG24) was significantly ($p \leq 0.001$) the heaviest for KK chicken followed by HC, CH, C and H, while the ADG24 was remarkably the lightest for L chicken. In line with the study, the differences in BW, BWC and ADG are possibly attributed to variations in genetic potential[26]. The combined effect of genotype and feeding might be the reasons for variations in body weight (BW), body weight change (BWC) and daily weight gain (ADG) among different strains of chickens and/or birds[26].

Effect of genotype and sex on growth traits of KK, CH, HC, C, H and L chicken genotypes (8-24 weeks or sexed age): The result of the effect of genotype and sex on growth traits of different chickens was presented in Table 3. The highest body weight change and daily weight gain (BWC8-24, ADG8-24) were noticed in the KK followed by HC and CH, whereas the lowest BWC8-24 and ADG8-24 were discovered in L followed by H and C chickens at sexed ages (8-24 weeks). The KK chicken had superior feed intake (AFI8-24) to HC and CH but L chicken had the least AFI8-24 followed by H and C (8-24 weeks). The KK had better conversion ratio (FCR8-24) compared to CH and HC, whereas L chicken had the worst FCR8-24 followed by H and C (8-24 weeks). Fast growing chickens had notably higher BWC, ADG, AFI and better FCR compared to slow growing chickens. Also, BWC, AFI and FCR were affected by genotypes[27,28]. Male chickens exhibited higher BWC8-24, owned more ADG8-24, showed more AFI8-24 and revealed better FCR8-24 compared to females (8-24 weeks). Male chickens had higher BW, ADG and FI but lower FCR than females[29,30]. The differences between genders might be attributed to influences of hormones[31]. The interactions of genotype and sex had significant effect on BWC8-24, ADG8-24, AFI8-24 and FCR8-24 similar to the results reported by Abdullah *et al*.[32] and Obike *et al*.[33]. In contrast, BWC, ADG, AFI and FCR were unaffected by genotype and sex interactions[34]. Similarly, there was an insignificant interaction effect between breed and gender in BWC, ADG, AFI and FCR[19].

Effect of genotype on AFI and FCR of different chickens at different ages: Effect of genotype on AFI and FCR of different chickens at different ages were shown in Fig. 1. The feed intake up to 8 weeks of age (AFI8) was significantly the highest for KK and HC, higher for CH and C, high for H, while L had the lowest for AFI8. In addition, the feed intake from 8 to 16 weeks of age (AFI16) was remarkably the highest for KK, higher for HC, high for CH, low for C, lower for H, but L had the lowest for AFI16. Also, the feed intake up to 24 weeks of age (AFI24) was considerably the highest for KK, higher for HC and CH, high for C, lower for H, whereas L had the lowest for AFI24. In line with current finding, the difference in AFI in different age groups is attributed to the size variation of the chickens[12,19]. The genotypes with relatively heavier slaughter weights had relatively higher AFI[12,20,25]. Furthermore, the variation in AFI of chickens might also be affected by multiple factors including sex and age[11,35]. Feed conversion ratio (FCR) is a performance index that indicates how best feed consumed by birds is utilized for meat production. The feed conversion ratio up to eight weeks of age (FCR8) was significantly the lowest for KK, lower for HC, low for CH, high for C and higher for H, while L had the lowest for FCR8. The feed conversion ratio from 8 to 16 weeks of age (FCR16) was significantly the lowest for KK, lower for HC and CH and high for C and H, but L had the highest for FCR16. The feed conversion ratio up to 24 weeks of age (FCR24) was significantly the lowest for KK, lower for HC and CH, high for C and higher for H, whereas L had the highest for L for FCR24. The FCR can be affected by genotypes[34]. Moreover, exotic breeds had notably better FCR than other dual-purpose breeds investigated[35]. The results of this study agreed that genotype significantly affected FCR. The difference in FCR among genotypes might be due to the effect of genetic manipulation[36].

Effect of genotype and sex on morality rate (MR) of different chickens at different ages: The effect of genotype and sex on mortality rate (MR) of different chickens at different ages is shown in Fig. 2-3. The mortality rate up to 8 weeks of age (MR1) was significantly ($p \leq 0.01$) the lowest for L (2.24%) and

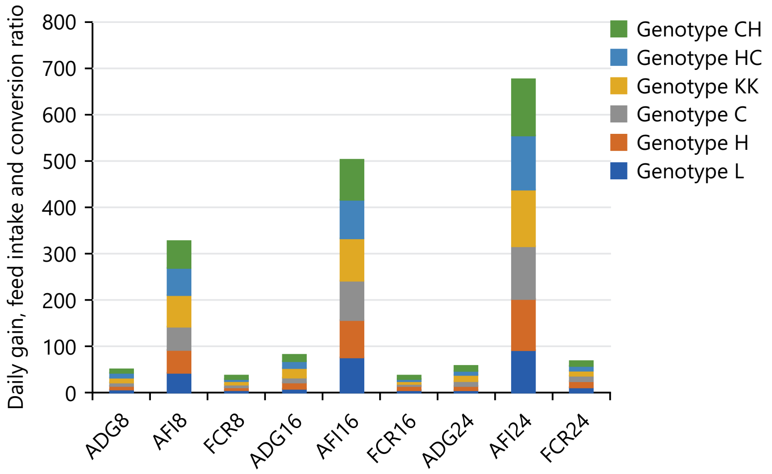

Fig. 1: Effect of genotype on AFI and FCR at 0-8, 8-16 and 0-24 weeks, respectively

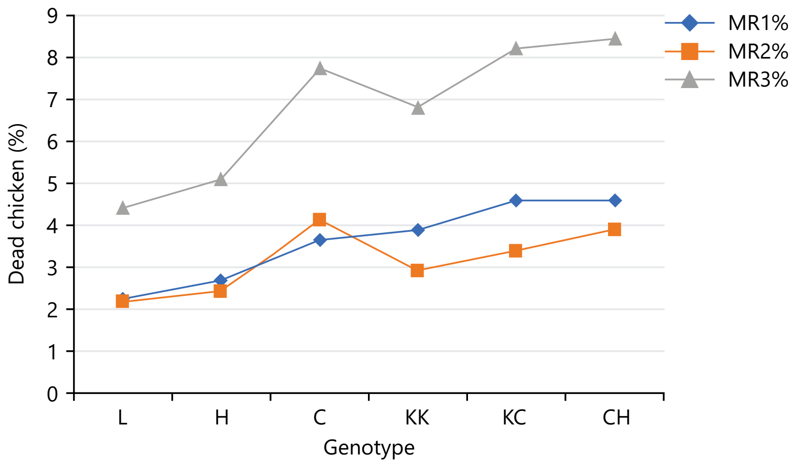

Fig. 2: Effect of genotype on mortality rate at 0-8, 8-16 and 0-24 weeks, respectively

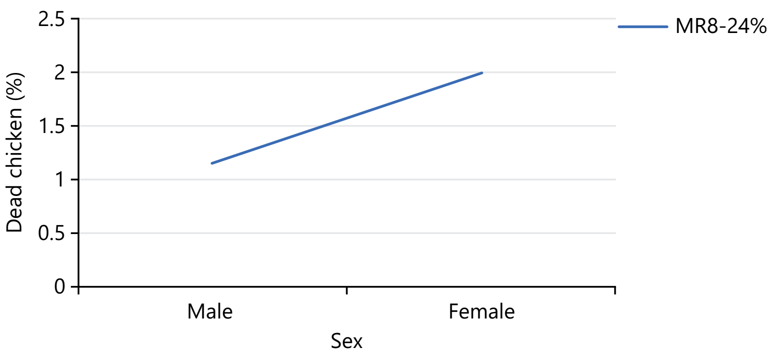

Fig. 3: Mortality rate (%) male and female chickens at 8-24 weeks

H (2.68%), high for C (3.63%) and KK (3.88%) and the highest for HC (4.57%) and CH (4.57%) genotypes. The mortality rate from 8 to16 weeks of age (MR2) was significantly ($p \leq 0.01$) the lowest for L (2.17%) and H (2.41%), low for KK (2.92%), higher for HC (3.39%) and CH (3.87%) and the highest for C (4.11±0.30) genotypes. The highest mortality rate was recorded in Kuroiler and Koekoek but the lowest was observed in Sasso-R from 8-16 weeks[19]. The mortality rate up to 24 weeks of age (MR3) was significantly ($p \leq 0.001$) the lowest for L (4.41%), lower for H (5.09%), low for KK (6.80%), high for C (7.74%), higher for CH (8.21%) and the highest for CH (8.44%) genotypes. The rate of mortality affected by genotypes[26].

Table 3: Effect of genotype and sex on growth traits of KK, CH, HC, C, H and L chicken genotypes (8-24 weeks or sexed age)

Category	Genotype (Mean±SE)						Sex (S)		p-value		
Parameter	Koekoek genotype	Cosmopolitan♂*♀Improved horro	Cosmopolitan	Improved horro♂*♀cosmopolitan	Improved horro	Indigenous	Male	Female	G	S	G×S
BWC8-24	1661.42±21.45^{a}	1325.76±17.01^{bc}	1130.45±13.46^{c}	1410.03±18.66^{b}	1067.83±13.47^{d}	891.94±11.51^{e}	1410.52±19.60^{a}	993.78±13.41^{b}	***	***	***
ADG8-24	13.84±0.68^{a}	11.05±049^{c}	9.42±0.38^{d}	11.75±0.44^{b}	8.90±0.31^{de}	7.43±0.24^{e}	11.75±0.52^{a}	8.28±0.34^{b}	***	***	***
AFI8-24	90.58±1.73^{a}	85.25±1.33^{b}	83.44±1.28^{c}	86.65±1.51^{b}	80.64±1.23^{d}	76.43±1.03^{e}	83.64±1.45^{a}	75.28±1.22^{b}	***	***	***
FCR8-24	6.54±0.08^{e}	7.71±0.09^{d}	8.86±0.07^{c}	7.37±0.10^{d}	9.06±0.08^{b}	10.29±0.05^{a}	7.12±0.09^{b}	9.09±0.06^{a}	***	***	***

[abcde]Mean under the same category bear different superscript letters are significantly different, ***p<0.001, **p<0.01, *p<0.05, SE: Standard error, BWC8-24, ADG8-24, AFI8-24 and FCR8-24 stand for body weight (g), daily weight gain (g), feed intake and feed conversion ratio from 8-24 weeks or sexed age

Table 4: Effect of genotype and sex on carcass characteristics of KK, CH, HC, C, H and L chickens

Category	Genotype (Mean±SE)						Sex (S)		p-value		
Parameter	Koekoek genotype	Cosmopolitan♂*♀Improved horro	Cosmopolitan	Improved horro♂*♀cosmopolitan	Improved horro	Indigenous	Male	Female	G	S	G×S
SW (g)	2378.47±35.18^{a}	2113.62±33.22^{bc}	2074.86±32.19^{bc}	2159.83±36.95^{b}	1896.54±31.68^{c}	1465.58±34.03^{d}	2310.74±54.83^{a}	1718.89±40.57^{b}	***	***	***
DW (g)	1829.81±28.52^{a}	1687.31±23.19^{bc}	1676.86±19.63^{bc}	1698.49±24.07^{b}	1497.56±20.41^{c}	1193.69±22.36^{d}	1903.13±37.22^{a}	1287.91±31.64^{b}	***	***	***
DW (%)	76.89±2.91^{d}	79.83±2.24^{b}	80.77±2.11^{b}	78.64±2.51^{c}	78.91±1.93^{c}	81.38±2.08^{a}	82.36±2.47^{a}	74.92±1.96^{b}	**	***	**
EV (g)	1748.94±26.04^{a}	1614.17±23.83^{b}	1631.86±18.69^{b}	1639.31±20.16^{b}	1443.08±19.17^{c}	1162.59±20.65^{d}	1814.62±28.14^{a}	1240.86±22.71^{b}	***	***	***
EV (%)	73.49±1.84^{d}	76.37±1.30^{c}	78.62±1.55^{b}	75.90±1.22^{c}	76.09±1.38^{c}	79.26±1.49^{a}	78.53±1.72^{a}	72.19±1.48^{b}	**	***	**

[abcd]Mean under the same category bear different superscript letters are significantly different, ***p<0.001, **p<0.01, *p<0.05, SE: Standard error, SW: Slaughter weight (g), DW: Dressed weight (g), DW: Dressed weight (%), EV: Eviscerated weight (g) and EV: Eviscerated weight (%)

Nonetheless, the rate of mortality was slightly influenced among genotypes[12]. The mortality rate from 8 to 24 weeks of age (MR8-24) was significantly higher in females (1.98%) than in males (1.15%). The rate of mortality of birds in the tropics during the rearing period is less than 15%[37]. The difference in mortality rate might be due to the combined effect of genetic and non-genetic factors[38].

Effect of genotype and sex on carcass characteristics of KK, CH, HC, C, H and L chickens: The slaughter weight (SW) and dressed weight (DW) were significantly the highest for KK, higher for HC, high for CH and C and lower for H, but L had the lowest SW weeks of age (Table 4). Consistent with the current study, PK genotype had meaningfully higher SW and DW compared to others (PK>HR = TL>GF)[12]. On the other hand, Ho had notably lower SW and DW than that of others studied (Ku Sa-R<Ko<Ho)[19]. The eviscerated weight (EV) was significantly the highest for KK, higher for HC, C and CH, high for H; however, L had the lowest EV at 24 weeks of age. The EV approved significant variation among genotypes[21]. The genotypes with heavy body weight have higher EV compared to lighter weight genotypes[7]. Also, EV might be affected due to dietary[39]. The DW% was significantly the highest for L, higher for C and CH, high for H and HC, while KK had the lowest DW% at 24 weeks of age. The EV% was significantly the highest for L, higher for C, high for CH, H and HC, while KK had the lowest EV% at 24 weeks of age. The SW, DW, EV, DW and EV% were significantly higher in males than in females at 24 weeks of age. The SW, DW, EV, DW and EV% were significantly influenced by genotype and sex interaction. The significantly lower proportion of DW and EV heavier chickens from relatively lighter chickens could be due to the variation of share of the less valuable edible and non-edible carcass cut parts[21]. In line with the result, Motsepe *et al.*[6] and Kryeziu *et al.*[19] illustrated that the SW, DW, EV, DW and EV% were genotype and sex dependent. Genotype by sex interaction could affect SW, DW, EV, DW and EV% values[40,41]. On the contrary, SW, DW, EV, DW and EV% were insignificantly varied by genotype and gender interaction[27,29].

Effect of genotype and sex on breast, drumstick and thigh characteristics of KK, CH, HC, C, H and L chickens: The breast weight (BWT) was significantly the highest for KK, higher for C, high for HC and CH and lower for H, but L had the lowest BWT at 24 weeks of age (Table 5). The drumstick weight (DWT) was considerably the highest for KK, higher for HC, high for CH, intermediate for CH, low for C and lower for H, whereas L had the lowest BWT at 24 weeks of age. The thigh weight (TWT) was substantially the highest for KK, higher for HC, high for CH, low for C and lower for H, but L had the lowest TWT at 24 weeks of age. The BWT, DWT and TWT varied among genotypes[19]. The PK genotype had notably bigger BWT, DWT and TWT compared to HR, TL and GF genotypes[12]. The genotypes and sexes with lighter bone frames and fast runners could have lower sized BWT, DWT and TWT[42].

The BWT% was significantly the highest for L, higher for H, high for C, CH and KK, but HC had the lowest BWT% at 24 weeks of age. The CB had the highest proportion of BWT followed by WB and EB genotypes[24]. Conversely, Ross chickens had the highest proportion of BWT compared to JA, medium and ISA dual chickens. Scholars explained that genotypes with less proportion of BWT might be affected by the size of less valuable carcass parts[43]. The DWT% was significantly the highest for KK, higher for HC, high for CH, low for C and lower for H, whereas L had the lowest DWT% at 24 weeks of age. The proportion of DWT was profoundly affected by genotypes.

The TWT% was significantly the highest for KK, higher for HC, high for CH and low for C, whereas H and L had the lowest TWT% at 24 weeks of age. On the other hand, the proportion of TWT slightly differed across chickens[29]. The BWT, DWT and TWT were significantly higher in males than in females at 24 weeks of age. In line with the study, males had substantially higher BWT, DWT and TWT than females[44]. The BWT, DWT and TWT% were significantly higher in males than in females at 24 weeks of age. Agreeably, males had substantially higher BWT, DWT and TWT% than females[45]. Additionally, males had significantly higher BWT% than females[46]. The BWT, BWT, DWT, DWT, TWT and TWT% were significantly affected by genotype and sex interaction. In agreement, BWT, DWT and TWT were remarkably influenced

Table 5: Effect of genotype and sex on breast, drumstick and thigh characteristics of KK, CH, HC, C, H and L chickens

Category	Genotype (Mean±SE)						Sex (S)		p-value		
Parameter	Koekoek genotype	Cosmopolitan♂* ♀Improved horro	Cosmopolitan	Improved horro♂* ♀cosmopolitan	Improved horro	Indigenous	Male	Female	G	S	G×S
BWT (g)	403.86±6.39^{a}	362.06±4.43^{bc}	372.64±5.62^{b}	363.93±7.03^{bc}	346.87±4.58^{c}	285.35±4.99^{d}	496.58±7.56^{a}	298.23±5.19^{b}	***	***	***
BWT (%)	16.98±0.53^{bc}	17.13±0.49^{bc}	17.96±0.43^{bc}	16.85±0.45^{c}	18.29±0.21^{ba}	19.47±0.26^{a}	21.49±0.84^{a}	17.35±0.31^{b}	**	**	**
DWT (g)	270.66±5.68^{a}	217.58±4.19^{c}	205.83±4.73^{cd}	239.53±5.91^{b}	175.24±4.07^{de}	128.41±3.85^{e}	281.45±6.47^{a}	136.14±5.02^{b}	***	***	***
DWT (%)	11.38±0.54^{a}	10.31±0.59^{c}	9.92±0.41^{dc}	11.09±0.72^{b}	9.24±0.43^{d}	8.76±0.37^{e}	12.18±0.82^{a}	7.92±0.49^{b}	**	**	**
TWT (g)	311.34±5.84^{a}	246.66±4.82^{c}	224.71±5.16^{cd}	263.28±6.18^{b}	196.86±4.33^{d}	147.14±4.09^{e}	308.95±5.24^{a}	162.26±4.71^{b}	***	***	***
TWT (%)	13.09±0.39^{a}	11.67±0.32^{bc}	10.83±0.44^{dc}	12.19±0.42^{ba}	10.38±0.17^{d}	10.04±0.19^{d}	13.37±0.53^{a}	9.44±0.26^{b}	**	**	**

^{abcd}Mean under the same category bear different superscript letters are significantly different, ***p<0.001, **p<0.01, *p<0.05, SE: Standard error, BWT (g): Breast weight (g), BWT (SW%): Breast weight (SW%), DWT (g): Drumstick weight (g), DWT (SW%): Drumstick weight (SW%), TWT (g): Thigh weight (g) and TWT (SW%): Thigh weight (SW%)

Table 6: Effect of genotype and sex on some carcass components of KK, CH, HC, C, H and L chickens

Category	Genotype (Mean±SE)						Sex (S)		p-value		
Parameter	Koekoek genotype	Cosmopolitan♂* ♀Improved horro	Cosmopolitan	Improved horro♂* ♀cosmopolitan	Improved horro	Indigenous	Male	Female	G	S	G×S
Wing (g)	103.49±3.57^{a}	90.67±3.31^{bc}	87.97±3.29^{c}	93.01±3.75^{b}	78.71±3.14^{d}	58.16±2.84^{e}	112.53±3.87^{a}	65.66±2.93^{b}	***	***	***
Back (g)	224.05±4.17^{a}	191.28±3.22^{bc}	184.87±2.93^{c}	200.22±3.74^{b}	162.91±3.08^{d}	119.15±3.06^{e}	229.23±4.64^{a}	134.93±3.16^{b}	***	***	***
Neck (g)	93.71±1.99^{a}	79.47±1.71^{c}	76.35±1.58^{c}	82.72±1.82^{b}	70.36±1.57^{d}	52.03±1.41^{e}	91.51±2.24^{a}	63.77±1.62^{b}	**	***	**
Gizzard (g)	51.61±1.73^{a}	40.79±1.36^{c}	38.59±1.34^{c}	44.06±1.59^{b}	28.64±1.31^{d}	20.37±1.27^{e}	51.07±1.83^{a}	26.64±1.30^{b}	***	***	***
Liver (g)	48.52±1.68^{a}	38.68±1.61^{bc}	36.52±1.57^{c}	40.82±1.65^{b}	30.53±1.44^{d}	21.54±1.39^{e}	42.98±1.71^{a}	29.39±1.45^{b}	***	***	***
Heart (g)	13.56±0.96^{a}	11.41±0.74^{b}	10.58±0.65^{c}	11.88±0.77^{b}	9.29±0.51^{c}	6.89±0.48^{d}	13.41±1.19^{a}	7.74±0.64^{b}	**	***	**
AFT(g)	44.48±1.59^{a}	32.13±1.47^{b}	26.14±1.43^{c}	34.77±1.53^{b}	23.52±1.38^{c}	17.44±1.35^{d}	39.97±1.65^{a}	24.92±1.42^{b}	***	***	***

^{abcd}Mean under the same category bear different superscript letters are significantly different, ***p<0.001, **p<0.01, *p<0.05, SE: Standard error, Wing (g): Wing weight (g), Back (g): Back weight (g), Neck (g): Neck weight (g), Gizzard (g): Gizzard weight (g), Liver (g): Liver weight (g), Heart (g): Heart weight and AFT (g): Abdominal fat (g) by breed and sex interaction[40]. However, the BWT, DWT and TWT% were comparably varied by genotype and sex interaction[29]. The difference in breast, drumstick and thigh weights and proportions might be due to multiple factors such as genotype, sex and their interactions[45].

Effect of genotype and sex on carcass components of KK, CH, HC, C, H and L chickens: The wing weight (wing) was significantly the highest for KK followed by HC and CH, while L had the lowest wing weight followed by H and C at 24 weeks of age (Table 6). The back weight (back) was significantly the highest for KK followed by HC and CH, but L had the lowest back weight followed by H and C at 24 weeks of age. The neck weight (neck) was substantially the highest for KK, higher for HC, high for CH and C and low for H; however, L had the lowest neck at 24 weeks of age. In line with the finding by Kryeziu *et al.*[19] genotypes with heavy live weights had higher wing, back and neck weights. The wing, back and neck weights were notably higher in males than in females in agreement with the study reported by Musundire *et al.*[40]. The wing, back and neck were significantly affected by genotype and sex interaction. The differences in wing, back and neck weights could be attributed to genotype, strain, sex and diets[47]. The gizzard weight (gizzard) was significantly the highest for KK, higher for HC, high for CH and C, low for H, but L had the lowest gizzard at 24 weeks of age. The gizzard was significantly higher in males than in females at 24 weeks of age. The gizzard was significantly affected by genotype and sex interaction. The liver weight (liver) was significantly the highest for KK, higher for HC, high for CH, intermediate for C and low for H, whereas L had the lowest liver at 24 weeks of age. The liver was significantly higher in males than in females at 24 weeks of age. The liver was significantly affected by genotype and sex interaction. The heart weight (heart) was significantly the highest for KK, higher for HC and CH and high for C and H; by contrast, L had the lowest heart at 24 weeks of age. The heart was significantly higher in males than in females at 24 weeks of age. The heart is significantly affected by genotype and sex interaction. The abdominal fat weight (AFT) was significantly the highest for KK, higher for HC and CH, high for C and low for H but L had the lowest AFT at 24 weeks of age. The AFT was noticeably higher in males than in females at 24 weeks of age. In line with the study of Misztal and Lovendahl[48], males had significantly higher AFT than females. In contrast, females accumulated notably higher AFT than males[49]. Females deposit similar AFT to males. The AFT was considerably affected by genotype and sex interaction. Edible offal which includes gizzard, liver and heart are important components of chicken meat[16]. Higher gizzard, liver, heart and AFT weight in chickens with heavy weight[12]. The direct association between body weight and the weight of internal organs could be liable to higher edible offal between genotypes and sexes[48]. The difference between edible offal and AFT of chickens might be attributed to genetic and non-genetic factors[50]. In line with the result of the study Misztal and Lovendahl[48], genotypes and sexes with higher carcass and edible offal increase the edible harvest. The difference in edible offal such as giblets (gizzard, liver and heart) could be due to breed, age, sex and management. Genotypes and sexes with less abdominal fat had more lean meat and best for health-conscious consumers[23].

CONCLUSION AND RECOMMENDATION

Koekoek (KK) chickens had the highest body weight, body weight change and daily weight gain, followed by HC, CH and C, with Indigenous chickens (L) and Improved Horro (H) having the lowest. The mortality rate was lowest in L, followed by H and KK, with CH having the highest. Males had superior growth metrics and lower feed conversion ratios and mortality rates compared to females. Genotype and sex interactions significantly influenced slaughter weight, dressed weight, eviscerated weight and individual carcass parts, with KK consistently outperforming other genotypes. In conclusion, these findings highlight the substantial impact of genotype and sex on growth and carcass traits, providing valuable reference data for future genetic and dietary studies.

SIGNIFICANCE STATEMENT

The present study is significant as it evaluates how genotype and sex influence growth and carcass characteristics in various chicken breeds, including the newly introduced Cosmopolitan and genetically improved Horro chickens. By comparing these with Indigenous and Koekoek chickens, the study provides essential data on optimizing poultry for meat and egg production in diverse systems. The findings will help in refining crossbreeding strategies, understanding genetic variations and improving breeding programs. It is crucial for enhancing poultry productivity and sustainability in Ethiopia and similar regions, offering valuable insights for future genetic and dietary improvements.

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REFERENCES

1. Mekasha, T.J. and F. Tarp, 2021. Understanding poverty dynamics in Ethiopia: Implications for the likely impact of COVID-19. Rev. Dev. Econ., 25: 1838-1868.
2. Safari, A., J. Ahmadpanah, M. Jafaroghli and H. Karimi, 2021. Comparative study of growth patterns for three strains of broiler chickens using mathematical models. Agric. Conspectus Scientificus, 86: 75-82.
3. Adebambo, A.O., C.O.N. Ikeobi, M.O. Ozoje, O.O. Oduguwa and A.A. Olufunmilayo, 2011. Combining abilities of growth traits among pure and crossbred meat type chickens. Arch. Zootecnia, 60: 953-963.
4. Bai, A., S.W. Ruban, P.V. Spandan, A.I.G. Barry, S.N. Kumar, H.C. Indresh and C.S. Nagaraja, 2022. Carcass and meat quality characteristics of native chicken reared under backyard and farm setting in Karnataka. Asian J. Dairy Food Res., 41: 111-115.
5. Ahmad, S., A. Mahmud, J. Hussain and K. Javed, 2019. Morphological and carcass traits of three chicken genotypes under free-range, semiintensive, and intensive housing systems. Turk. J. Vet. Anim. Sci., 43: 342-352.
6. Motsepe, R., M. Mabelebele, D. Norris, D. Brown, J. Ngambi and M. Ginindza, 2016. Carcass and meat quality characteristics of South African indigenous chickens. Indian J. Anim. Res., 50: 580-587.
7. Kalia, S., V.K. Bharti, D. Gogoi, A. Giri and B. Kumar, 2017. Studies on the growth performance of different broiler strains at high altitude and evaluation of probiotic effect on their survivability. Sci. Rep., Vol. 7. 10.1038/srep46074.
8. Munisi, W.G., A.M. Katule and S.H. Mbaga, 2015. Comparative growth and livability performance of exotic, indigenous chickens and their crosses in Tanzania. Livest. Res. Rural Dev., Vol. 27.
9. Deng, S., T. Xing, C. Li, X. Xu and G. Zhou, 2022. The effect of breed and age on the growth performance, carcass traits and metabolic profile in breast muscle of Chinese indigenous chickens. Foods, Vol. 11. 10.3390/foods11030483.
10. Weimer, S.L., S. Zuelly, M. Davis, D.M. Karcher and M.A. Erasmus, 2022. Differences in carcass composition and meat quality of conventional and slow-growing broiler chickens raised at 2 stocking densities. Poult. Sci., Vol. 101. 10.1016/j.psj.2022.101833.
11. Zelleke, G., M. Urge, G. Animut, W. Esatu and T. Dessie, 2022. Comparative growth performance and carcass characteristics of guinea fowl (*Numida meleagris*) and three chicken genotypes. Ethiopian J. Sci. Technol., 15: 81-99.
12. Mikulski, D., J. Celej, J. Jankowski, T. Majewska and M. Mikulska, 2011. Growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access. Asian-Australas. J. Anim. Sci., 24: 1407-1416.
13. Tůmová, E. and D. Chodová, 2018. Performance and changes in body composition of broiler chickens depending on feeding regime and sex. Czech J. Anim. Sci., 63: 518-525.
14. Biazen, A., U. Mengistu, A. Negassi, A. Getenet, A. Solomon and D. Tadelle, 2021. Comparative growth performance, carcass characteristics and meat quality of local horro and exotic cockerels of tropical origin fed growers diet. Open J. Anim. Sci., 11: 62-83.
15. Youssao, I.A.K., I.T. Alkoiret, M. Dahouda, M.N. Assogba and N.D. Idrissou *et al*., 2012. Comparison of growth performance, carcass characteristics and meat quality of Benin indigenous chickens and Label Rouge (T55×SA51)). Afr. J. Biotechnol., 11: 15569-15579.

16. Clavijo, V. and M.J.V. Flórez, 2018. The gastrointestinal microbiome and its association with the control of pathogens in broiler chicken production: A review. Poult. Sci., 97: 1006-1021.
17. Stinckens, A., A. Vereijken, E. Ons, P. Konings and P. van As *et al*., 2015. Art meets science: The cosmopolitan chicken research project. Facts Views Vision ObGyn, 7: 163-172.
18. Ibrahim, D., G. Goshu, W. Esatu and A. Cahaner, 2019. Dual-purpose production of genetically different chicken crossbreeds in Ethiopia. 2. Egg and meat production of the final-crossbreed females and males. Poult. Sci., 98: 3405-3417.
19. Kryeziu, A.J., M. Kamberi, S. Muji, N. Mestani and S. Berisha, 2018. Carcass traits of broilers as affected by different stocking density and sex. Bulg. J. Agric. Sci., 24: 1097-1103.
20. Taye, S., G. Goshu and S. Abegaz, 2022. Effect of crossbreeding on growth performance of improved Horro crosses with Koekoek and Kuroiler chicken breeds. Poult. Sci. J., 10: 35-44.
21. Tadesse, D., W. Esatu, M. Girma and T. Dessie, 2015. Comparative study on some egg quality traits of exotic chickens in different production systems in East Shewa, Ethiopia. Afr. J. Agric. Res., 10: 1016-1021.
22. Hassen, H., F.W.C. Neser, A. de Kock and E. van Marle-Koster, 2009. Study on the genetic diversity of native chickens in northwest Ethiopia using microsatellite markers. Afr. J. Biotechnol., 80: 1347-1353.
23. Hailemariam, A., W. Esatu, S. Abegaz, M. Urge, G. Assefa and T. Dessie, 2022. Effect of genotype and sex on breast meat quality characteristics of different chickens. J. Agric. Food Res., Vol. 10. 10.1016/j.jafr.2022.100423.
24. Choo, Y.K., S.T. Oh, K.W. Lee, C.W. Kang and H.W. Kim *et al*., 2014. The growth performance, carcass characteristics, and meat quality of egg-type male growing chicken and white-mini broiler in comparison with commercial broiler (Ross 308). Korean J. Food Sci. Anim. Resour., 34: 622-629.
25. Petracci, M., F. Sirri, M. Mazzoni and A. Meluzzi, 2013. Comparison of breast muscle traits and meat quality characteristics in 2 commercial chicken hybrids. Poult. Sci., 92: 2438-2447.
26. Mueller, S., L. Taddei, D. Albiker, M. Kreuzer, M. Siegrist, R.E. Messikommer and I.D.M. Gangnat, 2020. Growth, carcass, and meat quality of 2 dual-purpose chickens and a layer hybrid grown for 67 or 84 D compared with slow-growing broilers. J. Appl. Poult. Res., 29: 185-196.
27. Olanrewaju, H.A., S.D. Collier, J.L. Purswell and S.L. Branton, 2019. Effects of light-sources and photoperiod on hemato-physiological indices of broilers grown to heavy weights. Poult. Sci., 98: 1075-1082.
28. Gafar, E.G., S.G. Abdo, M.Y. Mahrous and M.A. Kamal, 2022. Effect of strain and sex on productive performance and carcass traits in some broiler chickens. Arch. Agric. Sci. J., 5: 77-78.
29. Cruz, F.L., L.K.V. Saraiva, G.E. Silva, T.M. Nogueira, A.P. Silva and P.B. Faria, 2018. Growth and carcass characteristics of different crosses of chickens raised in an alternative system. Semin.: Agric. Sci., 39: 317-328.
30. do Nascimento, D.C.N., L.R.B. Dourado, J.C. de Siqueira, S.B.P. de Lima and M. da Conceição Macêdo da Silva *et al*., 2018. Productive characteristics of broiler chickens in hot weather: Effects of strain and sex. Semina: Cienc. Agrar., 39: 731-746.
31. Bosco, A.D., C. Mugnai, M.G. Amato, L. Piottoli, A. Cartoni and C. Castellini, 2014. Effect of slaughtering age in different commercial chicken genotypes reared according to the organic system: 1. Welfare, carcass and meat traits. Ital. J. Anim. Sci., Vol. 13. 10.4081/ijas.2014.3308.
32. Abdullah, A.Y., N.A. Al-Beitawi, M.M.S. Rjoup, R.I. Qudsieh and M.A.A. Ishmais, 2010. Growth performance, carcass and meat quality characteristics of different commercial crosses of broiler strains of chicken. J. Poult. Sci., 47: 13-21.
33. Obike, O.M., E.N. Nwachukwu and I.E. Ukewulonu, 2014. Effect of strain and associations of some fertility and hatchability traits of indigenous guinea fowls raised in the rain-forest Zone of South-East Nigeria. Global J. Anim. Breed. Genet., 2: 98-102.
34. Chen, C., Z. Su, Y. Li, P. Luan and S. Wang *et al*., 2021. Estimation of the genetic parameters of traits relevant to feed efficiency: Result from broiler lines divergent for high or low abdominal fat content. Poult. Sci., 100: 461-466.

35. Bamidele, O., E.B. Sonaiya, O.A. Adebambo and T. Dessie, 2020. On-station performance evaluation of improved tropically adapted chicken breeds for smallholder poultry production systems in Nigeria. Trop. Anim. Health Prod., 52: 1541-1548.
36. Jahanpour, H., A. Seidavi, A.A.A. Qotbi, R. van Den Hoven, S.R.E. Silva, V. Laudadio and V. Tufarelli, 2015. Effects of the level and duration of feeding restriction on carcass components of broilers. Arch. Anim. Breed., 58: 99-105.
37. FAOUN, 2003. Egg Marketing: A Guide for the Production and Sale of Eggs. Food & Agriculture Org., Rome, Italy, ISBN: 9789251049327, Pages: 121.
38. Olawumi, S.O., S.O. Fajemilehin and S.S. Fagbuaro, 2012. Genotype × sex interaction effects on carcass traits of three strains of commercial broiler chickens. J. World's Poult. Res., 2: 21-24.
39. Cassandro, M., M. de Marchi, M. Penasa and C. Rizzi, 2015. Carcass characteristics and meat quality traits of the padovana chicken breed, a commercial line, and their cross. Ital. J. Anim. Sci., Vol. 14. 10.4081/ijas.2015.3848.
40. Musundire, M.T., T.E. Halimani and M. Chimonyo, 2018. Effect of age and sex on carcass characteristics and internal organ weights of scavenging chickens and helmeted guinea fowls. J. Appl. Anim. Res., 46: 860-867.
41. Haunshi, S., S. Devatkal, L.L.L. Prince, R. Ullengala, K. Ramasamy and R. Chatterjee, 2022. Carcass characteristics, meat quality and nutritional composition of Kadaknath, a native chicken breed of India. Foods, Vol. 11. 10.3390/foods11223603.
42. Ojedapo, L.O., O. Akinokun, T.A. Adedeji, T.B. Olayeni, S.A. Ameen and S.R. Amao, 2008. Effect of strain and sex on carcass characteristics of three commercial broilers reared in deep litter system in the derived Savannah Area of Nigeria. World J. Agric. Sci., 4: 487-491.
43. Ahokpossi, A.G.A.C., A.G. Bonou, K. Tona, I.Y.A. Karim and Y. Ameyapoh, 2023. Influence of age at slaughter and sex on carcass characteristics and technological and sensory quality of Goliath chicken meat. Vet. World, 16: 194-203.
44. Alemneh, W., K. Berihun and A. Melesse, 2021. Comparative study on carcass quality characteristics of indigenous chickens and their F1-crosses with the sasso chicken breed in Sheka Zone, South Western Ethiopia. Int. J. Food Sci. Agric., 5: 692-697.
45. Akinsola, K. and S. Olawumi, 2018. Strain by feed restriction interaction effect on carcass characteristics and meat quality of broiler chickens. Int. J. Vet. Sci. Anim. Husb., 3: 29-32.
46. Eleroğlu, H., A. Yıldırım, M. Duman and A. Şekeroğlu, 2017. Edible giblets and bone mineral characteristics of two slow-growing chicken genotypes reared in an organic system. Braz. J. Poult. Sci., 19: 1-6.
47. Tavárez, M.A. and F.S. de los Santos, 2016. Impact of genetics and breeding on broiler production performance: A look into the past, present, and future of the industry. Anim. Front., 6: 37-41.
48. Misztal, I. and P. Lovendahl, 2012. Genotype by Environment Interactions in Commercial Populations. In: Environmental Physiology of Livestock, Collier, R.J. and J.L. Collier (Eds.), John Wiley & Sons, Inc., Hoboken, New Jersey, ISBN: 9781119949091, pp: 289-307.
49. Hailemariam, A., W. Esatu, S. Abegaz, M. Urge, G. Assefa and T. Dessie, 2022. Serum biochemical and meat fatty acid profiles of different chicken genotypes. Open J. Anim. Sci., 12: 287-302.
50. Senbeta, E.K., 2017. Growth performance and rearing costs of Fayoumi and White Leghorn chicken breeds. East Afr. J. Sci., 11: 37-42.