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Effects of stocking density on broiler chicken growth, organ weight and diet economics in a Philippine setting

Zandro M. Aguilar[1] and Jesse Jay O. Villanueva[1,*]

[1]*College of Agriculture, Department of Animal Science, Mindanao State University, Marawi City*
* *Corresponding author (jessejay.villanueva@gmail.com)*

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Abstract

The study evaluated the effects of stocking density on the growth performance, organ weight, and diet economics of broiler-type chickens in the specific setting and conditions of small-scale poultry farmers in Marawi City, Philippines. Using a completely randomized design (CRD), a total of 120 Cobb birds were randomly distributed to 4 treatments in 12 pens measuring 1 m^2. The 4 treatments consisted of stocking densities of 4, 8, 12 and 16 birds/m^2 with 3 replications per treatment. From 1 to 26 days, the average daily gain, average daily feed intake, and feed conversion ratio of the broiler chickens at various stocking densities showed substantial changes in growth performance ($P<0.05$). Among the treatment groups, the final body weight of chickens under 8 birds/m^2 was heaviest ($P<0.05$) on day 26. The organs of broiler chickens, however, showed no significant change ($P>0.05$) in absolute and relative weight. Diet economics also indicated no significant variations between live and carcass weight ($P>0.05$). Despite this, chickens under 8 birds/m^2 had the highest margin over feed cost. Thus, the stocking density rate of 8 birds/m^2 is recommended for the given setting and conditions.

Key words: Cobb birds, growth performance of broilers, small-scale poultry production, Marawi City

Introduction

Poultry farmers around the world strive to optimize the kilogram of chicken produced per square meter of area while avoiding production losses due to overpopulation (Abudabos et al., 2013). Stocking density, defined as the number of birds or weight per floor surface area, is a significant environmental component for broiler production and welfare (Berg and Yngvesson, 2012). This has been found to have a significant effect on broiler chickens' average body weight gain (Gholami et al., 2019; Nasr et al., 2021; Guardia et al., 2011; and Esmail et al., 2020), feed conversion ratio (Ravindran and Thomas, 2004; Valdivie et al., 2004; and Sreehari and Sharma, 2010), and organ weight and economic returns (Wang et al., 2015).

Higher stocking densities in broilers result in higher mortality, reduced meat yield, more leg problems, and cannibalism (Tuerkyilmaz, 2008). Low feed consumption, poorer growth rates, and poor-quality carcasses have also been reported as consequences of high stocking density. Furthermore, a rise in airborne infections has been linked to excessive stocking density (Poultry world, n.d.). Research also suggests that stocking levels may not only have a negative influence on bird welfare but also diminish average daily growth (ADG), indicating a loss of economic efficiency on broiler chicken performance (Bergeron et al., 2020).

Stocking density, which is determined by economic factors and market demand, can affect total and body weight per square unit (Imaeda, 2000). The density per m^2 varies depending on slaughter age, free space availability, breed type, and other factors; thus, the possible ranges are from 11 to 20 chicks per m^2 (Van Horne and Bondt, 2014).

But while stocking density has influences on the performance and welfare of broilers, studies have also pointed out that housing environment and environmental management might even be more critical (Feddes et al., 2002; Dawkins et al., 2004). However, controlling climatic conditions to improve the welfare and performance of birds in various regions is expensive (Costantino et al., 2018).

In the Philippines, while the poultry industry is a big business (Pe, 2014), and which includes small-scale backyard poultry production, there is scarcity of studies on the effects of stocking density on broiler chicken performance. Thus, this experiment will be conducted to evaluate the effects of stocking density on the growth performance, organ weight, and diet economics of broiler chickens in a specific Philippine setting. The purpose is to offer small-scale poultry farmers in the country with recommendations on appropriate stocking density based on the results of a locally-sited experiment, following common practice in local small-scale poultry production.

Materials and Methods

Place and Duration of Study

The study was conducted at the Poultry House, Department of Animal Science, College of Agriculture, Mindanao State University, Marawi City, from March to April 2022. The city has a tropical rainforest climate with a yearly temperature of 25.28°C, which is -1.94% lower than Philippine average temperatures. It has 302.62 mm of precipitation, with 335.96 rainy days year-round (Weather and Climate, 2022).

Birds, Pens, Experimental Design, and Management

One hundred twenty (120) one-day-old Cobb birds with similar average body weights were randomly assigned to four treatments with three replicate pens. Using the Completely Randomized Design (CRD), the density treatments were 4, 8, 12, and 16 birds/m^2. From the age of 1 to 26 days, all birds were fed a commercial diet.

For the pens, an open-wire-mesh poultry house was constructed, similar to the common poultry structures used by small-scale farmers in the area (see Figure 1). Wire mesh partitioning was used to create 12 pens, each measuring 1 m^2. Before the experiment began, the house was thoroughly cleaned and disinfected. Each pen has a thoroughly sterilized feeder and drinker that allowed for *ad libitum* feed and water intake. To protect the birds from stress, they were given water-soluble vitamins and electrolytes. Light was provided for approximately 24 hours in the form of natural light during the day and artificial light during the night as practiced by small-scale poultry farmers. The layout of the experiment is shown in Table 1.

Figure 1. Open-wire mesh pen

Table 1. The layout of the experiment.

Treatments	Number of birds per replication			Total numbers of birds
	R_1	R_2	R_3	
T_1	4	4	4	12
T_2	8	8	8	24
T_3	12	12	12	36
T_4	16	16	16	48
Grand Total	40	40	40	**120**

Data Collection and Measurements

Growth Performance. Individual bird body weights (BW) and daily feed allotments were recorded weekly using the rechargeable digital weighing scale (max. weight, 40kg.; min. weight, 200 g.; graduation, 2g.). The average daily gain (ADG), average daily feed intake (ADFI), and feed conversion ratio (FCR) for each treatment, feeding phase, and the overall period were calculated using the formula below.

$$\text{Average Daily Gain} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Number of days}}$$

$$\text{Average Daily Feed Intake} = \frac{\text{Total feed intake}}{\text{Number of days}}$$

$$\text{Feed Conversion Ratio} = \frac{\text{Average daily feed intake}}{\text{Average daily gain}}$$

Organ Weights. On the 26th day of the experiment, nine (9) birds from each treatment were randomly chosen, slaughtered, and de-feathered in order to determine the live and carcass weights in absolute and relative weight using the formula below. The responses were determined by removing internal organs such as the gizzard, heart, liver, and spleen.

$$\text{Absolute weight} = \text{actual weight of organs, g}$$

$$\text{Relative weight} = \frac{\text{actual weight of organs, g}}{\text{final weight (LW), g}} \text{ x } 100$$

Diet Economics. Feed cost per bird, value of gain per bird, feed cost per kilogram of gain, and margin over feed cost (MOFC) were calculated using the method below on the current market price on both a living weight (LW) and carcass weight basis throughout the study.

$$\text{Feed Cost/bird} = \text{total feed intake x feed price}$$

$$\text{Value of gain/bird} = \text{weight at 26 days X curent price (liveweight and carcass weight)}$$

$$\text{Feed cost/kg gain} = \frac{\text{feed cost}}{\text{weight at 26}}$$

$$\text{MOFC} = \text{value of gain/bird} - \text{feed cost}$$

Statistical Analysis

The data obtained from the experiment were analyzed by one-way ANOVA using SAS statistical software (SAS Institute Inc., 2013. SAS/ACCESS® 9.3.1 Inter Cary, NC: SAS Institute Inc.). The significance of differences among treatments was tested using Tukey's Honestly Significant Difference (HSD). Statistical significance was established at P<0.05.

Results and Discussion

Growth Performance

Table 2 shows the growth performance of 120 broiler chickens after nutrient assimilation under different stocking densities of similar unit area (1 m^2). There was a significant difference (P<0.05) observed in the final body weight (BW), average daily gain (ADG), average daily feed intake (ADFI), and feed conversion ratio (FCR) of broiler chickens under different stocking

Table 2. Growth performance of broiler chicken under different stocking density rates.

ITEM	TREATMENT (birds/m^2)				SEM	*P-value*
	4	8	12	16		
BW, g						
d 1	0.147^{ab}	0.151^{a}	0.139^{ab}	0.128^{b}	0.008	0.041
d 26	1.668^{a}	1.670^{a}	1.519^{a}	1.331^{b}	0.069	0.0009
Day 1-7						
ADG, g	0.047^{ab}	0.048^{a}	0.046^{ab}	0.039^{b}	0.003	0.030
ADFI, g	0.071^{a}	0.064^{ab}	0.055^{bc}	0.047^{c}	0.004	0.001
FCR	1.516^{a}	1.326^{ab}	1.200^{b}	1.211^{b}	0.104	0.019
Day 8-14						
ADG, g	0.080^{a}	0.077^{ab}	0.075^{ab}	0.065^{b}	0.005	0.025
ADFI, g	0.108^{a}	0.103^{a}	0.100^{ab}	0.086	0.006	0.009
FCR	1.342^{a}	1.334^{a}	1.257^{a}	1.344^{a}	0.085	0.570
Day 15-21						
ADG, g	0.105^{a}	0.108^{a}	0.098^{a}	0.094^{a}	0.007	0.145
ADFI, g	0.138	0.116	0.131	0.112	0.022	0.449
FCR	1.333	1.199	1.342	1.193	0.214	0.732
Day 22-26						
ADG, g	0.238^{a}	0.239^{ab}	0.215^{ab}	0.192^{b}	0.010	0.002
ADFI, g	0.177^{a}	0.163^{ab}	0.159^{ab}	0.135^{b}	0.014	0.032
FCR	1.632	1.649	1.309	1.550	0.180	0.156
Day 1-26						
ADG, g	44.141^{a}	44.244^{a}	41.192^{ab}	37.807^{b}	1.919	0.010
ADFI, g	0.124^{a}	0.106^{b}	0.105^{b}	0.085^{c}	0.005	0.0002
FCR	1.834	1.656	1.799	1.667	0.079	0.052

BW = body weight; ADG = average daily gain; ADFI = average daily feed intake; FCR = feed conversion ratio; SEM = standard error of means

$^{a-b}$values within a row having a common superscript letter are different (P<0.05).

densities.

On day 26, the final BW of chickens under 8 birds per m^2 was heavier (P<0.05) as compared to other treatments with higher density rates. As shown in the table, the ADG of chickens from day 0 to 26 decreased (4 m^2/bird: 44.141; 8 m^2/bird: 44.244; 12 m^2/bird: 41.192; 16 m^2/bird: 37.807) as the stocking density rate increased. The result indicates that stocking density rate affected the growth performance of broiler chickens. Thus, in high density stocking conditions, a decrease in ADG was evident due to reduced feed intake, and this in turn resulted in the depreciation of total gained weight or reduced weight rates of chickens. This affirms the findings of Gholami et al. (2019) that stocking density had a significant effect (P<0.05) on the average body weight gain during the grower and whole periods of broiler chickens. Nasr et al. (2021) also found out in their study that stocking density with 17 birds/ m^2 had the lowest body weight. As reported by Guardia et al. (2011), an increase in stocking density was found to depress the daily BW gain of broilers during the last period of rearing, and this could be due to competition in feed, water, and space as well as the increase in temperature.

From day 0 to 26, the ADFI of broiler chickens under different stocking density rates is also significantly influenced (P<0.05). The ADFI was observed to decrease as the stocking density increased. In high stocking density, daily feed intake was found to decrease because of low feed consumption prompted by number of birds per cage competing for feed, water, and space. According to Guardia et al. (2011), ADG were found to be negatively affected by the increase in stocking density because of reduced feed consumption. As expounded by Esmail (2020), aside from reduced feed intake, hypermobility spectrum disorders also cause loss of feed energy as a result of immunological responses and other body adjustments.

Meanwhile, the FCR of broiler chickens is high under 4 birds/m^2, followed by 8 birds/ m^2 and 12 birds/m^2. The lower FCR is evident on broiler chickens under 16 birds/m^2. The differences in FCR recorded in the first and second week were significant (P<0.05). The lower FCR values indicate the better feed efficiency of birds. FCR was low in high stocking density as feed was consumed by the increased number of chickens, successfully converting it to body mass. On the other hand, FCR was high at low stocking density due to the decreased number of chickens consuming the amount of feed that was higher than their actual requirement, thus resulting in feed wastage. These results agreed with Ravindran and Thomas (2004), Valdivie et al. (2004), and Sreehari and Sharma (2010) who all observed that feed conversion was better at high stocking density than low.

Overall, from day 1 to 26, significant differences were observed decreasingly (P<0.05) in the ADG, ADFI, and FCR of broiler chickens under different stocking density rates in a similar unit area (1 m^2). The results imply that the higher the stocking density rate was, the poorer was the performance of broiler-type chicken in terms of growth. However, considering that successful broiler chicken rearing at high stocking densities has also been documented (Wang et al., 2015), there is a possibility that there are other causes for this discrepancy, including management techniques, the environment, and stress.

Organ Weight

Table 3 depicts the absolute and relative organ weight of broiler chickens under different stocking density rates of similar unit area (1 m^2). A significant difference was observed (P<0.05) in the live weight (LW) of broiler chickens. The liveweight is anticipated to decline as well, as shown by the growth performance data, as ADG and ADFI declined under high stocking density conditions. As overcrowding prevented the birds in high stocking density from reaching their maximum growth potential, live weight decreased. This implies that LW is affected by stocking density. As mentioned by Dabi (2017), the depression in final LW gain due to increased stocking density may be caused by limited physical access to feeders, leading to reduced feed consumption and overcrowding stress.

On the other hand, the carcass weight of chickens under different stocking densities showed no significant difference (P>0.05). Thus, stocking density does not affect the dressing weight of chicken. This agreed with the conclusion of Tong et al. (2012) that stocking density did not affect the carcass and eviscerated carcass yields and abdominal fat yields. Such result was also

Table 3. Absolute and relative organ weight of broiler chickens under different stocking density rate.

ITEM	TREATMENT (birds/m^2)				SEM	*P-value*
	4	8	12	16		
Live weight, kg	1.747^{ab}	1.884^{a}	1.607^{ab}	1.599^{b}	0.151	0.030
Carcass weight, kg	1.246	1.430	1.253	1.234	0.185	0.238
Absolute weight, g						
Heart	11.000	14.000	10.000	11.000	3.000	0.087
Spleen	5.000	4.000	4.000	4.000	1.000	0.724
Gizzard	22.000	20.000	17.000	18.000	4.000	0.090
Liver	36.000	40.000	35.000	38.000	7.000	0.585
Relative weight, %						
Heart	0.623	0.760	0.624	0.691	0.160	0.419
Spleen	0.266	0.597	0.249	0.273	0.451	0.495
Gizzard	1.253	1.082	1.047	1.113	0.241	0.490
Liver	2.052	2.161	2.184	2.390	0.328	0.366

SEM = standard error of means
$^{a-b}$values within a row having a common superscript letter are different (P<0.05).

consistent with the findings of Dozier et al. (2006) that stocking density did not influence carcass yield relative to BW.

In absolute weight, no significant difference (P>0.05) was observed in the heart, spleen, gizzard, and liver. This means that the mentioned organ weight of chickens under different treatments was not affected by their respective stocking density rates. In relative weight, no significant difference was also observed (P>0.05) in the weight of all the organs of broiler chickens. Thus, the result indicates that stocking density rate did not affect the weight of the organs. As reported by Gholami et al. (2019), carcass weight is influenced by stocking density, but the meat quality and organ weight percentage are not significantly affected. This is in contrast with the conclusion of Qaid et al. (2016) that birds reared at lower density showed higher intramuscular fat, spleen, liver weight, liver NADP-isocitrate, and NADP-malate dehydrogenase activity.

Diet Economics

Table 4 shows the diet economics of broiler chicken under different stocking density rates of similar unit area (1 m^2). The margin over feed cost (MOFC) of broiler chickens was not significantly different (P>0.05) based on live weight. The MOFC for 8 birds per m^2 was PhP187.73, while it was PhP167.57, PhP160.15, and PhP153.51 for 16, 4, and 12 birds per m^2, respectively. The varying stocking density rates used had an impact on the numerical gain in profit per bird.

In addition, treatments with increased stocking densities posed a high economic return, almost similar to those with reduced stocking densities. Therefore, high stocking density conditions could still maximize productive returns as long as other factors regarding poultry production would be carefully considered. According to Wang et al. (2015), increasing stocking densities in broiler production can still produce great economic returns from a production unit as long as other external factors such as feed

Table 4. Diet economics of broiler chicken under different stocking density.

ITEM	TREATMENT (birds/m²)				SEM	*P-value*
	4	8	12	16		
Live weight						
Feed cost, PhP	97.598	88.085	87.486	75.396	4.018	0.001
Value of gain	257.75	276.63	241.00	239.88	23.541	0.044
Feed cost/gain	57.160[a]	48.158[b]	54.655[ab]	47.677[b]	5.522	0.016
MOFC	160.15	187.73	153.51	167.57	24.425	0.117
Carcass weight						
Feed cost, PhP	97.598[a]	88.085[a]	87.486[a]	75.306[b]	4.018	0.001
Value of gain	249.17	286.00	250.05	246.83	25.374	0.063
Feed cost/gain	79.938[a]	62.710[ab]	70.542[ab]	62.423[b]	10.733	0.033
MOFC	217.58	254.50	219.00	215.33	27.362	0.099

MOFC = margin over feed cost; SEM = standard error of means
Liveweight price = PhP 150.00; Carcass weight price = PhP 200.00
[a-b]values within a row having a common superscript letter are different (P<0.05).

and water adequacy, temperature/ventilation, environment, and effective management practices are properly taken into account.

In carcass weight, no significant difference (P>0.05) was observed in the MOFC of broiler chickens. The MOFC of chickens with 8 birds per m² was PhP254.50, whereas those with 12, 4, and 16 birds per m² had MOFCs of PhP219.00, PhP217.58, and PhP215.33, respectively. There was no significant difference found on the MOFC of chickens under different stocking density, as carcass weight was not affected as well by stocking density. Therefore, stocking density did not affect the possible economic return or the diet economics of broiler chickens.

Conclusion

The stocking density rates of 4, 8, 12, and 16 birds/m² influenced the overall growth performance of broiler chickens. On days 1 to 26, a significant difference was observed on the ADG, ADFI, and FCR of treatments. The BW, ADG, and ADFI decreased as the stocking density rate increased. Meanwhile, the FCR is lowered in broiler chickens under a high stocking density rate. In both absolute and relative weight of organs, no significant difference was observed in the heart, spleen, gizzard, and liver. In diet economics, still no significant differences were observed (P>0.05) in the MOFC of chickens based on live and carcass weights. From the overall findings, a stocking density rate of 8 birds per m² is suggested for the small-scale poultry farmers of Marawi City, Lanao del Sur.

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