Ghanaian Journal of Animal Science
Journal of the Ghana Society of Animal Production
GJAS, Volume 17, Number 1, 2026

Influence of Stocking Density on the Performance, Physiological Traits and Litter Quality in Slow Growing Broilers

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https://dx.doi.org/10.4314/gjansci.v17i1.6

ABSTRACT

Stocking chickens beyond the optimal stocking density (SD) leads to poor production performance and welfare challenges. Whether or not dual-purpose chickens (SASSO, XL44 × SA31A) might be able to perform to their genetic potential under high SD (HSD) was investigated in this study, with the hypothesis that a higher SD would not affect the growth performance, gastrointestinal pH, carcass and bone traits, flock uniformity, and litter quality in dual-purpose chickens during a 49-day trial. At d 9 post-hatch, 325 chickens were allocated to three SD treatments (low SD, 15 birds per 2.0 m^2; medium SD, 20 birds per 2.0 m^2; high SD, 30 birds per 2.0 m^2) with 5 replications per treatment in a CRD. Data on body weight (BW), gain, feed intake (FI), feed conversion ratio (FCR), gastrointestinal pH, organ weight (% BW), BW uniformity and litter quality were collected. Birds in the low SD (LSD) group consistently had the highest (P < 0.05) BW, gain, and FI, followed by those in the medium SD (MSD) throughout the trial (d 16, 23, 30, 37, 44, 51, and 58 post-hatch). On d 23 post-hatch, birds under the HSD had marginally better (P = 0.052) FCR than those on the LSD. On d 44 post-hatch, none of the variables were influenced by SD. However, birds on the LSD numerically showed higher (P > 0.05) BW gain and FI. Stocking density had no effect (P > 0.05) on gut pH, bone traits (length, diameter, weight, and BS of tibia and femur), and litter quality on d 58. It was concluded that while HSD does not affect gastrointestinal pH and bone health, it significantly hampers production performance and BW uniformity, and so LSD of 15 birds per 2.0 m^2 (7.5 birds/ m^2) is recommended for dual-purpose chickens.

Keywords: *bone traits, dual-purpose chickens, poultry, stocking density and welfare*

INTRODUCTION

Commercial poultry requires favourable environmental conditions to achieve their genetic potential. Significant deviations beyond commercially optimal levels can compromise feed utilization, growth performance, and welfare of poultry and affect the economy and sustainability of poultry production. Meanwhile, excessively high stocking density (SD) has negative consequences for poultry production and welfare (Erasmus, 2017; Jhetam et al., 2022b). The SD in poultry production has raised welfare concerns over the years as some poultry producers, in an attempt to reduce housing, equipment, and labour costs per pen, tend to increase SD in their sheds. Because profitability per unit space increases with SD, appropriate increases in SD are practiced in commercial poultry production (Gholami et al., 2020).

A high SD raises litter temperature and increases moisture and nitrogen of the litter, metabolic heat, and microbial activity. Consequently, the poor quality of the litter adversely affects the

ambient environment by elevating dust and ammonia levels and humidity (Heck, 2026). This leads to respiratory issues in the shed. The detrimental effects of high SD on production traits such as feed consumption (Rahimi et al., 2011; Cengiz et al., 2015; Lee et al., 2018), growth rate (Selle and Ravindran, 2008; Guardia et al., 2011), egg production (Mtileni et al., 2007; Geng et al., 2020), slaughter weights, and bone traits (Buijs et al., 2012; Li et al., 2019) have been reported. Heat stress and increased levels of ammonia due to high SD, as well as the increased incidence of foot pad lesions (Dozier et al., 2005; Cengiz et al., 2018), high heat stress, and reduced locomotion have all been documented as some of the effects of high SD.

Some strains of chickens have been reported to perform well under stressed conditions. One such strain is the dual-purpose chicken popularly referred to as SASSO chickens. The SASSO strain is reported to adapt well to the harsh climatic conditions of Africa (Yakubu, 2018). They are mostly managed by small-scale poultry holders under below-average production conditions such as poor feeding, disease control, and high SD either for their eggs or meat. There are no legislation or industry standards specifying space requirements for these slow-growing broilers (SASSO) for farmers who wish to raise them in a shorter production period. A study by Dozier et al. (2005) recommended an SD of 30 kg/m^2 for heavy broilers, suggesting that anything beyond that adversely affects performance. For native laying hens, Geng et al. (2020) recommended an SD of 7 hens/m^2 or less. However, little is known about the effect of SD on the performance of the SASSO (XL44 × SA31A) reared under commercial environments in hot tropical climatic conditions.

Thus, this study hypothesized that rearing slow-growing broilers (SASSO, XL44 × SA31A) at different SD (low, medium, and high) would not make any difference in their growth performance, gastrointestinal pH, bone and carcass traits, flock uniformity, and litter quality.

MATERIALS AND METHODS

Experimental birds and management

The experiment was conducted at poultry section of the Department of Science Education of University of Skill Training and Entrepreneurial Development. Three hundred and fifty (350) slow-growing [SASSO, (XL44 × SA31A)] day-old chicks were sourced from Agri Depot hatchery in Kumasi (Ghana). They were reared together from d 0 in a deep litter brooder housing, using fresh softwood shavings as litter material at 5 cm thickness until 9 d. They had *ad libitum* access to a pre-starter commercial diet and water and 24-hour light throughout the pre-starter phase (d 0-9). The Concept 5 feed formulation program (Creative Formulation Concepts, LLC, Annapolis, MD) was used to formulate typical Ghanaian commercial starter and grower poultry diets for the experimental duration of 49 d.

Experimental design

On d 9, birds of similar weights were selected and randomly allotted to 3-floor treatment pens bedded with wood shavings and measuring 2.0 m^2 in 5 replications, each in a completely randomized design (CRD). The SD were 15 birds per 2.0 m^2 (7.5 birds m^2) as low SD (LSD), 20 birds per 2.0 m^2 (10 birds m^2) as medium SD (MSD), and 30 birds per 2.0 m^2 (15 birds m^2) as high SD (HSD). A brooding condition was provided until d 28, when the housing was reverted to the typical open-curtain housing practiced in Ghana. Diets were offered *ad libitum* throughout the starter (d 9 to 28) and grower phases (d 28 to 58). The diets were offered in a mash form in all the phases.

Response Variables

Bird performance

Feed intake (FI), body weight (BW), gain, feed conversion ratio (FCR), and livability were calculated weekly. The FI was calculated by subtracting feed leftover from feed supplied. The BW was determined by dividing the cumulative pen weight by the number of birds in the pen. The gain was calculated as the difference between the birds' BW and their initial BW. The FCR was calculated by dividing the difference between the pen weight and the sum of the initial bird weight and dead bird weight by the feed consumption for the same period. Livability was calculated by dividing the number of birds by the initial total number of birds and multiplying by a factor of 100. The pens were monitored for mortality twice daily, and post-mortem examinations were conducted on dead birds through-

Table 1: Ingredient and feed composition of the diet (%, as-is basis)

Ingredient	Starter diet	Grower-finisher diet
Maize	58.0	60.0
Wheat bran	12.5	18.0
Soybean meal	16.0	11.0
Fishmeal	11.0	9.0
Premix	0.5	0.5
Oyster shell	0.5	0.5
Salt	0.5	0.5
Dicalcium phosphate	1.0	0.5
Calculated nutrient composition		
Energy, K cal/g	3030	3200
Crude protein %	22.0	18.0
% Ca	0.90	0.80
Available P %	0.45	0.40
Lysine	1.21	1.01
Methionine	0.52	0.48

Vitamin A, 8,000,000 IU; Vitamin B1, 1300 mg, Vitamin B2, 2500 mg, Vitamin D3, 3000 IU; Vitamin E, 10, 000 IU; Vitamin K3, 1,500 mg; Vitamin B6, 1,000 mg; Vitamin B12, 6 mg, Nicotinic Acid, 5,000 mg, Pantothenic Acid, 4000 mg; Choline Chloride, 8000 mg; Copper, 2,500 mg; Cobalt, 700 mg; Iron, 4,500 mg; Zinc, 55, 000 mg; Methionine, 50,000 mg; Lysine, 200,000 mg; Selenium (1%), 1,300 mg; Iodine, 2,000 mg; Manganese, 60, 000 mg; Antioxidant, 625 mg.

out the study period. The FI and FCR (feed intake/weight gain) were corrected for mortality.

Gastrointestinal pH

On d 58, two birds of average BW per replicate pen were selected and euthanized by rapid cervical dislocation and eviscerated. The crop, proventriculus, gizzard, duodenal, jejunal, ileal, and caecal pH were detected using a pH tester (Hanna Instruments, UK) by directly inserting the pointed tip into the digesta in the lumen of the proximal end of each segment of the same bird whilst ensuring that the pH electrode did not touch the walls. Once all the readings for each bird had been taken, the probe was rinsed with distilled water. The mean of the two readings per segment of the tract was then calculated.

Bone traits

The femur and tibiae of the two birds used for the gastrointestinal pH were collected from the right leg to determine the breaking strength (BS) and ash contents. For the determination of BS, the femur and tibiae were defleshed by hand using a scalpel. The resulting femurs and tibiae were then subjected to testing on a universal texture analyzer (Inspekt table50-1, Hegewald & Peschke, Meß- Germany) set up with a 50 KN load cell and 3-point fixture bed at a test speed of 10 points of data per second. The machine was run by a BenQ computer (24-inch IPS monitor) with Blue Hill 3 software.

Relative organ weight

The liver, breast meat, fat pad, feet, thigh, heart, and empty gizzard were taken from each of the two sampled birds stated above and weighed. In the case where the part is paired, the right was taken. Each part was expressed as a percentage of live BW.

Flock uniformity

The uniformity of BW of each bird in each replicate pen was recorded on d 30 and 58. Flock weight uniformity is often defined as the percentage of individuals within 10% of the mean BW, and the variability of this uniformity can be expressed as the CV of the individual BW. The CV (%) of each pen was calculated as (STDEV.P (BW) of each bird in the pen) ÷ Average (BW of each bird in the pen)) *100.

Litter score and litter dry matter

The litter in each experimental pen and hock burn were scored by visual appraisal at d 58 according to the methods of Zanu et al. (2020). The scoring was done on a scale of 0 to 10, where a score of 0 denotes wet litter and 10 denotes fresh litter as shown below: 0: The whole floor surface is caked from bottom to top of the layer; 1: The whole floor surface is caked. Some parts are caked from bottom to top; some parts are only caked on the upper layer; 2: The whole floor space is caked but the lower layer is friable; 3: >75% of the floor surface is caked; 4: >50% of the floor surface is caked; 5: Litter under the waterline is caked from top to bottom; 6: Upper layer of the litter under the waterline is caked; 7: Litter under the waterline is wet but still friable; 8: Litter under the waterline is damp; 9: The litter is not fresh anymore but still friable and dry everywhere in the pen; 10: Fresh litter. Again, at d 58, litter samples from 6 different locations in each replicate pen of approximately 1 kg were collected into plastic bags. Each sample was

weighed before and after drying in an oven at 105°C for 168 h (after reaching constant weight) to determine DM content.

Statistical analysis of data

Data were analyzed using the General Linear Models (GLM) procedure of Minitab 20.3 statistical software. Tukey pairwise comparison test was used to separate treatment means ($P < 0.05$). All statistical analyses were declared significantly different at $P < 0.05$.

RESULTS AND DISCUSSION

The present study was designed with the hypothesis that dual-purpose chickens (SASSO) would respond more favourably to HSD compared to their counterparts at MSD and LSD with no adverse effect on their growth performance, gastrointestinal pH, bone and carcass traits, flock uniformity, and litter quality.

Growth performance

At d 16 (Table 2), birds in the LSD group recorded the highest ($P < 0.05$) BW and gain, followed by those in the MSD. Similarly, the FI of birds in the HSD was lowest ($P < 0.05$) and followed by those in the MSD.

On d 23 (Table 3), birds in the HSD consumed less but tended ($P = 0.052$) to be more efficient in converting feed to BW compared to the LSD birds. On d 30 (Table 4), BW and gain were highest in the LSD and lowest in the HSD ($P >$

Table 2: Effect of low, medium, and high stocking densities on the performance of birds, d 0 -16

Treatments	BW, g	Gain, g	FCRc	Intake, g	% Livability
LSD	317.3[a]	152.0[a]	2.147	321.3[a]	100
MSD	297.0[ab]	132.0[ab]	2.198	290.0[b]	100
HSD	283.2[b]	121.6[b]	2.273	272.8[c]	100
SEM	5.77	5.19	0.059	5.85	-
P-value	0.037	0.038	0.715	0.001	-

Means that do not share a letter are significantly different ($P < 0.05$)
BW, Bodyweight; FCRc, corrected feed conversion ratio
SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD, medium stocking density (20 birds per 2.0 m^2) and HSD, high stocking density (25 birds per 2.0 m^2)

Table 3: Effect of low, medium, and high stocking densities on the performance of birds, d 0 -23

Treatments	BW, g	Gain, g	FCR	Intake, g	% Livability
LSD	490.6	325.3	2.504	813.3[a]	100
MSD	469.4	304.4	2.447	744.3[b]	100
HSD	466.4	304.8	2.338	712.0[b]	100
SEM	5.52	4.68	0.029	13.60	-
P-value	0.146	0.107	0.052	0.001	-

Means that do not share a letter are significantly different ($P < 0.05$)
BW, Bodyweight; FCRc, corrected feed conversion ratio
SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD, medium stocking density (20 birds per 2.0 m^2) and HSD, high stocking density (25 birds per 2.0 m^2)

0.05). The FI was highest ($P < 0.05$) in the LSD and MSD groups and lowest in the HSD group. On d 37 (Table 5), birds in the LSD recorded the highest BW ($P > 0.05$). Feed intake was higher in the LSD group ($P = 0.059$). On d 44 (Table 6), none of the variables were responsive to the different SDs, though birds in the LSD showed higher ($P > 0.05$) BW, gain, and intake. On d 51 (Table 7) and 58 (Table 8), the BW, gain, and FI in the LSD and MSD were similar ($P > 0.05$), but they were higher in the HSD ($P < 0.05$).

Table 4: Effect of low, medium, and high stocking densities on the performance of birds, d 0-30

Treatments	BW, g	Gain, g	FCR	Intake, g	% Livability
LSD	670.8	505.4	2.690	1360[a]	99
MSD	655.0	490.0	2.660	1299[ab]	96
HSD	636.1	474.5	2.541	1203[b]	96
SEM	9.46	8.64	0.044	25.90	0.876
P-value	0.351	0.370	0.357	0.028	0.385

Means that do not share a letter are significantly different ($P < 0.05$)
BW, Bodyweight; FCRc, corrected feed conversion ratio
SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD, medium stocking density (20 birds per 2.0 m^2) and HSD, high stocking density (25 birds per 2.0 m^2)

Table 5: Effect of low, medium, and high stocking densities on the performance of birds, d 0 -37

Treatments	BW, g	Gain, g	FCR	Intake, g	% Livability
LSD	806.7	641.4	2.897	1850	96
MSD	744.5	579.5	2.971	1720	90
HSD	743.8	582.2	2.787	1620	92
SEM	16.2	15.70	0.049	41.10	1.58
P-value	0.198	0.199	0.336	0.059	0.325

Means that do not share a letter are significantly different ($P < 0.05$)
BW, Bodyweight; FCRc, corrected feed conversion ratio
SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD, medium stocking density (20 birds per 2.0 m^2) and HSD, high stocking density (25 birds per 2.0 m^2)

Table 6: Effect of low, medium, and high stocking densities on the performance of birds, d 0-44

Treatments	BW, g	Gain, g	FCR	Intake, g	% Livability
LSD	900.4	735.1	2.948	2169	83
MSD	833.3	668.3	3.059	2039	81
HSD	812.8	651.2	2.922	1900	83
SEM	18.00	17.40	0.440	52.90	2.29
P-value	0.109	0.109	0.437	0.111	0.930

Means that do not share a letter are significantly different ($P < 0.05$)
BW, Bodyweight; FCRc, corrected feed conversion ratio
SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD, medium stocking density (20 birds per 2.0 m^2) and HSD, high stocking density (25 birds per 2.0 m^2)

Table 7: Effect of low, medium, and high stocking densities on the performance of birds, d 0 -51

Treatments	BW, g	Gain, g	FCR	Intake, g	% Livability
LSD	943.2[a]	777.9[a]	3.399	2644[a]	75
MSD	926.3[a]	761.3[a]	3.284	2491[ab]	78
HSD	840.6[b]	679.0[b]	3.302	2244[b]	78
SEM	16.30	15.60	0.057	63.30	3.23
P-value	0.009	0.009	0.714	0.018	0.890

Means that do not share a letter are significantly different (P < 0.05)
BW, Bodyweight; FCRc, corrected feed conversion ratio
SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD, medium stocking density (20 birds per 2.0 m^2) and HSD, high stocking density (25 birds per 2.0 m^2)

Table 8: Effect of low, medium, and high stocking densities on the performance of birds, d 0 - 58

Treatments	BW, g	Gain, g	FCR	Intake, g	% Livability
LSD	1203[a]	1037.6[a]	3.314	3420[a]	71
MSD	1098[a]	932.6[a]	3.354	3119[ab]	73
HSD	1077[b]	915.2[b]	3.167	2896[b]	76
SEM	22.90	22.10	0.074	81.80	3.72
P-value	0.039	0.035	0.594	0.017	0.861

Means that do not share a letter are significantly different (P < 0.05)
BW, Bodyweight; FCRc, corrected feed conversion ratio
SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD, medium stocking density (20 birds per 2.0 m^2) and HSD, high stocking density (25 birds per 2.0 m^2)

The observations in the present study are consistent with earlier reports that HSD reduces growth performance traits in most poultry (Sun et al., 2013; Zhang et al., 2013; Lee et al., 2018; Jhetam et al., 2022a). Several reasons have been adduced for the poor growth performance of birds reared under the HSD. For instance, heat stress resulting from the increased temperature inside the litter and between the birds with HSD is blamed (Almeida et al., 2018). The lower FI observed in birds under the HSD in the present study is consistent with several studies (Dozier et al., 2005; Mtileni et al., 2007; Farhadi and Hosseini, 2016; Li et al., 2019; Chauhan et al., 2022; López-López et al., 2022). High environmental temperature is another key factor that has been shown to affect the microclimate of birds, as poor airflow due to inadequate air exchange increases ammonia at the level of the bird, reducing the dissipation of body heat to the atmosphere, affecting FI and general growth performance. Though water consumption was not measured in the present study, it is likely that the high temperature created in the microclimate in the HSD might have led to high water intake over feed intake. A similar study by Feddes (2002) indicated that as the water intake in birds reared in HSD increased, feed intake reduced. In that study, birds housed at 11.9 birds/m^2 (LSD) consumed less water (5,093 mL/bird) than those in the other treatments (range 5,390 to 5,546 mL/bird). Additionally, the reduced growth rate in birds reared at HSD might be attributed to disruption in the gut microflora, which helps in digestion, absorption of nutrients, and improvement of intestinal microarchitecture (Liu et al., 2021). Furthermore, inhalation of a greater amount of toxins produced in the HSD group might have contaminated the litter and resulted in reduced levels of enzyme activity, leading to

poor digestion and absorption of nutrients.

However, in this study, the FCR was not affected by the SD, though birds in the HSD recorded better FCR. This seems to support the findings of previous studies that reduced feed intake may not necessarily be detrimental but rather improve the FCR when SD increases (Feddes, 2002; Sun et al., 2013). Notwithstanding, it is important to note that when the number of birds produced per year is considered, the high SD would be superior. For instance, assuming that the time between flocks is 14 days, the highest SD would take 2 more days (59.8 days) to reach the best growth of 1203 g in the low SD (58 days). Further, 148 birds would be produced under the high SD compared to 76 and 99 birds in the low SD and medium SD, respectively, assuming density does not trigger extra mortality. This suggests that up to a critical threshold, SD might increase profits. However, this gain may be wiped out in poorly ventilated and excessively hot houses as a result of compromised health, welfare, and productivity of birds. Again, high SD generates less total meat per unit area. While individual birds may be larger in low SD and healthier, total shed returns are reduced due to low output volume. The motivation for choosing high SD is the reduction in labour, equipment, energy, and housing costs.

Like in most studies (Feddes et al 2002; McKeith et al 2020), the various SD did not make any difference in mortality. In the present study, even though mortality was a bit high across the SD. Some of the causes of the mortalities per post-mortem analysis were due to coccidiosis, a common incidence in the study site. Since the cases of coccidiosis were initially high in the group under high SD, it is suspected that there might have been a transfer of the disease to the other groups through handling and managerial duties.

Gastrointestinal pH, bone traits, carcass traits, and litter quality

None of the pH of the segments of the gastrointestinal tract (Crop, proventriculus, gizzard, duodenum, jejunum, ileum, and caeca), bone traits (length, diameter, weight, and BS of tibia and femur), litter score, and litter DM were influenced ($P > 0.05$) by SD at d 58 (Table 9). A literature search revealed scarcity of data on the effect of SD on gastrointestinal pH in chickens. Nonetheless, in a study by Tsiouris et al. (2015), the duodenum and caeca pH of broilers were influenced by SD, being lower in the duodenum and higher in the caeca in birds reared under HSD. It was expected in the present study that the pH of the intestinal digesta would have been altered by litter downgrading in the HSD group and would influence intestinal microbiota, thus affecting the pH. Furthermore, it was also hypothesized that litter downgrading would increase the concentrations of corticosteroids in the excreta of the HSD group due to stress and affect the intestinal microbiota and the gut pH, as was also reported by Dawkins et al. (2004).

None of the bone traits measured in the present study was influenced by SD, supporting the findings of Ma et al. (2020), that both LSD and HSD do not affect femur length, diameter, and

Table 9: Effect of low, medium, and high stocking densities on the gastrointestinal pH of birds, d 58

Treatments	Crop pH	Proventriculus pH	Gizzard pH	Duodenal pH	Jejunual pH	Ileal pH	Caecal pH
LSD	5.15	2.10	2.15	5.18	5.84	5.84	6.84
MSD	5.23	1.68	2.19	5.51	5.92	5.68	6.88
HSD	5.19	1.77	2.29	5.48	6.02	5.72	6.89
SEM	0.15	0.10	0.06	0.15	0.07	0.05	0.02
P-value	0.979	0.216	0.612	0.650	0.593	0.357	0.576

Means that do not share a letter are significantly different ($P < 0.05$); SEM, pooled standard error of means.
Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD - medium stocking density (20 birds per 2.0 m^2); and HSD - high stocking density (25 birds per 2.0 m^2)

weight. However, in the experiment of Ma et al. (2020), the BS of the femur was reduced at the HSD. Again, Fawcett et al. (2020) did not record any difference in the femur and tibial BS in pullets reared at different SD. It was expected in the present study that HSD would have reduced the physical activity of the birds and increased mechanical injuries, thus reducing the integrity of the bones. In this study, the tibiae were shorter under HSD, though not significant, as was also reported by Buijs et al. (2012). In a work by Lee et al. (2018), a lower BS was observed in birds reared at HSD.

Regarding carcass and organ traits, there seem to be inconsistencies in their response to SD among previous studies. The weight of the breast, fat pad, thigh, heart, bursa, pancreas, and gizzard in the present did not respond to the various SDs except for the liver. Other studies by Abo Ghanima et al. (2021) and Dozier et al. (2005, 2006) also showed no significant difference in the weight of the liver, gizzard, heart, abdominal fat, breast, and thigh of broilers at various SDs. However, other studies have reported the influence of SD on, for instance, the bursa of Fabricius (Lee et al., 2018), contrary to what was observed in the present work. It has been suggested that stress reduces the weight of lymphoid organs (Aguanta et al., 2018), but this seems not to be the case in the present study. The birds used in the present study might have tolerated the stress at HSD better.

Unlike Guardia et al. (2011), Dozier et al. (2006), and McKeith et al. (2020), who reported poor litter quality in the HSD group, no adverse impact of SD was detected on litter (wood shavings) quality in the present study at d 58. However, other studies such as those reported by Bailie et al. (2018) and Farhadi and Hosseini (2016) suggest that HSD does not always worsen litter quality *per se*. The variation of the current results compared to past studies likely stems from differences in the rate of SD, duration of

Table 10: Effect of low, medium, and high stocking densities on the femur and tibial traits of birds, d 58

Treatments	Tibial length, mm	Femur length, mm	Tibial diameter, mm	Femur diameter, mm	Tibial wt, %	Femur wt, %	Tibial BS, N	Femur BS, N
LSD	93.84	68.56	6.36	7.47	0.42	0.33	145.3	223.2
MSD	95.08	69.76	6.42	7.51	0.40	0.32	146.4	198.4
HSD	92.36	68.17	6.45	7.67	0.40	0.33	148.8	205.30
SEM	0.50	0.35	0.14	0.06	0.01	0.01	3.71	7.56
P-value	0.068	0.160	0.971	0.311	0.494	0.758	0.935	0.414

Means that do not share a letter are significantly different (P < 0.05); SEM, pooled standard error of means.
Treatments: LSD - low stocking density (15 birds per 2.0 m^2); MSD - medium stocking density (20 birds per 2.0 m^2) and HSD - high stocking density (25 birds per 2.0 m^2)

Table 11: Effect of low, medium, and high stocking densities on the gastrointestinal carcass traits (%) BW of birds, d 58

Treatments	Breast, %	Fat pad, %	Thigh, %	Liver, %	Heart, %	Bursa, %	Pancreas, %	Gizzard, %
LSD	2.798	1.132	8.716	4.446	0.531	0.119	0.262	1.035
MSD	2.831	0.996	8.400	3.997	0.545	0.069	0.255	1.008
HSD	3.045	1.219	8.619	3.686	0.609	0.103	0.226	1.131
SEM	0.121	0.072	0.104	0.134	0.018	0.011	0.010	0.333

Means that do not share a letter are significantly different (P < 0.05); SEM, pooled standard error of means.
Treatments: LSD - low stocking density (15 birds per 2.0 m^2); MSD - medium stocking density (20 birds per 2.0 m^2) and HSD - high stocking density (25 birds per 2.0 m^2)

Table 12: Effect of low, medium, and high stocking densities on litter score, litter DM (%) and BW uniformity (%) of birds

Treatments	Litter score, d 58	Litter DM, d 58	BW uniformity, d 30	BW uniformity, d 58
LSD	0.240	76.18	20.65	22.32[b]
MSD	0.280	79.07	23.14	25.72[ab]
HSD	0.400	76.57	19.94	31.51[a]
SEM	0.073	1.11	0.842	1.55
P-value	0.679	0.550	0.282	0.036

Means that do not share a letter are significantly different (P < 0.05); BW, Bodyweight; SEM, pooled standard error of means. Treatments: LSD, low stocking density (15 birds per 2.0 m^2); MSD - medium stocking density (20 birds per 2.0 m^2) and HSD - high stocking density (25 birds per 2.0 m^2)

the trial, the amount and type of litter used, and other managerial practices, as these factors would influence litter quality.

Flock bodyweight uniformity

The BW uniformity was not affected (P > 0.05) by the different SD at d 30. But at d 58, BW uniformity was more even (P < 0.05) in birds at the LSD compared to those in the HSD. The poorer BW uniformity observed in the HSD group is consistent with a recent report by Choi et al. 2026, that increasing the density of the flock reduces the uniformity of BW. The implication for uneven flock BW uniformity is the downgrade of the birds in processing plants where automated lines require consistent carcass sizes. Also, the cost of feeding a flock of inconsistent BW to attain acceptable market weight might be higher and lead to significant economic loss. There is little research on how HSD affects flock uniformity of dual-purpose (SASSO) chickens to compare to the present findings. However, this study by Feddes et al. (2002) showed that birds housed at 23.8 birds/m^2 resulted in poorer flock BW uniformity, confirming the result of the present study.

CONCLUSION

Overall, this study suggests that while crowding dual-purpose (SASSO) chicken compromises growth performance, their ability to convert feed to BW, gastrointestinal pH, bone and carcass traits, flock uniformity, and litter quality are not adversely influenced by harsh management conditions, particularly when reared in the open-sided housing. Thus, they may be well suited to dynamic and harsh conditions that exist in most farms in hot African regions. Therefore, strict spacing and feeding are recommended for optimal performance. The resilience of the birds to high stocking densities regarding FCR, gastrointestinal pH, bone traits, carcass traits, and litter quality supports their suitability for open rangelands over confined deep litter systems.

ACKNOWLEDGMENT

The authors would like to acknowledge Agri Depot (Ghana) for providing the chickens for this study. We also thank Mr. Felix Boakye of the Forestry Research Institute of Ghana, Fumesua, for the technical assistance in the use of the universal testing machine for determining the bone-breaking strength.

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