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Research Paper

Impacts of Rearing Seasons and Stocking Density on Welfare Components of *Sonali* Chickens (*Gallus domesticus* L.) in Rajshahi, Bangladesh

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ABSTRACT: *Vital factors such as stocking density (SD) and rearing seasons (RS) influence the welfare components (WC) like day-old chick (DOC price), selling price of live birds, live weight, offal weight, carcass weight, carcass ratio, gross cost, gross profit and cost-benefit ratio (CBR) of the poultry enterprise throughout the world. Here we report the effects of four RS viz., winter, summer, rainy and spring and three SD viz., small, medium and large flock size on some WC of Sonali chicken farms from nine Upozillas under Rajshahi District of Bangladesh. Both DOC and selling prices of the marketable-sized Sonali chickens were found to be affected significantly ($P<0.001$) by the RS, being the lowest in winter and the highest in summer. The live weight of the chickens was also affected significantly ($P<0.01$) by the RS, being the lowest in rainy and the highest in spring. The average age of the marketable-sized birds was 56.60±4.94 days, which did not vary significantly between RS and SD during the study period. Offal weight, carcass weight and carcass ratio of the experimental chickens were also affected significantly ($P<0.01$, $P<0.05$ and $P<0.01$, respectively) due to the seasonal variations. Even thought the gross rearing cost of the Sonali farming was not affected significantly ($P>0.05$) by the RS, gross profit and CBR were both influenced significantly ($P<0.001$) by the RS. Results on the effects of SD on some WC revealed that feed consumption per bird per day (FCBD) and carcass weight were not affected significantly ($P>0.05$), while live weight, offal weight and carcass ratio were found to be affected significantly ($P<0.001$, $P<0.001$ and $P<0.01$, respectively). The highest live weight was recorded in small farms, the lowest offal weight in large farms, the highest carcass weight in small farms and the highest carcass ratio was yielded by the large farms in Rajshahi. The present findings would help decide the Sonali chicken breeders to design their production and marketing strategies with respect to these vital WC of the poultry enterprise in the study area.*

KEYWORDS: *Rearing seasons (RS), Stocking density (SD), Welfare components (WC), Selling price of live birds, Live weight, Offal weight, Carcass weight, Carcass ratio, Cost-benefit ratio (CBR).*

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I. INTRODUCTION

Poultry production worldwide is aimed at a stocking density (SD) of birds that will promote bird welfare and remain economically efficient at different rearing seasons (RS) [1, 2]. *Sonali* is a cross-bred product of Rhode Island Red (RIR) cocks and Fayoumi hens which was introduced in the northern parts of Bangladesh during 1996-2000, and it has a similar phenotypic appearance to that of indigenous and non-descript *Deshi* chickens [3]. There is limited information on the interactive effects of SD and RS on this popular and economically feasible chicken breed of the country [4], which led to design the present investigation.

Previous report on productivity and profitability of broiler chickens was found to be influenced by RS of the poultry birds in Bangladesh [5]. Broilers were highly vulnerable to a wide range of seasonal variations which greatly influenced their productivity as well as welfare components such as live weight, food conversion ratio (FCR) and cost-benefit ratio (CBR) in India [2]. In the country, season-wise variations in day-old chick

(DOC) price, number of marketable chickens produced per farm, mortality, and prices of live *Sonali*, broiler (Cobb 500) and *Deshi* chickens along with welfare components like feed cost, medicinal cost, miscellaneous costs, gross cost (GC), gross return (GR), net profit and profitability index per flock have been estimated recently [4, 6].

Stocking density (SD) in terms of flock size of the poultry birds is a vital factor because the primary aim of broiler producers is to maximize the live body weight of chickens produced per unit area and simultaneously prevent production losses due to overcrowding (Bergeron et al. 2020). Some studies showed that reducing SD improved broiler performance [7] while others indicated that reducing SD had no influence [8] or had a negative impact [9, 10]. The body weight gain, feed intake (FI) and carcass weight, for examples, were decreased when SD was increased [11]. In South Africa, there was significant effect of SD on the relative weights of the wing and abdominal fat in Ross 308 and Cobb Avian 48 broilers [12]. The consequence of high SD in commercial production of broiler chickens under the changing climate predisposed the chickens to adverse conditions of impaired health status, growth performance and meat quality in Nigeria [13] and Germany [14]. Increased SD also reduced body weight, weight gain and FCR values and increased FI broiler chickens in Egypt [15]. In S. Korea, broiler chickens raised at high SD had significantly less body weight, body weight gain and FI with increasing stress responses like greater blood heterophil: lymphocyte concentrations than those raised at low SD [16].

As regards the poultry welfare parameters, commercial *Sonali* farmers could earn almost twice as much income as with the same flock size of *Deshi* chicken farmers [17]. In terms of producing live chickens for marketing, productivity and profitability of *Deshi*, Fayoumi and *Sonali* farms varied significantly during RS of both January-June and July-December [18]. A reduction of FI and FCR in response to increasing SD is not only reported in broiler chickens, the quality of carcasses was also diminished because of deformed and broken legs in overcrowded flocks [19]. There is an optimum SD that will maximize economic returns, and birds raised at high SD must receive adequate feeder and drinker space [20, 21]. Welfare parameters like productivity, mortality, live weights, edible weights and edible ratios of poultry chickens were found to be associated with the SD and RS. Highest number of birds was produced in spring followed by winter, summer and rainy seasons, whereas the highest mortality was recorded in larger farms in winter followed by rainy, summer and spring seasons [6]. Recent data from *Sonali* farms in Jashore, Bangladesh, revealed that body weight gain, FCR and other economic indicators in this breed was SD- as well as RD-dependent under intensive farming conditions [22]. Keeping the aforesaid review of literature in mind, here we report the effects of four RS *viz*., winter, summer, rainy and spring and three SD *viz*., small, medium and large on some WC of *Sonali* chicken farms from nine Upozillas under Rajshahi District of the country.

II. MATERIALS AND METHODS

Study area

Randomly selected 60 *Sonali* poultry farms situated all over nine Upozillas (upgraded Police Stations) of Rajshahi District, Bangladesh (Figure 1), were included in the study. Farmers' participation and co-operation to dispose necessary information, convenient communications to and from the farms and availability of experimental data were considered for selecting the poultry farms of the study area. Identity of the farms and their owners were kept anonymous from the commercial point of view.

Figure 1: Map of Bangladesh (right) showing Rajshahi District and the Upozillas under study (Source: www.google.com/earth)

Rearing seasons (RS)

Poultry data for four consecutive rearing seasons *viz*., winter (Dec-Feb), summer (Mar-May), rainy (Jun-Aug) and spring (Sep-Nov) over two fiscal years 2019-2020 and 2020-2021 were collected. Fifteen farms, five replications each for small, medium and large, per season were included in the survey. The poultry farm owners were interviewed and the desired data were collected though interview schedule designed for the purpose. The farms were visited twice a week to gather the detail information on welfare components described below.

Stocking densities (SD)

In terms of SD, the experimental farms were categorized into small (<1000 birds), medium (1000-2999 birds) and large (3000 birds) ones. Five small farms, and 10 medium and large farms each, were selected at random for collecting data on feed consumption per bird per day (FCBD) in g, live weight (g), offal weight (g), carcass weight (g) and carcass ratio from a total of 25 *Sonali* farms from the study area mentioned above.

Welfare components (WC)

WC of the poultry farms under study included day-old chick (DOC) price, live weight (g), offal weight (g), edible carcass weight (g), carcass ratio, selling price of marketable chickens (Tk), gross cost (Tk), gross profit (Tk) and cost-benefit ratio (CBR). Drainage blood weight of the scarified chickens, feather and skin weights, head, liver, kidney and viscera weights constituted the offal weight. Live weight minus offal weight gave the carcass weight whereas carcass weight ÷ live weight yielded the carcass ratio. Finally, CBR was calculated by using the formula gross profit ÷ gross cost. The age of all the experimental birds was recorded in days.

Statistical analyses

Initially, descriptive statistics such as mean ±SD values were calculated from the raw data and presented in bar diagram and/or histograms. Finally, the experimental data were subjected to one-way analysis of variance (ANOVA), where the levels of significance were set at $P<0.05$, and the means were separated using least significant difference (LSD) tests [23]. All experimental data were analyzed using SPSS for Widows (version 21.0).

III. RESULTS AND DISCUSSION

Effects of RS on WC

Processed data for the effects of RS on welfare components like DOC price, selling price, live weight, offal weight, carcass weight, carcass ratio, gross cost, gross profit and cost-benefit ratio have been shown in

Appendix Table 1. DOC price was found to be affected significantly (P<0.001) by the RS of the *Sonali* chickens in the study area. It was the lowest (Tk. 17.73) in winter, followed by spring (Tk. 25.60) and rainy (Tk. 28.33) seasons, and the highest (Tk. 30.00) in summer (Figure 2).

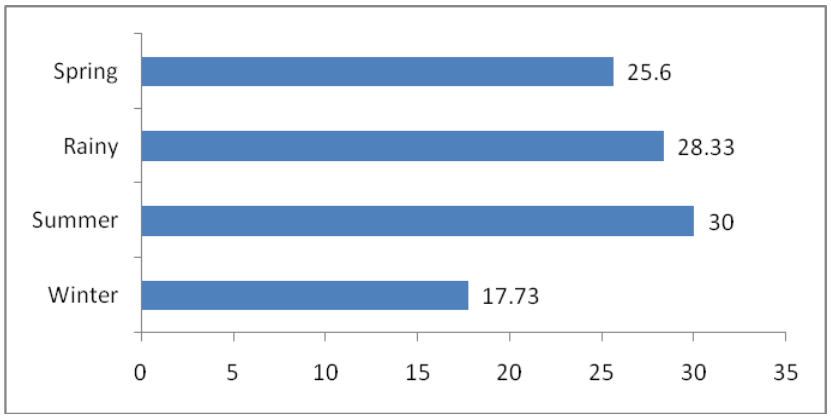
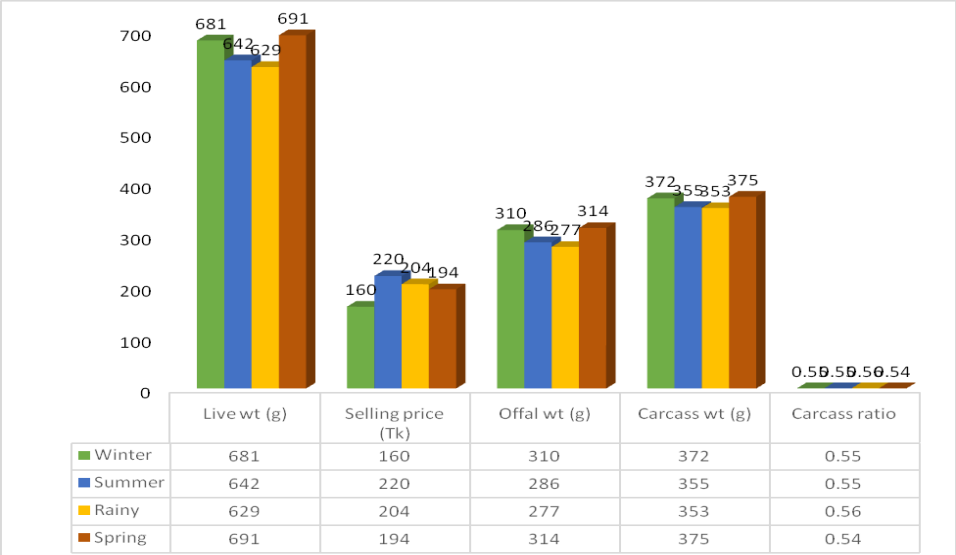


Figure: 2 Effects of RS on DOC price in *Sonali* chickens in Rajshahi, Bangladesh

Similar to DOC price, the selling price of the marketable *Sonali* chickens was also influenced significantly (P<0.001) by the RS (Figure 3). The selling price was the lowest (Tk. 160/kg) in winter, followed by spring (Tk. 194/kg) and rainy (Tk. 204/kg) seasons, but the highest (Tk. 220/kg) in summer.



	Live wt (g)	Selling price (Tk)	Offal wt (g)	Carcass wt (g)	Carcass ratio
Winter	681	160	310	372	0.55
Summer	642	220	286	355	0.55
Rainy	629	204	277	353	0.56
Spring	691	194	314	375	0.54

Figure 3: Effects of RS on some economic efficiency parameters of *Sonali* farming in Rajshahi, Bngaldesh

Unlike DOC and selling prices, live weight of the marketable-sized *Sonali* chickens was the lowest (626.67g) in rainy seasons, followed by summer (641.67g) and winter (680.67g), and the highest (690.67g) in spring. Thus, the live weight of the chickens was found to be affected significantly (P<0.01) by the RS (Fig. 3). The average age of the marketable-sized birds was 56.60±4.94 days, which did not vary significantly between RS and SD during the study period.

Similar to live weight, offal weight, carcass weight and carcass ratio of the experimental *Sonali* chickens were also affected significantly (P<0.01, P<0.05 and P<0.01, respectively) due to the seasonal variations (Figure 3). The lowest and the highest values were recorded respectively in rainy and spring for both offal and carcass weights, whereas the carcass ratio was found to be the lowest in spring and the highest in rainy season.

Even thought the gross cost of the *Sonali* farming was not affected significantly (P>0.05) by the RS, gross profit and cost-benefit ratio were both influenced significantly (P<0.001) by the RS. The lowest and the

highest values for the three vital economic efficiency parameters were: Tk. 90.87 in winter and Tk. 101.53 in summer; Tk. 109.40 in winter and Tk. 142.33 in spring; and 1.20 in winter and 1.50 in spring, respectively (Figure 4).

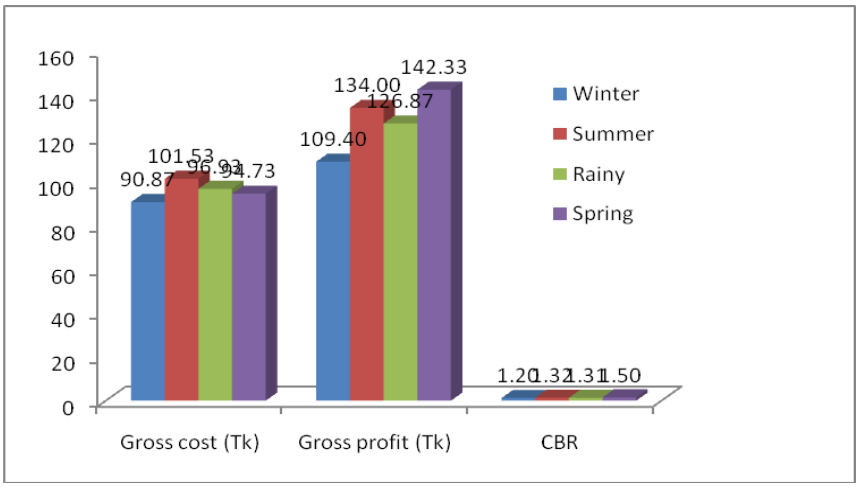


Figure 4: Effects of RS on gross cost, gross profit and cost-benefit ratio for *Sonali* farming in Rajshahi, Bangladesh

Effects of SD on WC

Processed data for the effects of SD on FCBD, live weight, offal weight, carcass weight and carcass ratio have been presented in Appendix Table 2. The values of FCBD in the small, medium and large flock size were 62.00g, 56.70g and 54.60g, respectively (Figure 5).

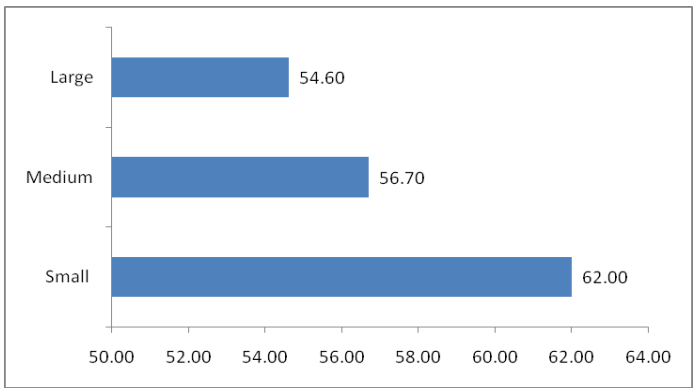


Figure 5: Effects of SD on feed consumption per bird per day in *Sonali* chickens in Rajshahi, Bangladesh

The corresponding live, offal and carcass weights were 680.00g, 305.80g and 374.20g; 641.50g, 268.90g and 372.90g; and 628.30g, 256.80g and 371.80g, respectively. The carcass ratio for the three flock sizes were 0.55, 0.58 and 0.59, respectively (Figure 6). In a nutshell, therefore, FCBD and carcass weight were not affected significantly ($P>0.05$), while live weight, offal weight and carcass ratio were found to be affected significantly ($P<0.001$, $P<0.001$ and $P<0.01$, respectively) by the SD of *Sonali* chickens under study. The highest live weight of 680.00g was recorded in small farms, the lowest offal weight of 256.80g was found in large farms, the highest carcass weight of 374.20g was recorded in small farms and the highest carcass ratio of 0.59 was yielded by the large farms in the study area (Figure 7).

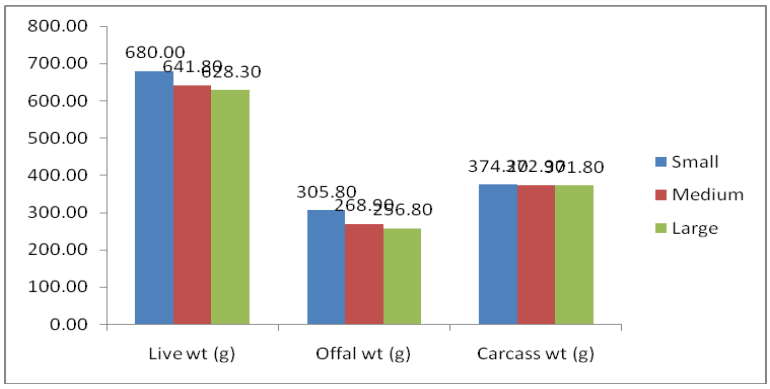


Figure 6: Effects of flock size on live, offal and carcass weights in *Sonali* chickens in Rajshahi, Bangladesh

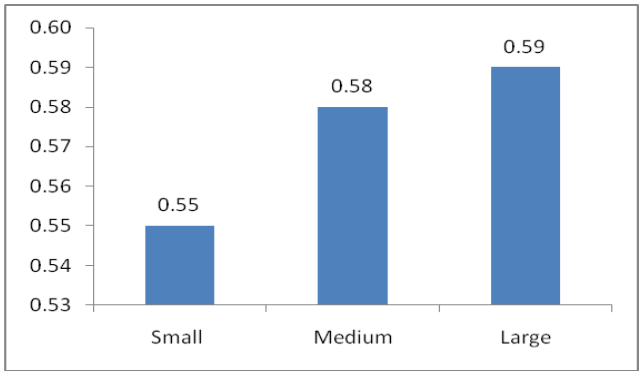


Figure 7: Effects of flock size on cost-benefit ratio in *Sonali* chickens in Rajshahi, Bangladesh

Currently, there is paucity of information on the effects of RS and SD on WC of *Sonali* chickens in terms of their live weight, selling price, carcass ratio and CBR in the study area. Here we report the lowest DOC and live chicken selling prices in winter and the highest in summer. The live weight was lowest in rainy season but highest in spring whereas the carcass ratio was lowest in spring and highest in rainy season. The CBR, on the other hand, was lowest in winter and highest in spring.

An early study showed that the body weight gain, feed consumption, FCR and meat yield of Ross broilers were adversely affected by increasing SD in Mississippi, USA [11]. Similarly, in South Africa, the relative weights of the wing and abdominal fat of Ross 308 and Cobb Avian 48 broilers were significantly decreased by increasing SD, and the breeds performed better in winter [12]. High SD was found to decrease broiler performance in South Korea [10]. Other than SD, RS affected performance in broiler chickens in Assam, India, where final body weight, FCR, livability and BCR were highest in winter in comparison with those in monsoon and post-monsoon rearing seasons [2]. Birds at lower SD (5 birds/m^2) performed better in terms of growth and market values compared to those at higher SD (10-15 birds/m^2) in Nigeria [13]. These findings corroborate to those of our except for minor fluctuations owing to differences in genotype, environment and rearing conditions of the birds. Studies on a large set of data from commercial broiler facilities in Canada suggest that the SD has little impact on mortality and the quality of the meat where increased growth rates were observed at higher SD [1], which was contrasting to previous findings [10, 12, 13].

Higher SD significantly decreased body weight and growth performance of Cornish Cross cockerel broilers in Germany [14]. Higher SD might also be associated with a surge in airborne pathogens causing respiratory disease and increased mortality in chickens as reported in Egypt [15]. Likewise, higher SD of broiler chickens impaired growth performance and intestinal barrier function with increasing stress responses in South Korea [16]. SD was noted to be one of the most important stress factors that affect production and yield in poultry farming in the USA [19], where higher SD caused reduced feed consumption, lower growth rates and poor carcass quality. In Iran, SD had a significant effect on feed intake (FI) and FCR and body weight gain [20]. Medium-sized farms having moderate density of 10-17 chicks/m^2 showed the highest production index and most economic benefit [21].

Poultry birds reared in large farms consumed greater FCBD values compared to those reared in small- and medium-sized farms. Consequently, the live weights, offal weights and carcass ratios of the chickens differed significantly due to the present farm size. Season-wise variations were significant for DOC price, live weights, offal weights, carcass weights, carcass ratios, gross profits and CBR values. Unfortunately, however, these results are slightly different from those reported earlier in the same study area [6]. Experiments aimed at evaluating the effects of RS and SD on other such available poultry breeds in the study area as *Deshi*, Fayoumi, Cobb 500 and RIR would therefore be worth considering in the near future.

IV. CONCLUSIONS

In the present study, it has been clearly demonstrated that RS and SD had profound impacts on such welfare components (WC) of poultry as DOC price, FCBD, live weight, offal weight, carcass weight, carcass ratio, selling price, gross cost (GC) of rearing, gross profit (GP) and profitability in terms of cost-benefit ratio (CBR) for *Sonali* chicken farms in the study area. Higher selling price of live chickens in summer could compensate the losses due to lower prices in winter. Similarly, higher CBR in spring would also make up deficits incurred by the farm owners in winter. The present findings would therefore help decide the *Sonali* chicken breeders to design their production and marketing strategies with respect to these vital WC of the poultry enterprise in the study area.

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Disclosure of conflict of interest: Authors declare no conflict of interest.

Statement of informed consent: Informed consent was obtained from all the farm owners who participated in the study. All their information was kept confidential.

Appendix Table 1: Effects of rearing seasons on some welfare components of *Sonali* farming in Rajshahi (n=60 farms)

Rearing Seasons	DOC Price (Tk)	Live Weight (g)	Offal Weight (g)	Carcass Weight (g)	Carcass Ratio	Selling Price (Tk)	Gross Cost (Tk)	Gross Profit (Tk)	CBR
Winter (n=15 farms)	17.73 ±2.15^{c}	680.67 ±65.71^{a}	309.60 ±37.55^{a}	372.33 ±27.60^{a}	0.55 ±0.01^{b}	160.00 ±14.64^{b}	90.87 ±7.22	109.40 ±8.69^{c}	1.20 ±0.05^{c}
Summer (n=15 farms)	30.00 ±2.04^{a}	641.67 ±47.91^{a}	286.47 ±26.52^{b}	354.53 ±22.51^{a}	0.55 ±0.01^{b}	220.00 ±14.64^{a}	101.53 ±10.42	134.00 ±14.59^{b}	1.32 ±0.05^{b}
Rainy (n=15 farms)	28.33 ±2.16^{a}	628.67 ±50.02^{b}	276.73 ±27.83^{b}	353.13 ±21.75^{ab}	0.56 ±0.02^{a}	204.00 ±11.21^{a}	96.93 ±12.83	126.87 ±14.94^{b}	1.31 ±0.05^{b}
Spring (n=15 farms)	25.60 ±2.67^{b}	690.67 ±58.88^{a}	314.20 ±33.39^{a}	374.80 ±26.27^{a}	0.54 ±0.01^{b}	194.00 ±11.21^{b}	94.73 ±11.94	142.33 ±13.22^{a}	1.50 ±0.08^{a}
F-values	86.16	4.27	4.88	3.24	5.33	56.79	2.54	17.15	68.89
Probabilities	<0.001	<0.01	<0.01	<0.05	<0.01	<0.001	ns	<0.001	<0.001

DOC= Day-old chick; Carcass ratio= Carcass weight ÷ Live weight; CBR= Cost-benefit ratio; ns= not significant (P>0.05); n= number of farms; Dissimilar superscripts differ significantly by least significant difference (LSD) tests at P <0.05. Figures represent mean ±SD values; Data collected for a period of two year from December 2019 to November 2021.

Appendix Table 2: Effects of stocking densities on some welfare components of *Sonali* farming in Rajshahi (n=25 farms)

Stocking Densities (No. birds)	Bird age (days)	FCBD (g)	Live Weight (g)	Offal Weight (g)	Carcass Weight (g)	Carcass Ratio
Small; n=5 (<1000)	56.00 ±4.18	62.00 ±5.70^{a}	680.00 ±7.91^{a}	305.80 ±9.07^{a}	374.20 ±13.68^{a}	0.55 ±0.02^{b}
Medium; n=10 (1000-2999)	56.00 ±5.16	56.70 ±4.90^{ab}	641.80 ±16.97^{b}	268.90 ±12.83^{b}	372.90 ±14.03^{a}	0.58 ±0.02^{a}
Large; n=10 (≥3000)	57.50 ±5.40	54.60 ±7.00^{b}	628.30 ±15.95^{c}	256.80 ±20.81^{c}	371.80 ±8.46^{a}	0.59 ±0.02^{a}
F-values	0.259	2.56	19.28	15.63	0.07	8.11
Probabilities	ns	ns	<0.001	<0.001	ns	<0.01

FCBD= Feed consumption per bird per day; n= number of farms; Carcass ratio= Carcass weight ÷ Live weight; Dissimilar superscripts differ significantly by least significant difference (LSD) tests at P <0.05. Figures represent mean ±SD values; Data collected for a period of two year from December 2019 to November 2021.

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