Comparative Analysis of Slaughter Performance and Meat Flavor Traits of Quality Chicken under Cage Rearing and Free-range Farming Conditions

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Abstract **[Objective]** The paper was to compare the slaughter performance and meat flavor of quality chicken under cage rearing and free-range farming conditions. **[Method]** A total of 400 1-day-old cocks, S07 line cultivated by Sichuan Dahen Poultry Breeding Co., Ltd. (bred for 4 successive generations), were kept in cages until the end of 5 weeks of age, which were then divided into cage rearing and free-range farming groups. All cocks were fed with the same diet, and slaughter tests and meat quality analysis were carried out at the end of 10 and 22 weeks of age, respectively. **[Result]** The live weight, carcass weight and abdominal fat percentage in cage rearing group were significantly higher than those in free-range farming group ($P<0.01$), and the percentage of half-eviscerated yield and percentage of eviscerated yield in cage rearing group were significantly higher than those in free-range farming group ($P<0.05$), but there were no significant differences in dressing percentage, percentage of leg muscle and percentage of breast muscle. The intramuscular fat (IMF) content and muscle fiber density of chicken in cage rearing group were significantly higher than those in free-range farming group ($P<0.01$), but there was no significant difference in inosinic acid (IMP) content. The content of IMF and IMF increased with the increase of feeding age, but the deposition rate of intramuscular fat was higher than that of IMF in late feeding period. **[Conclusion]** The study will provide reliable guidance for production and market consumption of high quality chicken.

Keywords Quality chicken; Free-range farming chicken; Slaughter performance; Flavor traits of meat

Free-range farming chickens refer to the meat-type chickens that are grazed by using natural ecological resources such as forest land, orchard, grassland and barren hills and slopes. This mode of production has a considerable scale in China's vast rural areas, and its products also have stable consumer groups and consumer markets. Particularly, it needs to be made clear that in the development process of standardized large-scale breeding with breeding facilities as the main content, free-range farming chicken production can be described as a transition breeding method from traditional animal husbandry to modern animal husbandry[1]. Consumers seem to prefer chicken produced in this way, judging it to be of better quality and flavor. By measuring slaughter performance and indexes related to meat quality traits of quality chicken under cage rearing and free-range farming conditions, the study compared the effects of breeding methods on slaughter performance and meat flavor traits of quality chicken to explore whether there are differences in chicken products under different breeding methods, so as to provide more reliable guidance for production and market consumption of quality chicken.

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1 Materials and Methods

1.1 Animals and grouping A total of 400 1-day-old cocks, S07 line cultivated by Sichuan Dahen Poultry Breeding Co., Ltd. (bred for 4 successive generations), were kept in cages until the end of 5 weeks of age, which were then divided into cage rearing and free-range farming groups since 6 weeks of age. The 150 cocks were selected for each group. The free-range farming density was 80 cocks/667 m^2. The trial lasted until the end of 22 weeks of age.

During the brooding period, all cocks were fed with Zhengda chick feed, with free access to feed; the cocks of 6–8 weeks of age were fed with Zhengda medium chicken feed; the cocks of 9–12 weeks of age were fed with 80% chicken complete feed+20% corn; the cocks of 13–16 weeks of age were fed with 70% chicken com-

plete feed+30% corn; the cocks of 17–22 weeks of age were fed with 60% chicken complete feed+40% corn. The feeding restriction began from 6 weeks of age, and cocks in different groups followed the same feeding plan. The average feed volume per cock was 60 g/day at 6 weeks of age, and then the average daily feed intake increased by 4–5 g/week to 120 g/day at 22 weeks of age. During the test, the feed was weighed every morning according to the number of experimental cocks in each group and the feed consumption of each cock at a specific growth stage. It was ensured that the same volume of feed was provided to each cock in the whole process of the two feeding methods. The feed was supplemented once in the morning and evening, and the supplementary feeding amount accounted for half each time.

1.2 Measurement items and methods

1.2.1 Slaughter trait. At the end of 10 and 22 weeks of age, 50 cocks were randomly selected from each group for slaughter, and their live weight was weighed before slaughter. All cocks were fasted for 8 h before slaughter, but had free access to drinking water. The slaughter traits included live weight, carcass weight, eviscerated weight, eviscerated weight with giblet, chest muscle weight, leg muscle weight, abdominal fat weight and sebum thickness, *etc*. The measurement methods were strictly in accordance with *Poultry Production Performance Nomenclature and Measurement Statistical Methods* (NY/T 823-2004).

1.2.2 Flavor traits of meat.

1.2.2.1 Determination of intramuscular fat content (IMF). The leg muscle was taken and removed visible fat. The fresh samples were crushed and air-dried, and the IMF content was determined by Soxhlet extraction method. The IMF content mentioned in this paper was the percentage of fat content in chicken dry matter.

1.2.2.2 Determination of inosinic acid (IMF). Appropriate amount of samples were homogenized with a homogenizer, and 5 g of chicken samples were put into a 50 mL centrifuge tube. After 15 mL of 5% perchloric acid solution was added, the samples were stirred and mixed in a vortex mixer, and then shaken on a shaker for 10 min. After centrifuged at 4 000 r/min for 5 min, the supernatant was filtered into a 100 mL beaker through medium speed filter paper. The precipitate in the centrifuge tube was added with 15 mL of 5% perchloric acid solution for secondary extraction following the steps described above. The filtrates obtained were merged together. The solution was adjusted to pH 6.5 with 1 mol/L and 0.01 mol/L sodium hydroxide solution, then transferred to 100 mL volumetric flask and set to a constant volume with ultra-pure water. The solution was filtered by water-soluble filter membrane. The content was determined by liquid chromatograph: chromatographic column, HCC18 (6 mm×150 mm); mobile phase, 1% triethanolamine, pure methanol solution; flow rate, 0.8 mL/min; column temperature, 40 ℃; UV detection wavelength, 254 nm; injection volume, 20 μL. The sample concentration was: $C_i=Cs\times Aj/As$. Here, C stands for the concentration; A stands for the corresponding peak area; s stands for the standard sample; i stands for the sample.

1.2.2.3 Determination of muscle fiber diameter and density. Muscle fiber data were measured by Nikon 90i microscopic imaging system, and the diameter and density of muscle fiber were measured directly by Image-Pro plus5.1 software.

1.3 Data analysis SPSS16.0 was used to analyze the difference of slaughter performance and meat quality performance between cage rearing group and free-range farming group.

2 Results and Analysis

2.1 Comparative analysis of slaughter performance The slaughter performance of Dahen quality S07 line cocks at the age of 10 weeks under cage rearing and free-range farming conditions are shown in Tab.1. The live weight and carcass weight of cocks in cage rearing group were 1 368.5 and 1 241.5 g, respectively, and the dressing percentage was 90.7%. The percentage of half-eviscerated yield, percentage of eviscerated yield, percentage of leg muscle and percentage of breast muscle were 84.5%, 69.7%, 16.4%, 21.8% and 0.3%, respectively. The live weight and carcass weight of cocks in free-range farming group were 1 150.5 and 1 035.6 g, respectively, and the dressing percentage was 90.0%. The percentage of half-eviscerated yield, percentage of eviscerated yield, percentage of leg muscle and percentage of breast muscle were 80.2%, 65.0%, 15.2%, 23.0% and 0.06%, respectively. There were extremely significant differences in live weight, carcass weight and abdominal fat percentage ($P<0.01$), and significant differences in percentage of half-eviscerated yield, percentage of eviscerated yield, percentage of leg muscle and percentage of breast muscle ($P<0.05$), but no significant differences in dressing percentage between cage rearing and free-range farming groups.

The slaughter performance of S07 line cocks at the age of 22 weeks under cage rearing and free-range farming conditions are shown in Tab.2. The live weight and carcass weight of cocks in cage rearing group were 3 471.40 and 164.00 g, respectively, and the dressing percentage was 91.11%. The percentage of half-eviscerated yield, percentage of eviscerated yield, percentage of leg muscle and percentage of breast muscle were 86.30%, 74.03%, 16.30%, 24.64% and 2.53%, respectively. The live weight and carcass

weight of cocks in free-range farming group were 3 267.40 and 2 979.00 g, respectively, and the dressing percentage was 91.14%. The percentage of half-eviscerated yield, percentage of eviscerated yield, percentage of leg muscle and percentage of breast muscle were 85.04%, 71.42%, 16.48%, 24.42% and 1.58%, respectively. There were extremely significant differences in live weight, carcass weight and abdominal fat percentage ($P<0.01$), and significant differences in percentage of half-eviscerated yield and percentage of eviscerated yield ($P<0.05$), but no significant differences in dressing percentage, percentage of leg muscle and percentage of breast muscle between cage rearing and free-range farming groups. The results showed that feeding methods did not affect dressing percentage, percentage of leg muscle and percentage of breast muscle, but affected carcass weight, percentage of half-eviscerated yield, percentage of eviscerated yield and body fat deposition. In general, the meat production performance of cocks in cage rearing group was better than that of free-range farming group.

2.2 Comparative analysis of meat flavor traits The results of meat flavor indexes of cocks of 10 and 22 weeks of age in different groups are shown in Tab.3 and Tab.4. As shown in Tab.3, there were extremely significant difference in IMF content and muscle fiber density of 10-week-old cocks ($P<0.01$), significant difference in diameter of muscle fiber ($P<0.05$), and no significant difference in IMP content under different feeding methods. The IMF content in cage rearing group was significantly higher than that in free-range farming group, indicating that feeding method significantly affected the deposition of fat; the muscle fiber density in free-range farming group was significantly lower than that in the cage rearing group, because exercise promoted the development of muscle fiber tissue, which led to thickened muscle fibers and increased diameter, showing that the muscle tenderness was reduced and the muscle was more "chewy". As shown in Tab.4, there were extremely significant difference in IMF content and muscle fiber density of 22-week-old cocks ($P<0.01$), significant difference in diameter of muscle fiber ($P<0.05$), and no significant difference in IMP content under different feeding methods, which was basically consistent with that at 10 weeks of age. The IMF content and IMP content of chicken aged 10 and 22 weeks were compared. The deposition rules of IMF and IMP varied among different ages, and the deposition amount of IMF was significantly higher than

Tab.1 Statistical analysis of slaughter performance of S07 line cocks at the end of 10 weeks of age

Item	Live weight//g	Carcass weight//g	Dressing percentage//%	Percentage of half-eviscerated yield//%	Percentage of eviscerated yield//%	Percentage of breast muscle//%	Percentage of leg muscle//%	Abdominal fat percentage//%
Cage rearing group	1 368.5±83.1^{A}	1 241.5±78.7^{A}	90.7±1.2	84.5±1.3^{a}	69.7±1.7^{a}	16.4±0.7^{a}	21.8±0.8^{a}	0.30±0.3^{A}
Free-range farming group	1 150.5±85.2^{B}	1 035.6±76.4^{B}	90.0±1.3	80.2±2.1^{b}	65.0±2.3^{b}	15.2±0.3^{b}	23.0 ±0.8^{b}	0.06±0.1^{B}

Note: Different lowercase and capital letters in the same column represent significant and extremely significant differences at 0.05 and 0.01 levels, respectively; the same below.

Tab.2 Statistical analysis of slaughter performance of S07 line cocks at the end of 22 weeks of age

Item	Live weight//g	Carcass weight//g	Dressing percentage %	Percentage of half-eviscerated yield//%	Percentage of eviscerated yield//%	Percentage of breast muscle//%	Percentage of leg muscle//%	Abdominal fat percentage %
Cage rearing group	3 471.40±197.21^{A}	3 164.00±205.71^{A}	91.11±0.91^{a}	86.30±1.01^{a}	74.03±1.21^{a}	16.30±0.76^{a}	24.64±0.87^{a}	2.53±0.46^{A}
Free-range farming group	3 267.40±265.23^{B}	2 979.00±245.08^{B}	91.14±1.31^{a}	85.04±2.77^{b}	71.42±2.74^{b}	16.48±0.98^{a}	24.42 ±0.95^{a}	1.58±0.63^{B}

Tab.3 Statistical table of main meat quality indexes of S07 line cocks (10 weeks of age)

Item	IMF//%	IMP//mg/g	Diameter of muscle fiber//μm	Density of muscle fiber//individual/mm^2
Cage rearing group	2.01±0.55^{A}	2.39±0.08^{A}	29.86±0.02^{a}	969.55±218.05^{A}
Free-range farming group	1.60±0.47^{B}	2.48±0.12^{A}	32.19±0.03^{b}	828.66±331.43^{B}

Tab.4 Statistical table of main meat quality indexes of S07 line cocks (22 weeks of age)

Item	IMF//%	IMP//mg/g	Diameter of muscle fiber//μm	Density of muscle fiber//individual/mm^2
Cage rearing group	3.28±0.69^{A}	2.68±0.07^{A}	45.48±0.04^{a}	481.49±176.26^{A}
Free-range farming group	2.52±0.56^{B}	2.73±0.09^{A}	48.96±0.04^{b}	449.35±161.25^{B}

that of IMP. For example, the IMF content increased by 63.18% from 10 to 22 weeks of age in cage rearing group, while IMP content increased by only 12.13%. The IMF content increased by 57.50% in free-range farming group, while the IMP content increased by only 10.08%.

3 Discussion and Conclusion

3.1 Effect of breeding methods on slaughter performance Analysis of slaughter performance at the end of 10 weeks of age showed that there was no significant difference in dressing percentage between cage rearing group and free-range farming group, indicating that the dressing percentage of chickens from 6 to 10 weeks of age was not affected by feeding methods, which was consistent with the research results of Deng *et al*.[2] on the effects of different feeding methods on carcass traits of Gushi chickens and some exotic chickens. Meanwhile, the percentage of half-eviscerated yield, percentage of eviscerated yield and percentage of breast muscle in cage rearing group were significantly higher than those in free-range farming group, while the percentage of leg muscle and abdominal fat percentage were significantly and extremely lower than those in free-range farming group. The above results demonstrated that cage rearing can significantly improve the growth rate and partial meat production performance of quality chicken, but also significantly improve the deposition of abdominal fat[3]. Li *et al*.[4] analyzed the influence of free-range farming and cage rearing combination on the growth of local chickens and pointed out that free-range farming and cage rearing combination had a trend of increasing the percentage of leg muscle. Zheng *et al*. [5] compared the carcass quality of 12-week-old cocks under different feeding methods, and suggested that free-range farming could significantly improve the percentage of leg muscle, which is consistent with the result of this test that the percentage of leg muscle in free range group was significantly higher than that in cage rearing group, indicating that the increase of field activity of free-range farming chickens increased the percentage of leg muscle.

The dressing percentage, percentage of eviscerated yield and percentage of half-eviscerated yield of cocks at the end of 22 weeks of age were significantly higher than those at the end of 10 weeks of age, indicating that the growth potential of S07 line cocks of Dahen chickens is greater after 10 weeks of age. Chen *et al*.[6] compared the slaughter traits of chickens in free-range farming mode with those in cage rearing group, and found that feeding methods had no significant effect on dressing percentage, but had significant effect on percentage of eviscerated yield, percentage of half-eviscerated yield and abdominal fat rate. Sun *et al*.[7] studied the effects of cage rearing and free-range farming on slaughter performance of Wenchang chicken, and found that the live weight, carcass weight, percentage of eviscerated yield, percentage of half-eviscerated yield and abdominal fat percentage of caged chickens were significantly higher than those of free-range farming chickens. Qu *et al*.[8] analyzed the effect of breeding methods on slaughter performance of yellow chickens, and the results showed that compared with flat rearing group and free-range farming group, the percentage of breast muscle was the lowest and the percentage of leg muscle was the highest in cage rearing group, and the abdominal fat percentage was the lowest in free-range farming group. In conclusion, different breeding methods have great influence on slaughter traits of chickens, and the indexes of slaughter traits are different under different breeding methods. Generally speaking, the carcass weight, abdominal fat percentage, percentage of eviscerated yield and percentage of half-eviscerated yield of caged chickens were higher than those of free-range farming chickens. Most of the results are consistent with the results of this test, namely, the meat production performance of caged chickens is better than that of free-range farming chickens.

3.2 Effects of breeding methods on meat quality traits More and more research results have showed that IMP is an important substance affecting chicken flavor (delicate flavour) while IMF determines chicken flavor[9–11], and these two traits have become important indicators to measure meat quality[12,19]. In this study, the IMP content and IMF content of cocks in free-range farming group and cage rearing group at 10 and 22 weeks of age were compared and analyzed. The results showed that there was no significant difference in IMP content between the two groups at the same age, while the difference in IMF content was significant, specifically, the IMF content in cage rearing group was significantly higher than that in free-range farming group. This is consistent with the research results of Zhou *et al*.[13] on the influence of feeding methods on IMP content and IMF content of chicken. In addition, muscle fiber density is also an important index affecting meat quality. Generally, the greater the muscle fiber density, the finer the muscle fiber, the stronger the water-holding capacity, the more tender the meat quality, the relatively good the meat quality; on the contrary, the smaller the muscle fiber density, the thicker the diameter, the weaker the water-holding capacity, the rougher the meat quality, the relatively poor the meat quality[14–15]. Han *et al*.[16] showed that the muscle fiber density of free-range farming chickens was significantly lower than that of captive chickens; the muscle fiber density of chest muscle decreased significantly by 10.9%,

while the muscle fiber density of leg decreased by 42.9%, indicating that the muscle meat quality of free-range farming chickens was rougher than that of captive chickens. Wu *et al.*[17] analyzed the effects of free-range farming and cage rearing on muscle quality of Xuancheng chickens and pointed out that the muscle fiber diameter of leg muscle was significantly positively correlated with elasticity and chewiness, and the chewiness of leg muscle of caged chickens that were under free-range farming in early stage and cage rearing in late stage was significantly improved compared with that of whole term free-range farming chickens. In this test, the muscle fiber density of chickens in cage rearing group was extremely higher than those in free-range farming group at 10 and 20 weeks of age, indicating that the meat quality of chickens in free-range farming group was rough because movement promoted the development of muscle fiber organization, thickened the muscle fibers and increased the diameter, thus making the muscles feel more "chewy". This is in agreement with the research results of Lv[18].

The deposition of IMP and IMF were different in chickens at 10 and 22 weeks of age. Obviously, the deposition efficiency of IMF was higher than that of IMP after 10 weeks of age, and there was little change in IMP content. The content of IMP is related to the concentration of ATP. With the increase of age, the activity of ATP synthesis and degradation enzyme decreases, so that the amount of IMP also decreases; but the body's ability of using energy to synthesize fats gradually increases. Young chickens generally have fine muscle fiber and good taste, and the chicken also tastes better at this time, but chicken fat deposition is still little at this time, so chicken flavor is not enough. With the increase of age, fat deposition will increase, the IMF content of chicken will continue to increase to a certain level, and the flavor and taste will also reach the best. After adulthood, chickens have thickened muscle fiber diameter, decreased tenderness and increased abdominal fat percentage, but IMF will not increase or begin to decrease, and the overall taste of chicken decreases. Chen *et al.*[19] studied the deposition rules of IMP and IMF in chicken and pointed out that the IMF content increased with age, while IMP content did not change significantly with age. Wang *et al.*[20] also pointed out that free-range farming weeks of age had no significant effect on IMP content, which was basically consistent with the results of this study.

Overall, it can be concluded that compared with free-range farming mode, cage rearing had better meat production performance in modern poultry production, and free-range farming chickens had no significant advantages in meat flavor, for example, the IMF content reflecting meat flavor was lower than that of caged chickens, which is also consistent with the research results of other scholars. Fanatico *et al.*[21-22] believed that feeding methods had no significant effect on meat flavor, and variety and growth rate were the main reasons for the difference in meat flavor. Husak *et al.*[23] suggested that cage rearing, organic rearing and free-range farming had little influence on the quantity and quality of chicken products, and consumers' preference for free-range farming chickens might be based on some intangible value attributes.

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