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Combining Abilities for Carcass Yield Performance in Diallel Crosses of Five Indigenous Chicken Strains under an Improved Production System in Zambia

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Abstract

Indigenous chickens contribute to income generation, nutrition, and food security in rural poultry production in Zambia. Local environmental conditions suit these chickens well; they demonstrate disease resistance, and they require minimal management. However, their growth performance and carcass yield are inferior to those of commercial breeds. This study evaluated the genetic potential and combining abilities of five Zambian indigenous chicken strains—Naked Neck, Frizzled Feathered, Normal Feathered, White-spotted, and Short-legged—using a diallel crossing design under improved management conditions. A total of 150 First filial (F_1) chickens were assessed for fasted live weight, bled weight, pluck weight, eviscerated weight, and weights of the drumstick, thigh, breast, internal organs, and wings at 20 weeks of age. Genetic analysis of carcass traits was performed using the AGD-R software to determine GCA, SCA, and RE applying Griffing's experimental Method I, Model II. The findings showed crossbred chickens generally exhibited superior performance compared to purebreds; the Na × S cross demonstrated the highest fasted live weight (1987.8 g), bled weight (1789.7 g), and breast weight (306.5 g), while the Na × W cross also showed notable performance (fasted live weight: 1844.3 g; breast: 267.3 g). Among purebreds, White Spotted chickens were the heaviest (fasted live weight: 1890.0 g; breast: 329.3 g). Males were significantly heavier than females across all traits (fasted live weight: 1882.4 ± 253.4 g vs. 1450.9 ± 247.1 g; $P < 0.05$). Diallel analysis indicated a predominance of non-additive gene action, with specific combining ability (SCA) contributing more to variation than general combining ability (GCA). The FS cross exhibited the highest positive SCA effects (fasted live weight: 250.1 g; pluck weight: 197.5 g). Notable GCA effects were observed in White-spotted (fasted live weight: 94.4 g) and Normal Feathered (-83.5 g), while reciprocal effects were evident in SNa (fasted live weight: 247.4 g) and NNa (113.3 g). These findings demonstrate the potential for targeted crossbreeding, particularly involving Naked Neck, White Spotted, and Frizzled Feathered strains, to enhance carcass traits in indigenous chickens.

Introduction

Indigenous chickens are vital to rural poultry production across Zambia, providing an essential source of income, nutrition, and food security for small-scale farmers (Kanyama et al.2024). These chickens are well adapted to local environmental conditions, exhibit natural disease resistance, and require minimal management input (Bwalya and Kalinda 2014). However, their productivity, particularly in terms of growth performance and carcass yield, remains relatively low compared to that of commercial poultry breeds (Padhi 2016). From a quantitative genetics perspective, the phenotypic performance of economically important traits, such as body weight and carcass yield, is determined by the combined effects of genotype, environment, and their interactions. While improvements in management, nutrition, and housing can enhance performance, sustainable gains in carcass yield largely depend on exploiting heritable genetic variation (Desta 2021). This highlights the importance of structured genetic improvement strategies that complement the improved production systems. Improving the genetic potential of indigenous chickens through systematic breeding programs can enhance their economic value and sustainability in smallholder production systems (Shyam et al. 2023).

Traditional breeding practices have always been about identifying best performing chickens in the population and mating the best to the best to obtain superior chickens. This is crucial for identifying strains that exhibit superior growth and carcass traits. However, there is a challenge on how the different strains would perform in a crossbreeding program. The diallel analysis framework proposed by Griffing (1956) remains one of the most widely applied approaches for estimating the combining ability effects and variances. Griffing's method partitions genetic variation into GCA, SCA and RE components, thereby providing insights into the relative importance of additive and non-additive gene actions (Ahmed et al.2019). Griffings proposed four diallel methods that include parents, F_1 crosses, and reciprocal crosses, allowing for flexibility in various experimental setups. Griffing's diallel approach has been widely applied in poultry and other livestock species to study the inheritance of growth, reproductive, and carcass traits (Kabir et al.2014; Musa et al. 2015; Siwendu et al. 2013; Sungkhapreecha et al. 2022). Understanding these genetic components is critical for designing breeding strategies aimed at improving carcass yield and overall performance.

Limited research has been conducted on optimizing the genetic potential of indigenous chickens for meat production under improved management systems. The evaluation of GCA, SCA, and RE would provide valuable insights for developing breeding strategies that improve meat production while preserving the adaptability and resilience of indigenous chickens. The findings will help develop long-term breeding programs, which will eventually improve poultry productivity and rural livelihoods. Hence, this

study aimed to assess the genetic potential of five indigenous chicken strains in Zambia through diallel crossing to determine their combining abilities for carcass traits.

Materials and methods

Study area

The experiment was carried out at the School of Agricultural Sciences' Field Station, located at 28°20.278' E and 15°28.646' S on the University of Zambia's Great East Road Campus in Lusaka, Zambia. The study area has a tropical climate, with annual rainfall ranging from 700 to 1,400 mm. The average ambient temperature during the study period (December 2023 - August 2025) ranged from 9°C in winter to 30°C in summer. The annual average relative humidity was 61.5%, whereas the monthly averages ranged from 34% in July to 86% in February.

Experimental animals

A full diallel crossing design involving five strains of indigenous Zambian chickens—Naked Neck, Frizzled Feathered, Normal Feathered, White Spotted, and Short Legged was used for the study. A foundation population of 150 indigenous chickens, comprising 125 dams (25 per strain) and 25 sires (5 per strain), was established to generate experimental birds. A total of 25 genetic groups resulted from the diallel crossing: 5 purebred, 10 crossbred, and 10 reciprocal matings. Fertile eggs were collected from the foundation stock and incubated under standard conditions, and the hatched chicks were used to establish the F_1 generation. Each chick was identified with leg tags, and body weight was recorded weekly until 20 weeks of age. A total of 150 first filial (F_1) progeny (3 males and 3 females per genetic group) were randomly selected from the resulting genetic groups and evaluated to determine the effects of crossbreeding on carcass traits.

Housing and management

From hatch to four weeks of age, the chicks were brooded in a well-ventilated facility under a continuous lighting program. The brooding temperature was initially maintained at 32°C using infrared heat lamps and gradually reduced by 2–3°C per week until the ambient temperature was attained. During this period, the chicks were fed a commercial starter diet containing 22% crude protein (CP) and 3,299 kcal/kg metabolizable energy (ME), with feed and clean drinking water provided ad libitum. At four weeks of age, the birds were transferred to rearing pens measuring 2.7 × 3.2 m with deep litter flooring in a well-ventilated open-sided house exposed to natural daylight. The stocking density was maintained at eight birds per square meter. From four to 14 weeks of age, the birds were fed a grower diet containing 19% CP and 3299 kcal/kg ME, with feed and water supplied ad libitum. Sex differentiation was performed at 10 weeks of age based on comb development. From 14 to 20 weeks of age, the birds were maintained on a finisher diet containing 18% CP and 3299 kcal/kg ME under uniform management conditions. Feed and water were provided ad libitum during the experimental period. All chickens were vaccinated in accordance with a standard health management program. Vaccinations against infectious bursal disease (Gumboro) were administered via drinking water on days 10, 18, and 52, whereas Newcastle disease vaccinations were administered via drinking water on days 14 and 24 and boosted on day 70 using the eye-drop method. Fowlpox vaccination was administered on day 42 using the wing-web-stab technique. To minimize post-vaccination stress, a vitamin-electrolyte stress pack was provided in the drinking water following each vaccination.

Carcass traits measurements

At 20 weeks, 3 males and 3 females were randomly selected from each pen, representing each genetic group, and weighed individually. These birds were then isolated and fasted for 12 hours. Thereafter, they were weighed again and humanely slaughtered following the procedures described by Kumar et al. (2022). The carcass evaluation procedure involved defeathering, evisceration, and cutting the carcasses into various primal cuts. Measured carcass traits included pre-slaughter live weight, bled weight, carcass weight, weights of the breast, drumstick, thigh, and wing.

Statistical Analysis

Mean performances and variances for the carcass traits for the different genetic groups were analyzed using the General Linear Models (GLM) approach implemented in R statistical software (R Core Team, 2026). Assumptions of normality and homogeneity of variances were checked using residual diagnostics to ensure the validity of the model as outlined by Bolboacă and Jäntschi (2009). The analysis on carcass traits evaluated the effects of genetic group, sire genotype, and sex on carcass characteristics of the chickens. The genetic group and sex were considered fixed effects, while sire genotype was treated as a random effect to account for genetic variability among sires. The following linear mixed model was fitted for the carcass traits:

$$\mathrm{Y_{ijk}} = \mu + \mathrm{G_i} + \mathrm{S_j} + \mathrm{X_k} + \mathrm{e_{ijk}} \qquad \mathrm{eq.1}$$

Where: $\mathrm{Y_{ijk}}$: the observation on the carcass trait of the k[th] bird;

μ; the population mean;

$\mathrm{G_i}$

the random effect of i[th] genetic group;

$\mathrm{S_j}$: random effect of the j[th] sire genotype;

$\mathrm{X_k}$

fixed effect of the sex (male or female);

$\mathrm{e_{ijk}}$

random error.

Significant differences were separated using Duncan's New Multiple Range Test (DNMRT) ($P < 0.05$). Carcass traits were further subjected to genetic analysis using the AGD-R software (Analysis of Genetic Designs in R for Windows) Version 5.1 (Rodríguez et al. 2015) to estimate GCA, SCA, and RE. The analysis was conducted using Griffing's experimental Method I, Model II, in which parents, F_1 crosses, and reciprocal crosses were included, and all genetic effects were assumed to be random (Griffing 1956). The linear statistical model used for the analysis of carcass traits under Griffing's Method I, Model II, was expressed as:

$$\mathrm{Y_{ijk}} = \mu + \mathrm{g_i} + \mathrm{g_j} + \mathrm{s_{ij}} + \mathrm{r_{ij}} + \mathrm{e_{ijk}} \qquad \mathrm{eq.2}$$

where:

Y_{ijk}= the k[th] observation of each cross between i[th] strain and j[th] strain

μ = population mean

g_i= GCA effect for i[th] strain

g_j = GCA effect for j[th] strain

s_{ij}= SCA effect for the cross (i, j)

r_{ij} = reciprocal effect of the cross (i, j)

e_{ijk}= random effect associated with the ij[th] cross in the k[th] observation

Results and discussion

Carcass weights of the various genetic groups

The carcass weights of the various genetic groups of the indigenous chickens are presented in Table 1. There were significant differences in fasted live weight, bled, pluck, thigh, breast, and internal organ weight ($p < 0.05$) between genetic groups. However, there were no significant differences in eviscerated, drumstick, and wing weight ($p > 0.05$). It was observed that among purebreds, the White Spotted strain recorded the highest live weight, while the Short-Legged strain recorded the lowest. Crossbred groups such as Na×S, W×F, and S×F achieved live weights that exceeded those of the best-performing purebred, reflecting substantial heterotic effects. These findings are consistent with previous reports that crossbreeding indigenous chickens with exotic or other local strains can enhance growth performance through complementary gene action (Yakubu et al. 2010; Dana et al. 2011). The major factors determining body weight at slaughter include breed or strain, age of the chickens, and management level (Lambertz et al. 2018; Taha et al. 2013).

The reciprocal crosses, notably S×F and W×Na, showed higher carcass weights, suggesting that maternal or reciprocal effects may be contributive. These observations are in agreement with the findings of Dzungwe et al. (2022), who reported that reciprocal effects influenced carcass weight in crossbred chickens. The crosses Na×S, W×F, and S×F achieved bled weights comparable to W×W, underscoring the benefits of heterosis in enhancing bled weight. The observed increase in bled weights in these crosses suggests improved circulatory and muscular development, which are crucial for meat recovery (Liu et al. 2015). These results are consistent with the findings of Mokoena et al. (2025), who emphasized the importance of non-additive genetic effects in enhancing carcass recovery traits in indigenous chickens. A similar pattern was noted in pluck weight, with Na×S, W×F, and S×F exhibiting the highest values, significantly exceeding those of most purebreds. Among the parental strains, W×W demonstrated superior performance, followed by Na×Na. This finding indicates that both additive and non-additive genetic factors contributed to pluck weight, particularly in crosses involving White Spotted and Naked Neck, suggesting that these genetic interactions may improve overall meat quality and production efficiency in poultry.

The significant differences in thigh weights indicate that crossbreeding can improve lower-limb muscle development, which is crucial for meat production. The heaviest breast weights were found in W×W, Na×S, and Na×N. The substantial influence of breast size in some crossbred animals indicates strong benefits of crossbreeding, which could lead to improved meat production in these populations. This finding was consistent with the results reported by Tyasi et al. (2019), who suggested an impact of SCA on breast development. Higher internal organ weights were observed among Na×N and Na×S, suggesting pronounced non-additive effects influencing visceral development. The observed variation in carcass parts among purebreds and crossbreds emphasizes the importance of exploiting heterosis in indigenous Zambian chickens. These findings are in agreement with previous reports by Adebambo et al. (2010), Tyasi et al. (2021), and Mokoena et al. (2025), who demonstrated that crossbreeding between indigenous strains can enhance carcass yield and improve meat quality traits.

Table 1
Means of carcass weights (± standard deviation) in purebred, crossbred and reciprocal crossing of Zambian indigenous chickens

Genotype	N	Fasted live weight(g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal organ weight (g)	Wing weight (g)
Purebred										
FF	6	1618.2 ± 436.6^{e}	1524.5 ± 419.3^{d}	1374.3 ± 332.7^{c}	1040.5 ± 318.4^{a}	178.0 ± 61.3^{a}	170.8 ± 51.6^{e}	234.3 ± 35.0^{d}	180.1 ± 42.6^{f}	158.8 ± 39.9^{a}
NaNa	6	1679.8 ± 458.0^{e}	1609.2 ± 446.4^{d}	1482.8 ± 440.7^{c}	1247.2 ± 374.2^{a}	191.5 ± 66.7^{a}	200.7 ± 62.1^{e}	263.5 ± 75.1^{d}	202.5 ± 28.0^{f}	172.8 ± 48.8^{a}
NN	6	1671.5 ± 497.3^{e}	1617.5 ± 483.2^{d}	1467.7 ± 449.9^{c}	1203.7 ± 378.9^{a}	190.2 ± 71.2^{a}	192.5 ± 59.9^{e}	276.6 ± 81.8^{d}	223.2 ± 49.2^{c}	159.2 ± 45.6^{a}
SS	6	1297.2 ± 161.7^{e}	1256.0 ± 153.6^{d}	1134.2 ± 147.8^{c}	936.6 ± 125.9^{a}	108.7 ± 36.8^{a}	155.5 ± 28.7^{e}	210.7 ± 29.4^{d}	170.7 ± 12.7^{f}	123.8 ± 18.3^{a}
WW	6	1890.0 ± 459.6^{b}	1819.7 ± 441.3^{a}	1659.8 ± 403.3^{a}	1381.5 ± 367.0^{a}	216.0 ± 61.3^{a}	221.5 ± 48.9^{c}	329.3 ± 82.3^{a}	228.2 ± 53.6^{b}	170.5 ± 35.6^{a}
Crosses										
FN	6	1327.7 ± 154.8^{e}	1268.7 ± 145.3^{d}	1177.8 ± 156.3^{c}	956.8 ± 154.0^{a}	148.3 ± 24.4^{a}	144.8 ± 19.1^{e}	219.50 ± 25.2^{d}	179.3 ± 12.9^{f}	129.2 ± 16.1^{a}
FS	6	1797.7 ± 163.7^{d}	1691.3 ± 177.6^{b}	1537.3 ± 151.0^{b}	1314.0 ± 132.2^{a}	195.5 ± 45.2^{a}	204.0 ± 47.9^{d}	241.83 ± 69.1^{d}	180.7 ± 26.4^{f}	166.0 ± 12.5^{a}
FW	6	1674.3 ± 139.9^{e}	1597.8 ± 123.6^{d}	1475.5 ± 123.2^{c}	1255.7 ± 122.3^{a}	172.0 ± 42.0^{a}	169.7 ± 35.4^{e}	227.50 ± 67.2^{d}	211.0 ± 19.4^{d}	158.3 ± 12.6^{a}
NaF	6	1631.5 ± 259.9^{e}	1560.5 ± 249.5^{d}	1463.3 ± 230.3^{c}	1207.0 ± 327.1^{a}	175.2 ± 38.6^{a}	209.6 ± 38.2^{d}	276.67 ± 58.4^{d}	204.8 ± 5.4^{e}	146.5 ± 32.9^{a}
NaN	6	1801.5 ± 218.3^{d}	1742.5 ± 200.5^{b}	1605.5 ± 201.7^{a}	1327.2 ± 156.7^{a}	202.7 ± 33.7^{a}	219.2 ± 24.5^{c}	306.50 ± 42.3^{b}	235.7 ± 32.0^{a}	167.5 ± 19.3^{a}
NaS	6	1987.8 ± 379.4^{a}	1789.7 ± 176.9^{b}	1673.5 ± 137.3^{a}	1521.3 ± 201.2^{a}	231.2 ± 30.8^{a}	236.6 ± 25.2^{b}	306.50 ± 8.3^{b}	202.8 ± 12.0^{f}	177.7 ± 9.1^{a}
NaW	6	1844.3 ± 102.1^{c}	1758.5 ± 103.5^{b}	1599.3 ± 139.7^{a}	1341.0 ± 113.3^{a}	218.5 ± 22.7^{a}	237.7 ± 23.5^{a}	267.33 ± 26.3^{d}	185.7 ± 12.5^{f}	171.8 ± 13.3^{a}
SN	6	1613.7 ± 320.5^{e}	1523.2 ± 272.9^{d}	1392.5 ± 268.0^{c}	1240.0 ± 319.1^{a}	182.7 ± 58.3^{a}	188.0 ± 38.6^{e}	279.00 ± 47.4^{d}	175.6 ± 43.2^{f}	149.5 ± 29.0^{a}
SW	6	1696.0 ± 259.4^{e}	1662.8 ± 258.9^{c}	1486.5 ± 243.7^{c}	1255.8 ± 212.1^{a}	184.0 ± 42.9^{a}	200.0 ± 34.2^{e}	260.33 ± 28.3^{d}	194.6 ± 11.9^{f}	165.0 ± 12.5^{a}

Genotype	N	Fasted live weight(g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal organ weight (g)	Wing weight (g)
Purebred										
WN	6	1639.1 ± 291.7^{e}	1590.8 ± 273.4^{d}	1438.2 ± 278.9^{c}	1188.7 ± 224.7^{a}	179.8 ± 55.1^{a}	213.3 ± 48.8^{c}	288.83 ± 58.6^{c}	182.2 ± 35.2^{f}	159.5 ± 32.8^{a}
Reciprocals										
FNa	6	1579.6 ± 267.8^{e}	1517.2 ± 246.9^{d}	1425.5 ± 239.0^{c}	1177.8 ± 337.5^{a}	171.5 ± 38.8^{a}	184.3 ± 38.1^{e}	271.7 ± 57.1^{d}	198.2 ± 7.2^{f}	143.3 ± 33.0^{a}
SF	6	1909.7 ± 153.5^{b}	1754.7 ± 63.5^{b}	1612.0 ± 26.7^{a}	1423.8 ± 50.8^{a}	181.2 ± 24.9^{a}	172.7 ± 40.4^{e}	270.8 ± 39.0^{d}	161.8 ± 24.5^{f}	168.8 ± 17.1^{a}
SNa	6	1493.0 ± 194.6^{e}	1424.7 ± 180.6^{d}	1320.8 ± 172.4^{c}	1091.7 ± 154.8^{a}	164.0 ± 37.8^{a}	167.0 ± 21.3^{e}	242.3 ± 34.4^{d}	205.8 ± 42.2^{e}	139.5 ± 29.2^{a}
NF	6	1391.0 ± 291.7^{e}	1279.8 ± 249.5^{d}	1169.7 ± 188.7^{c}	1050.3 ± 194.4^{a}	170.7 ± 50.7^{a}	173.2 ± 32.9^{e}	208.7 ± 21.7^{d}	158.2 ± 3.9^{f}	152.2 ± 27.9^{a}
NNa	6	1696.3 ± 526.1^{e}	1231.5 ± 681.3^{d}	1480.3 ± 448.1^{c}	1259.0 ± 389.7^{a}	185.2 ± 61.4^{a}	197.0 ± 58.5^{e}	291.3 ± 87.2^{c}	197.5 ± 72.1^{f}	154.3 ± 46.8^{a}
NS	6	1450.0 ± 330.9^{e}	1394.7 ± 320.3^{d}	1311.0 ± 340.3^{c}	1151.0 ± 364.1^{a}	180.7 ± 70.8^{a}	177.3 ± 52.2^{e}	263.2 ± 79.4^{d}	177.3 ± 37.1^{f}	146.7 ± 36.5^{a}
NW	6	1569.5 ± 247.1^{e}	1523.3 ± 240.9^{d}	1377.7 ± 197.8^{c}	1141.8 ± 264.0^{a}	179.0 ± 37.6^{a}	188.5 ± 27.3^{e}	262.8 ± 46.7^{d}	192.7 ± 35.2^{f}	157.2 ± 18.9^{a}
WF	6	1926.5 ± 146.0^{a}	1766.5 ± 63.5^{b}	1636.3 ± 25.0^{a}	1451.5 ± 36.7^{a}	185.5 ± 23.3^{a}	180.7 ± 39.1^{e}	277.7 ± 38.7^{d}	169.2 ± 21.2^{f}	171.7 ± 16.6^{a}
WNa	6	1797.3 ± 225.0^{d}	1724.3 ± 216.6^{b}	1573.2 ± 207.8^{a}	1349.0 ± 245.7^{a}	191.8 ± 36.2^{a}	207.8 ± 24.7^{d}	288.2 ± 16.1^{c}	212.8 ± 23.1^{d}	165.0 ± 16.9^{a}
WS	6	1684.3 ± 459.6^{e}	1609.0 ± 228.4^{d}	1456.5 ± 233.5^{c}	1212.0 ± 190.5^{a}	181 ± 43.8^{a}	199.8 ± 34.1^{e}	258.7 ± 33.1^{d}	193.0 ± 12.1^{f}	162.2 ± 12.0^{a}

*F is Frizzled feathered, N is Normal feathered, Na is Naked neck, S is short legged and W is White spotted chickens sire.

$^{a-f}$: means in the same column having different superscripts are significantly different (P ≤ 0.05). N is the number of observations

Sire effects on carcass weight

Sire genotype had a significant effect on the carcass traits evaluated in this study (Table 2). The fasted live weight, bled, pluck, drumstick, and thigh weight were significantly influenced by sire ($P < 0.05$). Specifically, chickens sired by the Naked Neck and White Spotted showed superior fasted live weight, breast, drumstick, thigh, and wing weights compared to those sired by the Frizzled Feathered, Normal Feathered, and Short-Legged sires. There were no significant differences ($P > 0.05$) in the weight of

eviscerated and internal organs, which means that the effects of the sire were stronger on overall live weight and major muscle groups than on internal organs.

The observed variation in carcass traits among sires indicates a strong genetic influence on the growth performance and muscle deposition in indigenous Zambian chickens. The superior performance of the Naked Neck and White Spotted sires in terms of live weight and major muscle components agrees with previous studies, which reported that certain indigenous chicken strains exhibit higher carcass yield due to additive genetic effects (Adebambo et al. 2010; Teshome et al. 2025; Sungkhapreecha et al. 2022). The absence of significant sire effects on internal organs indicates that these traits may be more profoundly affected by environmental factors or maternal influences rather than by direct sire genes. This pattern is consistent with Sharma (2011), who observed that while the sire significantly affects growth and breast muscle yield, organ weights are less heritable and more strongly associated with management conditions. The significant differences in muscle weights among sires, particularly in the breast, wing, drumstick, and thigh, highlight the potential of selective breeding to enhance meat yield in indigenous chicken populations. Chickens sired by the Naked Neck and White Spotted produced not only higher overall weights but also exhibited greater muscle development, suggesting that these sires should be prioritized in breeding programs aimed at improving carcass traits.

Table 2
Sire effects on carcass weight

Sire effect	N	Fasted live weight (g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal weight (g)	Wing weight (g)
Frizzled feathered,	30	1599.4 ± 286.4^{b}	1519.9 ± 270.1^{b}	1398.1 ± 235.1^{b}	1149.0 ± 255.00^{a}	173.0 ± 43.6^{bc}	174.7 ± 42.1^{c}	238.9 ± 53.1^{b}	189.9 ± 26.5^{a}	151.1 ± 27.3^{bc}
Normal feathered,	30	1555.6 ± 386.3^{b}	1409.4 ± 424.7^{b}	1361.3 ± 340.3^{b}	1161.2 ± 311.9^{a}	181.1 ± 55.^{abc}	185.7 ± 45.5^{bc}	260.5 ± 69.4^{ab}	189.6 ± 47.4^{a}	153.9 ± 34.4^{abc}
Naked neck	30	1789.0 ± 314.8^{a}	1692.1 ± 260.1^{a}	1564.9 ± 250.6^{a}	1328.7 ± 261.1^{a}	203.8 ± 43.3^{a}	220.7 ± 39.0^{a}	284.1 ± 48.7^{a}	206.3 ± 25.3^{a}	167.2 ± 28.8^{a}
Short legged	30	1601.9 ± 295.9^{b}	1524.3 ± 258.2^{b}	1389.2 ± 241.5^{b}	1449.6 ± 232.1^{a}	164.1 ± 48.4^{c}	176.6 ± 34.8^{c}	252.6 ± 41.8^{b}	181.7 ± 32.5^{a}	149.3 ± 26.7^{c}
White spotted	30	1787.5 ± 300.3^{a}	1702.1 ± 269.1^{a}	1552.8 ± 258.7^{a}	1316.5 ± 243.8^{a}	190.9 ± 44.6^{ab}	204.6 ± 39.9^{ab}	288.5 ± 52.9^{a}	197.0 ± 36.9^{a}	165.7 ± 23.4^{ab}

*F is Frizzled feathered, N is Normal feathered, Na is Naked neck, S is short legged and W is White spotted chickens sire.

$^{a-i}$: means in the same column having different superscripts are significantly different (P ≤ 0.05). N is the number of observations

Sex effects on carcass weight

The results indicated that fasted live weight was significantly influenced by sex, with males maintaining higher weights than females across all genetic groups (Table 3). This pattern reflects the inherent sexual dimorphism in chickens. However, in some crossbred combinations, such as Na×W and S×F, female progeny attained live weights comparable to or exceeding those of males from lighter purebred groups.

This observation suggests that crossbreeding may mitigate sex-related disparities by exploiting heterotic effects. Crossbreeding has also been shown to improve the performance of female Nigerian and Ethiopian indigenous chicken ecotypes (Soliman et al. 2016; Dana et al. 2011). The result shows that hybridization could be a way to increase the number of carcasses produced by hens. The bled weight, which reflects the proportion of live weight recoverable after slaughter, also revealed significant sex-

associated differences. Males were consistently heavier than females across both purebred and crossbred groups. However, some female crosses, especially Na×S and F×W, showed better results, indicating that crossbreeding might help improve meat recovery traits, particularly in terms of yield and quality of the meat produced.

These findings match what Tyasi et al. (2021) found, highlighting how non-additive gene action can enhance carcass recovery traits in local chickens. The pattern of male superiority was also apparent in pluck weight, with males consistently recording higher values across genetic groups. However, crossbred females such as Na×W and S×F approached or exceeded the pluck weights of males from lighter-bodied strains, indicating that heterosis may partially compensate for the physiological disadvantage typically observed in females. Other indigenous chicken crossbreeding studies have observed similar trends, where heterotic gains reduced sex-related disparities in carcass traits (Soliman et al. 2016). Eviscerated weight, representing the net edible portion of the carcass, exhibited the most pronounced sex differences. Males yielded substantially higher eviscerated weights, particularly in White Spotted, Normal Feathered, and their crossbreds, confirming their superior carcass potential.

However, notable improvements were recorded among females in some crosses, including Na×S, Na×W, and S×F, where eviscerated yields surpassed those of purebred females and, in some cases, approached those of males from smaller-bodied groups. These findings highlight the potential of crossbreeding to enhance female carcass yield, thereby contributing to the development of dual-purpose crossbred hens with improved meat production capacity. Comparable outcomes have been reported in other African indigenous chicken crossbreeding programs, where hybrid females exhibited higher carcass yield relative to their purebred counterparts (Tyasi et al. 2021; Adebambo et al. 2010).

Across all genetic groups, males consistently recorded higher mean values than females for breast, drumstick, thigh, wing, and internal organ weights. Among purebreds, the White Spotted and Naked Neck strains exhibited higher carcass component weights in both sexes, whereas Short Legged chickens recorded the lowest mean values. Similar patterns were observed in crossbreds and reciprocal crosses, where males from combinations such as Na×S, S×N, and S×W outperformed their female counterparts. These findings are consistent with those of Kgwatalala et al. (2013), who reported that males were significantly heavier than females across carcass traits in Tswana indigenous chickens at 20 weeks of age. The consistently superior carcass performance observed in males may be attributed to hormonal and physiological differences between sexes.

Testosterone promotes protein accretion and muscle hypertrophy, resulting in greater breast, thigh, and drumstick development in males than in females (Brown et al. 2021; Zaytsoff et al.2019). In addition to sex effects, differences among genetic groups further emphasize the role of genotype in carcass yield. The superior performance of Naked Neck and White Spotted chickens may be linked to their adaptability and efficient feed utilization under semi-intensive conditions. Similar findings were reported by Rajkumar et al. (2011) and Hemanth et al. (2024), who attributed the superior carcass yields of Naked Neck chickens to reduced heat stress and improved metabolic efficiency.

Table 3
Sex effects on carcass trait performance of Zambian indigenous chicken strains

Genetic group	Sex	Fasted live weight (g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal weight (g)	Wing weight (g)
Purebreds										
NaNa	Female	1265.6 ± 50.9	1206.6 ± 51.0	1084.0 ± 26.4	907.7 ± 61.2	132.0 ± 2.7	144.3 ± 8.9	198.0 ± 9.0	195.3 ± 41.8	128.3 ± 1.5
	Male	2094.0 ± 84.3	2011.6 ± 97.2	1881.6 ± 86.9	1586.6 ± 22.5	251.0 ± 22.5	25.0 ± 5.0	329.0 ± 34.0	209.7 ± 0.6	217.4 ± 3.5
FF	Female	1225.3 ± 90.0	1149.6± 113.0	1075.7 ± 71.6	857.3 ± 82.0	123.0 ± 8.5	135.0 ± 17.5	208.6 ± 19.9	164.6 ± 14.3	124.3 ± 13.4
	Male	2011.0 ± 74.3	1899.3 ± 73.5	1673.0 ± 63.0	1223.7 ± 382.1	233.0 ± 15.5	206.7 ± 50.0	260.0 ± 26.2	195.5 ± 60.2	193.3 ± 15.3
SS	Female	1153.6 ± 53.5	1117.0 ± 29.6	999.7 ± 16.0	824.0 ± 17.0	106.0 ± 6.2	132.3 ± 17.9	186.0 ± 8.0	159.2 ± 1.2	108.0 ± 7.2
	Male	1440.6 ± 27.5	1395.0 ± 13.0	1268.6 ± 12.1	1049.0 ± 35.0	111.3 ± 57.7	178.7 ± 11.0	235.3 ± 16.5	182.0 ± 4.3	139.6 ± 5.5
WW	Female	1523.3 ± 336.8	1471.3 ± 308.7	1339.0 ± 277.3	1087.0 ± 270.5	167.6 ± 41.4	181.3 ± 27.4	263.0 ± 57.2	196.3 ± 52.4	143.4 ± 26.5
	Male	2256.6 ± 106.7	2168.0 ± 165.8	1980.6 ± 144.8	1676.0 ± 71.8	264.4 ± 26.1	261.7 ± 19.9	395.6 ± 21.1	260.0 ± 37.5	197.6 ± 15.6
NN	Female	1279.3 ± 179.0	1232.6 ± 162.5	1108.6 ± 150.0	909.7 ± 157.5	167.6 ± 41.4	144.0 ± 21.1	216.3 ± 49.0	184.7 ± 33.5	122.6 ± 23.5
	Male	2063.6 ± 353.4	2002.3 ± 336.0	1826.6 ± 311.1	1497.7 ± 273.5	247.6 ± 8.4	241.0 ± 38.2	337.0 ± 58.4	261.7 ± 21.8	195.6 ± 25.3
Crosses										
NaF	Female	1394.6 ± 23.4	1334.6 ± 47.4	1254.3 ± 34.9	914.0 ± 53.3	140.0 ± 3.0	176.0 ± 2.7	227.6 ± 34.4	204.3 ± 4.5	127.6 ± 3.8
	Male	1868.3 ± 5.1	1786.3 ± 20.2	1672.3 ± 18.1	1500.0 ± 84.6	210.3 ± 2.2	243.3 ± 15.4	325.6 ± 12.4	205.3 ± 7.2	165.3 ± 40.5
NaS	Female	1822.3 ± 56.5	1705.0 ± 136.8	1624.2 ± 91.0	1461.3 ± 103.5	225.3 ± 25.1	231.6 ± 23.1	302.0 ± 6.9	200.0 ± 11.5	173.6 ± 3.8
	Male	2153.3 ± 523.9	1874.3 ± 195.1	1722.6 ± 178.0	1581.3 ± 282.3	237.0 ± 40.6	241.7 ± 31.2	311.0 ± 8.0	205.7 ± 14.2	181.7 ± 12.1
NaW	Female	1751.6 ± 10.6	1665.3 ± 19.4	1472.3 ± 20.0	1238.3 ± 9.3	198.3 ± 8.3	217.3 ± 11.0	252.3 ± 3.5	189.3 ± 10.3	161.6 ± 4.7
	Male	1937.0 ± 13.1	1851.6 ± 18.7	1726.3 ± 6.7	1443.7 ± 19.4	238.7 ± 2.3	258.0 ± 4.4	282.3 ± 32.2	182.0 ± 15.7	182.0 ± 10.4
NaN	Female	1713.3 ± 127.2	1661.3 ± 127.1	1523.6 ± 113.4	1260.3 ± 108.7	184.0 ± 22.5	208.6 ± 13.8	313.3 ± 37.9	222.3 ± 29.6	155.3 ± 4.0
	Male	1889.6 ± 282.2	1823.7 ± 254.1	1687.3 ± 262.2	1394.0 ± 190.3	221.3 ± 35.9	229.6 ± 31.3	299.7 ± 53.4	249.0 ± 33.9	179.6 ± 21.7
FS	Female	1656.3 ± 76.1	1531.0 ± 30.8	1400.0 ± 12.1	193.3 ± 1.2	157.3 ± 26.1	164.4 ± 31.6	180.0 ± 17.3	200.7 ± 9.0	160.0 ± 10.5
	Male	1938.0 ± 41.3	1851.7 ± 28.4	1674.7 ± 17.5	1434.6 ± 4.6	233.6 ± 7.5	243.6 ± 5.0	303.7 ± 12.7	160.6 ± 21.5	172.0 ± 13.0

Genetic group	Sex	Fasted live weight (g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal weight (g)	Wing weight (g)
Purebreds										
FW	Female	1669.0 ± 167.7	1590.0 ± 137.4	1466.0 ± 134.5	1248.3 ± 138.4	166.3 ± 41.5	169.6 ± 39.5	207.6 ± 60.2	210.0 ± 19.7	154.0 ± 9.5
	Male	1679.6 ± 143.9	1605.6 ± 138.2	1485.0 ± 139.9	1263.0 ± 134.6	177.6 ± 50.9	169.7 ± 39.6	247.3 ± 80.5	211.0 ± 21.6	162.6 ± 15.9
FN	Female	1212.0 ± 25.0	1160.6 ± 23.0	1062.0 ± 31.1	829.0 ± 17.4	128.0 ± 2.6	130.3 ± 3.5	208.3 ± 23.6	170.3 ± 8.0	115.0 ± 3.6
	Male	1443.3 ± 138.6	1376.7 ± 132.4	1293.7 ± 141.1	1084.7 ± 100.0	168.8 ± 15.5	159.3 ± 16.2	230.7 ± 25.5	188.3 ± 10.5	143.4 ± 5.5
SW	Female	1463.6 ± 61.0	1435.8 ± 46.3	1274.0 ± 71.2	1064.3 ± 41.4	146.7 ± 2.8	169.3 ± 1.2	236.3 ± 8.50	184.7 ± 5.5	156.3 ± 1.5
	Male	1928.3 ± 51.0	1890.0 ± 103.3	1699.0 ± 89.1	1447.3 ± 27.8	221.3 ± 20.1	230.6 ± 10.0	284.3 ± 14.0	204.6 ± 5.0	173.7 ± 12.6
SN	Female	1327.0 ± 85.4	1280.0 ± 93.1	1151.3 ± 70.9	879.3 ± 200.9	130.3 ± 16.1	153.3 ± 11.2	238.0 ± 24.0	144.0 ± 40.5	123.3 ± 6.6
	Male	1900.3 ± 54.6	1766.3 ± 11.6	1633.7 ± 11.0	1368.0 ± 23.1	235.0 ± 5.5	222.6 ± 2.5	320.0 ± 2.0	207.3 ± 3.8	175.6 ± 2.1
WN	Female	1380.6 ± 24.1	1352.6 ± 45.0	1191.0 ± 5.2	1029.3 ± 73.5	130.0 ± 1.0	170.0 ± 1.0	241.3 ± 3.2	165.0 ± 2.0	129.7 ± 2.5
	Male	1897.7 ± 108.3	1829.0 ± 121.2	1685.3 ± 105.7	1348.0 ± 211.3	229.6 ± 11.9	256.7 ± 18.0	336.3 ± 42.4	199.3 ± 47.0	189.3 ± 3.5
Reciprocal										
FNa	Female	1336.7 ± 35.2	1293.0 ± 22.9	1207.7 ± 20.3	874.0 ± 51.	136.3 ± 3.2	169.7 ± 1.5	223.3 ± 32.2	196.7 ± 7.6	124.0 ± 5.3
	Male	1822.6 ± 31.1	1741.3 ± 32.7	1643.3 ± 8.3	1481.7 ± 71.6	206.6 ± 5.8	199.0 ± 54.5	320.0 ± 10.0	199.6 ± 8.0	162.6 ± 39.7
SNa	Female	1380.7 ± 162.6	1311.3 ± 134.5	1220.3 ± 145.1	998.0 ± 83.0	138.7 ± 12.1	154.6 ± 19.5	243.6 ± 19.8	173.0 ± 31.1	121.3 ± 7.6
	Male	1605.3 ± 174.9	1538.0 ± 157.8	1421.3 ± 151.5	1185.3 ± 163.5	189.3 ± 38.6	179.3 ± 17.1	241.0 ± 50.5	238.7 ± 16.0	157.6 ± 32.8
SF	Female	1846.0 ± 99.4	1716.3 ± 67.9	1597.3 ± 28.8	1405.3 ± 67.4	168.0 ± 17.1	147.7 ± 17.6	251.6 ± 24.7	152.3 ± 21.5	164.3 ± 3.2
	Male	1973.3 ± 192.0	1793.0 ± 32.5	1626.6 ± 17.5	1442.3 ± 30.0	194.3 ± 27.1	197.7 ± 43.4	290.0 ± 45.8	171.3 ± 27.7	173.3 ± 25.7
WNa	Female	1625.0 ± 23.8	1558.0 ± 33.3	1413.7 ± 6.7	1168.6 ± 5.0	162.3 ± 2.5	194.3 ± 4.5	283.3 ± 3.1	212.7 ± 4.6	154.4 ± 5.0
	Male	1969.6 ± 192.0	1890.7 ± 182.2	1732.6 ± 177.6	1529.3 ± 230.9	221.3 ± 25.5	221.3 ± 30.8	293.0 ± 23.9	213.0 ± 36.1	175.6 ± 18.8
WF	Female	1868.6 ± 105.0	1735.3 ± 78.5	1630.0 ± 35.6	1442.0 ± 46.0	174.0 ± 19.1	158.3 ± 16.0	257.6 ± 25.7	161.7 ± 12.3	168.0 ± 3.6
	Male	1984.3 ± 179.5	1797.6 ± 31.6	1642.6 ± 13.3	1461.0 ± 31.2	197.0 ± 24.3	203.0 ± 45.4	297.7 ± 43.3	176.6 ± 28.4	175.3 ± 25.0
WS	Female	1431.0 ± 5.6	1413.3 ± 8.1	1250.7 ± 30.7	1041.0 ± 2.7	143.7 ± 1.5	169.3 ± 1.2	230.0 ± 2.0	182.7 ± 3.5	154.0 ± 2.0

Genetic group	Sex	Fasted live weight (g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal weight (g)	Wing weight (g)
Purebreds										
	Male	1937.6 ± 79.1	1804.6 ± 124.5	1662.3 ± 91.0	1383.0 ± 55.0	219.0 ± 19.5	230.3 ± 10.5	287.3 ± 16.5	203.3 ± 5.5	170.3 ± 12.5
NNa	Female	1247.0 ± 138.6	1200.3 ± 132.5	1099.6 ± 134.5	929.0 ± 114.5	130.7 ± 7.0	147.0 ± 23.5	221.0 ± 27.5	151.3 ± 78.5	113.6 ± 9.1
	Male	2145.7 ± 258.8	1262.7 ± 1067.7	1861.0 ± 221.6	1589.0 ± 199.8	239.7 ± 21.5	247.0 ± 22.5	361.6 ± 58.5	243.7 ± 20.7	195.0 ± 20.5
NF	Female	1125.3 ± 16.2	1055.3 ± 56.0	1001.3 ± 26.5	882.6 ± 19.6	132.7 ± 4.0	144.0 ± 8.6	206.0 ± 13.9	156.0 ± 3.5	137.0 ± 32.9
	Male	1656.6 ± 15.8	1504.3 ± 35.9	1338.0 ± 56.9	1218.0 ± 98.8	208.7 ± 45.5	202.3 ± 8.6	211.3 ± 31.0	160.3 ± 3.5	167.3 ± 12.8
NS	Female	1148.3 ± 25.4	1102.3 ± 6.5	1000.3 ± 3.0	818.7 ± 3.2	116.0 ± 1.0	129.7 ± 1.5	190.7 ± 1.2	143.7 ± 4.1	113.3 ± 1.5
	Male	1751.6 ± 6.7	1687.0 ± 3.0	1621.6 ± 3.1	1483.3 ± 7.0	245.3 ± 2.5	225.0 ± 2.0	335.6 ± 4.0	211.0 ± 4.6	180.0 ± 4.0
NW	Female	1426.7 ± 148.4	1391.7 ± 157.8	1272.3 ± 135.5	1011.0 ± 138.8	152.0 ± 18.0	177.7 ± 19.4	252.3 ± 47.7	192.7 ± 49.7	146.0 ± 13.9
	Male	1712.3 ± 263.6	1655.0 ± 261.0	1483.0 ± 214.7	1272.7 ± 321.9	206.0 ± 32.0	199.3 ± 33.0	273.3 ± 53.2	191.6 ± 24.5	168.3 ± 17.9
Overall	Female	1450.9 ± 247.1[b]	1386.8 ± 226.7[a]	1268.8 ± 212.2[b]	1164.3 ± 991.9[b]	148.8 ± 30.3[b]	164.8 ± 30.0[b]	233.5 ± 40.8[b]	180.5 ± 32.2[b]	139.2 ± 21.7[b]
	Male	1882.4 ± 253.4[a]	1752.2 ± 294.5b	1637.7 ± 205.3[a]	1397.7 ± 207.1[a]	216.3 ± 39.6[a]	220.2 ± 36.7[a]	296.4 ± 52.5[a]	205.2 ± 33.9[a]	175.7 ± 23.1 [a]

*F is Frizzled feathered, N is Normal feathered, Na is Naked neck, S is short legged and W is White spotted chickens.

[a– i]:means in the same column having different superscripts are significantly different (P ⍰ 0.05). N is the number of observations.

Combining abilities of the different indigenous chicken strains

The GCA, SCA, and RE were estimated for various carcass traits and are given in Table 4.

General combining abilities

The GCA effects in Table 4 revealed that White Spotted positively contributed to most carcass traits, such as bled and pluck weight, indicating a strong additive genetic influence. Similarly, Naked Neck showed favorable GCA for live and pluck weight, whereas Normal Feathered and Frizzled Feathered suggest that these strains possess favorable additive genes that can be transmitted consistently to their progeny, thereby contributing to improved carcass traits. The presence of significant GCA effects implies that selection within these parental lines can be an effective strategy for genetic improvement of carcass yield in Zambian indigenous chickens. Short Legged generally exhibited negative GCA effects for these traits, highlighting their limited additive contribution to carcass improvement. These results suggest that the selection of superior parental lines with high GCA as noted by Tyasi et al. (2021) and Adebambo et al. (2010), particularly White Spotted and Naked Neck, would be effective in improving carcass yield in subsequent generations.

Specific combining abilities

The estimates of SCA in Table 4 exhibited significant variation among the cross combinations, indicating a predominance of non-additive gene action and the presence of heterosis for several carcass traits. Among the evaluated crosses, the F×S combination demonstrated the highest positive SCA effects for fasted live weight, bled weight, and pluck weight and also contributed substantially to drumstick and thigh weights. This suggests strong dominance and epistatic interactions influencing carcass development in this cross. Positive SCA effects were also observed in crosses such as Na×S and W×N for selected traits, indicating favorable cross-specific gene interactions. Conversely, crosses including F×N and N×W consistently showed negative SCA estimates, reflecting poor specific combining ability and limited heterotic advantage for carcass performance. The dominance and epistatic interactions expressed in the superior crosses thus contributed to improved carcass yield in the crossbred progeny. These findings corroborate earlier reports that non-additive gene effects play a major role in the heterotic expression of carcass traits in indigenous chickens (Tyasi et al. 2021). Similar observations were reported by Sharma (2011) and Adebambo et al. (2010), who found that crossbred chickens exhibited positive heterosis for several carcass traits. Collectively, these results underscore the importance of identifying cross combinations with high SCA effects to exploit heterosis and enhance meat production in indigenous chicken improvement programs.

Reciprocal effects

The S×Na cross exhibited a large positive reciprocal effect for all carcass traits, except internal organ weight, indicating that the type of crossing significantly affected carcass outcomes. Conversely, some crosses, such as W×F and N×F, had negative RE for multiple traits, suggesting that maternal inheritance can reduce carcass performance. These results are consistent with those of Soliman et al. (2016), who reported significant maternal effects in reciprocal crosses of indigenous and commercial chicken strains. The reciprocal effects highlighted the maternal and cytoplasmic influences on carcass traits (Negash and Getachew, 2025).

Table 4
General combing abilities, Specific combining abilities and Reciprocal Effects (RE) on Carcass traits of the various genetic groups of the Indigenous Zambian Chickens

Genetic group	Number of chickens	Fasted live weight (g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal organ weight (g)	Wing weight (g)
GCA										
NaNa	6	52.4	27.2	57.5	-4.2	9.7	13.6	12.8	11.9	3.7
FF	6	-19.3	-20.9	-28.6	-89.2	-7.0	-14.4	-18.7	-10.6	-2.1
SS	6	-44.1	-33.3	-47.4	57.3	-10.8	-6.8	-10.6	-9.6	-5.2
WW	6	94.4	117.7	83.0	14.9	9.8	11.6	14.1	6.7	7.7
NN	6	-83.5	-90.6	-64.5	21.2	-1.7	-3.8	2.4	1.5	-4.1
SCA										
NaF	6	25.9	-21.7	-18.9	-14.6	-1.8	-12.8	-2.5	-3.3	-1.6
NaS	6	65.4	43.8	33.9	-27.6	16.1	2.6	7.2	9.1	2.6
NaW	6	7.3	26.9	-7.5	53.3	3.1	5.1	-14.1	-12.4	-0.4
NaN	6	-52.6	-255.5	-62.6	-34.1	-8.8	-11.1	-7.6	-19.1	-6.6
FS	6	250.1	207.8	197.5	119.8	23.6	17.1	20.6	-1.5	17.2
FW	6	58.6	15.9	48.3	146.9	-6.6	-14.5	-7.7	1.0	1.9
FN	6	-204.6	-183.7	-186.4	-209.4	-14.4	-15.2	-34.6	-15.1	-10.7
SW	6	-26.9	-18.0	-17.4	-119.2	1.1	2.7	-8.9	3.7	3.6
SN	6	-81.8	-64.3	-40.8	-694.5	-1.0	-5.3	-7.9	0.8	-1.4
WN	6	-34.8	-33.8	-30.3	-23.4	-0.4	-12.4	-13.0	5.0	-1.2
RE										
FNa	6	-94.2	-36.9	-37.7	4.8	-11.9	5.4	15.1	7.3	-14.1
SNa	6	247.4	182.5	176.3	214.8	33.6	34.8	32.1	-1.5	19.1
SF	6	-56.3	-31.7	-37.3	-54.9	7.2	15.7	-14.5	9.4	-1.4
WNa	6	23.5	17.1	13.1	-4.0	13.3	14.9	-10.4	-13.8	3.4
WF	6	-126.1	-84.3	-80.4	-97.9	-6.8	-5.5	-25.1	20.9	-6.7
WS	6	5.8	26.9	15.0	21.9	1.3	0.1	0.8	0.8	1.4
NNa	6	113.3	-19.1	96.7	-4.9	3.3	5.9	18.8	10.2	3.8
NF	6	-31.7	-5.6	4.1	-46.8	-11.2	-14.2	5.4	10.6	-11.5
NS	6	-7.3	13.3	10.4	485.9	11.6	0.8	14.3	-8.3	-0.2
NW	6	-73.3	-39.6	-63.9	-151.8	-11.3	0.7	-5.5	-14.0	-2.8

*N is the number of observations.

F is Frizzled Feathered, N is Normal Feathered, Na is Naked Neck, S is Short Legged and W is White Spotted chickens.

GCA is general combining ability, SCA is specific combining ability and RE is reciprocal effect.

Estimates of variance components on carcass weights

The variance components analysis for carcass weights of indigenous Zambian chickens in Table 5 revealed that specific combining ability effects were highly significant for most carcass traits. In contrast, general combining ability effects were not significant. For instance, SCA accounted for significant variation in fasted live ($P < 0.05$), bled ($P < 0.05$), and pluck weight ($P < 0.05$), indicating the importance of non-additive genetic effects such as dominance and epistasis in controlling these traits, according to the report by Adebambo et al. (2010). Conversely, GCA effects for all carcass traits were not significant ($P > 0.05$), suggesting that additive gene effects played a minor role in determining overall carcass weight in the studied populations. This is in contrast to what was reported by Adebambo et al. (2010), who found and showed that both additive and non additive effects were significant ($p < 0.05$) in determining carcass traits.

The reciprocal effects were significant for fasted live weight ($P < 0.05$), implying that maternal or cytoplasmic effects may influence growth and carcass development in certain crosses. Other traits, such as eviscerated weight, showed non-significant RE, indicating that maternal effects were less important for internal organ carcass yield. The dominance-to-additive variance ratio (GCA/SCA) was consistently low across all traits, ranging from 0.07 to 0.28 for most weights, further confirming the predominance of non additive gene action over additive effects. Negative ratios for eviscerated weight highlight the potential influence of environmental or experimental variation on this trait.

SCA showed a strong contribution ($P < 0.001$) to breast weight, whereas GCA and RE were not significant ($P > 0.05$). This pattern suggests that crossbreeding is more effective than within-strain selection for improving breast yield in indigenous chickens. Similar findings have been reported by El-Attrouny et al. (2021), who observed that breast muscle development is enhanced by heterotic effects rather than direct additive inheritance.

Drumstick, wing, and breast weights showed highly significant SCA effects ($P < 0.05$), whereas GCA and RE were non-significant. This indicates that the muscle mass of the drumstick is primarily influenced by dominance and epistasis. Unlike most other carcass traits, thigh weight showed significant GCA ($P < 0.05$), SCA ($P < 0.05$), and RE ($P < 0.05$). This finding shows that both additive and non-additive gene actions, as well as maternal effects, play a role in the differences in thigh weight (Tyasi et al. 2019; Mokoena et al. 2025). The relatively higher GCA/SCA ratio (> 1) further highlights the role of additive variance in this trait. Thus, direct selection and crossbreeding programs may simultaneously improve thigh weight.

The inheritance of internal organ weights showed a mixed pattern. Overall internal organ weight exhibited significant SCA effects ($P < 0.05$), whereas GCA and RCA were non-significant. This confirms that non-additive variance is central to variation in overall internal tissue mass. The results are consistent with previous diallel studies that found dominance effects primarily influenced internal organ weight (Soliman et al. 2016). For wing weight, SCA effects were highly significant ($P < 0.05$), whereas GCA and RE were non-significant. This highlights the importance of non-additive genetic variance in wing muscle inheritance. The strong SCA influence indicates that crossbred progeny may show greater variability and heterotic advantages for this trait, consistent with earlier findings in diallel studies (Tyasi et al. 2019).

Table 5
Estimates of Variance Components for carcass traits of the indigenous chickens of Zambia

Variance Component	Fasted live weight (g)	Bled weight (g)	Pluck weight (g)	Eviscerated weight (g)	Drumstick weight (g)	Thigh weight (g)	Breast weight (g)	Internal organ weight (g)	Wing weight (g)
GCA	1.4^{NS}	3.4^{NS}	1.8^{NS}	-6.5^{NS}	29.8^{NS}	120.4^{*}	120.5^{NS}	6.7^{NS}	10.2^{NS}
SCA	2.0^{***}	1.2^{***}	1.3^{***}	5.9^{NS}	284.7^{***}	91.5^{*}	370.0^{***}	1.1^{*}	83.1^{**}
RE	6.2^{*}	7.5^{NS}	2.4	1.2^{NS}	88.7^{NS}	178.4^{*}	96.3^{NS}	5.2^{NS}	27.8^{NS}
Error	6.2	7.8	4.5	8.5	144.5	118.8	267.8	1.4	65.4
Additive	2.8	6.8	3.6	-1.3	59.6	240.7	241.0	1.3	20.4
Dominant	2.0	1.2	1.3	5.9	284.7	91.5	369.9	1.1	83.1
GCA/SCA	7.1	2.8	1.4	-1.1	0.1	1.3	0.3	5.9	0.1
*N is the number of observations,									

GCA is the General Combining Ability, SCA is the Specific Combining Ability and RE is the Reciprocal Effect.

^{NS} is not significant***, **, * significant difference at 0.1%, 1% and at 5%

Conclusion

Crossbreeding among indigenous Zambian chicken strains resulted in significant improvements in carcass weight and primal cut yield. Crosses involving the Naked Neck and White Spotted strains consistently outperformed other genetic groups, demonstrating the practical value of heterosis for meat production. The substantial sire effects suggest that genetic advancement in carcass characteristics can be expedited via sire selection. Diallel analysis revealed that non-additive genetic effects were the primary determinants of carcass performance, with additional contributions from reciprocal effects.

Recommendations

Breeding programs should focus on maintaining and evaluating superior cross combinations, particularly those involving the Naked Neck and White Spotted strains. Further studies examining the consistency of these combining ability effects across environments and their genetic correlations with other production traits are warranted.

Declarations

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics approval

ERES Converge, Lusaka, Zambia, was approved (No. 1595 2021) for the study. The feeding, housing, handling, and experimentation involving the chickens were conducted following the guidelines outlined (ASAS, 2020).

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Author Contributions

Mayoba Barbara Moono conceptualized, designed, and wrote the manuscript. Mubanga Mwale and Joseph Gibson Mbewe collected data and wrote the manuscript. Wilson Nelson Mubanga Mwenya and Idowu Kolawole Odubote supervised the project and reviewed the manuscript. All authors viewed and approved the final draft of the manuscript.

Data Availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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