

Research Note: Effects of the rearing method and stocking density on carcass traits and proximate composition of meat in small-sized meat ducks

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ABSTRACT The present study was conducted to evaluate the effects of different rearing methods and stocking densities on carcass yield and proximate composition of meat in small-sized meat ducks. A total of 555 one-day-old birds were randomly allocated to six treatment groups (three replicates per treatment, sex ratio 1/1) with a 2 × 3 factorial arrangement of two rearing methods (reared in cage or net) and three stocking densities (5 [low], 7 [medium], or 9 [high] birds/m²) until day 70. Five male and five female birds from each replicate were randomly selected and processed to determine the carcass yield. Proximate composition was determined by proximate analysis using the breast and thigh muscles. There was no interaction effect between the rearing method and stocking density on carcass yield. The rearing method affected the thigh muscle rate, which was higher in the cage groups ($P < 0.05$). The final BW and abdominal fat rate decreased with increasing

density ($P < 0.05$), whereas the thigh muscle rate increased ($P < 0.05$). There were significant interaction effects ($P < 0.05$) between the rearing method and stocking density on the content of protein, fat, and collagen. The content of fat and moisture was greater and lower, respectively, in the cage groups ($P < 0.05$). The content of moisture, fat, and collagen with a medium density was higher ($P < 0.05$). In addition, the content of protein and fat was lower in the ducks fed in nets at low and high densities ($P < 0.05$), respectively; the collagen content of breast and thigh muscle was lower in the ducks fed in cages and nets, respectively, at a low density ($P < 0.05$). Our findings provide valuable insights into the single and interactive effects of the rearing method and stocking density on duck slaughter performance and proximate composition of meat. The results indicate that a rearing system with a cage pattern and a medium density is better than other arrangements for small-sized meat ducks.

Key words: meat duck, rearing method, stocking density, carcass yield, proximate composition

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INTRODUCTION

China is a major producer and consumer of meat ducks, with an annual output of more than 3.5 billion ducks, accounting for 75% of meat duck production worldwide (Hou, 2019). Duck meat plays an important role in the Chinese poultry market. In recent years, with the improvement of people's consumption level and the pursuit of product quality, small-sized

meat ducks (slaughter age > 70 D, BW < 1.8 kg), which have a unique flavor and high nutritional value, have been well received by consumers. Small-sized meat ducks are mainly bred from indigenous ducks in China and are usually used for deep processing, such as dry-cured, roast, marinated, pickled, salted, and sauced duck production. Good performance, excellent meat quality, and a high FCR have become new directions for modern meat duck production. In addition, global environmental issues have accelerated changes in traditional rearing methods, which have transitioned from conventional free range and open water outdoors to confinement in birdhouses. As a result of these changes, the feeding technique for small-sized meat ducks needs to be optimized to promote the breeding process and satisfy market demand.

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Domestic duck breeding has gradually changed from the traditional rearing method to the diversified modern pattern, including net, cage, fermentation bed, and other specific patterns under intensive systems. The cage pattern can make full use of the birdhouse space but limits the activity of the ducks, and limited activity increases their vulnerability to diseases and other problems. The net pattern can improve the survival rate, production efficiency, and quality; however, the cost of birdhouse construction is high, and the uneven surface and large mesh of the net can easily lead to foot injuries. Several studies have reported that different rearing methods have important effects on the slaughter performance and meat quality of ducks. You and Yang (2008) found that the growth and production performance of net-rearing was better than that of floor-rearing cherry valley ducks. Chen et al. (2018) found that the growth rate and feather quality were better when small-sized meat ducks were fed in nets, while the percentages of carcass yield, semi-eviscerated yield, and eviscerated yield were much higher when they were fed in cages. These results serve as a reference for our study. Importantly, our study focused on the proximate composition of meat in addition to slaughter performance.

Stocking density is another important factor of a rearing system, and it is critical for poultry production and welfare. Higher economic returns can be obtained as the number of birds per unit of space increases, but the economic profit may come at the cost of a decrease in the performance, health, and welfare of the birds if densities are excessively high. A high stocking density can reduce performance as a result of several factors, such as high environmental temperatures of the birds per unit, inadequate air exchange, increasing ammonia levels, and impeded access to feed and water (Simsek et al., 2011). The effects of a high stocking density on broilers was reviewed by Estevez (2007), and the negative consequences included decreases in the final BW, feed intake, and FCR and a greater incidence of footpad dermatitis, scratches, bruising, poor feathering, and condemnations. Zhang et al. (2015), who studied Pekin ducks, indicated that a high stocking density induced compensatory reactions of the immune system and led to spleen atrophy, while a medium stocking density could increase oxidative stress in the birds.

Several national and local standards for meat-type ducks have been promulgated (NY/T 2122-2012, DB32/T 2692-2014), which primarily specify the nutrient requirements and breeding techniques for large-sized meat ducks, such as Pekin duck and cherry valley duck. There is no standard for the production of small-sized meat ducks. This work was supported by a national project, which was carried out for national technical regulations and standards, including the rearing method and stocking density of small-sized meat ducks. In this project, the lowest stocking density of 5 birds/m² was selected to balance cost and economic profit.

Studies on the interactive effects of the rearing method and stocking density in small-sized meat ducks

are quite rare. The objective of the present study is to examine the main and interactive effects of typical rearing methods used in commercial meat duck production in China and stocking densities on carcass yield and the proximate composition of meat in small-sized meat ducks. Our findings will provide valuable insights into the breeding of small-sized meat ducks.

MATERIALS AND METHODS

Ethics Statement

All the animal procedures were implemented in strict accordance with the guidelines proposed by the China Council on Animal Care and the Ministry of Science and Technology of the People's Republic of China. All experimental ducks were managed and handled according to the guidelines established and approved by the Animal Care and Use Committee of Yangzhou University (approval number: 151-2014). All efforts were made to minimize the suffering of the animals.

Animals and Experimental Design

A total of 555 one-day-old small-sized meat ducks (E strain, 277 males and 278 females) were obtained from Ecolovo Group, China. All the ducks were incubated contemporaneously and housed in the same environment (temperature, humidity, ventilation, and other variables) in an experimental facility until day 70. Half of the facility is equipped with cages, and the remainder is equipped with the net rearing system.

This study was carried out in a 2 × 3 factorial arrangement with 2 different rearing methods—cage and net patterns—and 3 different stocking densities—5, 7, and 9 birds/m²—designated as low, medium, and high stocking densities, respectively. All the ducks were randomly divided into 6 treatments with a male-to-female ratio of 1:1. Each treatment had three replicates, which were balanced for the average initial BW. For the cage pattern, a total of 303 birds were kept in 45 cages that had a length, width, and depth of 140 × 70 × 38 cm (approximately 1 m² per cage). The ducks were housed at densities of 5 (18 cages), 7 (15 cages), or 9 (12 cages) birds/cage. Each replication consisted of 6, 5, and 4 adjacent cages for low, medium, and high stocking densities, respectively. Feed lines were placed on one side of the cage. A nipple drinking line was installed overhead in the middle of the cage (5–10 birds/nipple). For the net pattern, a total of 252 birds were kept in nine pens (160 × 250 cm, 4 m²), which were 90 cm above the ground. Each replication was reared separately in a single pen (20, 28, and 36 birds/pen in low, medium, and high stocking densities, respectively) consisting of a stainless-steel frame with a flat wire net cover. Each pen had two-side trough feeders and drinking nipples (three automatic drinking nipples on one side of the pen).

In the birdhouse, the lighting was continuous, and the temperature was set initially at 32°C and reduced

gradually by 1°C per day until reaching 18°C. The relative humidity was set initially at 75% and reduced gradually by 5% per week until reaching 55%. During the experimental period, all the ducks had free access to feed and water on an ad libitum basis, and the mortalities and BW of dead birds in each treatment were recorded daily. All the ducks were reared with the same diet (Table 1) from hatching to 70 D of age.

Carcass Characteristics and Proximate Analysis

At the end of the experiment (70 D of age), after 12 h of fasting, five male and five female birds from each replicate were randomly selected to be weighed (live weight, LW) and slaughtered in a poultry processing plant. The defeathered carcass, including the head and feet, was weighed as the carcass weight. The carcass was then eviscerated manually and weighed as the semi-eviscerated weight (SEW), which was measured as the carcass weight after the removal of the trachea, esophagus, gastrointestinal tract, crop, spleen, pancreas, gallbladder, and gonads. Eviscerated weight (EW) was measured as the SEW after the removal of the head, feet, heart, liver, gizzard, glandular stomach, and abdominal fat. Carcass yield was calculated as a percentage of LW. Breast muscle, thigh muscle, and abdominal fat pad, including the leaf fat surrounding the cloaca and gizzard, were separated and weighed, and their weights are denoted by BMW, TMW, and AFW, respectively. Breast and thigh muscle yields were calculated as

percentages of EW. Abdominal fat percentage was calculated by AFW/(AFW + EW), following the standard issued by the Ministry of Agriculture and Rural Affairs (2004).

The breast and thigh muscle samples from each treatment were used to measure the proximate composition. All exterior fat and connective tissue were removed before the proximate analysis, which was performed to determine the percentage of moisture, protein, fat, and collagen. Frozen samples were thawed at 4°C for 24 h before analysis. Each sample was coarse ground through a tabletop grinder to obtain a sample of approximately 200 g. Samples were analyzed using an Association of Official Analytical Chemists–approved (Anderson, 2007) near-infrared spectrophotometer (FOSS FoodScan 78,800; Dedicated Analytical Solutions, Hillerod, Denmark). Independent readings ($n = 15$) were taken from each sample and averaged to obtain the final reported values. All measurements were performed in triplicate.

Statistical Analysis

The data were analyzed by a completely randomized design with two-way ANOVA using the GLM procedure in SAS (version 9.4; SAS Institute Inc., Cary, NC). The model included the main effects of the rearing method and the stocking density, as well as their potential interactions. Duncan's multiple comparison procedure was used to test the differences for significance. The data were assumed to be statistically significant when $P < 0.05$.

RESULTS AND DISCUSSION

Carcass Characteristics

The carcass characteristics of the small-sized meat ducks are presented in Table 2. The data of all the carcass traits, including LW, EW, SEW, BMW, TMW, and AFW, were absolutely normal, with a semi-eviscerated yield and eviscerated yield of above 70 and 60%, respectively. Although there was no interactive effect between the rearing method and stocking density on these variables, each factor substantially affected the carcass traits. The rearing method affected the thigh muscle rate, which was higher in the cage groups than that in the net groups ($P < 0.05$), while there were no differences in other slaughter performances ($P > 0.05$). Zhang et al. (2018a) reported that the net pattern was beneficial to the growth performance of Chaohu ducks, although this pattern had some negative effects on carcass traits, meat quality, and serum profiles. On the contrary, Chen et al. (2015) found that the net pattern proved to be the best production system for the welfare traits of cherry valley ducks, but it was not the best choice for optimal growth performance. The final BW decreased when the stocking density was 9 birds/m² ($P < 0.05$), which agrees with the results of previous works (Xie et al., 2014; Zhang et al., 2018b). The

Table 1. Compositions and nutrients of the experimental diets (% , as fed).

Item	0 to 7 D	8 to 21 D	22 to 42 D	43 to 70 D
Ingredient (%)				
Corn	10.32	10.63	47.18	21.27
Wheat middling	15.41	15.00	6.89	20.00
Wheat bran	-	-	20.00	30.01
Rice noodles	35.21	34.99	-	10.00
Rice bran	15.81	15.00	3.00	5.00
Peanut meal	-	-	3.00	2.37
Corn gluten meal	-	-	5.00	-
Soybean meal	12.63	13.70	5.94	2.50
Nucleotide slag	2.00	2.00	-	-
Limestone powder	1.52	1.58	1.90	1.96
Calcium hydrogen phosphate	1.10	1.10	1.01	0.84
Compound premix ¹	6.00	6.00	6.00	6.00
Formulated nutrient profile (g/kg)				
Crude protein	185.00	190.00	170.00	170.00
Crude fat	20.00	30.00	35.00	35.00
Crude fiber	60.00	50.00	70.00	70.00
Crude ash	90.00	80.00	100.00	100.00
Calcium	10.00	10.00	10.00	10.00
Phosphorus	5.00	5.50	4.50	4.50
Sodium chloride	6.00	6.00	6.00	6.00
Methionine	4.00	4.00	2.80	2.80
Moisture	140.00	130.00	130.00	130.00

¹Supplied per kilogram of total diet: bentonite, 44.46 g; lysine, 3.24 g; DL-MHA-FA (88%), 0.99 g; threonine, 0.73 g; sodium chloride, 4.40 g; sodium bicarbonate, 2.00 g; sodium sulphate, 2.00 g; Herbalife, 0.20 g; choline chloride (60%), 1.00 g; Jin Duowei, 0.53 g; Jin Yvkang, 0.15 g; C-811 enzyme, 0.30 g.

Table 2. Effects of the rearing method and stocking density on carcass yield in small-sized meat ducks at 70 D of age.

Items	Number of samples	Density (birds/m ²)	LW (g)	EW (g)	Eviscerated yield (%)	Semi-eviscerated yield (%)	Breast muscle (%)	Thigh muscle (%)	Abdominal fat (%)
Cage	30	5	1441.41 ± 95.85	918.22 ± 76.49	63.18 ± 2.30	69.45 ± 2.06	13.11 ± 1.04	11.70 ± 1.10	1.36 ± 0.72
	30	7	1456.50 ± 123.55	935.73 ± 88.84	64.88 ± 2.74	70.74 ± 2.91	13.10 ± 0.73	11.99 ± 1.30	1.22 ± 0.37
	30	9	1415.61 ± 123.67	912.81 ± 86.68	64.15 ± 2.02	70.17 ± 2.59	13.02 ± 1.32	12.49 ± 1.17	1.15 ± 0.47
Net	30	5	1543.42 ± 62.61	984.27 ± 38.33	63.65 ± 1.43	69.89 ± 1.32	13.59 ± 1.19	10.53 ± 0.95	1.72 ± 0.43
	30	7	1439.10 ± 120.93	920.95 ± 90.49	63.57 ± 2.21	69.43 ± 2.19	12.71 ± 2.01	11.64 ± 2.08	1.27 ± 0.60
	30	9	1414.00 ± 104.89	889.36 ± 81.53	62.90 ± 1.67	68.87 ± 2.02	12.66 ± 1.02	11.92 ± 1.04	1.15 ± 0.60
Rearing	90	cage	1438.09 ± 113.00	922.05 ± 82.93	64.07 ± 2.42	70.12 ± 2.54	13.07 ± 1.04	12.07 ± 1.21 ^a	1.24 ± 0.53
	90	net	1453.52 ± 113.96	926.73 ± 84.23	63.38 ± 1.86	69.36 ± 1.95	12.92 ± 1.58	11.45 ± 1.63 ^b	1.34 ± 0.59
Density	60	5	1477.41 ± 97.99 ^a	946.17 ± 70.50	63.38 ± 1.96	69.64 ± 1.77	13.31 ± 1.11	11.21 ± 1.18 ^b	1.51 ± 0.63 ^a
	60	7	1447.34 ± 120.83 ^{a,b}	927.47 ± 88.71	64.15 ± 2.51	70.01 ± 2.58	12.88 ± 1.57	11.80 ± 1.76 ^{a,b}	1.25 ± 0.50 ^{a,b}
	60	9	1414.76 ± 112.59 ^b	901.87 ± 83.71	63.57 ± 1.94	69.56 ± 2.39	12.85 ± 1.19	12.22 ± 1.13 ^a	1.15 ± 0.53 ^b
P value	Rearing		0.1956	0.5945	0.1313	0.1398	0.7641	0.0209	0.2531
	Density		0.0160	0.0767	0.2836	0.5938	0.3114	0.0172	0.0304
	Rearing × density		0.0586	0.0880	0.2254	0.2659	0.3991	0.5209	0.4468

^{a,b}Within a column for each factor, different superscripts indicate significant differences ($P < 0.05$).

Eviscerated yield, % = EW/LW × 100; semi-eviscerated yield, % = SEW/LW × 100; breast muscle, % = BMW/EW × 100; thigh muscle, % = TMW/EW × 100; abdominal fat, % = AFW/(AFW + EW) × 100.

Abbreviations: EW, eviscerated weight; LW, live weight.

abdominal fat rate also decreased with increasing density ($P < 0.05$). In addition, the thigh muscle rate increased with increasing density ($P < 0.05$), which is completely consistent with the results of the study by Osman (1993). Dozier et al. (2006) and Simsek et al. (2011) observed that the stocking density had a significant effect on the meat production capacity of the animals. Mallick et al. (2018) found that the BW, weight gain, and FCR of white Pekin ducks were higher in low-density groups than those in medium- and high-density groups. Taboosha (2014) also reported that the BW of broiler mule ducks grown at low- and medium-density groups was significantly higher than that of birds stocked at a high density. Similarly, the stocking density had a significant effect on all carcass traits studied as a percentage. However, in the present study, increasing the stocking density did not influence the yield of EW, SEW, and breast muscle ($P > 0.05$; Table 2). These nonsignificant effects of stocking density on the meat yield of carcasses were also observed in previous studies (Baeza et al., 2003; Thomas et al., 2004; Mallick et al., 2018).

Proximate Analysis

Meat quality is usually reflected by several indicators, such as pH, drip loss, meat color, and shear force. In this study, only the proximate composition was analyzed, including moisture, protein, fat, and collagen, which are summarized in Table 3. The moisture content of both breast muscle and thigh muscle varied between 73 and 74%. The protein content of breast muscle varied from 22.93 to 23.82%, while it was about 2% lower in the thigh muscle, which had a protein content that ranged from 20.87 to 21.94%. The protein content of small-sized meat ducks was higher than that of the commercial ducks reported by Bang et al. (2010). The fat content of breast muscle varied from 1.72 to 2.52%, while it was about 0.5% higher in thigh muscle, whose fat content ranged from 2.32 to 3.16%. The collagen content of

both breast muscle and thigh muscle varied between 1 and 2%, while it was about 0.5% lower in thigh muscle. There were significant interaction effects ($P < 0.05$) between the rearing method and stocking density on the content of protein, fat, and collagen in both breast muscle and thigh muscle, but there was no interactive effect ($P > 0.05$) on moisture. In general, the fat content in the cage groups was greater than that in the net groups ($P < 0.05$). Ruiz et al. (2001) reported that the sensory properties and nutritional value of meat were largely affected by the fat content. In addition, higher fat content reflects muscle succulence and flavor (Bosselmann et al., 1995). The moisture content was lower in the cage groups ($P < 0.05$), and a lower moisture content reflects higher nutrient content in the muscle. Michalczuk et al. (2016) reported that the rearing system did not affect the moisture, protein, fat, ash, pH, shear force, or color of breast muscles in Pekin ducks. Michalczuk et al. (2017) also revealed that the rearing system of Muscovy ducks had no significant effect on the chemical composition and physicochemical properties, except for cooking loss. The content of moisture, fat, and collagen in groups with a medium density was higher than that in groups with high and low densities ($P < 0.05$). Ahaotu and Agbasu (2015) revealed that the pH value of breast muscle increased significantly with increasing density. For Pekin ducks, the stocking density caused no significant changes in the color of breast and thigh muscles, but the holding capacity was significantly affected by the stocking density. Because of the interactive effect between the rearing method and stocking density, combined with their individual effects, the cage pattern with a medium density could be the most appropriate rearing system for improving the proximate composition of small-sized meat ducks.

In conclusion, the individual effects of the rearing method or stocking density and the interactive effect between them were important for different traits. However, it is difficult to establish a one-size-fits-all rearing

Table 3. Effects of the rearing method and stocking density on the proximate composition of meat in small-sized meat ducks at 70 D of age.

Items	Number of samples	Density (birds/m ²)	Breast muscle				Thigh muscle			
			Moisture (%)	Protein (%)	Fat (%)	Collagen (%)	Moisture (%)	Protein (%)	Fat (%)	Collagen (%)
Cage	30	5	73.19 ± 0.82	23.69 ± 0.77 ^{a,b}	2.33 ± 0.38 ^{a,b}	1.91 ± 0.27 ^c	73.61 ± 0.69	21.09 ± 0.24 ^c	2.99 ± 0.41 ^a	1.71 ± 0.20 ^b
	30	7	73.61 ± 0.17	23.33 ± 0.39 ^{b,c}	2.52 ± 0.13 ^a	2.36 ± 0.17 ^a	73.82 ± 0.35	20.87 ± 0.17 ^c	3.16 ± 0.16 ^a	1.87 ± 0.26 ^{a,b}
	30	9	73.86 ± 0.24	23.82 ± 0.90 ^a	1.77 ± 0.35 ^d	2.12 ± 0.20 ^b	73.60 ± 0.30	21.65 ± 0.43 ^{a,b}	2.33 ± 0.38 ^b	1.53 ± 0.23 ^c
Net	30	5	73.85 ± 0.49	23.72 ± 0.23 ^{a,b}	1.72 ± 0.31 ^d	2.10 ± 0.25 ^b	73.43 ± 0.29	21.94 ± 1.20 ^a	2.32 ± 0.62 ^b	1.34 ± 0.33 ^d
	30	7	73.84 ± 0.44	23.59 ± 0.67 ^{a,b}	2.04 ± 0.31 ^c	2.11 ± 0.31 ^b	73.67 ± 0.86	21.27 ± 0.61 ^{b,c}	2.96 ± 0.64 ^a	1.97 ± 0.27 ^a
	30	9	74.06 ± 0.59	22.93 ± 0.49 ^c	2.13 ± 0.20 ^{b,c}	2.18 ± 0.21 ^b	73.84 ± 0.89	21.21 ± 0.37 ^c	2.54 ± 0.43 ^b	1.71 ± 0.20 ^b
Rearing	90	Cage	73.55 ± 0.57 ^b	23.61 ± 0.74	2.21 ± 0.44 ^a	2.13 ± 0.28	73.68 ± 0.48	21.20 ± 0.45	2.83 ± 0.49 ^a	1.71 ± 0.27
	90	Net	73.92 ± 0.51 ^a	23.37 ± 0.62	2.00 ± 0.32 ^b	2.14 ± 0.26	73.71 ± 0.77	21.42 ± 0.78	2.64 ± 0.61 ^b	1.72 ± 0.36
Density	60	5	73.46 ± 0.77 ^b	23.70 ± 0.61	2.09 ± 0.46 ^b	1.99 ± 0.28 ^b	73.53 ± 0.56	21.43 ± 0.87 ^a	2.72 ± 0.60 ^b	1.56 ± 0.32 ^b
	60	7	73.72 ± 0.35 ^a	23.46 ± 0.56	2.28 ± 0.34 ^a	2.24 ± 0.28 ^a	73.79 ± 0.64	21.07 ± 0.49 ^b	3.06 ± 0.47 ^a	1.92 ± 0.26 ^a
	60	9	73.96 ± 0.45 ^a	23.37 ± 0.85	1.95 ± 0.34 ^b	2.15 ± 0.20 ^a	73.72 ± 0.67	21.43 ± 0.46 ^a	2.43 ± 0.42 ^c	1.62 ± 0.23 ^b
<i>P</i> value	Rearing		0.0006	0.1207	<0.0001	0.9372	0.9942	0.0516	0.0188	0.5002
	Density		0.0034	0.1084	<0.0001	0.0010	0.2094	0.0027	<0.0001	<0.0001
	Rearing × density		0.1534	0.0006	<0.0001	0.0011	0.3915	<0.0001	0.0010	<0.0001

^{a-d}Within a column for each factor, different superscripts indicate significant differences ($P < 0.05$).

method or stocking density that benefits all traits. The results of the present study may provide a basic understanding of the effects of the rearing method and stocking density on carcass traits and the proximate composition of meat in small-sized meat ducks. The results of this study indicate that cage feeding could be the most appropriate pattern. A high stocking density could cause growth depression, and a low density could result in low utilization and economic loss. Therefore, the cage pattern with a medium density is appropriate for this breed. In addition, further studies on growth performance, health and welfare traits, other important meat quality indicators, and the balance between the cage pattern and intensive fattening will be performed to provide deeper insights into the breeding of small-sized meat ducks.

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