Effects of varying group sizes on performance, body defects, and productivity in broiler chickens

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Abstract

This study aimed to determine the changes in the performance, welfare, and productivity level of broiler chickens reared at various group sizes and non-grouped (single flock) under intensive field conditions. Two treatments were tested as a concept in all trials. In the GF (grouped flock) house, the grouping was applied at 6000 (GF 1 or large GF), 4000 (GF 2 or medium GF), and 3000 (GF 3 or small GF) broilers in the first, second and third trials, respectively, without changing the stocking density. In the SF (single flock) house, classical intensive rearing was applied without grouping the whole 20000 broilers during each of 3 trials (SF 1, 2, and 3). The results showed that large and medium GF chickens had higher BW than SFs at slaughter age. In SF 2 chickens, only HB level was significantly higher in the second trial (1.39 vs. 1.17). In the third trial, the FPD, HB, and BB scores of SF 3 chickens were higher when compared to small GFs at 1.85 to 1.41, 1.48 to 1.22, and 2.27 to 1.89, respectively. Chickens reared in GFs had more BW, FI, and better FCR and EPEF values when compared to SF chickens. BW, FI, and EPEF were observed to be lower —while FCR was higher—when SF chickens were compared to GFs. Upon considering the EPEF value along with welfare parameters, it has been observed that rearing chickens in groups of 3000 may increase productivity by up to 54.8% according to intensive conditions.

Introduction

Broiler chicken production is one of the most crucial animal protein sources for human nutrition, and approximately 7 billion chickens were slaughtered worldwide in 2018 (FAOSTAT 2020). Notably, genotypes, environments, and their interaction affect the performance of broiler chickens. Moreover, genetic selection, as well as housing and management conditions greatly affect the productivity and output of broiler production (Sarıca and Erensayın 2018). Increased house capacity and the intensive production model were accompanied by increased stocking density and group sizes. However, unlike intensive production, poultry—like many other animal species—tend to live in groups or flocks in nature (Christman and Lewis 2005). The position of individuals in a group may have benefits related to preventing danger from the outside environment, access to resources (e.g., feed and water), or reduced antagonistic relationships with animals in other groups (Hemelrijk 2000). Group size and density can affect the performance, welfare, social behavior, movement, and spatial use of chickens (Estevez 2007; Estevez et al. 2007; Averos and Estevez 2018), which can cause social and physical restrictions in chicken activity (Grigor et al. 1995). Feed efficiency worsened with larger group size, while smaller flock size increases livability (Tind and Ambrosen 1988). In broiler chickens reared in small and medium group sizes, the slaughter weight and weekly live weight gain have been shown to be higher than in large flock sizes (Ghosh et al. 2012; El-Tahawy et al. 2017). Moreover, increased stocking density and group size increase competition among animals, which causes psychological and physiological stress that negatively affects the welfare of chickens. Hock burn, breast blisters, and especially footpad dermatitis are known welfare problems that can cause painful issues and reduced efficiency for broiler chickens (Bradshaw et al. 2002; Buijs et al. 2009; Hepworth et al. 2010).

Intensive production is widely used for broiler production at large capacities. In this type of production system, the hypothesis is that grouping may increase performance, body defects, and productivity traits in broilers. Most of the studies on group size are generally carried out under trial conditions and with limited chicken populations. However, conducting this study under field conditions is considered important in terms of its effectiveness and applicability. This study aimed to reveal changes in the performance, welfare, and productivity level of broiler chickens reared at various group sizes and without grouping under intensive field conditions.

Materials And Methods

Trial Design

Three trials were conducted from October to November 2019, December 2019 to January 2020, and February to March 2020 (named Trials 1, 2, and 3, respectively). Each trial was performed simultaneously in two separate houses. Ross-308 broiler chicks, which were obtained from a commercial hatchery at 1 d old, were distributed to both houses according to the trial design. Both houses were fully environmentally controlled. The climate was regulated automatically using ventilation controlled mechanically by fans, while the lighting was provided artificially. The poultry houses were cleaned, washed, and disinfected after each trial. The floors were concrete, and the litter was rice husk (approximately 8–10 cm thickness) for each trial. All animals were provided with feed and water *ad-libitum*. Feeds were provided using a commercial feed mill, and their nutritional values are provided in Table 1.

Table 1
Nutritional values of feeds used in the trials

Nutrients	**Broiler chick starter (1 to 11 days)**	**Broiler chick (11 to 21 days)**	**Broiler chicken (21 to SA [1])**
Crude protein (%)	23	22	20
ME (Kcal/kg)	3000	3050	3150
Crude cellulose (%)	4.0	4.0	4.0
Crude ash (%)	7.0	6.0	6.0
Ca (%)	1.10	1.00	0.90
Phosphorus (%)	0.65	0.60	0.55
Methionine (%)	0.50	0.45	0.45
Lysine (%)	1.30	1.20	1.20

[1] SA: Slaughter age (Chickens were slaughtered at 39, 41 and 39 d-old; in trial 1, 2 and 3, respectively.)

Chicks received continuous light during the first two days and were then maintained on the following light cycles: 23L (light): 1D (dark) (3–7 d old), 22L: 2D (8–21 d old), and 21L: 3D (22 d old to slaughter age). The light intensity was 15–20 lux at a chicken level during each trial. Feeding and drinking were performed using a spiral feeder and nipple drinker system, which are widely used in broiler production, and sufficient equipment was provided for each chicken. Both houses were similar in terms of their structural traits and only their capacities differed. In the trials, the size of the grouped (multiple flocks) house was 13.5×60 m and the ungrouped (single flock) house was 13.5×80 m. During the production period, all health protection and biosecurity measures were taken. Chicks were obtained from the hatchery with *Infectious Bronchitis (IB)* and *Newcastle Disease (ND)* vaccines. Additionally, *Infectious Bursal Disease (IBD)* and *ND* vaccinations were performed in the house through the production periods.

Two treatments were tested as a concept in all trials. One of the poultry houses was divided into groups of varying sizes in each trial (grouped flock: GF). Rearing was applied as a single flock in the other house without grouping (single flock: SF). Additionally, thinning was applied to SF chickens at 32, 32, and 34 d old in the first, second, and third trials, respectively. Summary information for the trial designs is provided in Table 2.

Table 2
Specifications of houses and trial designs

Specifications	**Trial 1 (Oct-Nov 2019)**		**Trial 2 (Dec 2019-Jan 2020)**		**Trial 3 (Feb-Mar 2020)**	
Treatments	**GF 1**	**SF 1**	**GF 2**	**SF 2**	**GF 3**	**SF 3**
Floor space (m^2)	810	1080	810	1080	810	1080
House capacity (chickens)	12000	20000	12000	20000	12000	20000
Number of groups	2	1	3	1	4	1
Floor space of groups (m^2)	405	1080	270	1080	202.5	1080
Chickens in each group	6000	20000	4000	20000	3000	20000
% of thinned chickens	-	33.4	-	10.3	-	21.1
Age at thinning (days)	-	32	-	32	-	34
Age at slaughter (days)	39	39	41	41	39	39
[SF: Single flock: non-grouping 20000 chickens in all trials and GF: Grouped flock: 6000, 4000 and 3000 chickens in a group named as GF 1: large GF, GF, 2: medium GF and GF 3: small GF, respectively].						

In the first trial, the large group flock (GF 1 or large GF: 6000 chicks per group) and the non-grouped single flock under intensive conditions (SF 1: 20000 chicks) were compared. The GF house was divided equally into two groups (pen dimensions for each group: 30×13.5 m). A total of 6000 chicks were placed in each group (405 m^2) for a stocking density of 14.8 birds/m^2. When the first trial was terminated, slaughtering was performed at 39 d old.

In the second trial, the medium grouped flock (GF 2 or medium GF: 4000 chicks per group) and the non-grouped single flock under intensive conditions (SF 2: 20000 chicks) were compared. The GF house was divided into three equal areas of 270 m^2, and 4000 chickens were reared at a stocking density of 14.8 birds/m^2 per group. The second trial ended with the transfer of chickens at 41 d old to a commercial slaughterhouse.

In the third trial, the small grouped flock (GF 3 or small GF: 3000 chicks per group) and the non-grouped single flock under intensive conditions (SF 3: 20000 chicks) were compared. In the third trial, the GF house was divided into four equal groups, each with a floor area of 202.5 m^2. In this trial, 3000 chickens were reared at a 14.8 birds/m^2 stocking density in each group. The third trial ended with the transfer of chickens to a slaughterhouse at 39 d old.

In the SF house, classical intensive rearing was applied without grouping the whole house during each of the three trials (SF 1, 2, and 3). A total of 20000 chicks were placed in a 1080 m^2 area, resulting in a stocking density of 18.5 birds/m^2. Additionally, in trials 1, 2, and 3, SF chickens were thinned by 33.4, 10.3, and 21.1%, at 32, 32, and 34 d old, respectively. For GF treatments, the first, second, and third trials were terminated at 39, 41, and 39 d old for SF chickens, respectively.

Data Collection

The same procedures were applied for data collection in all trials. In the GF house, two groups were created for the first trial (large GF or GF 1). When the chicks were transferred from the hatchery to the house, 150 random chicks were individually weighed, and an equal number of chicks were placed into two groups. These operations were performed for three groups (medium GF or GF 2) in the second trial and four groups in the third trial (small GF or GF 3) in the GF house. Weekly body weights (BWs) were determined individually for 150 chickens from each group with a 5 g precision scale. Unlike for GFs, SF chickens were thinned at different ages, and their BWs were taken from the slaughterhouse in all trials. Feed intake (FI) and feed conversion ratio (FCR) were determined for the entire production period on a house basis. FCR was measured as *kg FI/kg BW*. The number of dead chickens was determined daily, given as % livability: [*(100 – mortality (%)]* for each entire trial period. European Production Efficiency Factor (EPEF) was used to determine productivity according to Huff et al. (2013): *[livability (%) x BW (kg) x 100 / FCR x trial duration (d)]*. The mean slaughter age (days) of SF chickens was determined for each trial using the following equation: *[(numbers of thinned chickens x BW at thinning) + (numbers of chickens at the end of the trial x BW at slaughter)] / total numbers of slaughtered chickens].* The climatic environment data (temperature, humidity, air velocity) of the SF and GF houses were obtained daily with sensors connected to automation. On the final day of each trial, the BWs and body defects were determined. Body defects include footpad dermatitis (FPD), hock burn (HB), and the breast burn-redness (BB) level of 150 animals (75 male and 75 female) randomly from each group. FPD, HB, and BB levels were determined using a visual scoring system between 0–3 scale (Erensoy et al. 2020b; de Jong et al. 2014; Welfare Quality 2009). Litter moisture content was determined after the chickens were slaughtered. Litter samples were collected from three different places in each group and mixed. Then, 100 g of this mixture was dried at 60 ^{o}C for 48 h and moisture content was measured (Yamak et al. 2016). Data collection and measurement methods for the SF treatment were performed using the same procedure as the GF treatment.

Statistical Analysis

The suitability of continuous data for variance analysis was tested using Levene's test, and it was determined to be suitable for normal distribution ($P > 0.05$). In the evaluation of parametric data (e.g., BW, temperature, humidity, air velocity, etc.), variance analysis was performed for each trial. Duncan's multiple comparison test was used to compare means. The non-parametric Kruskal-Wallis test was used to compare the non-parametric values expressed by score and percentage (e.g., FPD, HB, BB, and livability), while the Mann-Whitney U test was used to compare the means (Özdamar 2002; Önder 2018). SPSS package program (Version 25.0) was used for data analysis.

Results

The effects of grouping or non-grouping at different flock sizes on the BW of chickens are shown in Table 3 (see weekly changes in Fig. 1). The chick weight (CW) of SF chicks was 41.6, 44.5, and 44.7 g, while the CW of GF chicks was 41.5, 45.0, and 44.9 g. Differences in chick weights were similar among all group sizes and SF 1, 2, and 3. However, CW differed for large GF chickens. Moreover, BW was significantly higher in large GF chickens than SF 1 in all ages except CW ($P < 0.05$). No significant differences in BW were observed for medium GF, except at 14 and 28 d old. No difference in BW was observed between SF 3 and small GF chickens at 7 and 28 d old ($P > 0.05$), while BW was significantly higher in small GF chickens at 35 d old (2143.8 g in SF 3 vs. 2184.4 g in small GF; $P < 0.05$, Table 3).

Table 3
The effects of grouping or non-grouping on BW of chickens between 0–35 d old

Trial	Treatments [1]	CW	7	14	21	28	35
1	SF	41.6	179.5	484.2	875.9	1402.8	1980.6
	GF	41.5	184.3	523.9	983.1	1497.8	2039.4
	SEM	0.14	1.06	3.27	7.64	10.27	13.89
	Effects						
	Treatment	0.730	0.032	0.000	0.000	0.000	0.046
	GF	0.010	0.156	0.087	0.000	0.182	0.357
	1	41.9	186.2	530.5	1026.4	1514.5	2054.7
	2	41.0	182.4	517.2	939.8	1481.1	2024.1
2	SF	44.5	184.2	564.9	1077.8	1712.5	2342.6
	GF	45.0	184.2	527.8	1062.6	1793.1	2347.9
	SEM	0.16	1.20	4.30	6.82	10.45	15.75
	Effects						
	Treatment	0.128	0.981	0.000	0.294	0.000	0.875
	GF	0.840	0.005	0.000	0.001	0.000	0.551
	1	44.9	188.3	534.9	1018.7	1827.6	2337.9
	2	44.9	177.0	493.1	1077.8	1726.0	2376.2
	3	45.1	187.3	555.3	1091.3	1825.6	2329.5
3	SF	44.7	172.9	476.6	925.8	1531.5	2143.8
	GF	44.9	175.7	499.7	978.0	1560.9	2184.4
	SEM	0.16	1.00	3.25	4.45	9.23	9.05
	Effects						
	Treatment	0.554	0.188	0.001	0.000	0.134	0.035
	GF	0.175	0.014	0.171	0.341	0.002	0.953

[1] SF: Single flock; GF: Grouped flock [Group sizes in each grouped flock (1 and 2 represent a group size of 6000 in the 1st trial (large GF); 1, 2 and 3 represent a group size of 4000 in the 2nd trial (medium GF); 1, 2, 3 and 4 represent a group size of 3000 in the 3rd trial (small GF)].

[a, b, c…] Different letters in the same column show the significance between means. SEM: Standart error of means.

Trial	Treatments [1]	CW	7	14	21	28	35
	1	45.3	170.5b	496.9ab	968.13	1511.9c	2189.9
	2	44.7	180.0a	510.5a	978.67	1528.1bc	2182.7
	3	45.3	178.9a	502.5ab	991.87	1616.3a	2174.9
	4	44.3	173.3ab	488.8b	973.33	1587.2ab	2190.0

[1] SF: Single flock; GF: Grouped flock [Group sizes in each grouped flock (1 and 2 represent a group size of 6000 in the 1st trial (large GF); 1, 2 and 3 represent a group size of 4000 in the 2nd trial (medium GF); 1, 2, 3 and 4 represent a group size of 3000 in the 3rd trial (small GF)].

[a, b, c…] Different letters in the same column show the significance between means. SEM: Standart error of means.

The effects of grouping or non-grouping at different flock sizes on slaughter age BW and body defects are provided in Table 4. Contrary to small GF chickens, it was determined that the large and medium GF chickens had higher BW than SFs at slaughter age (*P*< 0.01). Chickens reared in large GFs had 91.4 g more BW than SF 1 and 53.5 g more than SF 2 in medium GFs. Males had more BW than females in all three trials. The BWs of males and females in the first, second, and third trials were 2797.9 and 2335.0 g, 3059.7 and 2549.3 g, and 2668.5 and 2253.1 g, respectively. When chickens reared in large and medium GFs were compared to SFs, it was determined that the interaction effect was significant in terms of BW at slaughter age (*P*< 0.05, Table 4).

Table 4

The effects of grouping or non-grouping on slaughter age BW and body defects*

Trial no	Treatments [1]	Gender	BW [2] (g)	FPD (0–3)	HB (0–3)	BB (0–3)
1	**SF**	**F**	2334.5c	1.93(2:1–3)a	1.51(2:0–2)	2.39(2:2–3)
		M	2671.7b	1.65(2:0–3)b	1.55(1.5:1–3)	2.50(2.5:2–3)
	GF	**F**	2335.2c	1.89(2:0–3)a	1.61(2:0–3)	2.41(2:1–3)
		M	2866.6a	1.80(2:0–3)ab	1.57(1:1–3)	2.46(3:1–3)
	SEM		17.24	0.034	0.030	0.027
	Effects					
	Treatments		0.000	0.318	0.631	0.820
	SF		*2491.8*	*1.79(2:0–3)*	*1.53(2:0–3)*	*2.45(2:2–3)*
	GF		*2583.2*	*1.85(2:0–3)*	*1.59(2:0–3)*	*2.43(2:1–3)*
	Gender		0.000	0.018	0.636	0.236
	F		*2335.0*	*1.90(2:0–3)*	*1.58(2:0–3)*	*2.40(2:1–3)*
	M		*2797.9*	*1.75(2:0–3)*	*1.56(1:1–3)*	*2.47(3:1–3)*
	Interaction		0.001	0.050	0.899	0.597
2	**SF**	**F**	2478.0c	1.25(1:0–3)	1.31(1:0–3)b	2.19(2:1–3)ab
		M	3065.4a	1.43(1:0–3)	1.47(1:1–3)a	2.30(2:1–3)a
	GF	**F**	2584.4b	1.21(1:0–3)	1.12(1:1–2)c	2.09(2:1–3)b
		M	3056.8a	1.28(1:0–3)	1.23(1:1–2)bc	2.31(2:1–3)a
	SEM		16.37	0.030	0.023	0.028
	Effects					

* Body defects are given as [mean (median: minimum-maximum)].

[1] SF: Single flock; GF: Grouped flock [Group sizes in each grouped flock (1 and 2 represent a group size of 6000 in the 1st trial (large GF); 1, 2 and 3 represent a group size of 4000 in the 2nd trial (medium GF); 1, 2, 3 and 4 represent a group size of 3000 in the 3rd trial (small GF)].

[2] Body weights at 39, 41 and 39 d-old slaughter age in 1st, 2nd and 3rd trials, respectively; FPD: Foot pad dermatitis; HB: Hock burn; BB: Breast burn; F: Female; M: Male.

[a, b, c…] Different letters in the same column show the significance between means. SEM: Standart error of means.

Trial no	Treatments [1]	Gender	BW [2] (g)	FPD (0–3)	HB (0–3)	BB (0–3)
	Treatments		0.002	0.220	0.000	0.431
	SF		*2748.2*	*1.33(1:0–3)*	*1.39(1:0–3)*	*2.24(2:1–3)*
	GF		*2801.7*	*1.24(1:0–3)*	*1.17(1:1–2)*	*2.19(2:1–3)*
	Gender		0.000	0.034	0.004	0.001
	F		*2549.3*	*1.22(1:0–3)*	*1.18(1:0–3)*	*2.12(2:1–3)*
	M		*3059.7*	*1.33(1:0–3)*	*1.31(1:1–3)*	*2.30(2:1–3)*
	Interaction		0.015	0.098	0.000	0.007
3	**SF**	**F**	2239.8	1.84(2:1–3)a	1.45(1:1–2)a	2.28(2:1–3)a
		M	2667.9	1.86(2:1–3)a	1.51(1.50:1–3)a	2.26(2:1–3)a
	GF	**F**	2260.4	1.49(1:0–3)b	1.23(1:1–2)b	1.89(2:1–3)b
		M	2668.8	1.33(1:0–3)b	1.21(1:1–2)b	1.88(2:1–3)b
	SEM		14.53	0.032	0.022	0.028
	Effects					
	Treatments		0.636	0.000	0.000	0.000
	SF		*2439.5*	*1.85(2:1–3)*	*1.48(1:1–3)*	*2.27(2:1–3)*
	GF		*2471.4*	*1.41(1:0–3)*	*1.22(1:1–2)*	*1.89(2:1–3)*
	Gender		0.000	0.030	0.943	0.637
	F		*2253.1*	*1.62(2:0–3)*	*1.31(1:1–2)*	*2.03(2:1–3)*
	M		*2668.5*	*1.49(1:0–3)*	*1.31(1:1–3)*	*2.00(2:1–3)*
	Interaction		0.668	0.000	0.000	0.000

* Body defects are given as [mean (median: minimum-maximum)].

[1] SF: Single flock; GF: Grouped flock [Group sizes in each grouped flock (1 and 2 represent a group size of 6000 in the 1st trial (large GF); 1, 2 and 3 represent a group size of 4000 in the 2nd trial (medium GF); 1, 2, 3 and 4 represent a group size of 3000 in the 3rd trial (small GF)].

[2] Body weights at 39, 41 and 39 d-old slaughter age in 1st, 2nd and 3rd trials, respectively; FPD: Foot pad dermatitis; HB: Hock burn; BB: Breast burn; F: Female; M: Male.

[a, b, c…] Different letters in the same column show the significance between means. SEM: Standart error of means.

Chickens reared in SF 1 and large GFs did not differ in FPD, HB, and BB in the first trial ($P > 0.05$, Table 4). In SF 2 chickens, only HB level was significantly higher in the second trial (1.39 vs. 1.17). In the third trial, the FPD, HB, and BB scores of SF 3 chickens were higher when compared to small GFs at 1.85 to 1.41, 1.48 to 1.22, and 2.27 to 1.89, respectively ($P < 0.01$). Additionally, it was determined that gender affected FPD in all three trials; however, males had higher HB and BB scores than females ($P < 0.05$) in the second trial only.

According to the trial, the distributions of FPD, HB, and BB severity are shown in Figs. 2, 3, and 4, respectively. In the first, second, and third trials, percentages of no FPD sign in SF and GF chickens had at 2.7 and 5.0%, 6.7 and 7.6%, 0.0, and 3.7%, respectively. Chickens reared in large GFs had higher levels of severe FPD than those reared in small and medium GF and SF chickens. Regarding the level of FPD severity, there was no difference between chickens reared in medium GF and SF 2. It was determined that the severity of FPD in chickens reared in medium GF was less (Fig. 2).

Severe HB level was 8.7% in chickens reared in large GF, compared to 2.7% for SF 1. However, HB was generally less severe in chickens reared in GF; only mild severe HB was determined at 78.0, 83.3, and 48.3% of chickens reared in small, medium, and large GFs, respectively. Additionally, severe lesions were not observed in chickens from small and medium GFs (Fig. 3).

In all GF and SF groups, every chicken showed signs of BB. Severe BB was observed in 49.3% of the chickens reared in large GF, while this value was 44.7% for SF 1 chickens. Chickens in medium and small GFs had proportionally less medium and severe redness than those in SF 2 and 3 (Fig. 4).

The ambient temperature, relative humidity, air velocity, and litter moisture levels of the SF and GF houses are provided in Table 5, while weekly changes are shown in Fig. 5. In all trials, the differences between temperature, humidity, and air velocity in SF and GF houses were insignificant ($P > 0.05$). Temperatures ranged from 26.5 to 27.0 ^{o}C, relative humidity ranged from 60.4 to 65.8%, and air velocity ranged from 0.17 to 0.23 m/s. However, air velocities in the GF 3 house differed among pens in the third trial ($P < 0.05$). Likewise, in the second and third trials, litter moisture levels differed between different regions of the GF house ($P < 0.05$).

Table 5
Ambient temperature, relative humidity, air velocity and litter moisture

Trial no	Treatments [1]	Temperature (°C)	Humidity (%)	Air speed (m/s)	Litter moisture (%)
1	SF	26.9	62.9	0.23	33.8
	GF	26.2	65.8	0.17	38.2
	SEM	0.19	0.97	0.02	1.731
	Effects				
	Treatment	0.101	0.162	0.190	0.252
	GF	0.558	1.000	0.167	0.092
	1	26.3	65.8	0.14	41.8
	2	26.1	65.8	0.21	34.5
2	SF	26.5	64.4	0.28	35.2
	GF	27.0	60.4	0.24	30.6
	SEM	0.26	1.30	0.021	1.54
	Effects				
	Treatment	0.385	0.191	0.423	0.141
	GF	0.786	1.000	0.171	0.001
	1	27.2	60.4	0.18	40.9a
	2	27.2	60.4	0.23	26.4b
	3	26.7	60.4	0.29	24.5b
3	SF	27.0	62.8	0.22	39.5
	GF	26.9	62.3	0.21	34.2
	SEM	0.19	0.92	0.017	3.53
	Effects				
	Treatment	0.880	0.841	0.838	0.473

[1] SF: Single flock; GF: Grouped flock [Group sizes in each grouped flock (1 and 2 represent a group size of 6000 in the 1st trial (large GF); 1, 2 and 3 represent a group size of 4000 in the 2nd trial (medium GF); 1, 2, 3 and 4 represent a group size of 3000 in the 3rd trial (small GF)].

[a, b, c…] Different letters in the same column show the significance between means. SEM: Standart error of means.

Trial no	Treatments [1]	Temperature (°C)	Humidity (%)	Air speed (m/s)	Litter moisture (%)
	GF	0.979	1.000	0.039	0.000
	1	27.0	62.3	0.14b	51.4a
	2	27.0	62.3	0.16ab	28.1bc
	3	26.8	62.3	0.26a	32.4b
	4	26.8	62.3	0.27a	25.0c

[1] SF: Single flock; GF: Grouped flock [Group sizes in each grouped flock (1 and 2 represent a group size of 6000 in the 1st trial (large GF); 1, 2 and 3 represent a group size of 4000 in the 2nd trial (medium GF); 1, 2, 3 and 4 represent a group size of 3000 in the 3rd trial (small GF)].

[a, b, c…] Different letters in the same column show the significance between means. SEM: Standart error of means.

Some productivity traits of SF and GF treatments are provided in Table 6. Unlike chickens reared in GFs, SF chickens were thinned at 32, 32, and 34 d old in trials 1, 2, and 3, respectively. All SF and GF chickens were slaughtered at 39, 41, and 39 d old in trails 1, 2, and 3, respectively (Table 2 and Table 6).

Table 6
The effects of grouping or non-grouping on productivity of chickens at varying group sizes

Trial no	Treatments [1]	Slaughter age [2]	BW (g)	Feed intake (g/bird)	FCR [3]
1	SF	36.6	1947.7	3669.7	1.884
	GF	39.0	2583.2	3954.9	1.531
2	SF	39.9	2122.3	3732.3	1.759
	GF	41.0	2801.7	4455.4	1.590
3	SF	37.9	1887.3	3565.3	1.889
	GF	39.0	2464.6	3893.3	1.580

[1] SF: Single flock [non-grouping 20000 chickens in each trial] and GF: Grouped flock [6000, 4000 and 3000 chickens in a group named as trial 1: large GF, 2: medium GF and 3: small GF, respectively].

[2] The slaughter age (day) means of SF chickens were determined using following equation; *[(numbers of de-populated chickens * BW) + (numbers of chickens at end of the trial * BW)] / total numbers of slaughtered chickens]*.

[3] Feed conversion ratio (FCR) was determined by equation *[feed (g)/BW (g)]*.

Chickens reared in GFs had more BW, FI, and better FCR and EPEF values when compared to SF chickens. BW, FI, and EPEF were observed to be lower—while FCR was higher—when SF chickens were compared to GFs. The BW of chickens in SF and GF flocks differed based on the mean slaughter age. Considering the mean slaughter ages, chickens reared in large, medium, and small GFs had 635.5, 679.4, and 577.3 g more BW and consumed 285.2, 723.1, and 328.0 g more feed to reach this BW compared to SF 1, 2, and 3, respectively. Additionally, the FCRs of chickens reared in large, medium, and small GFs were 0.353, 0.169, and 0.390 units better than those of SF 1, 2, and 3, respectively (Table 6). However, no significant differences in livability were observed between chickens reared in all SF and GF treatments when each trial was evaluated within itself (Fig. 6). The grouping of flocks improved the EPEF of chickens reared in large, medium, and small GFs when compared by 51.5, 40.6, and 54.8% compared to SF 1, 2, and 3, respectively (Fig. 7).

Discussion

Most broiler chickens are reared in intensive conditions throughout the world to maximize productive efficiency (Robins and Phillips 2011). Although this system maximizes production efficiency, it makes sustainability difficult by worsening certain physiological and welfare traits of chickens (Averos and Estevez 2018). This is due to stocking densities and group sizes being very high under intensive production. This situation affects the performance, welfare, social behavior, activity, and use of space in broiler chickens (Estevez 2007; Estevez et al. 2007). The present study focused on comparing the performance, welfare, and productivity of broilers reared in the classical intensive production system (SF 1, SF 2, and SF3) with the application of thinning and varying group sizes (large GF or GF 1, medium GF or GF 2, and small GF or GF 3).

The results of the present study were compatible with those (Ghosh et al. 2012), and it was determined that large and medium flock sizes had improved slaughter BWs when compared to SF 1 and SF 2. However, broiler chickens reared in small groups did not differ in BW compared to intensive non-grouped flocks. These results are similar to those of Rind et al. (2004) and Türkyılmaz (2008) and differ from those of El-Tahawy et al. (2017). Additionally, the BWs at slaughter age for male chickens in all GFs and SFs were higher than those of females, which implies that males have better growth traits than females due to their biological properties (Schmidt et al. 2009; Erensoy et al. 2020a). Moreover, when different group sizes were compared with intensive conditions, they had different effects on the BW of males and females. Males in large GFs had higher BWs than males in SF 1, while females in medium GFs had higher BWs than females in SF 2 at slaughter age. This situation relates to groupings and stocking density; thus, it is better to deal with social hierarchy, activity restrictions, competition between chickens, and welfare problems in smaller groups compared to chickens reared under intensive systems (Bradshaw et al. 2002; Buijs et al. 2009; Hepworth et al. 2010).

The emergence and development of FPD, HB, and BB were similar across all treatments. Notably, their level and severity vary depending on the BW, age, level of moisture, and the presence of irritant chemicals in the litter (Meluzzi et al. 2008; Kaukonen et al. 2016). Moreover, these ailments represent essential problems in the context of broiler health (Toppel et al. 2019). Poor ventilation management deteriorates litter quality, resulting in reduced welfare and performance (Kaukonen et al. 2016). However, it is not easy to provide uniform ventilation due to the large house volumes used for intensive and large capacity production. Therefore, it is not possible to provide identical climatic environmental conditions for chickens in each region of a house. Therefore, the distribution of chickens within houses is not homogeneous and stocking density may vary from region to region (Lacy and Czarick 1992; Czarick and Lacy 2008). Negative pressure tunnel ventilation was used in the present study, and it was observed that the stocking density increased to an overcrowded level closer to the fresh air inlets. Although no differences in litter moisture levels were observed among treatments, chickens in small GFs had significantly lower levels of FPD, HB, and BB than chickens reared in SF 3 ($P < 0.05$, Table 5). However, litter moisture has been shown to increase in large GFs. Dividing a house into four sections (small GF or GF 3) is thought to prevent the development of FPD, HB, and BB levels by reducing intra-chicken movement to areas with poor litter, thereby preventing and balancing regional crowding when compared to dividing the area into two (large GF) and three (medium GF) sections or using the SF method.

The proportions of chickens with severe FPD, HB, and BB in large GFs were found to be relatively higher when compared to small and medium GFs, being somewhat closer to those of SF groups. This implies that grouping 6000 chickens or rearing using two groups does not result in a lower proportion of chickens exhibiting severe body defects when compared to rearing 20000 broilers in a single flock. However, rearing chickens in groups of 4000 (medium GF: 3 groups) and 3000 (small GF: 4 groups) decreases the incidence of severe body defects and improves their welfare compared to SFs and large GFs. Improved welfare conditions were provided by preventing bird migration and homogenous chicken distribution by grouping 3 or 4 pens in a house (Lacy and Czarick 1992; Malone 2004; Czarick and Lacy 2008). Since the mean values of temperature, humidity, and air velocity were similar in the GF and SF house in all trials, this suggests that the climatic environment conditions did not affect the performance, body defects, and productivity of chickens reared in the SF and GF houses (Table 5).

Thinning is applied to a small portion (between 10% and 40%) of broiler chickens with a low market weight in intensive field conditions. After this process, the rest of the flock is sent to the slaughter in 1 or 2 weeks. Thinning is frequently integrated into the field, which provides economic benefits (Russa et al. 2005; Meluzzi et al. 2008; Sarıca and Erensayın 2018).

Age and BW at thinning were also considered in evaluating EPEF for efficiency (Huff et al. 2013; Aviagen 2018). Due to thinning, SF flocks' mean slaughter age and performance parameters decreased (low BW and poor FCR). It was observed that GFs that were not thinned were better than those thinned and not grouped. Although this technique is compatible with the market’s need for integration, it significantly affects producers' overall productivity and profitability. However, thinning has biosecurity risks due to the movement of people, tools, and equipment between farms (Allen et al. 2008). The results presented by

Villarroel et al. (2018) are incompatible with the results of the present study since no significant differences in livability were observed between GF and SF chickens (Fig. 6).

In conclusion, grouping in broiler chicken production helps to provide optimal conditions by facilitating the management of the house environment. It is believed that the problems caused by undesired bird migration may be prevented by grouping chickens, especially in houses where tunnel ventilation is utilized. Compared to intensive conditions in the field, the level and severity of FPD, HB, and BB were lower in chickens reared in groups of 3000 or 4000. Upon considering the EPEF value along with welfare parameters, it has been observed that rearing chickens in groups of 3000 may increase productivity by up to 54.8% compared to single flock.

Declarations

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Author contribution

All listed authors have made substantial contributions to the research design, analysis, or interpretation of data, and drafting the manuscript. All authors have approved the submitted version.

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Data availability

Not applicable.

Code availability

Not applicable.

Declarations

Ethical statement

All methods and procedures were approved by Ondokuz Mayis University Ethical Committee for Experimental Animals (Samsun, Turkey).

Conflict of interest

The authors declare that they have no conflicts of interest.

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Figures

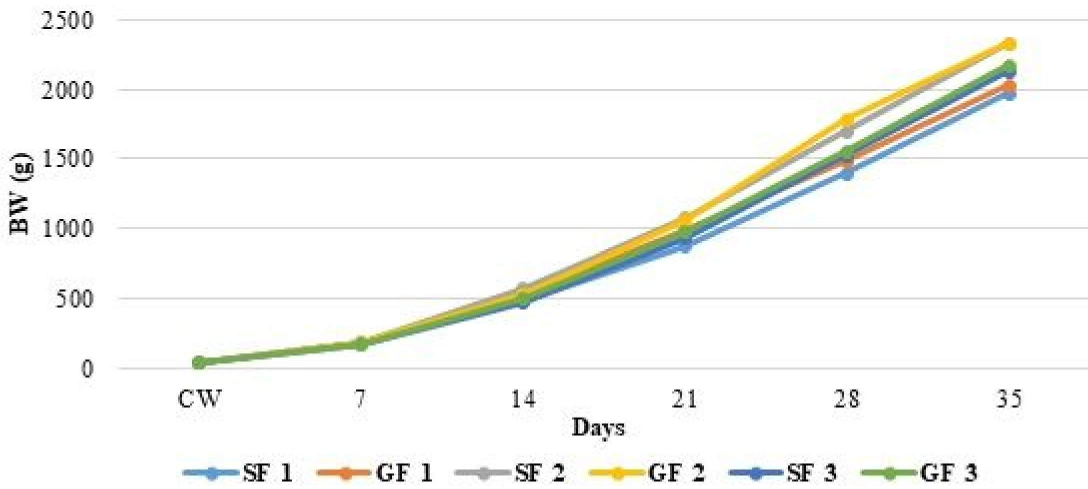

Figure 1

Body weight changes of chickens between 0-35 d reared in SF and GF [SF: Single flock: non-grouping 20000 chickens in SF 1, SF 2 and SF 3 and GF: Grouped flock: 6000, 4000 and 3000 chickens in a group named as GF 1: large GF, GF, 2: medium GF and GF 3: small GF, respectively].

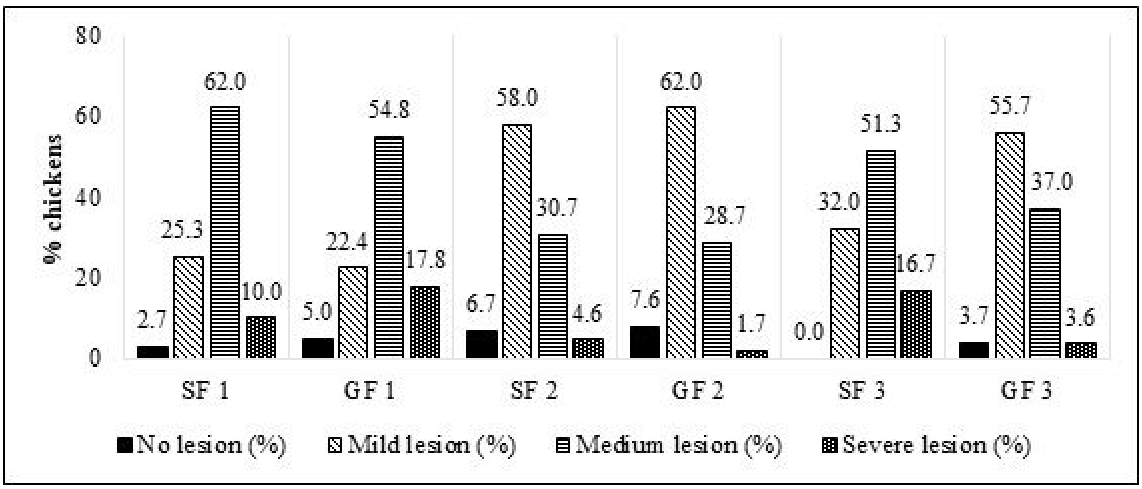

Figure 2

Distribution of foot-pad dermatitis levels of chickens reared in SF and GF [SF: Single flock: non-grouping 20000 chickens in SF 1, SF 2 and SF 3 and GF: Grouped flock: 6000, 4000 and 3000 chickens in a group named as GF 1: large GF, GF, 2: medium GF and GF 3: small GF, respectively].

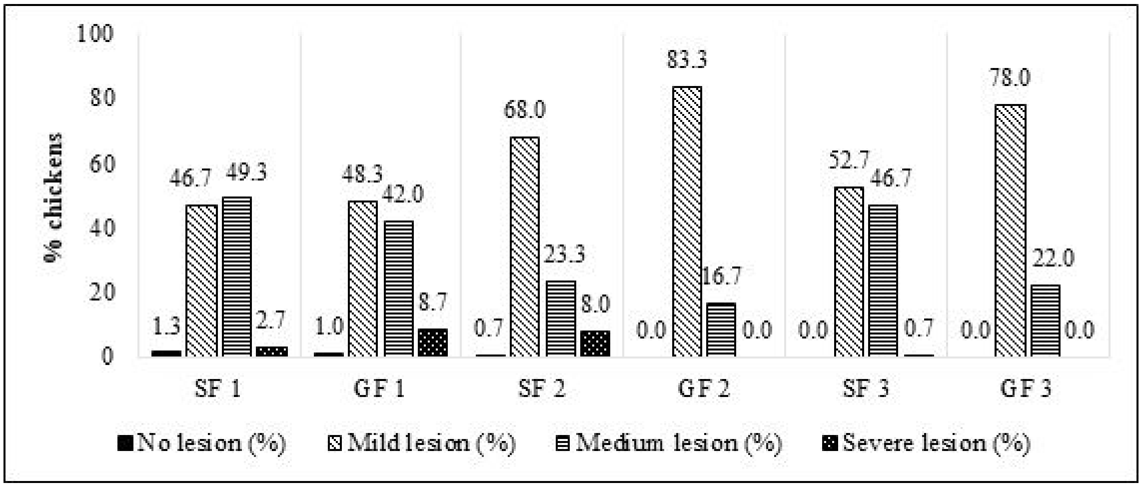

Figure 3

Distribution of hock-burn levels of chickens reared in SF and GF [SF: Single flock: non-grouping 20000 chickens in SF 1, SF 2 and SF 3 and GF: Grouped flock: 6000, 4000 and 3000 chickens in a group named as GF 1: large GF, GF, 2: medium GF and GF 3: small GF, respectively].

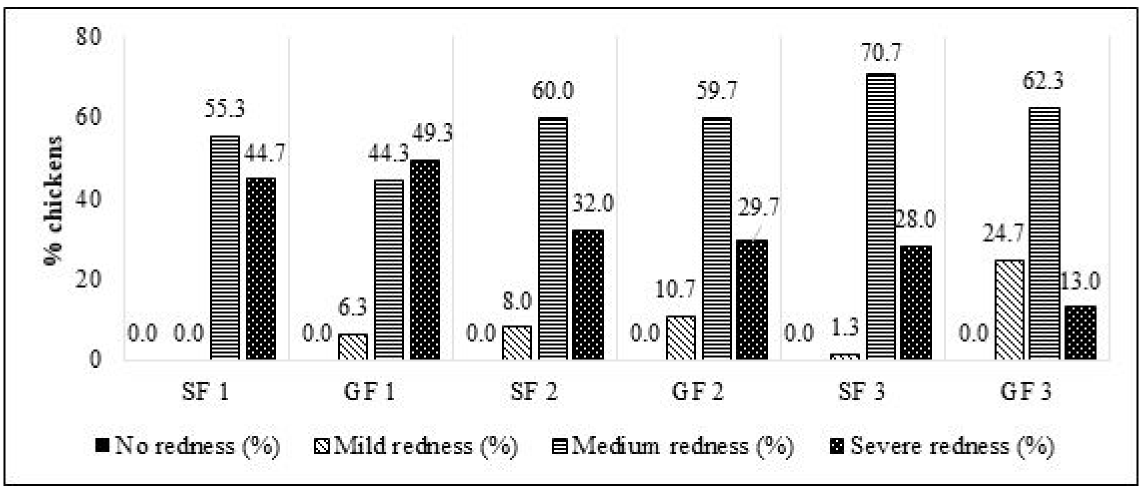

Figure 4

Distribution of breast-burn levels of chickens reared in SF and GF [SF: Single flock: non-grouping 20000 chickens in SF 1, SF 2 and SF 3 and GF: Grouped flock: 6000, 4000 and 3000 chickens in a group named as GF 1: large GF, GF, 2: medium GF and GF 3: small GF, respectively].

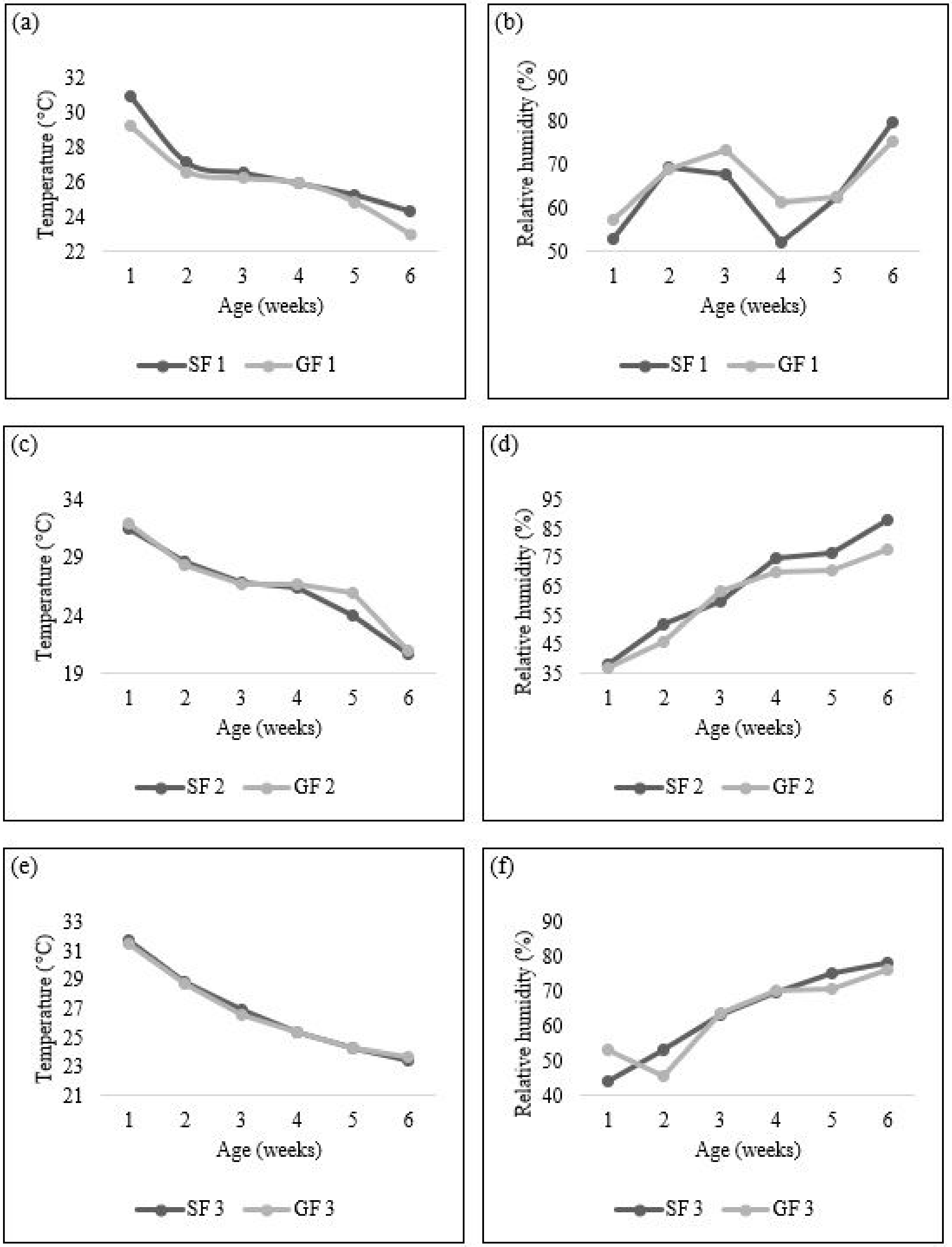

Figure 5

Weekly changes of temperature and relative humidity of SF1 and GF 1 (a, b), SF 2 and GF 2 (c, d), SF 3 and GF 3 (e, f)

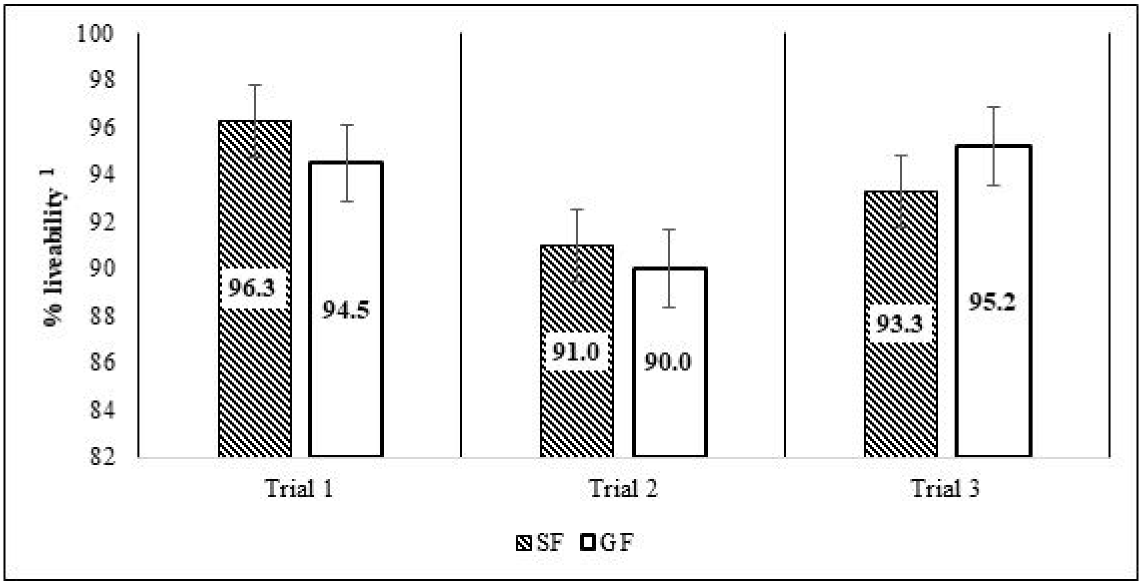

Figure 6

Livability percentages of chickens reared in SF [non-grouping 20000 chickens in each trial] and GF [6000, 4000 and 3000 chickens in a group named as trial 1: large GF, 2: medium GF and 3: small GF, respectively]. 1 Liveability(%): [100-(number of dead chickens*100/total number of chickens)]

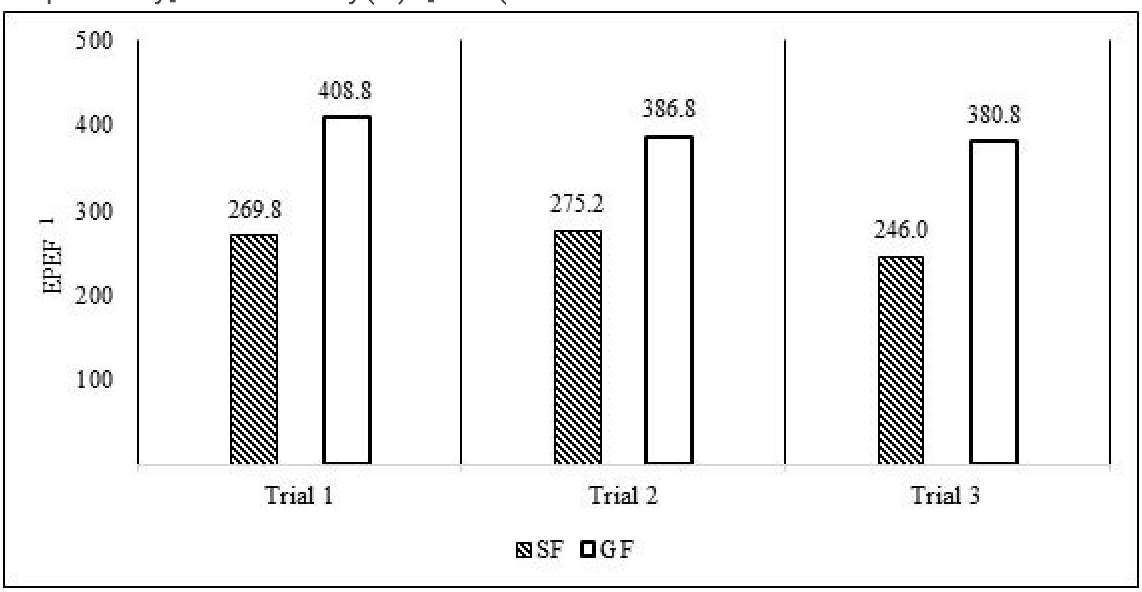

Figure 7

EPEF values of chickens reared in SF [non-grouping 20000 chickens in each trial] and GF [6000, 4000 and 3000 chickens in a group named as trial 1: large GF, 2: medium GF and 3: small GF, respectively]. 1 EPEF: European production efficiency factor [% liveability × BW (kg) × 100 / feed conversion ratio × trial duration (d)] of chickens.