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Effect of Stocking Density on Growth Performance and Carcass Characteristics of Broilers Grown to 3 Kg under Antibiotic Free Diets[1,2]

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ABSTRACT

Background: Stocking densities could have a significant impact on birds when reducing or eliminating antimicrobials (antibiotic-free; ABF) in poultry diets. This study investigated the effects of stocking densities on growth performance and carcass characteristics of broilers fed antibiotic-free diets grown to 3 kg.

Methods: A total of 888 1-d-old Ross × Ross 708 chicks were randomly distributed into 24 pens. The treatments were four stocking densities including 29, 33, 39 and 42 kg of BW/m^2; each treatment was represented by six replicates. Treatments were blocked within the room to account for any variations in room conditions. Treatment assignments were randomized within each block. Used bedding was obtained from commercial farms to simulate commercial conditions and litter microflora. Birds were fed antibiotic-free (ABF) diets and provided a three phase-feeding program (Starter: 0-14 d, Grower: 15-28 d and Finisher: 29-42 d). Feed and water were provided *ad libitum*. Birds and feed were weighed on 1, 14, 28 and 42 d of age to measure growth performance. On d 43, 10 (5 males and 5 females) birds from each pen were processed to determine weights and yields.

Result: The BW and BW gain, live weight, carcass weights and carcass yield percentage were not affected by stocking density. Also, mortality was not affected by stocking density. However, FI and FCR for the starter period were significantly elevated ($P<0.001$ and $P<0.001$, respectively) at lower stocking densities, but were not different for the remainder of the growout. In conclusion, stocking densities evaluated from 29 to 42 kg/m^2 with appropriate environmental management has a negligible effect on overall production and processing yield in ABF broilers.

Key words: Broilers, Growth-performance, Stocking-density, Welfare.

INTRODUCTION

The poultry industry is making rapid progress in improving the efficiency of the production and supply of broiler meat to consumers, which have significantly increased over the past decade (Alltane *et al*., 2018; Namakparvar *et al*., 2018). This is expected to continue in the future due to the relative price-competitiveness compared to other meat products (Caspari *et al.,* 2010; Petracci *et al.,* 2015). In addition, poultry meat production globally will further grow by 2.4% per year over the next 20 years and the total production in 2030 will be around 160 million tons that will have a share of 39% in total meat production (Mulder, 2011). However, as the demand for animal protein products increases, increasing animal production and production efficiencies will be critical to the continued viability of the U.S. poultry and livestock industries. Moreover, the progress of the poultry industry and improvement of the production are essential to provide the protein requirements because the world's population is projected to reach 15.9 billion by 2050 (Amini *et al*., 2015, Costantino *et al.,* 2018). Consumer demand for breast meat has driven a shift in market composition towards increased market weights (Kuck and Schnitkey, 2021). The rapid progresses include improved genetics, nutrition and changes in environmental management (light, temperature, stocking density), resulting in more rapid broiler growth and welfare management (Kidd, 2009; Marcos and Fausto, 2016; Hartcher and Kum, 2019).

Stocking densities may play a significant role on bird performances when reducing or eliminating antimicrobials (antibiotic-free; ABF) in poultry diets. Stocking density can influence nearly all aspects of live production including economics, production efficiency, welfare/well-being, health and final product quality (Alaeldein, *et al*., 2013; Majid

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et al., 2020). The benefits of increasing stocking density include improving productivity, making full use of limited available areas and increasing income. However, increasing stocking density beyond a certain range may negatively affect live performance and welfare of broilers. The strain of broiler chicks, slaughter age, average body weight of each bird, access to feeder space and the building size among other factors can influence stocking density selection (Horne and Bondt, 2014). In addition, the total final body weight per area unit can be influenced by stocking density as determined by economic conditions and market demand (Imaeda, 2000). Several studies that evaluated several factors associated with poultry stocking density revealed the impacts on broilers raised at higher densities when compared with birds raised at lower densities (Dozier *et al*., 2005, Hassanein 2011; Simitzis *et al.,* 2012). Higher stocking densities are harmful to birds during the finisher phase when the body weight per unit area ratio is remarkably high. Most available reports were conducted with 3 kg broilers reared with antibiotic-inclusive diets. These have limited applicability to today's market where around 60% of broilers are reared with antimicrobial free (ABF) diets. Hence, this study investigated the effects of stocking densities on growth performance and carcass characteristics of broilers fed antibiotic-free diets grown to 3 kg.

MATERIALS AND METHODS

All procedures relating to the use of live birds in this study were reviewed and approved by the USDA-ARS Animal Care and Use Committee at the Mississippi State location (license number: 19-3). In this study, a total of 888 1-d-old Ross×Ross 708 chicks were randomly distributed into 24 pens based on stocking density treatment assignment. Stocking density treatments of 29, 33, 39 and 42 kg of BW/m^2 were selected based on EU (2007), National Chicken Council (2017) and Global Animal Partnership (2017) recommendations. Pens were adjusted to a total area of 34 ft^2 for this study. Commercial stocking densities of 1 ft^2/bird (Dozier *et al*., 2005; Thaxton *et al*., 2006) were typically employed to maintain commercially relevant feeder and drinker space allotments to stimulate typical feeding and drinking behavior observed in commercial practice. Each pen was equipped with one tube feeder and nipple drinkers. Pens air temperature was initially set at 32°C and was decreased according to the schedule in Table 1. Lighting provided with 5000K LED bulbs. Lighting intensity, photoperiod and room temperature were adjusted according to the schedule in Table 1. Birds were fed antibiotic-free (ABF) diets and offered a three phase-feeding program (Starter: 0-14 d, Grower: 15-28 d and Finisher: 29-42 d) diets on a biweekly change schedule with corn-soy diets according to NRC (1994). Starter feed was provided as crumbles and subsequent feeds were offered as whole pellets. Feed and water were provided *ad libitum*. Litter material was sourced from a commercial farm to mimic commercial conditions and litter microflora.

The experimental treatments were 4 stocking densities (29, 33, 39 and 42 kg of BW/m^2) and consisted of 30, 34, 40 and 44 chicks per pen, respectively at placement with six replicates. Treatments were blocked within the room to account for any variations in room conditions. Treatment assignments were randomized within each block.

Birds and feed on a pen basis were weighed on d 1, 14, 28 and 42 d of age for the computation of BW and feed intake (FI). Cumulative bi-weekly feed intake was calculated by subtracting the remaining feed weights in the feeders from the initial feed weights in the feeders. The incidence of mortality was recorded daily. Necropsies and cause of death (when determined) were performed on all birds that died during the trials by onsite veterinarian. Cumulative BW and FI were recorded from each pen at bi-weekly intervals. Cumulative bi-weekly BW gain (BWG) was calculated by subtracting initial (d 1) BW from the current BW of the birds. Feed conversion ratio (FCR) was calculated by dividing FI with BWG and it was corrected for mortality.

On d 42, 10 (5 males and 5 females) birds from each pen were randomly selected for processing. Birds were weighed and subjected to a 12-h feed withdrawal period. These birds were weighed on the day of processing (d 43) and this weight was used to calculate carcass and breast meat yield. Thereafter, the birds were placed in coops and transported to the poultry processing plant. Birds were electrically stunned, bled, scalded, mechanically picked and mechanically eviscerated. The whole carcass (without neck, giblets, abdominal fat pad) and abdominal fat pad were weighed. Carcasses were split into front and back halves and placed on ice for 4 h after which the front halves were deboned to obtain weights of skinless, boneless, breast fillets (pectorals major muscle) and breast tenders (pectorals minor muscle). Carcass yield, abdominal fat pad and total breast meat yields (sum of pectoralis major and minor muscles) were determined using live weights (post-feed withdrawal) of the broilers selected for processing at 43 d of age.

The experimental design was a randomized complete block design with room location as the blocking factor. Each treatment was represented by six replicate pens. Pen was considered the experimental unit. Treatments were blocked within the room to account for any variations in room conditions. Treatment assignments were randomized within each block. All mortalities were subjected to arcsine

Table 1: Air temperature and lighting program.

Age	Temperature (C)	Light intensity (lux)	Light program
Placement	32	30	23L:1D
4	31	10	23L:1D
8	29	10	20L:4D
14	27	10	20L:4D
21	24	10	20L:4D
28	21	5	18L:6D
35	18	5	18L:6D
41	18	5	23L:1D

transformation prior to statistical analysis. The mixed model ANOVA with PROC MIXED procedure of SAS software (SAS Institute Inc., Cary, USA, 2013) was used to analyze the data. Least-squared means comparisons on day 14, 28 and 42 were separated with Tukey's Honestly Significant Different Test; significance was considered at $P \leq 0.05$.

RESULTS AND DISCUSSION

Initial mean BW was 0.043 kg and was not different among treatments (P = 0.737). The effects of stocking density on BW, BW gain (BWG), FI and FCR are presented in Table 2. The BW and BW gain (BWG) were not affected by stocking density throughout the experimental period, which agreed with other studies (Gupta *et al*., 2017; Ruby *et al*., 2022). Previous studies (Shanawany, 1988; Feddes *et al*., 2002; Dozier *et al*., 2005; Dozier *et al*., 2006) reported significant declines in body weight with increasing stocking density. It should be noted that marked genetic improvement has occurred since these studies were conducted and may account for the lack of differences observed in the current study. For example, Dozier *et al*. (2005) was conducted in the same facility as the current study and required 49 d to reach 3 kg where only 42 d was required in the current study. Increasing stocking density significantly depressed FI during the starter phase ($P<0.0001$) and has been previously observed in multiple diet phases (Shanawany, 1988; Feddes *et al*., 2002; Dozier *et al*., 2006; Al-Homidan and Robertson, 2007; Ghosh *et al*., 2012). Increasing stocking density necessarily limits feeder space and limited feeder space has also been linked to reduced FI (Lemons and Moritz, 2015; Purswell *et al*., 2021), particularly during the starter period (Purswell *et al*., 2021). Feed conversion (FCR) decreased at stocking densities above 29 kg/m^2 ($P<0.0001$) during the starter period and agrees with Dozier *et al*. (2005). However, in contrast to Dozier *et al*. (2005), improved FCR did not persist in later diet phases. Birds consumed more

Table 2: Effects of density on growth performance of broilers grown to 3 kg body weight[1].

Treatments	14 d	28 d	42 d	14 d	28 d	42 d
		BW (kg)			BWG (kg)	
29 kg/m^2	0.527	1.672	2.952	0.484	1.629	2.909
33 kg/m^2	0.535	1.737	3.149	0.492	1.694	3.105
39 kg/m^2	0.520	1.670	2.989	0.477	1.627	2.946
42 kg/m^2	0.533	1.693	3.002	0.489	1.650	2.959
Pooled SEM[2]	0.008	0.029	0.059	0.007	0.029	0.059
P-value	0.455	0.345	0.121	0.457	0.338	0.120
		FI (kg)			FCR (kg of feed/kg of gain)	
Treatments	14 d	28 d	42 d	14 d	28 d	42 d
29 kg/m^2	0.608^{a}	1.512	2.137	1.256^{a}	1.290	1.433
33 kg/m^2	0.583^{a}	1.560	2.256	1.179^{a}	1.258	1.414
39 kg/m^2	0.575^{a}	1.569	2.156	1.175^{a}	1.302	1.453
42 kg/m^2	0.466^{b}	1.562	2.124	0.946^{b}	1.234	1.405
Pooled SEM[2]	0.016	0.042	0.048	0.034	0.021	0.015
P-value	< 0.001	0.767	0.215	< 0.001	0.127	0.115

[ab]Means within a column and effect that lack common superscripts differ significantly ($P \leq 0.05$).

[1]BWG= BW gain, FI= Feed intake, FCR= Feed conversion ratio. All data are cumulative from placement.

[2]Pooled SEM for main effects (n = 6).

Table 3: Effects of density on carcass weights and yields of broilers grown to 3 kg body weight[1].

Treatments		Carcass		Fat		Breast		Tender	
	Live weight	Weight	Yield	Weight	Yield	Weight	Yield	Weight	Yield
	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)
29 kg/m^2	3.101	2.367	76.4	0.037	1.6	0.721	30.3	0.148	6.3
33 kg/m^2	3.155	2.388	75.8	0.033	1.4	0.747	31.2	0.148	6.2
39 kg/m^2	3.146	2.371	75.4	0.032	1.4	0.727	30.7	0.147	6.2
42 kg/m^2	3.085	2.338	75.9	0.033	1.4	0.717	30.5	0.142	6.1
Pooled SEM[2]	0.044	0.040	0.5	0.003	0.1	0.018	0.5	0.004	0.1
P-value	0.693	0.884	0.558	0.688	0.443	0.761	0.670	0.558	0.933

[1]Carcass without giblets, necks and abdominal fat are expressed as a percentage of live weight, while pectoralis major and minor breast muscles are expressed as a percentage of carcass weight.

[2]Pooled SEM for main effects (n=6).

Table 4: Effects of density on mortality of broilers grown to 3 kg body weight[1].

Treatments	Mortality (%)		
	14 d	28 d	42 d
29 kg/m^2	0.00	0.37	2.18
33 kg/m^2	0.00	0.33	0.33
39 kg/m^2	0.00	0.07	0.07
42 kg/m^2	0.25	0.25	0.25
Pooled SEM[2]	0.03	0.11	0.14
P-value	0.089	0.885	0.133

[1]Table values represent least squares means of six replicate pens. All data were arc-sine transformed prior to analysis.[2]Pooled SEM for main effects (n = 6).

diets with higher FCR under lower stocking densities in comparison with birds under 42 kg/m^2 higher stocking densities, but were not different for the remainder of the flocks. The effect of stocking density on FCR has varied in the literature, with no effects reported (Puron *et al*., 1995; Pettit-Riley and Estevez, 2001), increased FCR with increasing density (Bilgili and Hess, 1995; Dozier *et al.*, 2005; Dozier *et al*., 2006), or reduced FCR with increasing density (Shanawany, 1988). Decreasing FCR as stocking density increased may have resulted from excessive feeder space in lower density treatments. Feeder space ranged from 3.5 cm/bird at 29 kg/m^2 to 2.4 cm/bird at 42 kg/m^2. Feeder space can play a significant role in feed wastage and thus FCR as apparent feed consumption can increase (Purswell *et al.*, 2021).

The effects of stocking densities on preprocessing live weight, carcass characteristics, fat and yields of broilers at 43 d of age are presented in Table 3. There were no effects of stocking density on processing parameters observed in the present study. The results agreed with Dozier *et al*. (2005) and Sekeroglu *et al*. (2011) who reported stocking density did not influence carcass and abdominal fat yield relative to live BW.

The data obtained for mortality due to stocking density is presented in Table 4. No significant effects of stocking density on mortality were observed in this study and agrees with Ghosh *et al*. (2012). The effects of stocking density on mortality as reported in the literature are inconclusive, as density has been shown to have no effect (Feddes *et al*., 2002; Thomas *et al*., 2004; Dozier *et al*., 2006; Dozier *et al*., 2005) or increased stocking density resulted in increased mortality (Imeada, 2000; Hall, 2001).

CONCLUSION

Based on the results of the present study, it could be concluded that the overall live production characteristics including body weight, body weight gain and mortality were not affected by stocking density from 29 to 42 kg/m^2. Feed intake ($P<0.001$) and feed conversion ratio (< 0.001) were elevated during the starter period at 29, 33 and 39 kg/m^2 densities. Yield and associated processing characteristics were not affected by stocking density from 29 to 42 kg/m^2. Antibiotic-free production models can successfully employ stocking densities from 29 to 42 kg/m^2 with appropriate environmental management.

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Conflict of interest

There are no conflicts of interest for authors of the manuscript to declare.

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