Impacts of stocking density on the performance and welfare of broiler chickens

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Abstract

The current study was performed to investigate the influence of different stocking density rates on the performance, thermophysiological measurements as well as blood parameters of 0 to 30 d of age female Ross broiler. A total of 96 chicks were randomly distributed in a randomized complete block design among 12 cages. Three stocking density rates were applied; low (28.0 kg/m²), medium (37.0 kg/m²) and high (40.0 kg/m²). Results revealed that cumulative body weight gain (BWG) and feed intake (FI) were influenced (P<0.01) by the rate of stocking density, while no effect (P>0.05) were observed for broilers mortality-corrected feed conversion ratio (FCR). Higher BWG (P<0.01) and FI (P<0.05) were reported for low and medium density rates broilers in comparison to the high density rate broilers. Overall means of body temperature as well as head, neck, wing, body and shank surface temperatures have displayed (P<0.05) higher values in medium and high density rates broilers compared to the low density rate broilers. Furthermore, increasing the stocking density from 28 to 40 kg/m² induced a state of hemodilution in higher density rate broilers, which might explain the noticeable decrease in packed cell volume (PCV). Meanwhile, an increase in serum aspartate aminotransferase (AST) was observed in the higher density group, which might indicate hepatocellular injuries. It can be concluded that increasing the stocking density rate from 28 to 40 kg of BW/m² had evident impingement effects on the performance of broiler chicken and could jeopardize their welfare.

Introduction

The ultimate goal of poultry producers worldwide is to maximize kg of chicken produced per square meter of space while preventing production losses due to overcrowdings to achieve a satisfactory economic return. According to the industry, stocking density is currently expressed as a mass per unit of space rather than numbers of birds being reared in a given area (Thaxton et al., 2006). The advantage of using bird weight per unit area is that the standards are consistent regardless the target weight.

Several studies had been conducted to study the effect of stocking density (20 to 40 kg/m²) on broilers’ production and performance. However, the majorities of these studies were not always conclusive and had produced variable conclusions. Some studies showed large benefits in reducing stocking density on the performance of broilers (Bilgili and Hess, 1995; Dozier et al., 2005, 2006; Chmelničná and Solčianska, 2007; Míteni et al., 2007; Škrbic et al., 2009), while other documented that reducing stocking density had no influence (Thomas et al., 2004) or even had negative impacts on broilers performance (Feddes et al., 2002). The discrepancies between these studies clearly indicate for more oriented studies, to clarify our understanding of how broilers’ performance might be affected in different stocking density rates. Controlling the thermal environment of the broiler shed to a defined optimum is essential to minimize thermal stress and thus to ensure maximum production efficiency. Maintaining normal body temperature is merely a component or indication of this (Bessei, 2006).

Recently, on the other hand, much concern is expressed about stocking density of broilers in relation to the welfare issues such as behavioral and physiological stress. In 2007, the European Commission published the minimum standards on broiler welfare with a maximum stocking density of 30 kg/m² (0.073 m²/bird) of broiler chickens across the EU. Moreover, the National Chicken Council (2005) has established a voluntary welfare audit program for broiler companies to follow. This program guideline a range of densities from 28 to 40 kg of BW/m² for light broilers to 41.6 kg/m² for roasters.

Optimal environmental conditions and thermal comfort must be provided for broilers to maintain constant body temperature and to achieve their genetic potential for superior growth (Feddes et al., 2002; Yahav et al., 2004; Cangar et al., 2008). An interesting approach to study broilers’ welfare is to monitor their thermophysiological responses under different stocking density. Although few researchers have addressed how stocking density may affect broilers’ physiological stress responses (Feddes et al., 2002; Dawkins et al., 2004; Thaxton et al., 2006; Škrbic et al., 2009; Beloor et al., 2010), it is still not clear if stocking density has an impact on broilers’ thermophysiological responses.

It was hypothesized, therefore, that increasing stocking density rates would impose an impact on the performance and welfare of broiler chickens, where chicks in high density rate will express more pronounced responses compared to chicks in low density rate. Accordingly, the objective of the present study was to investigate the influence of different stocking density rates (expressed as final body weight/m²) on the performance (BWG, FI and FCR), thermophysiological measurements (body and surface temperatures) as well as blood (hematological and biochemical) parameters of Ross broiler chickens.

Materials and methods

Animals, treatments and managements

The current study was conducted in November and December 2011 by utilizing 96

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of 0-day-old female Ross 308 broiler chicks obtained from a commercial hatchery (Al-Wadi Poultry Farm Co., Riyadh, Saudi Arabia). Chicks were first sexed and grouped by weight in such a way as to reduce variation in mean body weight. Then, chicks were allotted to 12 cages in a 4 deck cage system to construct 4 replicates/treatment. Every cage had breadth of 3000 cm² (50 cm length, 60 cm width and 36 cm depth). Broilers were randomly assigned to 3 treatments based on a final body weight, low (28.0 kg/m²), medium (37.0 kg/m²) and high (40.0 kg/m²) stocking density rates, which were corresponded to 0.050, 0.037 and 0.030 m²/bird, respectively.

Chicks were maintained at 23 h light schedule, and feed and water were provided ad libitum. Chicks received the experimental diets in electrically heated battery brooders with raised wire floors; the ventilation system in the house was controlled. Furthermore, chicks had been vaccinated for Marek’s disease, Newcastle and infectious bronchitis. A typical starter (0-16 d) and finisher (17-30 d) diets based on corn and soybean meal diets were formulated in mashed form according to Table 1. These diets met the recommendations of commercial practice in Saudi Arabia. The study was pre-approved by the faculty ethics committee, King Saud University.

Ambient temperature and relative humidity measurements

Ambient temperature Tₛ (°C) and relative humidity (RH) (in percentage) were concurrently and continuously recorded at 3-h interval using 2 data loggers (HOBO Pro Series data logger, Model H08-032-08, ONSET Co., Cape Cod, MA, USA) placed inside the chamber and mounted at a height of approximately 2 m from the ground away from direct sources of water. A special data logging software (BoxCar Pro 4, ONSET Co.) was applied for programming the loggers and for data analysis. The obtained data (Tₛ and RH) were analyzed for the following parameters; mesor (mean level or midline value), nadir (rhythm’s minimum value), and daily thermal load (zenith - nadir) in a 24-h interval period.

Performance measurements

During the starter (0 to 16 d) and finisher (17-30 d) periods, body weight gain (g) and feed intake (g) were recorded weekly for each pen. Then, feed conversion ratio was computed (g:g). Mortality was checked daily and weights of dead broilers were used to adjust FCR (Mortality-corrected FCR).

Table 1. Dietary ingredients and chemical composition of starter and finisher diets.

| Ingredients, g/kg | Starter     | Finisher    |
|-------------------|-------------|-------------|
| Corn              | 542.6       | 564.0       |
| Soybean meal      | 361.0       | 341.0       |
| Palmit oil        | 54.0        | 59.0        |
| Dicalcium phosphate| 23.0       | 28.0        |
| Ground limestone  | 7.20        | 7.00        |
| DL-methionine     | 2.39        | 1.00        |
| Salt              | 3.00        | 3.00        |
| Vitamin premix    | 2.50        | 2.50        |
| Trace mineral mix | 0.50        | 0.50        |
| Choline chloride 60 | 1.00       | 0.50        |
| Sodium bicarbonate| 2.90        | 1.50        |

Calculated analysis

| ME, kcal/kg | 3100 | 3150 |
| Crude protein,% | 22.0 | 21.0 |
| Lysine,% | 1.20 | 1.10 |
| Methionine,% | 0.55 | 0.40 |
| Threonine,% | 0.84 | 0.81 |
| TSAA,% | 0.90 | 0.75 |
| Calcium,% | 1.00 | 0.90 |
| Non-phytate phosphorus,% | 0.45 | 0.40 |

*Vitamin-mix is supplied in the following per kg of diet: Retinyl acetate, 3.41 mg; cholecalciferol, 0.07 mg; DL-α-tocopheryl acetate, 27.5 mg; menadione sodium bisulfate, 6 mg; riboflavin, 7.7 mg; niacin, 14 mg; pantothenic acid, cyanocobalamin, 0.02; choline 486 mg; folic acid, 1.32 mg; pyridoxine HCl, 4.82 mg; thiamine mononitrate, 2.16 mg; D-biotin, 0.11 mg. *Mineral-mix is supplied in the following per kg of diet: manganese, 67 mg; zinc, 54 mg; copper, 2 mg; iodine, 0.5 mg; iron, 75 mg; and selenium, 0.2 mg. ME, metabolizable energy; TSAA, total sulfur amino acids.

Thermophysiological measurements

Body (rectal) temperatures Tₑ (°C) as well as head, neck, wing, body and shank surface temperatures Tₛ (°C) were determined twice daily (at 09:00 and 15:00 h) in 2 randomly selected chicks of each replicate at day 25, 26, 29 and 30 of the study.

Measurements were recorded using a pre-calibrated digital thermometer (ARTSANA digital thermometer, Grandate, CO, Italy) measured to the nearest 0.1°C for Tₑ. Meanwhile, left side thermograms (infra-red thermographic images) for head, neck, wing, body and shank surfaces were obtained using a forward-looking and automatically calibrating infrared camera (VisIR-Ti200 infrared vision camera, Thermoteknix Systems Ltd., Cambridge, UK) placed perpendicular and approximately 50 cm away from chick’s surface. This camera was equipped with 25° lens, 1.3 M pixel visible camera, LCD touch screen, and possesses a 7.5-13 μm spectral range in addition to a precision of ±0.1°C. After capturing, thermograms were stored inside a 250 MB internal memory, readout and analyzed using a special thermograms analysis program (TherMonitor, Thermoteknix Systems Ltd.). For all thermograms, the rainbow color scheme was chosen.

A total of 293 thermograms were analyzed by defining areas circumscribed by hand with the software polygon function. The software then calculated the average, minimum, and maximum Tₛ within the defined areas. Additionally, the distance between the chick and the camera as well as emissivity of animal body was supplied for the camera to compensate for the effects of different radiation sources. It’s worth pointing out that the recording time between chicks was kept to minimum, and similar body emissivity (0.97 Monteith and Unsworth, 1990) was used for all thermograms. Illustrations of head, neck, wing, body and shank thermograms of chicks belong to different stocking density rates are presented in Figure 1.

Haematological and biochemical measurements

Blood samples were withdrawn from 2 randomly selected chicks of each replicate via brachial venipuncture into EDTA tubes for hematological analysis and into plain tubes for serological analysis. Collected samples were placed inside an ice box and transferred to the laboratory. Within 1 hr after collection, EDTA tubes were used to analyze packed cell volume...
(PCV). Meanwhile, sera were prepared by centrifuging plain tubes at 5°C and 3000 rpm for 10 min. Thereafter, sera were transferred into eppendorf tubes and stored at -20°C until further analysis. Concentrations of total protein (g/dL), glucose (mg/dL), and aspartate aminotransferase (AST) (U/L) were determined using commercial kits (mdi Europa GmbH, Hannover, Germany).

Statistical analysis

All statistical analysis was performed using the Statistical Analysis System (SAS, 1996). One cage constituted one experimental unit. Three treatments were arranged in 4 replications in a randomized complete block design. Means for measurements showing significant differences in the analysis of variance were tested using the PDIFF option. The overall level for statistical significance was set at P<0.05. All values were expressed as statistical means±standard error of the mean (SEM), unless otherwise specified.

Results

Ambient temperature and relative humidity measurements

Results revealed no differences (P>0.05) in the measured means of Ta and RH among study days as well as measurement times (Table 2). In average, recorded daily overall means of Ta and RH during the present study were 24.95±0.26°C (SD) and 26.63±3.30% (SD), respectively. Meanwhile, zenith-nadir of Ta and RH during the study was 0.56°C and 9.60% respectively, which is a reasonable approximation of the uniform distribution of the environmental conditions throughout the study.

Performance measurements

Table 3 shows the effect of stocking density on broilers’ performance. During the starter period, BWG, FI and FCR had influenced (P<0.01) as stocking density increases from medium to high rates. Meanwhile, no significant differences in BWG, FI and mortality-corrected FCR were found (P>0.05) among densities groups during the finisher period (Table 3). On the other hand, cumulative BWG and FI were affected (P<0.01) by the rate of stocking density, while no effect (P>0.05) were observed on mortality-corrected FCR. Higher BWG (P<0.01) and FI (P<0.05) were reported for the low and medium density rates broilers in comparison to the high density rate broilers.

Figure 1. Thermograms of head, neck, wing, body and shank thermograms of chicks belong to low (A), medium (B), and high (C) stocking rates.
on some hematological and biochemical parameters of broilers’ blood profile. Result indicated that stocking density had no effect (P>0.05) on total protein and glucose concentration, while overall mean of PCV was decreased (P<0.01) and serum AST concentration was increased (P<0.05) as influenced by rate of stocking density (Table 5).

### Discussion

High stocking density rate has been previously observed to drastically reduce broilers’ growth rate, FI, mortality-corrected FCR and their carcass quality, as well as increase litter moisture and incidences of footpad and thighs lesions (Dozier et al., 2005, 2006; Chmeličná and Solčianska, 2007; Mtileni et al., 2007; Škrbic et al., 2009). Current findings are in accord with these observations, where BWG, FI and FCR of broilers were all improved as density rate decreased during the starter period, while these differences were negligible during the finisher period. Theories for BWG reduction at high stocking density have been proposed, one of these involves decrease in FI (Shanawany, 1988; Puron et al., 1995). Physical access to feeders was probably limited due to increased stocking density as well as to the competition between birds to get to the feeder. A linear decline in FI in broilers was reported by Shanawany (1988) as stocking density increased from 20 to 50 birds/m². Dozier et al. (2006) found a 6% decline in BW for densities above 35 kg/m² (0.052 m²/bird).

Based on the current results, it appears that a high density rate such as 40.0 kg/m² for finisher rate was reduced (16.0% and 15.6%, respectively) as density rate increased from 37.0 kg/m² to 40.0 kg/m²; however, no effect was observed in broilers cumulative FCR.

Based on the current results, it appears that a high density rate such as 40.0 kg/m² for finisher period sounds recommendable, as it would attain the economical goal of poultry producers where maximum kg of chicken may produced per few square meter of space. Nevertheless, these findings may not be interpreted to intend that such high stocking density rate may have no impingement on the broilers welfare. In the contrary, the outcomes of the thermophysiological responses and blood profile of broilers used in the current study clearly indicated that high stocking density rates in finisher broilers has dramatic impacts on broilers’ welfare.

| Table 2. Characteristics parameters of meteorological measurements throughout the study. |
|---------------------------------------------------------------|
| **Time of measurement** | **T_a, °C** | **RH, %** | **T_a, °C** | **RH, %** |
| **09:00 h** | **15:00 h** | **09:00 h** | **15:00 h** | **09:00 h** | **15:00 h** |
| Mesor | 25.09±0.15 | 26.56±3.22 | 24.80±0.28 | 26.60±3.69 |
| Zenith | 25.17±0.10 | 32.80±1.25 | 25.16±0.19 | 33.00±1.43 |
| Nadir | 24.79±0.06 | 24.30±0.90 | 24.61±0.10 | 23.40±0.74 |
| Thermal load | 0.38±0.09 | 8.50±1.14 | 0.55±0.15 | 9.60±1.21 |

T_a, ambient temperature; RH, relative humidity. Data are reported as mean ±SD.

| Table 3. Body weight gain, feed intake and feed conversion ratio at different ages of broiler chickens under different stocking density rates. |
|---------------------------------------------------------------|
| **Stocking density** | **Low** | **Medium** | **High** | **SEM** | **P value** |
| **Performance at 16 d** | | | | | |
| BWG, g | 490.4a | 452.1b | 354.4c | 18.4 | **
| FL, g | 736.6a | 715.6b | 594.6c | 25.6 | **
| FCR, g:g | 1.504ab | 1.5827bc | 1.6829c | 0.032 | *
| **Performance at 30 d** | | | | | |
| BWG, g | 880.5 | 877.4 | 790.8 | 28.6 | ns
| FL, g | 1378.4 | 1401.3 | 1288.2 | 49.57 | ns
| FCR, g:g | 1.5331 | 1.6127 | 1.6486 | 0.063 | ns
| **Cumulative 0-30 d** | | | | | |
| BWG, g | 1388.9a | 1329.5b | 1145.2c | 39.1 | **
| FL, g | 2115.0a | 2125.9b | 1892.8c | 63.7 | *
| FCR, g:g | 1.522 | 1.501 | 1.6586 | 0.046 | ns

BWG, body weight gain; FL, feed intake; FCR, feed conversion ratio. *Means in the row with different superscripts differ significantly. **P<0.05; ***P<0.01; ns, not significant.

| Table 4. Thermophysiological parameters as influenced by rates of stocking density. |
|---------------------------------------------------------------|
| **Stocking density** | **Low** | **Medium** | **High** | **SEM** | **P value** |
| **T_a, °C** | 40.4a | 40.5b | 40.7c | 0.03 | ***
| Head T_a, °C | 34.4a | 35.0b | 35.7c | 0.09 | ***
| Neck T_a, °C | 31.6a | 32.5b | 33.2c | 0.19 | ***
| Wing T_a, °C | 28.4a | 28.9b | 30.1c | 0.16 | ***
| Body T_a, °C | 30.5a | 30.7b | 32.3c | 0.15 | ***
| Shank T_a, °C | 34.5a | 35.3b | 36.5c | 0.08 | ***

T_a, body temperature; T_a, surface temperature. *Means in the row with different superscripts differ significantly; ***P<0.001.

| Table 5. Effect of stocking density on some hematological and biochemical parameters in broiler chicken. |
|---------------------------------------------------------------|
| **Stocking rate** | **Low** | **Medium** | **High** | **SEM** | **P value** |
| PCV, % | 30.3a | 28.0b | 26.5c | 0.63 | **
| Total protein, g/dL | 2.2 | 2.1 | 2.0 | 0.08 | ns
| Glucose, mg/dL | 273.2 | 271.1 | 258.6 | 8.45 | ns
| AST, U/L | 56.4a | 60.1b | 68.7c | 5.56 | *

PCV, packed cell volume; AST, aspartate aminotransferase. *Means in the row with different superscripts differ significantly; **P<0.05; ***P<0.01; ns, not significant.
Surface temperature is an indication of the amount of infra red radiation emitted (Bouzida et al., 2009). Body featherless areas (eye, ear, wing bar and shank) presented higher temperatures than the areas of the body covered by feathers (neck, back cape, flight feathers, breast, thigh, drumstick, and tail). Thus, it is more efficient for broiler to benefit from heat loss in featherless areas compared to surfaces covered with feathers (Cangar et al., 2008). Infrared cameras measure the amount of invisible heat energy emitted by body surfaces, convert them into temperatures, and then produce thermal images. The adoption of thermal imaging radiometric technology in biological sciences has created a simplified method for evaluation of body surface temperature (and its contribution to sensible heat loss) as well as identifying radiant temperatures with distinct and precision values (Bouzida et al., 2009; Naas et al., 2010). In the current study, broilers of low stocking density (28 kg/m²) maintained, as hypothesized, the lowest T₅₀ and Tₓₑ compared to the other broilers of higher stocking density rates. This came in accordance with the findings of Hall (2001), Dawkins et al. (2004) and Dozier et al. (2006), where they all observed a reduction of broilers’ welfare in stocking density rates higher than 35 kg/m².

Furthermore, the noticeable changes in blood profiles appeared in parallel to the observed changes in thermophysiological responses. Changes in broilers blood system could be a part of the thermoregulatory responses acquired by broilers exposed to stress (Arieli et al., 1979). Increasing the stocking density from 28 to 40 kg/m² induced a state of hemodilution in higher density rate broilers, which might explain the observed changes in PCV values. This response was probably aimed to modulate the supply of oxygen to accommodate the changes in body temperatures (Shlosberg et al., 1992). On the other hand, an increase in serum AST was observed in higher density rate broilers compared to the low density rate broilers. Liver plays an important role in metabolic body processes (Kaplan et al., 2003). Determination of serum enzymes panel is often reflects the degree of hepatocellular damage and leakage (Jaensch, 2000). Fluctuation of serum concentrations, tissue distribution and the half-life of each individual enzyme are the discrimination factors between these enzymes. Clearly, activity of this enzyme was modified in higher density group, which could indicate that increasing stocking density rate could have an adverse effect on chicken health.

Conclusions

Based on the presented evidences, it can be concluded that increasing the stocking density of broiler chicken in 30 days feeding period from 28 to 37 kg/m² of cage space influenced their BWG and FI and increased their stress as revealed by thermophysiological responses and blood profile. Furthermore, increasing the density to 40 kg/m² had resulted in poor performance and jeopardizes the welfare of broiler chickens. Nevertheless, investigating the effect of several environmental conditions including stocking density as well as microclimate ambient temperature, ventilation rate, air circulation, feeding and watering space and ammonia level, in addition to other aspects of management such as design and placement of feeders and waterers is highly recommended as future studies. Determining the efficacy of conventional ventilation systems in alleviating the possible high microclimate temperature between the birds under high stocking density rate is of further interest.

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