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Impact of Stocking Density on Broiler Chicken Performance, Blood Biochemisty, and Carcass Attributes in an Intensive Rearing System

Research Article

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ABSTRACT

The goal of the present study was to investigate the effects of stocking density on performance, welfare, haemato-biochemical indices, and carcass traits of broiler chickens raised under intensive rearing systems. Present investigation was conducted on broilers aged 6 weeks at poultry unit of Livestock farm complex, College of Veterinary and Animal Science, Navania, Udaipur (Rajasthan University of Veterinary and Animal Sciences) India. There were three treatment groups i.e., D1 with 8 birds/m^2, D2 served as control having 10 birds/m^2, D3 with 12 birds/m^2, respectively. Each treatment group showed a statistically significant ($P<0.05$) effect on body weights, growth, and feed conversion efficiency ($P<0.05$). Treatment group D1 had the highest body weight, body weight gain, better feed conversion ratio (FCR) at 42 days of age, followed by D2 (control) and D3. Stocking density significantly ($P<0.05$) influenced some behavior traits such as drinking and locomotion. Hemoglobin (Hb) and heterophil to lymphocytes (H/L) ratios were significantly affected ($P<0.05$) by all three stocking densities. Biochemical measures were unaffected between the three stocking densities. Except for the heart percentage, which was non-significant, stocking densities had a significant ($P<0.05$) influence on carcass traits such as neck, back, dressing, drum stick, liver, and gizzard percentages. The results of this study revealed that having a higher live body weight in a smaller space increases productivity when it comes to profitably rearing birds and keeping them for longer than 40 days.

KEY WORDS broilers, carcass, hemato-biochemical, performance, stocking density, welfare.

INTRODUCTION

Poultry is the world's second most popular meat, accounting for around 30% of worldwide meat production, following pork which accounts for 38%, (FAO, 2019). In terms of eggs and broiler meat, India ranks third and fourth position in the world. According to 20th Livestock Census (2019), India's total poultry population is 851.81 million, an increase of 16.81% from the previous Livestock Census (2012). In 2019, there has been a 45.78 percent increase in backyard poultry, bringing the total number of backyard poultry to 317.07 million. The whole commercial poultry market is worth 534.74 million, up by 4.5% from last year. A poultry industry contributes around 1% of the national GDP and about 14% of the livestock GDP in the livestock sector (Mishra, 2020). Rajasthan is the country's second largest livestock producer, with 56.8 million animals and 14.6 million fowls. In Udaipur, 5.04 million chickens are produced annually (FAO, 2019). In intensive poultry production systems, stocking density, or the amount of floor space per chicken, has a direct and indirect influence on weight gain in chickens. With the development of industrial chicken production, stocking density became increasingly important in order to improve production, liveliness, and health of broilers. As a result of its established effects on broiler chicken growth, stocking density is considered one of the most important environmental factors (Ayoola *et al.* 2014). Stocking densities directly impair the health and welfare of birds by limiting their movement. In turn, this has a negative impact on the broiler industry, since it hinders the growth of broilers, which in turn results in negative economic growth, since revenue increases linearly with density (Simitzis *et al.* 2012; Ayoola *et al.* 2014). Overall, stocking densities that reduce or increase floor space may reduce broiler chicken growth rates, feed efficiency, livability, and carcass quality. Stocking density is well documented as a critical stressor in intensive poultry production because it is associated with an increase in stress hormones, which result in turbulences in hemato-biochemical parameters like Hb, heterophil-lymphocyte ratio (H/L), glucose, cholesterol, total protein, total albumin and triglyceride levels (Onbasilar *et al.* 2008; Rambau *et al.* 2016).

Several studies have clearly shown the impact of stocking density on production performances and quality parameters, as well as on parameters considered reliable indicators of broiler health. Farmers in southern Rajasthan particularly in the Udaipur region rear broilers despite the high price of construction materials and lack of knowledge of stocking density in different seasons (Nikita *et al.* 2018; Mishra *et al.* 2019). Under intensive system of rearing poultry in southern Rajasthan, farmers need to consider housing density to maximize profitability and establish more precise stocking density standards for chicken breeds to ensure their effectiveness. Due to this, this study was designed with the objective of assessing the performance of broilers raised under different stocking densities. Results of this study will be useful to poultry farmers involved in poultry production and rearing.

MATERIALS AND METHODS

The experiment was conducted at Poultry Farm of Livestock Farm Complex, College of Veterinary and Animal Science, Navania, Vallabhnagar, Udaipur (Rajasthan University of Veterinary and Animal Sciences, Bikaner). One hundred and twenty (120) day old broiler chicks from a commercial hatchery in Ajmer, Rajasthan, were used for the study. In the brooding process, heat and light were provided by electrical hover brooders. The period of brooding lasted for 2 weeks.

Ethical permission

The institute's ethical standards were followed when handling animals. The Institutional Animal Ethics Committee (IAEC) authorized the experiment according to order no. 2143/G/Re/SL/22/RAJUVAS.

Experimental design, housing, feeding, and measured traits

A total of 120 birds were randomly assigned to three stocking densities up to six weeks of age. Stocking densities were considered experimental design treatments. Four replications were assigned to each treatment and every replication was allocated to eight chicks D1 (8 birds/m2), D2 (10 birds/m^2) which served as control, D3 (12 birds/m^2). Both sexes were reared together on deep litter floor. The experimental pens, drinkers, and feeding troughs were cleaned, disinfected, and sprayed against external parasites before the commencement of experiment. During the entire experimental period, all experimental chicks were handled identically and strict hygienic measures were taken as per standard practice. On the 4th and 14th days, broiler chicks were vaccinated against Ranikhet disease (F1 strain) and Infectious Bursal Disease. The chicks were given commercially available readymade broiler starter and broiler finisher feed as per BIS (2007) criteria provided (Tables 1 and 2). Each pen had a 1 m^2 space, equipped with one feeder and drinker that was always full of feed and water. All treatment groups received the same feed in the morning based on their weight. On the first day of the second week and thereafter, the residual feed was collected and weighed separately to determine the actual weekly feed consumption, which included any feed losses. Throughout the experiment, broiler chickens were given adlib access to fresh, clean drinking water.

During experimental period, bi-weekly body weights were recorded starting from initial to end of the experiment. The difference in body weight attained between two consecutive weeks was used to compute live weight increase at bi-weekly intervals. The feed conversion ratio was estimated by dividing the total feed intake by the chicks' body weight gain throughout the specified time period. The average feed consumption was computed by subtracting the total feed offered from the feed that was left over on the first day morning of the next week. No mortality observed in the whole research trial period

Behavioral observations

The observation was conducted according to Martin and Bateson's (2015) instructions, which involved scanning with the naked eye continuously from first to six weeks of age. Birds were observed twice daily, morning (9 a.m. to 10 a.m.) and evening (4 p.m. to 5 p.m.) respectively. All birds were scanned for 5 minutes before commencing a new 5 minutes scan of all behavior till the session completed.

Table 1 Ingredients and nutrient composition (% DM) of pre starter, starter and finisher rations

Ingredients	Broiler pre- starter	Broiler starter	Broiler finisher
Maize (%)	54.2	55.3	58.4
Soyabean meal (%)	42.0	40.9	37.7
Di-calcium phosphate (%)	1.5	1.5	1.5
Limestone powder (%)	2.0	2.0	2.1
Salt (%)	0.32	0.32	0.32
Supplements (g/100 kg)			
Mineral mixture	301	301	301
Vitamin mixture	149	149	149
Methionine	362	362	325
Lysine	168	129	100
Choline chloride	58	58	58
Chemical compositions			
Crude protein (%)	23.0	22.25	20.21
Metabolizable energy (kcal/kg)	3010.6	3100.1	3201.22
E:P ratio	130.46:1	139.38:1	158.37:1
Lysine	170	130	100

Table 2 Estimated proximate analysis of broiler pre- starter, starter and finisher ration

Particular	Pre- Starter (0-8 days)	Starter (9-21 days)	Finisher (22-42 days)
Moisture %	10.84	10.74	10.61
Crude protein %	22.47	21.55	19.38
Crude fat %	3.74	3.42	3.36
Crude fibre (CF %)	3.62	3.04	2.66
Total Ash	7.96	5.18	4.50
Acid insol. Ash	0.38	0.22	0.43
Calcium	1.18	1.18	1.03
Phosphorous	0.71	0.68	0.57
Salt	0.33	0.32	0.32

Drinking, mobility (bird movement), and cannibalism were among the documented behavioral tendencies (Table 3). Based on the total number of birds observed, the percentage of birds showing categorized behavior was calculated (Reiter and Bessei, 2009).

Blood samples collection and haemato-biochemical analysis

Blood samples of approximately 3 mL of wing vein from 2 representative birds of each replication were collected on the 42nd day of the experiment for hematological and serum biochemical parameters. Using an automated hematology analyzer, half of the blood was transferred to sterilized EDTA containing vacutainer tubes for the measurement of hemoglobin, heterophils, lymphocytes, H/L ratio. The remaining blood sample was placed in non-EDTA tubes for serum restoration.

The serum was collected and processed for analysis at a deep freezing temperature. Total protein, serum albumin, serum globulin, and albumin/globulin ratio were measured using an electronic biochemistry analyzer. By subtracting the concentration of serum albumin from total protein levels, the content of serum globulin was estimated.

Carcass traits

After the trial was completed, two birds from each group were chosen at random, fasted for 12 hours to empty their crop and then slaughtered for carcass traits using the halal technique (Singh *et al.* 2018). The weight of the individual birds was measured before slaughter to determine the dressing percentage. Weights of various cut parts of the carcass, including as neck, chest, back, wings, thighs, drum sticks, and internal organs (heart, liver, and gizzard) measured as a percentage of live body weight (Magala *et al.* 2012).

Dressing percentage (%)= (dressing yield of bird/live weight of bird) × 100

Contribution of carcass part (%)= (weight of freshly severed organ/final live body weight) × 100

Table 3 Ethogram of the recorded behaviors

Behavior	Description
Drinking	Birds while standing, sitting or drinking from waterer
Movement of bird (Locomotion)	Birds' mobility while walking or running
Cannibalism	Picking feathers , combs and vent pecking of other birds
Leg deformity	Twisting of legs or bone disorder

Statistical analysis

Data on growth, feed conversion efficiency, behavioral traits, haemato-biochemical indices, and carcass characteristics were entered into M.S. Excel and analyzed with SPSS software Version 22.0 (SPSS, 2015). A statistical technique of one-way ANOVA was used to compare means and if the probability value was less than 0.05, the difference was pronounced statistically significant. Duncan's Multiple Range Test was used to distinguish significant (P<0.05) differences across variables (Steel *et al.* 1997).

RESULTS AND DISCUSSION

The overall mean weekly feed intake of birds in groups D1, D2 (control), and D3 was 3851.17, 3773.43, and 3719.35 g, respectively (Table 4). The birds receiving stocking density of 12 birds/m^2 from group D3 had the lowest total average weekly feed consumption, according to the data. The overall mean weekly feed intakes of birds from all treatment groups showed a significant (P<0.05) effect. At 6 weeks of age, biweekly body weights of broiler chicken were higher in D1 (2201.82 g) stocking density, followed by D2 (2125.23 g) control group and lower in D3 (2022.60 g) stocking density, with differences in body weight being significant (P<0.01). Overall mean body weight gain for the whole experimental period was observed significantly (P≤0.01) higher in D1 stocking density, then control group D2 and lowest gain in D3 density group, respectively (Table 6).

The best and most significant (P<0.05) value of feed conversion ratio was found in D1 (1.70), which received a lower stocking density, followed by control group D2 (1.82) and highest in D3 group (1.91), respectively (Table 7).

Results pertaining to behavior of birds are presented in Table 8. The weekly drinking frequency was significantly (P≤0.05) affected by density.

Birds with lower to intermediate stocking density, such as D1 and D2 (control), exhibited the least amount of drinking behavior compared to the D3 higher stocking density group. The weekly movement of birds was highly and significantly (P≤0.01) influenced by stocking density and mean value for the weekly movement of birds for the 6th week were 58.30, 55.05 and 52.0 for treatment group D1, D2 and D3, respectively. Results showed that the mean weekly movement of birds was maximum in group D1 than control group D2 followed by treatment group D3, respectively. Weekly cannibalism had no statistically significant effect on different stocking densities.

The current study found that stocking density had a significant (P<0.05) effect on blood parameters such as haemoglobin and the ratio of heterophil to lymphocyte (Table 9). The higher hemoglobin levels were observed in D1 treatment group (11.05 g) with a lowest stocking density than D2 control group (10.47 g) and lowest level was recorded in higher stocking density. Higher percentages of H/L ratio were found in the D1 treatment group (0.34%) which had the lowest stocking density compared to D2 control group (0.31%) and the lowest level was found in the higher stocking density. Total protein, albumin, globulin, and the albumin to globulin ratio indicate an insignificant difference between the three stocking densities.

Table 10 depicts the carcass characteristics of broiler. Neck percentages were higher (5.65%) in the lowest density group D1 followed by D2 (4.70%) and the lowest percentage was found in the highest stocking density D3 (4.67%). Back weight percentage was likewise influenced by stocking densities (P<0.05), with the greatest mean value (15.27%) in the D2 control group, followed by D3 (14.97%) and D1 (14.60%) treatment groups. Highly (P≤0.01) significant impact of stocking density was found on dressing percentage of chicken in the present research. Birds reared at D2 control group recorded the highest dressing percentage of 80.6% followed by D1 (77.52%), While those raised at higher stocking density D3 had the lowest dressing percentage (75.60%). Likewise, significant (P≤0.05) influence of stocking density was observed on drum stick percentages. The highest percentage was found in D2 control group (4.85%) followed by D3 (4.75%) and lowest in lower density D3 group (4.02%). Gizzard and liver (giblet) percentages were significantly (P≤0.01) influenced by stocking density, the highest gizzard weight percentage was observed (1.31%) in birds reared at higher stocking density of D3 treatment group than in control group D2 (1.21%) and lowest percentage (1.04%) was recorded in D1 stocking density. Whereas liver weight percentage was higher in D2 (1.83%) followed by D3 (1.73%) and lowest in D2 control (1.65%) respectively.

Table 4 Means of weekly feed intake (g) of broilers of various ages under three stocking densities

Groups	Weeks							
	N	1	2	3	4	5	6	1-6
D1	32	134.29	324.18	603.93	723.10	900.223[b]	1165.07[c]	3851.17[c]
D2	40	129.86	334.78	574.61	724.32	877.803[b]	1132.05[b]	3773.43[b]
D3	48	136.1	301.35	572.05	719.28	834.69[a]	1126.11[a]	3719.35[a]
SEM	-	4.70	5.18	11.08	5.55	10.55	6.12	31.00
Significant	-	NS	*	NS	NS	**	**	*

D1: 8 birds/m^2; D2: 10 birds/m^2 which served as control and D3: 12 birds/m^2.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.
* (P<0.05) and ** (P< 0.01).
NS: non significant.

Table 5 Means of bi-weekly body weight (g) of broilers of various ages under three stocking densities

Groups	N	Weeks			
		0	2	4	6
D1	32	46.58	445.05[b]	1236.95[c]	2201.82[c]
D2	40	46.90	407.05[a]	1130.75[b]	2125.23[b]
D3	48	46.38	379.71[a]	1079.0[a]	2022.60[a]
SEM	-	0.72	6.99	36.70	49.77
Significant	-	NS	**	**	**

D1: 8 birds/m^2; D2: 10 birds/m^2 which served as control and D3: 12 birds/m^2.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.
** (P< 0.01).
NS: non significant.

Table 6 Means of bi-weekly body weight gain (g) broilers of various ages under three stocking densities

Groups	N	Weeks			
		0-2	2-4	4-6	0-6
D1	32	302.58[b]	821.56[b]	1137.29[b]	2261.43[b]
D2	40	287.66[a]	775.89[ab]	1001.27[a]	2064.83[a]
D3	48	282.56[a]	726.30[a]	934.02[a]	1942.89[a]
SEM	-	4.55	20.20	31.97	48.15
Significant	-	*	*	**	**

D1: 8 birds/m^2; D2: 10 birds/m^2 which served as control and D3: 12 birds/m^2.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.
* (P<0.05) and ** (P< 0.01).

Table 7 Means of weekly feed conversion ratio of broilers of various ages under three stocking densities

Groups	N	Weeks						
		1	2	3	4	5	6	1-6
D1	32	1.76	1.43[a]	1.61	1.63	1.62	2.02[a]	1.70[a]
D2	40	1.86	1.53[ab]	1.65	1.69	1.82	2.17[b]	1.82[b]
D3	48	1.90	1.57[b]	1.70	1.84	1.89	2.28[b]	1.91[c]
SEM	-	0.06	0.03	0.05	0.06	0.07	0.04	0.03
Significant	-	NS	*	NS	NS	NS	*	*

D1: 8 birds/m^2; D2: 10 birds/m^2 which served as control and D3: 12 birds/m^2.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.
* (P<0.05).
NS: non significant.

The thigh percentages of birds reared at D1 (6.40), D2 (6.37), and D3 (6.10) stocking densities were not significantly different. Breast weight percentages of birds at stocking densities of 8, 10, and 12 birds /m^2 did not differ significantly. Wing weight percentages was numerically higher in D2 (5.55) followed by D1 (5.45) and D3 (5.40) though statistically insignificant.

Stocking density showed insignificant effect on the percentage of heart in this study but the numerically higher value was seen in D3 (0.475) group followed by D2 (0.472) and D1 (0.46) stocking densities.

In the current investigation, increasing stocking density lowers feed intake and weight increase. The feed intake and weight gain was higher in lower density group (8 birds/m^2)

than intermediate (10 birds/m^2) and higher stocking density (12 birds/m^2). Many scientists have reported that high stocking density reduces broiler chicken growth performance when compared to low stocking density (Iyasere *et al.* 2012; Tong *et al*. 2012; Kenaleone *et al.* 2014; Cengiz *et al.* 2015; Farhadi *et al*. 2016; Heidari and Toghyani, 2018; Goo *et al*. 20). The motion of birds in a given area is disrupted with the aid of using excessive stocking density, making it extra hard for birds raised in excessive stocking density to get access to feeders and water. Likewise, Abudabos *et al.* (2013) found that birds reared on higher density suffered from moderate heat stress due to restricted heat exchange caused by crowding. However, the present investigation contradicts Silas *et al*. (2014) and Gupta *et al.* (2016), who observed no effect of stocking density on broiler chicken development performance.

Feed conversion ratio (FCR) was better in the lower density (8 birds/m2) group than in the middle (10 birds/m2) and higher stocking density (12 birds/m2) groups in this study. Lower feed conversion ratios indicate that birds are capable of efficiently converting feed into muscle. In Hybro PN broilers, elevating the stocking density from 15 to 19 birds/m2 had a negative impact on feed conversion per kg weight gain, in line with Sosnowka *et al.* (2005). It could be because birds have to travel further to reach a feeder, or if feeder space is limited, higher stocking density may impair feed conversion efficiency. Feddes *et al* (2002) and Houshmand *et al.* (2012) found that a density of 10 birds/m2 of floor space resulted in a significantly lower FCR than a density of 16 birds/m2 which was opposite to the current study. Other researcher's findings suggested that stocking density had little influence on FCR (Ventura *et al.* 2010; Petek *et al*. 2014; Wang *et al.* 2014; Gopinger *et al.* 2015; Farhadi *et al*. 2016; Gupta *et al*. 2016).

Overall, increasing stocking density (12 birds/m2) increased the frequency of drinking and locomotion in broiler chickens, while cannibalism had no effect on broiler chickens at any of the three stocking densities. In consistent to present study, Simitzis *et al.* (2012); Yanai *et al.* (2018) and Casanova *et al.* (2019) found increase in the frequency of drinking with increasing stocking density.

The observed results show that at low stocking density (8 birds/m2), chickens desired to stay near the feeders and drinkers, and there was no dissension among the birds for feed and water, whereas as density increases, chickens have to strive for their feed and water, which increases their thirst and alertness.

In this study, time spent on movement was found to decrease as stocking density increased. The present investigation indicates that when stocking density increases, more birds will be forced to stand due to a shortage of room for crouching or reclining. Likewise, Simitzis *et al.* (2012); Son (2013) and Yanai *et al.* (2018) found that increasing stocking density decreases mobility of birds. However, the current findings contradicted those of Estevez (2007) and Leone and Estévez (2008). According to Abudabos *et al.* (2013), there was no significant variation in movement, drinking, scratching, or roosting for commercial broilers at various stocking densities.

In the present investigation, higher stocking density of broilers affects their performance and physiological markers. Hb level and H/L ratio are regarded the most relevant measures for measuring physiological stress in birds, according to Cengiz *et al.* (2015) and Qaid *et al.* (2016). Present findings corroborated this, as increasing the stocking density resulted in a drop in Hb. Similarly, Park *et al.* (2018) reported that increasing stocking density significantly lowers hemoglobin (Hb) content. In humans and animals, a reduction in red blood cells and hemoglobin levels under normal environmental conditions may cause iron deficiency anemia. Even if there is no difference in plasma volume, chickens on high stress and high stocking density suffer from hem dilution due to increased water absorption. According to Tuerkyilmaz (2008) and Park *et al.* (2018) water can evaporate from cells, resulting in a reduction in the quantity of red blood cells and hemoglobin levels. Contradictory to the present findings, Sekeroglu *et al.* (2011) and Silas *et al.* (2014) found no effect hemoglobin on stocking density.

The impact of broiler stocking density on the H/L ratio has yielded varied findings. A number of researchers have discovered that as stocking density rises, the H/L ratio rises as well (Feddes *et al*. 2002; Zulkifli *et al.* 2004; Thaxton *et al.* 2006; Cengiz *et al*. 2015; Nasr *et al*. 2021). Stocking density has no effect on the H/L ratio, according to Heckert *et al.* (2002); Spinu *et al.* (2003); and Tuerkyilmaz (2008). Present findings showed that overcrowding stress reduced H/L ratio, which was similar to Chegini *et al.* (2018) who found that increasing stocking density reduced H/L ratio in Ross 308 male broilers.

In the current study, non-significant impacts of biochemical markers such as total protein, albumin, globulin, albumin to globulin ratio on stocking density was observed. The currents findings are comparable with the reports of Das and Lacin (2014); Gupta *et al.* (2016) and Kumar *et al.* (2017) who observed that some biochemical parameters were not influenced by stocking density in poultry. Differing to this, Karthiayani and Philomina (2015) and Singh *et al.* (2018) found that biochemical indices are influenced by varying stocking density.

The carcass characteristics revealed, group with lowest to moderate stocking density (8 and 10 birds/m^2) exhibited highest carcass weight % (neck, back, dressing, and drumstick) compared to the higher density group (12 birds/m^2).

Table 8 Proportion (%) of birds weekly drinking frequency, locomotion and cannibalism reared in different stocking densities

Groups	Weeks					
	1	2	3	4	5	6
			Drinking frequency			
D1	3.47	7.77[ab]	11.30[a]	16.10[a]	17.35[a]	19.77[a]
D2	3.67	8.02[ab]	12.17[b]	16.80[b]	18.12[b]	20.12[a]
D3	3.55	8.45[b]	12.72[c]	17.2[b]	18.57[b]	21.25[b]
SEM	0.08	0.11	0.19	0.15	0.17	0.22
Significant	NS	*	**	*	*	*
			Locomotion (movement of birds)			
D1	16.42	23.02[a]	35.50[b]	42.20[b]	48.25[b]	58.30[c]
D2	17.55	23.52[b]	34.90[b]	41.95[b]	47.82[ab]	55.05[b]
D3	18.0	23.77[b]	32.97[a]	38.70[a]	46.87[a]	52.05[a]
SEM	0.89	0.10	0.34	0.50	0.27	0.78
Significant	NS	*	*	*	*	**
			Cannibalism			
D1	2.47	3.57	7.57	14.90	21.67	28.45
D2	2.05	3.40	6.77	14.17	21.40	27.87
D3	1.70	3.22	6.90	14.47	21.25	27.92
SEM	0.45	0.15	0.42	0.44	0.18	0.53
Significant	NS	NS	NS	NS	NS	NS

D1: 8 birds/m^2; D2: 10 birds/m^2 which served as control and D3: 12 birds/m^2.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.
NS: non significant.

Table 9 Mean ± SE effect of three stocking density on haemato-biochemical parameters of broiler chickens

Groups	Hb (g)	H/L ratio %	TP (g/dL)	A (g/dL)	G (g/dL)	A/G ratio
D1	11.05±0.35[b]	0.34±0.17[b]	2.65±0.11	1.25±0.09	1.40±0.02	0.88±0.05
D2	10.47±0.18[b]	0.31±0.00[b]	2.88±0.12	1.59±0.13	1.28±0.06	1.25±0.14
D3	9.25±0.46[a]	0.27±0.02[a]	2.71±0.20	1.45±0.18	1.25±0.03	1.15±0.13
Significant	*	*	NS	NS	NS	NS

D1: 8 birds/m^2; D2: 10 birds/m^2 which served as control and D3: 12 birds/m^2.
Hb: hemoglobin; H/L: heterophil to lymphocyte ratio; TP: total protein; A: albumin and G: globulin.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
* (P<0.05).
NS: non significant.

Table 10 Carcass yield (Mean±SE, %) at three stocking densities

Carcass traits	Groups			Significant
	D1	D2	D3	
Neck	5.65±0.64[b]	4.70±0.40[a]	4.67±0.47[a]	*
Back	14.60±0.08[a]	15.97±0.14[b]	14.97±0.06[b]	*
Thighs	6.40±0.18	6.37±0.14	6.10±0.04	NS
Breast	32.0±0.04	32.30 ±0.14	32.32±0.16	NS
Wings	5.45±0.05	5.55±0.09	5.40±0.16	NS
Dressing	77.52±0.07[b]	80.60±0.09[c]	75.60±0.09[a]	**
Drumstick	4.02±0.04[a]	4.85±0.28[b]	4.75±0.28[b]	*
Abdominal fat	6.75±0.88	8.25±1.10	7.87±1.12	NS
Liver	1.65±0.01[a]	1.83±0.01[c]	1.73±0.01[b]	**
Gizzard	1.04±0.01[a]	1.21±0.004[b]	1.31±0.01[c]	**
Heart	0.47±0.004	0.46±0.004	0.47±0.006	NS

D1: 8 birds/m^2; D2: 10 birds/m^2 which served as control and D3: 12 birds/m^2.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.
* (P<0.05) and ** (P< 0.01).
NS: non significant.

These findings matched those of Abo-Alqassem *et al.* (2018) who found that intermediate density group (15 birds/m^2) had the highest dressing weight (1498.3 g) and carcass percent (76.7%) than the high density group. Similarly, Madilindi *et al.* (2018) reported that as stocking density decreases, carcass weight increases.

Feddes *et al.* (2002) on the other hand, discovered that when stocking density increased, the percentage of thigh, drumstick, and neck increased. Disagreeing to this, Ligaraba *et al.* (2016) found that stocking density showed insignificant effect on carcass traits. Only the breasts were found to have substantial effect by Siaga *et al.* (2017). Factors such as the season in which the birds were raised, genotypes, and feeding regimen could explain these disparities.

The present investigation depicted that as density increased, the weight of internal organs (excluding heart weight) increased as well. It was discovered that changes in density have no effect on heart percent. Ligaraba *et al.* (2016); Rambau *et al.* (2016) and Siaga *et al.* (2017) all observed no influence of stocking density on heart % in their studies. On the contrary, increasing stocking density resulted with a higher percentage of broiler heart, according to Onbasilar *et al.* (2008). Gizzard and liver weight percentage was observed highest in higher stocking density (12 birds/m^2) compared with the lower density groups (8, 10 birds/m^2). Chegini *et al.* (2018) confirmed these findings, indicating that liver weight was larger in Ross 308 males reared on high stocking density compared to low stocking density, and that the same was observed for quails reared on high stocking density (Mahrose *et al.* 2019b). This is probably due to overcrowding, which allows birds to eat feed rapidly at high stocking densities. As a result, the gizzard grows larger or expands more quickly in order to grind larger amounts of food. Furthermore, larger liver weight could be linked to the stressed broiler's enhanced liver lipids, resulted in a higher percentage of fat in the liver, according to Puvadolpirod and Thaxton (2000).

CONCLUSION

Finally, our findings provide quantitative information on the influence of broiler chicken stocking density on feed intake, feed conversion, body weight, weight gain, behavior traits, carcass metrics, and chosen haemato-biochemical indicators. Lower to intermediate stocking density in bird's results in increased body weight and improved feed conversion efficiency, according to the findings. Low stocking density benefits birds in terms of welfare since they are less stressed and have more freedom to express them. Decreased stocking density improved certain blood indicators. However, some biochemical markers viz., total protein, albumin, globulin level and albumin globulin ratio was unaffected among all the three stocking densities in the present study. Furthermore, it was also concluded that lower stocking density resulted in higher carcass yield. According to our findings, having a larger live body weight in a smaller space boosts profitability. When it comes to profitable rearing and retaining birds for more than 40 days, poultry farmers should choose a small to intermediate stocking density.

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