The Effect of Stocking Density on the Slaughter Performance and Meat Quality of Pekin Ducks

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Abstract

Background

The effect of stocking density on slaughter performance and meat quality were primarily investigated in this research. Pekin ducks were reared until slaughter age (42 days) in three different stocking density groups (three, five and seven ducklings/m²) in four replicate pens. To compare the slaughter performance of the ducklings' live weight, carcass weight, carcass yield, thigh and breast meat weight and yield, and edible giblets weight (heart, liver and gizzard) were investigated. The meat quality was compared between the treatment groups based on dry matter ratio, cooking loss, water holding capacity, pH values, and colour parameters (L*, a*, b*, c*, h* and ΔE^* values).

Results

Carcass weight, carcass yield, thigh and breast meat weight were found to decrease in parallel to the increasing stocking density, resulting in a reduction in thigh and breast meat weights and ratios ($P \leq 0.05$). Increasing the stocking density decreased the heart weight, and positively improved the liver and gizzard ratio ($P \leq 0.05$). However, it did not affect the meat quality parameters investigated in this research ($P \geq 0.05$). The breast meat of the ducks reared under higher stocking density had higher L*, h* and ΔE^* values, lower a* values ($P \leq 0.05$), and similar b* and c* values ($P \geq 0.05$).

Conclusions

Evaluating the overall research findings, it can be concluded that increased stocking density when rearing ducks negatively affects the slaughter performance where affecting only breast meat colour and weight of thigh meat with skin in investigated meat quality parameters. More detailed researches should be undertaken considering welfare and economic issues as well.

1. Introduction

Ducks (*Anas platyrhynchos domestica*) are more resistant to cold, hot and humid environments than most other poultry species, especially chicken, making them more durable and easier to grow for both farmers and commercial producers (Wright, 2008; Holderread, 2011; Anonymous, 2016a; Ekarius, 2007). The demand for duck meat has visibly increased in the last decade. In 2010, 2.1 billion ducks were reared and 4 million tons of duck meat was produced (FAO, 2010). Pekin duck is the primary duck meat source for European Union (EU). In EU, especially in France, Poland, Hungary and Germany, duck production is undertaken intensively and in some other countries within EU extensively. Through years of selection and breeding, several hybrid lines have been formed with lower fat deposits, higher weight gain, and better carcass yield (CY) and field performance (Wencek et al., 2012; Anonymous, 2016b). The slaughter weight of earlier ducks was 2.00–2.50 kg at seven weeks using two types of feed (Dogan, 1987; Testik et al., 1987). This value first increased to 3,195 gr (Leeson et al., 1980), then to 3,342 g (Knizetova et al., 1991) and finally to 3,750 g in more recent years (Holderread, 2011).

CY and the weight of edible components, such as liver, heart, and gizzard are important parameters of meat and slaughter performance in duck production. Duck liver is a very important source of income for producers and has a big market in Hungary and is mostly acquired from the hybrids of Pekin and Muscovy ducks (Holderread, 2011) around Europe.

The most common production period is seven to nine weeks, during which mostly two types of feed are used as the starter feed for the first two weeks and the grower – finisher feed for the last five weeks. When the ducks are reared for nine weeks for meat production, the starter feed is used for the first two weeks, the grower feed for the next five – six weeks, and finisher diets are used in the last one to two weeks (Knizetova et al., 1991).

As previously reported, Pekin ducks grow better in free range systems with access to swimmable water sources. With the growing poultry sector and industrialisation in production, environmentally controlled rearing houses have been commonly used worldwide to produce hybrid Pekin ducks with higher stocking density (SD), and recently, it was shown that ducks also grow well in industrial systems, such as floor rearing using different litter materials in commercial houses (Reiter et al., 1997; Chen et al., 2015; Jones et al., 2010).

A basic standard for duck production published by the EU (Anonymous, 1999) recommended producing ducks with a SD of 23.50 kg/m² for a mean live weight (MLW) of 3.35 kg (Defra, 2007). However, there is still a very large information gap about this topic. In the light of the studies mentioned, this experiment was conducted to understand the effects of SD on the slaughter performance and meat quality of Pekin ducks and obtain more detailed data to contribute to science and further research.

2. Material And Method

A total of 240 mixed-sex, day-old Grimaud Star 53 Pekin ducklings were obtained from a private duck meat production company in Bolu, Turkey for use in the experiment. The ducklings were reared in a research and development (R&D) house of a private duck growing facility with permission of the owner and the production company.

There were 12 trial pens in the fully automated, environmentally controlled R&D house heated by four pieces of 3,000 W electric oil radiator heaters (Flavel RI 3000M, Türkiye) and ventilated by a total of three tunnel fans, including two minimum ventilation fans with a flow of 1,100 m³/h (Bahcivan BPP 30, Turkey) and one cooling fan with a flow of 4,500 m³/h (Bahcivan BSM 400, Turkey), specifically chosen and mounted for the volume and insulation of the R&D house to achieve minimum ventilation and cooling when needed.

The day-old ducklings were weighed upon arrival at the farm's R&D house. Then, they were placed in pens having an area of 4 m² according to the trial plan, achieving three, five and seven ducklings/m² SD randomly. Pan feeders with a capacity of 10 kg feed and duck and broiler nipple drinkers (three nipples/50 cm pipeline) connected to individual water tanks pre-partitioned for easy measurement of water consumption were used in every single trial pen. The nutritive value of the feed was given in

Table 1. The pens were 2x2 m in dimensions. The lighting system of the house consisted of 12 led bulbs standing on each trial pen to achieve 75 lux maximum illumination at the beginning of the rearing period and dimmed after the first week to 30 lux and maintained until the end of the rearing period. For the first three days of life, the lights were kept on, then darkening began with 30 minutes per day and the dark period was increased by 30 minutes every day until it reached 10 hours on the 23rd day and maintained to the end of the rearing period. The starting rearing house temperature of the growing period was 32 °C, which was decreased by 0.5 °C every day until reaching 20 °C on day 25 and maintained at 20 °C until the end of the rearing period. The R&D house automated control system was specifically built for the R&D house to keep the intra climate stable and automatically control heaters, ventilation, cooling and lighting systems throughout the production term. The measurements were checked every four hours, and changes were made when needed.

Table 1
Nutritive Value of the Feed Used in the Trial

	Starter	Grower
	0–14 days	15 day - Slaughter
Metabolic Energy kcal/kg	2900.00	3100.00
Crude Protein, %	20.00	17.20
Crude Cellulose, %	4.00	4.05
Crude Fat, %	4.13	5.81
Crude Ash, %	6.33	6.33
Lysine, %	1.00	0.80
Methionine, %	0.55	0.40
Calcium, %	1.00	0.90
Phosphorus, %	0.72	0.65
Sodium, %	0.16	0.17
Vitamin A, IU	12000.00	12000.00
Vitamin D3, IU	5000.00	5000.00
Manganese, mg/kg	120.00	120.00
Zinc, mg/kg	110.00	110.00
Copper, mg/kg	16.00	16.00
Iodine, mg/kg	1.50	1.50
Selenium, mg/kg	0.30	0.30

At the end of the rearing period, eight male ducks from each treatment group, two from each rearing pen, were randomly chosen and transferred to the slaughterhouse of the company. The ducks were slaughtered in the company's integrated facility by hand on conveyors hanging stainless steel holders as described by Farouk et al. (2014) according to the Islamic Halal standards and EU legislations. After slaughter, the necks of the birds were removed and not included in any further measurement. After letting the blood drain, the hot carcass weights (CW) were determined. After 15 minutes, the weights of thigh meat with skin (STW), thigh meat without skin (SITW), breast meat with skin (SBW), breast meat without skin (SIBW) and edible giblets [heart weight (HW), liver weight (LW) and gizzard weight (GW)] were measured by a normal (± 1 mg) scale (TEM TNT 015D, Turkey). Using these data, CY and the yields of edible giblets [heart yield (HY), liver yield (LY), and gizzard yield (GY)] were calculated.

Dry matter (DM), pH, water holding capacity (WHC), cooking loss (CL) and colour analyses were also performed to investigate the effects of different treatments on meat quality. To obtain DM data, the DM plates were dried at 105 °C, and then the tares of these plates were measured. A laboratory scale (± 0.01 g) was used (Radwag AS220R2, Poland) to weigh 5-gr samples. These samples were then placed on the DM plates and dried at 105 °C until a stable weight was achieved and reweighed to obtain the water content of the meat before the procedure. The process was applied as explained by Anonymous (1990) and Jensen et al. (2004).

The pH level of the thigh and breast meat was measured by an automatic pH-meter (WTW 3110, Germany) using a glass pH probe (WTW Sentix 31, Germany). Before taking the measurements, the device was calibrated by ready-to-use pH4 and pH7 solutions. The measurements were separately undertaken from the same locations of the breast and thigh four hours after slaughter and cooling at + 4 °C for 24 hours.

The WHC values were obtained by the filter paper press method as recommended by Grau et al. (1953) from the same parts of the thigh and breast meat as the DM samples were taken. 300 mg of samples were weighed, placed between filter paper and millimetre paper, numbered individually, and pressed between two special plexiglass plates for three minutes. The measurements were taken twice: after 24 hours and 48 hours of slaughter. The samples between the two pieces of paper were taken out of the press and stapled on the corner of the paper. A tripod was set inversely on the laboratory table, and a digital SLR camera (Canon T1i, Japan) with a lens of 18–55f was attached to this tripod to obtain macro photos from the surface of the table under standard lighting conditions using a light box. The prepared samples were placed under this platform and photographed. These photos were transferred to the computer, and JI area calculation software was used to determine the area of meat and the area of water spread. The area of spread meat was extracted from the area of spread water to obtain the free water area. From the measurements performed, the WHC values were calculated as percentage by dividing the free water area to the total area.

To obtain the CL data, a laboratory (± 1 mg) scale (Radwag AS220R2, Poland) was used, and the process was carried out as described by Honikel (1998). 50 g of samples were taken from the thigh and breast

meats of the ducks (approximately 3 cm wide, 3 cm high and 5 cm long), weighed by the scale, and placed in a plastic heat – resistant sealed bag. The bags were individually numbered by water – resistant pen. The bags were immersed in a boiling water bath and kept there until the centre of the meat reached 75 °C. At this point, the samples were taken out of the boiling water and immersed in cold water with ice until they reached room temperature. Then, the meat was removed from the bag and weighed. The weight loss between the first and last measurements was calculated as the percentage of the CL value.

The colour measurements were taken from the thigh meat with skin, breast meat with skin, thigh without skin and breast without skin using a portable digital colorimeter (PCE_CSM5, PCE Instruments, USA). The colorimeter was precalibrated by a white and black plate provided. The colorimeter was also double-checked by another colorimeter (Minolta CR-400, Osaka, JAPAN) by measuring 10 samples in parallel and found to deliver the same measurement values. The L^* , a^* , b^* and hue (h^*) values were obtained from the automatic colorimeter as colour parameters, and these data were used to calculate the ΔE^* ($L^2 + a^2 + b^2$) and chroma ($C^* = \sqrt{a^{*2} + b^{*2}}$) values. The colour parameters were tested by the CIELab system with L^* values meaning dark to light (0-100), a^* values meaning green to red (-60 to + 60), and b^* values blue to yellow (-60 to + 60).

All meat quality evaluations were performed as described in the meat quality evaluation book of Anadolu University (Anonymous, 2010) and Nollet et al. (2009).

The trial was set according to a random-parcel plan. After gathering all the data and ensuring that it was homogeneous by applying the homogeneity tests (skewness and kurtosis analysis followed by the Shapiro-Wilk test), statistical analyses were performed on a computer using the ANOVA method and the post – hoc Tukey test using IBM SPSS 22 software programme (SPSS 2013, USA). The findings were obtained as means $\pm$ standard error of the means (SEM).

3. Results And Discussion

The main focus of this research was to investigate the effects of SD on slaughter performance, carcass quality, and some meat quality parameters in hybrid Pekin ducks. To investigate the slaughter performance, the main criteria were TLW, SW, CW and CY. All slaughter performance parameters were adversely affected by increasing the SD and the worst values were observed in the highest SD of seven ducks per m^2 as shown in Table 2. These data results are in line with previous research, reporting that the ducks reared reached 3.350 kg in around 48 days (Jones et al., 2010) and 3.518 kg in 49 days (Steczny et al., 2017), similar to the treatment groups of the current research (2.491 kg, 2.924 kg and 3.580 kg in 42 days). The weights of the ducks being lower in some of the treatment groups of the current study are considered to be due to the shorter duration of the rearing period in the trial. If the rearing period had been 48 days, all treatment groups would have reached and may have even exceeded the weights reported in the literature.

The weights of the ducks' body components (SIT, SIB, ST, BS, SITW and SIBW) were found to gradually decrease in parallel to the increasing SD (Table 2). The percentages of breast meat and thigh meat in carcass were 14.23% and 21.33%, respectively, which were higher than found in the study by Xie et al. (2014) reporting the breast and thigh meat percentages as % 13.4 and % 13.6, respectively. It is first thought that these differences might have been due to the total carcass weight being lower in our study since we did not include the neck in measurements. However, even when we adjusted the values, our values were higher, which suggests that the rearing conditions and management were better than the other researches undertaken, as well as the race and lines of birds used in the current trial were fine.

Table 2
The effects of SD on the slaughter performance of Pekin ducks (Mean $\pm$ SEM).

Stocking Density (SD) ducks/m ²				
	3	5	7	P Number
Total Live Weight, kg/m ²	10.71 $\pm$ 0.26 ^b	14.62 $\pm$ 0.43 ^b	17.43 $\pm$ 1.16 ^a	0.000
Slaughter Weight, g	3578 $\pm$ 105 ^a	2924 $\pm$ 73 ^b	2491 $\pm$ 168 ^b	0.000
Carcass Weight, g	1987 $\pm$ 66 ^a	1562 $\pm$ 50 ^b	1172 $\pm$ 35 ^c	0.000
Carcass Yield, %	55.51 $\pm$ 0.81 ^a	53.38 $\pm$ 0.68 ^a	47.90 $\pm$ 1.97 ^b	0.002
Fragment Weight, g				
Thigh (with skin)	546 $\pm$ 24 ^a	465 $\pm$ 14 ^b	342 $\pm$ 14 ^c	0.000
Breast (with skin)	504 $\pm$ 18 ^a	357 $\pm$ 22 ^b	200 $\pm$ 14 ^c	0.000
Thigh (without skin)	409 $\pm$ 17 ^a	354 $\pm$ 9 ^b	274 $\pm$ 7 ^c	0.000
Breast (without skin)	373 $\pm$ 18 ^a	238 $\pm$ 15 ^b	123 $\pm$ 6 ^c	0.000
Thigh Skin	137 $\pm$ 13 ^a	111 $\pm$ 11 ^b	68 $\pm$ 8 ^b	0.001
Breast Skin	130 $\pm$ 8 ^a	119 $\pm$ 9 ^b	76 $\pm$ 12 ^b	0.002
Fragment Yield, Carcass %				
Thigh (with skin)	32.66 $\pm$ 1.40 ^a	27.78 $\pm$ 0.83 ^b	20.44 $\pm$ 0.82 ^c	0.000
Breast (with skin)	24.49 $\pm$ 1.01 ^a	21.16 $\pm$ 0.55 ^b	16.39 $\pm$ 0.42 ^c	0.000
Thigh (without skin)	30.11 $\pm$ 1.07 ^a	21.33 $\pm$ 1.31 ^b	11.93 $\pm$ 0.82 ^c	0.000
Breast (without skin)	22.31 $\pm$ 1.09 ^a	14.23 $\pm$ 0.89 ^a	7.38 $\pm$ 0.38 ^c	0.000
Thigh Skin	6.92 $\pm$ 0.65	7.09 $\pm$ 0.66	5.71 $\pm$ 0.54	0.241
Breast Skin	6.60 $\pm$ 0.39	7.54 $\pm$ 0.38	6.56 $\pm$ 1.02	0.527
Edible Giblets Weight, g				
Liver	76 $\pm$ 6	78 $\pm$ 3	84 $\pm$ 4	0.460
Heart	17 $\pm$ 1 ^a	14 $\pm$ 1 ^b	11 $\pm$ 1 ^c	0.000
Gizzard	101 $\pm$ 3 ^a	83 $\pm$ 3 ^b	76 $\pm$ 4 ^b	0.000
Edible Giblets Yield, Weight %				

Stocking Density (SD) ducks/m ²				
Liver	2.11 ± 0.12 ^c	2.68 ± 0.09 ^b	3.43 ± 0.22 ^a	0.000
Heart	0.48 ± 0.02	0.87 ± 0.02	0.44 ± 0.02	0.504
Gizzard	2.82 ± 0.08	2.84 ± 0.14	3.09 ± 0.20	0.366
Edible Giblets Yield, Carcass %				
Liver	3.81 ± 0.24 ^c	5.04 ± 0.20 ^b	7.14 ± 0.30 ^a	0.000
Heart	0.86 ± 0.05	0.87 ± 0.02	0.94 ± 0.05	0.404
Gizzard	5.07 ± 0.10 ^{cb}	5.34 ± 0.28 ^b	6.46 ± 0.34 ^a	0.004
^{abc} Different superscript letters on the same line indicate statistical significance (p < 0.05).				

The mean CY was found to be % 52.26 in the experiment, which was lower than the findings of previous experiments; e.g., % 72.1 (İşgüzar, 2006) because we did not include the feet, neck and head in the total carcass weight. As reported by some researchers, the head of the ducks constitutes around % 5.20 of LW and % 7.23 of carcass, the necks of the ducks around % 7.30 of carcass, and the feet around % 3.47 of carcass. This means that in the current study, approximately % 18.00 of carcass weight was not evaluated. This was to eliminate the fluctuation of the total carcass measurements. The total CY in the current trial was around % 71.00, which is consistent with previous reports of as İşgüzar (2006) (%72.10) and Steczny et al. (2017) (% 70.25).

When the weights of edible giblets were analysed in relation to SD, a similar situation emerged. The heart and gizzard weights showed a tendency to decrease with the increasing SD ($P \geq 0.05$), and the lowest values were obtained from the SD of seven ducks per m² (Table 2). In contrast, the liver weights were observed to increase with the increasing SD, but the differences were not significant ($P \geq 0.05$).

When the yield data of the edible giblets were analysed based on the percentage to total live weight, liver yield was found to increase ($P \geq 0.05$) with the increasing SD, reaching the highest in the SD of 7 ducks per m². However, the heart and gizzard yields were not affected by SD ($P \geq 0.05$) (Table 2).

The analysis of edible giblets yield data in relation to the whole carcass revealed that the liver and gizzard yields increased in parallel to the increase in SD ($P \geq 0.05$), but the heart yield was found to be unaffected by SD in the experiment in percentage to whole carcass ($P \geq 0.05$). These data about edible giblets were in line with other researches' findings where percentages of giblets were reported as % 0.86 heart, % 1.13 liver and % 2.03 gizzard by Staczny et al. (2017) and % 0.88 heart, % 2.69 liver and % 6.41 gizzard by İşgüzar (2006).

None of the investigated meat quality parameters (pH, WHC, dry matter ratio, and cooking loss) were affected by SD ($P \geq 0.05$) (Table 3). The pH values obtained from the research were 6.41–6.61 for thigh

meat and 5.91–6.01 for breast meat, which is in agreement with the literature [Chen et al., 2015 (6.04 and 6.09); Ahaotu et al., 2015 (5.96 to 6.25); Michalczyk et al., 2016 (5.90)].

Table 3
The effects of SD on the meat quality of Pekin ducks (Mean $\pm$ SEM).

	Stocking Density (SD) ducks/m ²			
	3	5	7	P Number
pH				
Thigh, slaughter	6.60 $\pm$ 0.12	6.61 $\pm$ 0.10	6.41 $\pm$ 0.10	0.297
Thigh, 24 hours	6.65 $\pm$ 0.06	6.66 $\pm$ 0.05	6.43 $\pm$ 0.11	0.085
Breast, slaughter	5.91 $\pm$ 0.06	5.92 $\pm$ 0.07	6.01 $\pm$ 0.07	0.528
Breast, 24 hours	5.85 $\pm$ 0.02	5.99 $\pm$ 0.13	5.79 $\pm$ 0.06	0.207
Water Holding Capacity, %				
Thigh, Day 1	0.60 $\pm$ 0.05	0.62 $\pm$ 0.02	0.62 $\pm$ 0.04	0.936
Thigh, Day 2	0.57 $\pm$ 0.03	0.61 $\pm$ 0.07	0.65 $\pm$ 0.09	0.673
Breast, Day 1	0.75 $\pm$ 0.02	0.76 $\pm$ 0.02	0.83 $\pm$ 0.03	0.143
Breast, Day 2	0.71 $\pm$ 0.02	0.73 $\pm$ 0.02	0.82 $\pm$ 0.05	0.124
Dry Matter Ratio, %				
Thigh	23.55 $\pm$ 0.70	24.17 $\pm$ 0.88	23.33 $\pm$ 0.55	0.691
Breast	23.20 $\pm$ 0.34	23.24 $\pm$ 0.37	22.23 $\pm$ 0.50	0.178
Cooking Loss, %				
Thigh	16.90 $\pm$ 0.93	15.80 $\pm$ 1.19	15.55 $\pm$ 1.19	0.603
Breast	21.27 $\pm$ 1.44	19.42 $\pm$ 1.21	19.27 $\pm$ 0.92	0.441
^{abc} The different superscript letters on the same line indicate statistical significance (p < 0.05).				

Concerning meat colour, the L, h and Δ values increased only in skinless breast meat in parallel to the increasing SD (P $\leq$ 0.05). The colour values of the thigh meat with skin were higher in the SD of three ducks per m² (P $\leq$ 0.05), meaning that as the SD was reduced; the colour of the thigh meat with skin became more reddish. Other parameters were not affected by the different SDs applied in the research (P $\geq$ 0.05) (Table 4). Therefore, it can be stated that increasing the SD resulted in the skinless breast meat to become lighter in colour and increased the h and Δ values.

Table 4
The effects of SD on the meat colour of Pekin ducks (Mean $\pm$ SEM).

Stocking Density (SD) ducks/m ²				
	3	5	7	P Number
L* Value				
Thigh (with skin)	72.77 $\pm$ 0.75	70.59 $\pm$ 1.13	70.69 $\pm$ 1.77	0.459
Breast (with skin)	72.74 $\pm$ 4.29	73.46 $\pm$ 3.89	79.08 $\pm$ 0.76	0.343
Thigh (without skin)	50.10 $\pm$ 5.37	46.42 $\pm$ 0.48	47.47 $\pm$ 1.71	0.689
Breast (without skin)	49.24 $\pm$ 2.16 ^b	51.69 $\pm$ 1.88 ^{ab}	56.22 $\pm$ 1.57 ^a	0.047
a* Value				
Thigh (with skin)	4.99 $\pm$ 0.62 ^a	3.18 $\pm$ 0.28 ^b	3.29 $\pm$ 0.46 ^b	0.022
Breast (with skin)	6.95 $\pm$ 1.40	5.49 $\pm$ 0.59	4.50 $\pm$ 0.60	0.183
Thigh (without skin)	10.19 $\pm$ 1.47	11.62 $\pm$ 0.67	11.25 $\pm$ 0.61	0.563
Breast (without skin)	11.13 $\pm$ 0.65	10.44 $\pm$ 0.38	9.29 $\pm$ 0.50	0.059
b* Value				
Thigh (with skin)	6.77 $\pm$ 0.66	5.08 $\pm$ 1.10	5.62 $\pm$ 1.12	0.508
Breast (with skin)	11.30 $\pm$ 1.24	11.73 $\pm$ 1.62	13.36 $\pm$ 0.59	0.471
Thigh (without skin)	5.22 $\pm$ 1.78	5.66 $\pm$ 0.64	3.00 $\pm$ 1.35	0.277
Breast (without skin)	3.64 $\pm$ 0.65	4.21 $\pm$ 0.54	4.91 $\pm$ 0.31	0.241
c* Value				
Thigh (with skin)	8.55 $\pm$ 0.65	6.14 $\pm$ 1.02	6.71 $\pm$ 1.05	0.207
Breast (with skin)	13.83 $\pm$ 2.59	13.41 $\pm$ 1.12	14.13 $\pm$ 0.74	0.862
Thigh (without skin)	12.16 $\pm$ 1.01	12.96 $\pm$ 0.84	12.06 $\pm$ 0.90	0.739
Breast (without skin)	11.66 $\pm$ 0.78	11.33 $\pm$ 0.45	10.57 $\pm$ 0.38	0.365
h* Value				
Thigh (with skin)	53.82 $\pm$ 4.13	52.74 $\pm$ 5.53	55.44 $\pm$ 5.95	0.935
Breast (with skin)	59.27 $\pm$ 6.71	61.68 $\pm$ 6.91	71.89 $\pm$ 1.51	0.252
Thigh (without skin)	29.32 $\pm$ 9.71	25.52 $\pm$ 1.78	19.44 $\pm$ 4.36	0.505
Breast (without skin)	15.43 $\pm$ 2.70 ^b	21.72 $\pm$ 2.43 ^{ab}	28.25 $\pm$ 2.44 ^a	0.007

Stocking Density (SD) ducks/m ²				
ΔE Value				
Thigh (with skin)	73.29 $\pm$ 0.75	70.90 $\pm$ 1.19	71.06 $\pm$ 1.81	0.459
Breast (with skin)	74.13 $\pm$ 4.14	74.70 $\pm$ 3.97	80.36 $\pm$ 0.70	0.343
Thigh (without skin)	51.71 $\pm$ 5.21	48.24 $\pm$ 0.62	49.01 $\pm$ 1.80	0.699
Breast (without skin)	48.24 $\pm$ 0.62 ^b	52.95 $\pm$ 1.85 ^{ab}	57.23 $\pm$ 1.50 ^a	0.046
^{abc} The different superscript letters on the same line indicate statistical significance ($p < 0.05$).				

4. Conclusion

When the results of the research were evaluated in general, it was seen that the increase in the SD affected the slaughter performance criteria negatively but in contrast, most criteria related to meat quality were not affected. As a criterion for meat quality, the effect of SD on the colour of meat was only observed in the skinless breast meat having a lighter colour and the thigh meat with skin being reddish in the lower SD groups. Considering that these parameters influence consumer demand in the market, more attention must be paid to determine the optimal SD to increase not only field and slaughter performance, but also meat quality through more detailed and large-scale studies that also take into consideration economic parameters.

Abbreviations

L*: Lightness

A*: Red-Green Coordinate

B*: Yellow-Blue Coordinate

C*: Chroma

h*: Hue

ΔE^* : Metric calculation of colour difference

EU: European Union

CY: Carcass Yield

SD: Stocking Density

R&D: Research and Development

CW: Carcass Weight

STW: Thigh Meat with Skin Weight

SITW: Skinless Thigh Meat Weight

SBW: Breast Meat with Skin Weight

SIBW: Skinless Breast Meat Weight

HW: Heart Weight

LW: Liver Weight

GW: Gizzard Weight

HY: Heart Yield

LY: Liver Yield

GY: Gizzard Yield

DM: Dry Matter

WHC: Water Holding Capacity

CL: Cooking Loss

Declarations

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Author Information

Sabri Arda Eratalar planned and executed the growing period, collected the data and wrote the text completing the main part of the research, Ahmet Yaman performed meat quality analysis in the laboratory and Nezih Okur did statistical analyses of the data acquired.

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Ethics Declarations

Ethics Approval and Consent to Participate

The experiments were undertaken in commercial conditions and no physical, chemical and other stress giving methods were used on animals. The materials used were taken from animals commercially slaughtered in the industry. So no ethics approval was needed.

Consent for Publication

Not applicable.

Competing Interests

The authors declare no conflict of interest

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