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Research Article
Effects of Stocking Density and Genotype on the Growth Performance of Male and Female Broiler Chickens

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Abstract
Background and Objective: Currently, there is paucity of information in tropical and sub-tropical conditions on the interaction effects of genotype, sex and stocking density on optimum broiler performance and carcass characteristics, since the recommended densities are based on researches in temperate environments. Therefore, the interaction effects of genotype, sex and stocking density on growth performance and carcass characteristics were investigated. **Materials and Methods:** Male and female Ross 308 and Cobb Avian 48 broilers were reared at stocking densities of 30, 35 and 40 kg BW m^{-2} over 42 days. Data were analyzed by a three-way ANOVA for a $3\times2\times2$ factorial using the GLM procedure of Minitab 17. **Results:** During the entire period, genotype had no effect ($p>0.05$) on any growth performance traits. While, males consumed 8.5% more ($p<0.01$) feed, gained 11.5% more ($p<0.01$) body weight and were 10.9% heavier ($p<0.01$) at slaughter (day 42) than females. For stocking density, broilers reared at 30 kg BW m^{-2} consumed 9.0 and 12.8% more ($p<0.01$) feed, gained 7.4 and 9.4% more ($p<0.01$) body weight and were 6.8 and 8.7% heavier ($p<0.01$) at slaughter than those raised at 35 and 40 kg BW m^{-2}, respectively. Except the reduction ($p<0.05$) in breast percentage weights with increasing stocking density, neither genotype, sex nor stocking density influenced ($p>0.05$) percentage weights of carcass parts. There were also stocking density$\times$sex interaction effects ($p<0.05$) on feed consumption, genotype$\times$stocking density interaction effects ($p<0.05$) on the relative weights of the wing and abdominal fat and genotype$\times$sex interaction effects on 42 days body weight ($p<0.01$) and relative weight of the wing ($p<0.05$). **Conclusion:** The results showed that male Cobb Avian 48 raise at stocking density of 30 kg BW m^{-2} performed better in the sub-tropics specifically in winter.

Key words: Carcass, Ross 308, Cobb Avian 48, stocking density, FCR

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The aim of broiler producers worldwide is to maximize the kilograms of chicken produced per unit area and simultaneously prevent production losses due to over crowding. Some studies showed that reducing stocking density improved broiler performance[1,2]. Others indicated that reducing stocking density had no influence[3] or had a negative impact[4]. Dozier *et al.*[5] reported that body weight gain (BWG), feed intake and dressing percentage were depressed when stocking density was increased from 25-35 kg b.wt. m^{-2} but abdominal fat was not affected.

Lobago *et al.*[6] evaluated the performance of Cobb 500 and Ross 308 under the small scale production system and reported that Cobb 500 performed better than Ross. For example, a significantly higher proportion of Cobb 500 (65.7%) reached market weight than Ross (37.65%) at 8-9 weeks of age. Olawumi and Fagbuaro[7] compared the carcass characteristics of Marshall, Arbor Acre and Hubbard and reported that Marshall was superior to Arbor Acre and Hubbard in live body weight (BW) at 42 days of age but the strains were similar in dressing percentage, abdominal fat weight and liver and gizzard weights.

It has been reported that sex affects performance traits of chickens such as BW, BWG, feed intake and feed conversion ratio (FCR)[7]. Shahin and Abd Elazeem[8] and Ajayi and Ejiofor[9] reported that males were 14% heavier than females at 28 and 42 days of age. Sex also significantly affects carcass traits such as carcass composition, proportion of wing, thigh, neck and carcass fat and carcass meat with higher values in males than females. Castellini *et al.*[10], however reported that carcass characteristics were not greatly affected by sex.

Genotype×sex interaction effects on BW, BWG, feed intake and FCR were reported earlier[11,12]. Olawumi *et al.*[13] also observed significant genotype×sex interaction effects on most carcass traits including carcass weight, eviscerated weight, breast muscle weight, thigh weight, drumstick weight, leg weight and heart weight.

Broiler producers generally select stocking densities, strains and sex that allow the birds to reach market BW early in order to maximize their profit margins[12]. In many least developed countries however, there are many small-scale broiler producers that lack information on the appropriate strain-sex-stocking density combinations to maximize profit. Because of this lack of information, the study was undertaken to determine the effects of genotype, stocking density, sex and interaction effects, if any, on growth performance and carcass characteristics of broilers raises under a semi-arid sub-tropical environment.

MATERIALS AND METHODS

Ethical clearance: The experimental protocol used in this study, including animal management, housing and slaughter procedures, was approved by the University of Venda Ethics Committee (Project number: ARDF/15/ANS/1210).

Experimental site: The investigation was conducted in winter (July and August, 2015) at the Poultry Facility of the School of Agriculture, University of Venda, Thohoyandou (22°57'58"S and 30°29'05"E), South Africa. The climate of the area is sub-tropical with cold dry winters and hot rainy summers.

Housing: The broiler house used in the study was similar to those used by small-scale producers in the area. The building has dimensions 17 m×9 m. The walls of the width were constructed of red bricks from the floor to the ceiling while those of the length were constructed of red bricks for about a meter followed by 2.5 cm wire mesh to the ceiling. Heavy plastic sheeting on top of the wire mesh were used to control air movement into and out of the building since there were no fans in the facility nor a barometer to measure relative humidity. The house was divided into 36 pens. The floor was covered with saw dust and each pen was equipped with 2 tube feeders, 2 automatic drinkers as well as two 175 W infra-red bulbs for heating. The daily temperature in the house during the study ranged from 8-21°C with a mean of 18°C.

Experimental birds and general flock management: About 315 male and 369 female Ross 308 and 324 male and 378 female Cobb Avian 48 broilers were fed a commercial broiler starter diet to 21 days, grower diet to 35 days and finisher diet to 42 days of age (Table 1). The chicks were raised together in groups according to sex and strain for the first 6 days (acclimatization period). On day 7, the birds of each strain and sex were leg-banded, individually weighed and randomly allocated to three predetermined stocking densities

Table 1: Chemical composition of commercial broiler starter, grower and finisher feeds used in this study[a]

Composition	Starter	Grower	Finisher
Crude protein (g kg^{-1})	200.00	180.00	160.00
ME (MJ kg^{-1})	12.76	13.00	13.20
ME to CP rations (MJ g^{-1})	0.06	0.07	0.08
Fat (g kg^{-1})	25.00	25.00	25.00
Fiber (g kg^{-1})	50.00	60.00	70.00
Moisture (g kg^{-1})	120.00	120.00	120.00
Calcium (g kg^{-1})	12.00	12.00	12.00
Phosphorus (g kg^{-1})	6.00	5.50	5.00
Lysine (g kg^{-1})	12.00	10.00	9.00

[a]Supplied by meadow feeds, Randfontein, South Africa

(30, 35 and 40 kg BW m^{-2}). The number of birds per pen was calculated based on 42 days BW of 2.98 and 2.56 kg for male and female Ross, respectively and 2.93 and 2.49 kg for male and female Cobb, respectively. The number of birds per pen needed for the projected stocking densities was calculated according to the following formula described by Dozier *et al.*[5]:

$$\text{Birds/pen} = \frac{\text{Final treatment density (kg m}^{-2}\text{)} \times \text{Pen area (m}^2\text{)}}{\text{Projected final body weight}}$$

The calculated stocking densities of 30, 35 and 40 kg BW m^{-2} corresponded to 30, 35 and 40 males and 35, 41 and 47 females for Ross and 31, 36 and 41 males and 36, 42 and 48 females for Cobb broilers/pen. Each genotype-sex-stocking density combination was replicated three times. Feed and water were provided *ad libitum* and continuous lighting was provided by 40W fluorescent tubes.

Growth performance of broiler chickens: After the initial weighing on day 7, the birds were individually weighed weekly until 42 days of age and body weight gain were calculated using difference between final and initial body weight. Prior to each weighing, the birds were deprived of feed for 12 h. Feed consumed in each pen was recorded when the birds were weighed and feed conversion ratio was calculated (g feed: g gain).

Carcass characteristics of broiler chickens: After the last weighing, four birds were randomly sampled from each pen, slaughtered and eviscerated following the procedure described previously[14]. The weights of carcass parts and giblets were expressed as percentages of slaughter weight.

Statistical analysis: Pen means were used for BW, BWG, feed intake, feed efficiency and mortality rate, as well as carcass weight and the weights of the carcass parts. All data were analyzed by a three-way analysis of variance for a 3×2×2 factorial using the GLM procedure of Minitab 17 statistical software[15], followed by standard means separation using Tukey's procedure. Data were significant at $p<0.05$ and highly significant at $p<0.01$.

RESULTS

Growth performance: Means and standard errors for initial BW, 21 days BW, BWG, feed consumption (FC), FCR and mortality rate during the starter period are presented in Table 2. Stocking density significantly affected 21-day BW ($p<0.01$), BWG ($p<0.01$) and FC ($p<0.01$) but did not influence ($p>0.05$) FCR and mortality rate. The mean values of the affected traits decreased as stocking density increased. Genotype affected initial BW ($p<0.01$) and FC ($p<0.05$). Ross

Table 2: Effects of stocking density, genotype and sex on broiler performance until 21st day of rearing (starter period)

Parameters	N	IBW (g)	BW_{21} (g)	BWG_{7-21} (g)	FC_{7-21} (g/b/d)	FCR_{7-21} gf/gg	MR_{7-21} (%)
Stocking density means							
30 kg BW m^{-2}	12	149.0	783.0^a	631.0^a	76.00^a	1.70	1.7
35 kg BW m^{-2}	12	152.0	745.0^b	593.0^b	74.00^b	1.76	1.2
40 kg BW m^{-2}	12	150.0	714.0^c	560.0^c	69.00^c	1.72	2.1
SEM		1.1	7.9	2.0	4.40	0.04	0.6
Genotype means							
Ross	18	153.0^a	745.0	597.0	75.00^a	1.72	1.4
Cobb	18	148.0^b	751.0	592.0	71.00^b	1.77	1.9
SEM		1.1	6.5	7.0	1.00	0.04	0.6
Sex means							
Male	18	152.0^a	778.0^a	622.0^a	76.00^a	1.72	1.8
Female	18	149.0^b	717.0^b	566.0^b	70.00^b	1.73	1.5
SEM		1.1	6.5	7.0	1.03	0.04	0.6
Significance							
Stocking density (D)		ns	**	**	**	ns	ns
Genotype (G)		**	ns	ns	*	ns	ns
Sex (S)		*	**	**	**	ns	ns
D×G		ns	ns	ns	ns	ns	ns
D×S		**	ns	ns	ns	ns	ns
G×S		ns	ns	ns	ns	ns	ns
D×G×S		ns	ns	ns	ns	ns	ns

*$p<0.05$, **$p<0.01$, (ns) not significant, $p>0.05$, [a,b,c]For a trait, means carrying different superscripts are significantly different at $p<0.05$, N: Number of observations, IBW: Initial body weight, BW_{21}: Body weight at 21 days of age, BWG_{7-21}: Body weight gain, FC_{7-21}: Feed consumption, FCR_{7-21}: Feed conversion ratio, MR_{7-21}: Mortality rate, D: Stocking density, G: Genotype, S: Sex, g/b/d: Grams/bird/day, gf/gg: Gram feed per gram gain and SEM: Standard error mean

Table 3: Effects of stocking density, genotype and sex on broiler performance from 22-35 days of rearing (grower period)

Parameters	N	BW_{35} (g)	BWG_{22-35} (g)	FC_{22-35} (g/b/d)	FCR_{22-35} (gf/gg)	MR_{22-35} (%)
Stocking density means						
30 kg BW m^{-2}	12	1764.0	1019.0^{a}	155.0^{a}	2.16	1.10
35 kg BW m^{-2}	12	1642.0	933.0^{b}	138.0^{b}	2.11	2.30
40 kg BW m^{-2}	12	1613.0	886.0^{b}	135.0^{b}	2.15	0.40
SEM		57.9	34.4	4.3	0.07	0.60
Genotype means						
Ross	18	1727.0	975.0	143.0	2.10	0.80
Cobb	18	1619.0	917.0	142.0	2.20	1.70
SEM		47.2	28.1	3.5	0.06	0.50
Sex means						
Male	18	1778.0^{a}	1022.0^{a}	150.0^{a}	2.10	0.86
Female	18	1568.0^{b}	869.0^{b}	135.0^{b}	2.20	1.61
SEM		47.2	28.1	3.5	0.06	0.50
Significance						
Stocking density (D)		ns	*	**	ns	ns
Genotype (G)		ns	ns	ns	ns	ns
Sex (S)		**	**	**	ns	ns
D×G		ns	ns	ns	ns	ns
D×S		ns	*	ns	ns	*
G×S		ns	ns	ns	ns	ns
D×G×S		ns	ns	ns	ns	ns

*p<0.05, **p<0.01, (ns) not significant, p>0.05, a,bFor a trait, means carrying different superscripts are significantly different at p<0.05. N: Number of observations, BW_{35}: Body weight at 35 days of age, BWG_{22-35}: Body weight gain, FC_{22-35}: Feed consumption, FCR_{22-35}: Feed conversion ratio, MR_{22-35}: Mortality rate, D: Stocking density, G: Genotype, S: Sex, g/b/d: Grams/bird/day, gf/gg: Gram feed per gram gain and SEM: Standard error mean

was heavier initially and consumed more feed than Cobb but the genotypes did not differ (p>0.05) in 21 days feed intake, FCR and mortality rate. Sex affected initial BW (p<0.05) as well as 21 days BW (p<0.01), BWG (p<0.01) and FC (p<0.01) but did not affect (p>0.05) FCR and mortality rate. Males were heavier initially, consumed more feed, gained more body and were heavier at 21 days of age than females. There was a difference (p<0.01) in stocking density×sex interaction effect on initial BW.

During the grower period (Table 3) stocking density affected BWG (p<0.05) and feed intake (p<0.01) but did not affect the other traits. The group reared at the density of 30 kg BW m^{-2} consumed more feed and gained more BW than the broilers reared at the densities of 35 and 40 kg BW m^{-2} but the two latter groups did not differ (p>0.05) in these traits. Genotype did not affect (p>0.05) any of the traits, but sex affected 35-day BW (p<0.01) and BWG (p<0.01) as well as FC (p<0.01) but did not affect FCR and mortality rate. Males consumed more feed, gained more BW and were heavier at 35 days than females. Stocking density×sex interaction affected BWG (p<0.05) and mortality rate (p<0.05).

Stocking density affected (p<0.01) 42-day BW and feed intake during the finishing period (Table 4) but did not affect (p>0.05) BWG, FCR and mortality rate. Broilers reared at the density of 30 kg BW m^{-2} were heavier at 42 days than those reared at the densities of 35 and 40 kg BW m^{-2} but birds reared at the 2 higher densities did not differ (p>0.05) in this trait. As regards FC, intake decreased as stocking density increased. Genotype influenced (p<0.01) only FC, with Ross being a higher consumer than Cobb. Sex influenced (p<0.01) 42 days BW and FC, but did not affect the other traits. Males consumed more feed and were heavier than females at slaughter, but sex did not affect the other traits (p>0.05). There were genotype×stocking density (p<0.01) and genotype×sex (p<0.05) interaction effects on 42-day BW.

Over the entire study period (Table 5), stocking density affected 42 days BW (p<0.01), BWG (p<0.01) and FC (p<0.01). For each trait, broilers reared at the density of 30 kg BW m^{-2} had a higher mean than those reared at 35 and 40 kg BW m^{-2} but the two latter groups did not differ (p>0.05) in these traits. Genotype did not affect (p>0.05) any of the traits, but sex affected (p<0.01) 42 days BW, BWG and feed intake. Males consumed more feed, gained more BW and were heavier than females at slaughter, but sex had no influence (p>0.05) on FCR and mortality rate. There were genotype×stocking interaction effects on 42 days BW (p<0.01), BWG (p<0.01) and FCR (p<0.05), stocking density×sex interaction effects (p<0.05) on feed intake and a genotype×sex interaction effect on 42 days BW (p<0.05) and BWG (p<0.05).

Carcass characteristics: With regard to the percentages of carcass parts and giblets (Table 6), genotype and sex had no influence (p>0.05) on any of the traits but stocking density affected (p<0.05) breast percentage. The mean value of this

Table 4: Effects of stocking density, genotype and sex on broiler performance from 35-42 days of rearing (finisher period)

Parameters	N	BW_{42} (g)	$BWG_{35\text{-}42}$ (g)	$FC_{35\text{-}422}$ (g/b/d)	$FCR_{35\text{-}42}$ (gf/gg)	$MR_{35\text{-}42}$ (%)
Stocking density means						
30 kg BW m^{-2}	12	2346.0[a]	519.0	194.0[a]	2.69	0.30
35 kg BW m^{-2}	12	2186.0[b]	454.0	181.0[ab]	2.91	0.80
40 kg BW m^{-2}	12	2141.0[b]	511.0	175.0[b]	264.00	0.60
SEM		44.4	35.3	3.9	0.18	0.40
Genotype means						
Ross	18	2222.0	477.0	190.0[a]	2.89	0.70
Cobb	18	2227.0	512.0	176.0[b]	2.60	0.40
SEM		36.2	28.8	3.2	0.13	0.30
Sex means						
Male	18	2353.0[a]	516.0	192.0[a]	2.72	0.86
Female	18	2096.0[b]	473.0	174.0[b]	2.77	0.21
SEM		36.2	51.5	3.21	0.13	0.30
Significance						
Stocking density (D)		**	ns	**	ns	ns
Genotype (G)		ns	ns	**	ns	ns
Sex (S)		**	ns	**	ns	ns
D×G		**	ns	ns	ns	ns
D×S		ns	ns	ns	ns	ns
G×S		*	ns	ns	ns	ns
D×G×S		ns	ns	ns	ns	ns

*p<0.05, **p<0.01, (ns) not significant, p>0.05, [a,b]For a trait, means carrying different superscripts are significantly different at p<0.05, N: Number of observations, BW_{42}: Body weight at 42 days of age, $BWG_{35\text{-}42}$: Body weight gain, $FC_{35\text{-}42}$: Feed consumption, $FCR_{35\text{-}42}$: Feed conversion ratio, $MR_{35\text{-}42}$: Mortality rate, D: Stocking density, G: Genotype, S: Sex, g/b/d: Grams/bird/day, gf/gg: Gram feed per gram gain and SEM: Standard error mean

Table 5: Effects of stocking density, genotype and sex on broiler performance from 7-42 days of rearing (entire period)

Parameters	N	BW_{42} (g)	$BWG_{7\text{-}42}$ (g)	$FC_{7\text{-}42}$ (g/b/d)	$FCR_{7\text{-}42}$ (gf/gg)	$MR_{7\text{-}42}$ (%)
Stocking density means						
30 kg BW m^{-2}	12	2346.0[a]	2197.0[a]	133.0[a]	2.55	3.1
35 kg BW m^{-2}	12	2186.0[b]	2034.0[b]	121.0[b]	2.57	4.2
40 kg BW m^{-2}	12	2141.0[b]	1991.0[b]	116.0[b]	2.47	3.1
SEM		44.4	1.3	2.0	0.10	1.1
Genotype means						
Ross	18	2222.0	2074.0	125.0	2.54	2.9
Cobb	18	2227.0	2074.0	122.0	2.48	4.0
SEM		36.2	36.4	1.6	0.04	0.9
Sex means						
Male	18	2353.0[a]	2200.0[a]	129.0[a]	2.46	3.5
Female	18	2096.0[b]	1948.0[b]	118.0[b]	2.55	3.4
SEM		36.2	36.4	1.6	004.00	0.9
Significance						
Stocking density (D)		**	**	**	ns	ns
Genotype (G)		ns	ns	ns	ns	ns
Sex (S)		**	**	**	ns	ns
D×G		**	**	ns	*	ns
D×S		ns	ns	*	ns	ns
G×S		*	*	ns	ns	ns
D×G×S		ns	ns	ns	ns	ns

*p<0.05, **p<0.01, (ns) not significant, p>0.05, [a,b]For a trait, means carrying different superscripts are significantly different at p<0.05, N: Number of observations, BW_{42}: Body weight at 42 days of age, $BWG_{7\text{-}42}$: Body weight gain, $FC_{7\text{-}42}$: Feed consumption, $FCR_{7\text{-}42}$: Feed conversion ratio, $MR_{7\text{-}42}$: Mortality rate, D: Stocking density, G: Genotype, S: Sex, g/b/d: Grams/bird/day, gf/gg: Gram feed per gram gain and SEM: Standard error mean

trait decreased as stocking density increased. There were genotype×stocking density (p<0.05) and genotype×sex (p<0.05) interaction effects on wing percentage. With regard to the percentages of giblets, there were no effects (p>0.05) of stocking density, genotype and sex effects on any of the traits, but there was a significant stocking density×genotype interaction effect (p<0.05) on fat percentage.

Table 6: Percentages of carcass parts and giblets of males and females of two broiler genotypes raised at three stocking densities

	N	CAR	BRS	BAC	THI	WNG	DST	HRT	GZR	LIV	AFT
Stocking density means											
30 kg BW m^{-2}	12	82.70	27.40[a]	16.50	5.60	4.40	5.00	0.58	1.59	3.13	1.74
35 kg BW m^{-2}	12	80.60	26.30[ab]	15.80	5.50	4.30	5.00	0.52	1.55	3.02	1.81
40 kg BW m^{-2}	12	78.40	24.80[b]	15.40	5.30	4.20	4.90	0.51	3.69	2.71	1.77
SEM		1.39	0.57	13.00	0.12	0.09	0.09	0.00	1.20	1.14	0.10
Genotype means											
Ross	18	81.50	26.50	16.00	5.50	4.30	5.00	0.57	2.97	1.58	1.80
Cobb	18	79.70	25.40	15.70	5.40	4.30	4.90	0.50	1.59	0.64	1.75
SEM		1.14	0.47	0.29	0.10	0.07	0.07	0.47	0.29	0.10	0.07
Sex means											
Male	18	80.90	25.80	16.00	5.50	4.30	4.90	0.51	1.58	1.57	1.76
Female	18	80.30	26.60	15.80	5.40	4.30	4.90	0.57	2.97	0.64	1.78
SEM		1.14	0.47	0.29	0.10	0.07	0.07	0.40	1.00	0.93	0.10
Significance											
Stocking density (D)		ns	*	ns	ns	ns	ns	ns	ns	ns	ns
Genotype (G)		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sex (S)		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
D×G		ns	ns	ns	ns	*	ns	ns	ns	ns	*
D×S		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
G×S		ns	ns	ns	ns	*	ns	ns	ns	ns	ns
D×G×S		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

*p<0.05, (ns) not significant, p>0.05. [a,b]For a trait, means carrying different superscripts are significantly different at P <0.05. N: number of observations, CAR: Carcass, BRS: Breast, BAC: Back, THI: Thigh, WNG: Wing, DST: Drumstick, HRT: Heart, GZR: Gizzard, LIV: Liver, AFT: Abdominal fat, D: Stocking density, G: Genotype, S: Sex and SEM: Standard error mean

DISCUSSION

All birds had average weight of more than 2 kg at the end of the experiment (42 days), except for a 40 kg BW m^{-2} in terms of stocking density and female's treatment group in terms of sex. This indicate that the birds in those treatment groups that didn't perform better needed more time to gain weight in order to reach market weight. While, the better growth performance in other treatment group indicates that the conditions were conducive to produce broilers given that appropriate management practices are followed. Mortality was minimized as much as possible with all the treatments resulting in less than 5% mortality rate.

Some reports indicate that high stocking densities have no significant effects on broiler performance[16,17]. Contrary to these reports, other findings indicate that high stocking densities reduce growth rate, feed efficiency and livability[18]. The results of the study show that high stocking densities significantly reduced 21-day BW and FC during the starter period, BWG and feed intake during the grower period, slaughter weight and FC during the finishing period and BWG and FC during the entire study period. However, higher means were observed in broilers reared at stocking density of 30 kg BW m^{-2} than those reared at 35 and 40 kg BW m^{-2}, indicating that stocking density has critical implications on the performance of broiler chickens. Similar findings were reported by other authors[2,4,19,20]. According to Uzum and Toplu[21], the adverse effects of high stocking densities on broiler performance could be the result of increased stress from high house temperature, high ammonia concentration and competition for feed and water with increasing stocking density. Contrary to present findings, improved performance with increasing stocking density has been reported[5]. There are many conflicting reports on the effect of stocking density on FCR in broilers. Skoromucha *et al.*[22] reported that FCR increased with increasing stocking density whereas, Ligaraba *et al.*[20] and Sekeroglu *et al.*[23] observed that stocking density had no effect on feed conversion ratio. The study indicated that regardless of stocking density, all groups had similar efficient in feed conversion in all the phases of broiler production. This is consistent with a similar observation by Beg *et al.*[18]. On the contrary, Skrbic *et al.*[24] reported that high stocking density increased mortality rate. The authors related this to reduced air flow at the level of the bird. This led to reduced body heat dissipation to the air, poor air quality, increased house temperature, increased ammonia production, limited access to feed and water, as well as increased cannibalism, pushes and fights and hence reduced growth rate and livability and poor feed conversion ratio.

The results (Table 2) show that initially Ross was heavier and consumed more feed than Cobb but the two genotypes did not differ significantly in BWG, 21 days BW, FCR and mortality rate. The significant genotype effect on initial BW and FC during the starter period suggest that genetic differences exist between the genotypes in these traits as also observed[20,25]. One would expect that because of the strong positive genetic correlation between juvenile BW, (>0.9), Ross with its heavier initial BW would gain more BW and be heavier than Cobb on day 21. Similarly, because of the strong positive genetic correlation between BW and feed intake, one would expect that the higher feed intake of Ross would result in a heavier 21-day BW[26].

The similar feed conversion ratios of the two genotypes, despite the higher FC of Ross suggests that the two genotypes utilized the feed with the same degree of efficiency as was also reported in literature[25]. The genotype effect on FCR suggests that the genotypes did not differ much genetically in this trait[8]. Contrary to this, Skoromucha *et al.*[27] observed that genetic differences exist among broiler strains.

The results during the grower, finisher and entire study periods (Table 3-5) show that during the grower period genotype did not influence any of the traits but during the finisher and entire study period genotype affected only FC. These results are consistent with those of Moro *et al.*[28] that Ross and Cobb did not differ in productive performance. Contrary to this, Ligaraba *et al.*[20] found significant differences in productive performance among two strains viz Ross and Cobb. Similarly, Amao *et al.*[29] found genetic differences in BW, BWG, feed intake and FCR among Ross, Anak and Marshall strains. These discrepancies in results are probably due to the strains used in the studies and methodologies including ages at which the measurements were taken.

The better performance of males than females in initial BW, 21 days BW, BWG and FC during the starter period, 35 days BW, BWG and FC during the grower period, 42 days BW and feed intake during the finisher period and BWG and FC during the entire experimental period have been reported by Olawumi and Fagbuaro[7], Benyi *et al.*[19] and Ligaraba *et al.*[20]. Zerehdaran *et al.*[30] stated that the superiority of males over females in a trait cannot be attributed to a single factor, several factors including hormones for growth and fatness, greater competition for feed and water, aggressive behavior of male's social dominance and difference in nutritional requirement all play a part. The insignificant effect of sex on FCR during all the stages of growth suggests that the two sexes utilized the feed with the same degree of efficiency. The insignificant effect of sex on mortality rate during all the stages of production in this study is contrary to results obtained by Benyi *et al.*[19]. The authors reported a higher mortality rate in males than females and attributed this to the aggressive behavior of males resulting in fights, cannibalism and sometimes deaths.

The results show that three types of two-factor interactions affected some of the traits viz., stocking density×sex interaction effects on initial BW during the starter period, BWG and mortality rate during the grower period and feed intake during the entire experimental period, genotype sex interaction effects on 42 days BW and BWG during the study period as well as genotype×stocking density interaction effects on 42 days BW, BWG and FC during the entire experimental period. These interactions suggest that the respective traits are controlled jointly by stocking density and sex, genotype and sex and genotype and stocking density. These effects are manifested as differential responses of the males and females to the different stocking densities in the case of the stocking density×sex interaction, by the differential responses of the genotypes to the male and female environments in the case of the genotype×sex interaction and as the differential responses of the genotypes to the different stocking densities in the case of the genotype×stocking density interaction. In the case of mortality rate, males reared at the densities of 30 and 40 kg BW m^{-2} had 1.2 and 0.1% higher mortality rates than females but for the broilers reared at the density of 35 kg BW m^{-2} females had 3.5% higher mortality rate than males. For feed intake males reared at the stocking densities of 30, 35 and 40 kg BW m^{-2} consumed 2, 19 and 12 g more feed daily than their female counterparts. In the case of genotype×sex interaction effect on 42 days BW, Ross males were 378 g heavier than females whereas, in Cobb, males were only 128 g heavier than females. Regarding genotype×stocking density interaction, Ross reared at the stocking density of 30 kg BW m^{-2} were only 21 g heavier than Cobb whilst at the stocking density of 35 kg BW m^{-2} the difference was 243 g. At the stocking density of 40 kg BW m^{-2} however, Ross was 280 g lighter than Cobb. Genotype×environment interaction effects on productive performance have been reported by a few authors. For example, Eid *et al.*[11] and Benyi *et al.*[19] reported genotype×sex interaction effects on productive performance whilst Ligaraba *et al.*[20] and Benyi *et al.*[25] reported significant genotype×stocking density interaction effects on FC and mortality rate.

The heavier carcass parts (back, thigh, drumstick, wings, neck and shank) in males than females is similar to results obtained by Sola-Ojo and Ayorinde[31]. The non-significant differences in breast weight between males and females observed in this study contradict the findings of Solo-Ojo and Ayorinde[31] that breast was heavier in females than males. The higher weight of kidney observed in this study was also reported by Solo-Ojo and Ayorinde[31]. Females also had heavier gizzards and hearts than males. This result contradicts that of Ojedapo *et al.*[32], who reported that gizzard and heart weights were higher in males than females. In this study, the weight and percentage of abdominal fat were similar in males and females, Benyi *et al.*[25] on the other hand reported that abdominal fat weight and percentage were higher in females than males as early as 22 days of age. Almasi *et al.*[33] suggested that this could be because females start to store fat earlier than males, females start to store fat from 6 weeks compared to 8 weeks in males.

The results of this study showed that birds raises at the stocking density of 30 kg BW m^{-2} performed better in carcass and giblets weights but consumed more feed than those reared at 35 and 40 kg BW m^{-2}. However, stocking density significantly influenced breast percentage with no effect on other carcass parts and giblets. Similarly, a non-significant effect of stocking density on carcass characteristics was previously reported[18]. However, Hassanein[34] observed significant reductions in carcass, breast and thigh weights with increasing stocking density.

Although Ross and Cobb did not differ in weight gained during the study period, Cobb performed better in terms of FC and carcass weights than Ross. The insignificant effects of genotype on carcass and giblet weights agree with the results in literature[25,30].

The results also revealed that at all stages of growth males were superior to females in weight gain, carcass weights and percentages as well as in kidney, liver, fat weights and liver percentage but no significant effects were observed. On the contrary, Isoberam and Itori[35] reported that male chickens had significantly higher slaughter weight, carcass weight and dressing percentage than females.

CONCLUSION

The tropics and sub-tropics are characterized by extreme heat and humidity and scarce financial resources. Profitable broiler production in these areas requires a genotype that grows fast, consumes less feed, utilizes feed more efficiency and reaches market weight early. Cobb Avian 48 has more of these attributes than Ross 308. It is therefore recommended that for the efficient broiler production in the tropics and sub-tropics male Cobb Avian 48 reared at the stocking density of 30 kg BW m^{-2} could be considered.

SIGNIFICANCE STATEMENTS

This study discovers the possible synergistic effects of genotype, sex and stocking density combination that can be beneficial for optimum broiler performance and carcass characteristics. This study will help the researcher to uncover the critical area of appropriate strain-sex-stocking density combinations to optimize growth performance that many researchers were not able to explore. Thus, a new theory on genotype, sex and stocking density combination may be arrived at.

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