Comparison of Egg Quality and Meat Quality of Shouguang Chicken, Gushi Chicken, and Lohmann Layers under a Mixed Indoor Feeding and Woodland Free-Range System: A Postprint

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Abstract

This study aimed to compare the egg quality and meat quality differences among Shouguang chickens, Gushi chickens, and Lohmann layers under a combined intensive and woodland free-range rearing system. A total of 120 hens from each breed (Shouguang chicken, Gushi chicken, and Lohmann layer) at 90 days of age were selected, with 4 replicates per breed and 30 birds per replicate, and fed conventional basal diets under the combined intensive and woodland free-range system until 180 days of age. The results showed that, compared with Shouguang and Gushi chickens, Lohmann layers exhibited significantly higher egg weight ($P<0.05$), but significantly lower yolk color, albumen height, and Haugh unit ($P<0.05$). The contents of zinc, selenium, calcium, protein, and fat in eggs, as well as the contents of fat and protein in muscle, were significantly higher in Shouguang and Gushi chickens than in Lohmann layers ($P<0.05$). The muscle drip loss rate and shear force of Shouguang and Gushi chickens were significantly lower than those of Lohmann layers ($P<0.05$), while meat color was significantly higher ($P<0.05$). The contents of glycine, glutamic acid, isoleucine, and umami amino acids in muscle of Shouguang and Gushi chickens were significantly higher than those in Lohmann layers ($P<0.05$). In conclusion, eggs from Shouguang and Gushi chickens had larger yolks, higher protein content, and richer nutritional elements, whereas eggs from Lohmann layers had higher water content and poorer protein quality; muscle from Shouguang and Gushi chickens had longer shelf life, higher inosine monophosphate and amino acid contents, more tender meat, and richer nutrition compared with Lohmann layers; among the three chicken breeds, Shouguang and Gushi chickens exhibited superior egg quality and meat quality.

Full Text

Comparison of Egg Quality and Meat Quality among Shouguang Chickens, Gushi Chickens and Roman Layers under Mixed Pattern of Dry-Lot Feeding and Woodland Stocking

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Abstract: This study aimed to compare egg quality and meat quality among Shouguang chickens, Gushi chickens, and Roman layers under a mixed pattern of dry-lot feeding and woodland stocking. One hundred twenty 90-day-old hens of each breed were selected, with each breed divided into 4 replicates of 30 birds each. The chickens were fed a conventional basal diet until 180 days of age under a mixed dry-lot feeding and woodland stocking system.

The results showed that compared with Shouguang and Gushi chickens, Roman layers had significantly higher egg weight (P<0.05) but significantly lower yolk color, albumen height, and Haugh unit (P<0.05). The contents of zinc, selenium, calcium, protein, and fat in eggs, as well as protein and fat contents in muscle, were significantly higher in Shouguang and Gushi chickens than in Roman layers (P<0.05). The drip loss rate and shear force of muscle in Shouguang and Gushi chickens were significantly lower than those of Roman layers (P<0.05), while their meat color was significantly higher (P<0.05). The contents of glycine, glutamic acid, isoleucine, and flavor amino acids in muscle were also significantly higher in Shouguang and Gushi chickens than in Roman layers (P<0.05). In summary, eggs from Shouguang and Gushi chickens had larger yolks, higher protein content, and richer nutrients, whereas Roman layer eggs had higher water content and poorer protein quality. Moreover, the muscle of Shouguang and Gushi chickens had a longer shelf life, higher inosinic acid and amino acid contents, better tenderness, and richer nutrition compared to Roman layers. Among the three breeds, Shouguang and Gushi chickens exhibited superior egg and meat quality.

Keywords: Shouguang chickens; Gushi chickens; Roman layers; egg quality; meat quality; nutrients

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Introduction

As a major producer and consumer of poultry eggs, China's egg production now accounts for nearly 50% of the world's total output, with egg quality being a primary concern for consumers. Important indicators for measuring egg quality include external characteristics such as egg weight and yolk color, as well as internal attributes like nutrient content. Egg quality is influenced by multiple factors including chicken breed, diet composition, and feeding management.

With rising living standards, consumer preferences for broiler chickens are transitioning from quantity to quality, placing greater emphasis on meat quality. According to global poultry industry trends, high-quality chicken meat will gradually dominate the world market and become mainstream in poultry production. Chicken meat quality is affected by various factors, among which breed is a major determinant.

China is rich in chicken genetic resources, including local breeds, improved breeds, and introduced breeds. Shouguang chickens are characterized by their tolerance to roughage, strong broodiness, and disease resistance. Their meat is firm and delicious, and their eggs are popular in urban and rural markets, commanding prices significantly higher than ordinary eggs. Gushi chickens are an excellent local dual-purpose breed developed through long-term selective breeding and are one of the nationally protected livestock and poultry breeds. Roman layers are a cultivated brown-shell layer line with advantages including high egg production performance, excellent feed conversion rate, superior egg quality, strong adaptability, and disease resistance, making them one of the world' s famous improved lines. This study investigated the egg and meat quality of these three breeds to compare their differences, providing a scientific basis for understanding their germplasm characteristics and for breed selection, conservation, and utilization, while also offering theoretical guidance for consumers seeking high-quality eggs and meat.

Materials and Methods

1.1 Experimental Animals and Grouping

One hundred twenty 90-day-old hens each of Shouguang chickens, Gushi chickens, and Roman layers were selected. Each breed was divided into 4 replicates with 30 chickens per replicate. The birds were fed conventionally until 180 days of age under a mixed pattern of dry-lot feeding and woodland stocking. The indoor stocking density was 6 birds/m^2, and the grazing area was 0.5 mu per replicate (1 mu 667 m^2). During the trial period, birds had free access to feed and water, with other routine management procedures followed. The basal diet was formulated according to NRC (1994) nutrient requirements for laying breeders, with composition and nutrient levels shown in Table 1 .

Table 1 Composition and nutrient levels of the basal diet (air-dry basis) %

Items	Content
Ingredients	
Corn	

Items	Content
Soybean meal	
CaHPO	
Oyster shell meal	
Premix[1])	
Soybean oil	
NaCl	
Lys	
Met	
Total	
Nutrient levels	
ME/(MJ/kg)[2])	
CP	
EE	
Ca	
AP	
Met	
DLys	

[1]) The premix provided the following per kg of diet: VA 7,500 IU, VD 2,200 IU, VE 8 IU, VK 2 mg, VB 2.3 mg, VB 4.5 mg, VB 6 mg, VB 0.016 mg, nicotinic acid 30 mg, pantothenic acid 10 mg, biotin 0.12 mg, folic acid 0.25 mg, Mn 80 mg, Fe 58 mg, Zn 80 mg, Cu 8 mg, I 1 mg, Se 0.3 mg.

[2]) ME was a calculated value, while the others were measured values.

1.2 Experimental Instruments

Electronic balance (A006, Leqi), outside micrometer (283-240, Mitutoyo, Japan), ultra-low temperature freezer (MDF-U386S, Panasonic, Japan), egg shape index gauge (NFN384, FHK, Japan), multifunctional egg quality tester (EMT-7300, Japan), bacterial incubator (SPX-70B, Beifang Instrument), muffle furnace (FR-1236, Shanghai Farui), tenderness meter (C-LM3, Tenovo), high-performance liquid chromatograph (Prominence UFLC, Shimadzu, Japan), high-speed tissue homogenizer (FSH-2, Honghua Instrument), high-speed centrifuge (HR/T20MM, Herexi), and amino acid automatic analyzer (L-8800, Hitachi, Japan).

1.3 Experimental Methods

At 180 days of age, 12 fresh eggs laid on the same day were randomly collected from each breed for determination of egg quality, nutrient content, and bacterial colony count. At the end of the trial, two chickens close to the average body weight were selected from each replicate for slaughtering. Breast muscle samples were taken within 5 minutes post-slaughter from the middle portion of the pectoralis muscle for determination of routine physicochemical indicators, meat quality, and inosinic acid and amino acid contents.

1.3.1 Egg Quality Determination Egg weight, yolk weight, and albumen weight were measured using an electronic balance. Yolk ratio and albumen ratio were calculated as the percentage of yolk weight and albumen weight relative to egg weight, respectively. Egg shape index was measured using an egg shape index gauge. Shell thickness was measured at the blunt end, middle, and sharp end using an outside micrometer, with the average value recorded. Albumen height, yolk color, and Haugh unit were determined using a multifunctional egg quality tester.

1.3.2 Bacterial Detection in Eggs After shell disinfection, a small hole was made in each egg. Albumen and yolk were separately aspirated into test tubes containing 3 mL of physiological saline, mixed well, and streaked onto sterilized nutrient agar and MacConkey agar plates. The plates were incubated at 37 °C for 18 hours, and colony numbers were observed.

1.3.3 Determination of Nutrient Content in Eggs Trace element contents in eggs were determined by flame atomic absorption spectrometry. Specific methods for sodium (Na), selenium (Se), zinc (Zn), iron (Fe), and calcium (Ca) followed GB/T 5009.91-2003, GB/T 5009.93-2010, GB/T 5009.14-2003, GB/T 5009.90-2003, and GB/T 5009.92-2003, respectively. Moisture, ash, protein, and fat contents were determined according to GB/T 5009.3-2010, GB/T 5009.4-2010, GB/T 5009.5-2010, and GB/T 5009.47-2003.

1.3.4 Determination of Routine Physicochemical Indicators in Chicken Muscle From each bird, 100 g of left breast muscle was taken and pooled by group for analysis. Moisture content was determined by oven drying; dry matter by oven method; crude fat by Soxhlet extraction; crude protein by micro-Kjeldahl method; and crude ash by muffle furnace incineration. Trace element contents were determined by flame atomic absorption spectrometry. Chromium (Cr), copper (Cu), and manganese (Mn) contents followed GB 5009.15-2014, GB/T 5009.13-2003, and GB/T 5009.90-2003, respectively, while other elements were determined as described in section 1.3.3.

1.3.5 Determination of Meat Quality Meat pH (pH min and pH h, measured at 45 min and 24 h post-slaughter), meat color, water loss rate, water holding capacity, drip loss rate, shear force, and muscle fiber diameter were determined according to methods described in *Meat Science of Livestock and Poultry* [11].

1.3.6 Determination of Inosinic Acid and Amino Acid Contents in Muscle Inosinic acid content was determined by high-performance liquid chromatography. Sample pretreatment followed the method of Ye et al. [12]. Mobile phase: 5% acetonitrile and 95% ammonium formate buffer at a flow rate of 1 mL/min. Detection wavelength: 254 nm.

Amino acid contents (except tryptophan) were determined using an amino acid automatic analyzer after acid hydrolysis or oxidative hydrolysis (for methionine and cysteine) of samples.

1.4 Statistical Analysis

Data were analyzed using the ANOVA procedure of SPSS 19.0 software, with means compared using LSD multiple comparison tests. Results are expressed as mean ± standard deviation.

Results

2.1 Comparison of Egg Quality among Three Breeds

As shown in Table 2 , the egg weight of Roman layers was 57.13 g, which was 63.84% and 51.94% heavier than that of Shouguang chickens (34.87 g) and Gushi chickens (37.60 g), respectively ($P<0.05$). Yolk color followed the pattern: Gushi chickens > Shouguang chickens > Roman layers, with Roman layers being significantly different from the other breeds ($P<0.05$). Significant differences in yolk ratio were observed between Roman layers and Gushi chickens ($P<0.05$) but not between Roman layers and Shouguang chickens ($P>0.05$). The albumen ratio of Shouguang chickens was significantly lower than that of Gushi chickens and Roman layers ($P<0.05$). Albumen height of Roman layers was significantly lower than that of Shouguang and Gushi chickens ($P<0.05$). The Haugh units of Shouguang and Gushi chickens were significantly higher than those of Roman layers ($P<0.05$).

Table 2 Egg quality of three chicken breeds

Items	Shouguang chickens	Gushi chickens	Roman layers
Egg weight/g	34.87±3.18b	37.60±2.98b	57.13±3.28a
Egg shape index	1.35±0.06	1.34±0.03	1.35±0.06
Yolk color	10.34±1.43a	10.36±0.72a	8.09±0.69b
Egg yolk ratio/%	32.57±3.76ab	29.03±1.68b	33.14±1.31a
Eggwhite ratio/%	45.31±2.32b	49.57±2.49a	47.55±2.16a
Shell thickness/mm	39.32±0.85	38.85±0.91	36.18±2.86
Albumen height/mm	5.41±1.29a	6.71±1.37a	3.02±0.55b
Haugh unit	79.52±7.81a	81.44±6.59a	48.26±5.53c

In the same row, values with no letter or the same letter superscripts mean no significant difference ($P>0.05$), while different small letter superscripts mean significant difference ($P<0.05$). The same as below.

2.2 Comparison of Nutrient Contents in Eggs

As shown in Table 3 , the Na content in eggs of Roman layers was significantly higher than that of Shouguang and Gushi chickens (P<0.05). Se content followed the pattern: Shouguang chickens > Gushi chickens > Roman layers, with significant differences among all three breeds (P<0.05). The Zn content in eggs of Shouguang and Gushi chickens was significantly higher than that of Roman layers (P<0.05). The Fe content in eggs of Shouguang chickens was significantly higher than that of Roman layers (P<0.05). The Ca content in eggs of Shouguang and Gushi chickens was significantly higher than that of Roman layers (P<0.05). Compared with Roman layers, Shouguang and Gushi chickens had significantly higher protein and fat contents in eggs (P<0.05).

Table 3 Nutrient contents of eggs from three chicken breeds

Items	Shouguang chickens	Gushi chickens	Roman layers
Na/(×10 ² mg/g)	143.01±4.58b	157.60±4.28c	165.02±5.28a
Se/(×10 ² mg/g)	0.29±0.02a	0.14±0.03b	0.01±0.002c
Zn/(×10 ² mg/g)	1.51±0.13a	1.46±0.72a	0.09±0.01b
Fe/(×10 ² mg/g)	2.05±0.76a	1.13±0.68ab	1.01±1.31b
Ca/(×10 ² mg/g)	52.01±4.32a	50.57±2.49a	45.01±2.16b
Moisture/%	75.81±1.15b	76.25±1.25ab	78.01±2.25a
Ash/%	0.86±0.07	0.91±0.06	1.01±0.14
Protein/%	12.61±1.21a	12.48±1.35a	8.50±1.35b
Fat/%	10.02±0.56a	9.58±0.64a	8.01±1.02b

2.3 Comparison of Bacterial Counts in Eggs

No bacteria were detected in eggs from any of the three breeds.

2.4 Comparison of Routine Physicochemical Indicators in Muscle

As shown in Table 4 , the crude fat and crude protein contents in muscle of Shouguang and Gushi chickens were significantly higher than those of Roman layers (P<0.05), while other routine physicochemical indicators showed no significant differences (P>0.05).

Table 4 Routine physical and chemical indexes in muscle of three chicken breeds

Items	Shouguang chickens	Gushi chickens	Roman layers
Moisture/%	77.72±0.71	77.03±1.18	76.32±0.82
DM/%	22.03±0.51	22.28±0.36	21.70±1.19
CP/%	0.69±0.04a	0.65±0.03a	0.49±0.03b
Ash/%	0.98±0.05	0.92±0.10	0.97±0.06
EE/%	1.83±0.32a	1.78±0.45a	0.98±0.25b
Cr/(×10 ² mg/g)	0.68±0.17	0.68±0.32	0.49±0.12

Items	Shouguang chickens	Gushi chickens	Roman layers
Cu/($\times 10^{2}$ mg/g)	0.41±0.06	0.40±0.09	0.37±0.07
Fe/($\times 10^{2}$ mg/g)	11.60±2.65	11.81±3.03	9.12±1.02
Mn/($\times 10^{2}$ mg/g)	0.48±0.01	0.49±0.08	0.42±0.06
Se/($\times 10^{2}$ mg/g)	0.29±0.05	0.28±0.04	0.15±0.06
Zn/($\times 10^{2}$ mg/g)	3.87±1.07	3.54±1.19	2.58±0.25

2.5 Comparison of Meat Quality

As shown in Table 5 , no significant differences were observed in pH min, pH h, water holding capacity, or muscle fiber diameter among the three breeds ($P>0.05$). However, meat color and water loss rate of Roman layers were significantly lower than those of Shouguang and Gushi chickens ($P<0.05$), while drip loss rate and shear force were significantly higher ($P<0.05$).

Table 5 Meat quality of three chicken breeds

Items	Shouguang chickens	Gushi chickens	Roman layers
pH min	5.73±0.39	5.63±0.18	5.82±0.32
pH h	5.63±0.39	5.53±0.18	5.32±0.32
Meat color (expressed by OD value)	0.43±0.03a	0.48±0.06a	0.31±0.09b
Water holding capacity/%	75.26±2.04	76.65±2.03	74.49±3.03
Water loss rate/%	23.23±0.05a	24.92±0.10a	21.97±0.06b
Drip loss rate/%	3.68±0.67b	3.48±0.82b	5.49±1.12a
Shear force/N	23.25±1.26b	24.40±1.09b	26.67±1.02a
Muscle fiber diameter/ m	22.60±2.15	21.81±3.03	23.42±2.02

2.6 Comparison of Inosinic Acid and Amino Acid Contents in Muscle

As shown in Table 6 , the inosinic acid content in muscle of Shouguang and Gushi chickens was significantly higher than that of Roman layers (P<0.05). The contents of glutamic acid, glycine, isoleucine, and flavor amino acids in muscle of Shouguang and Gushi chickens were also significantly higher than those of Roman layers (P<0.05). No significant differences were observed among the three breeds for other amino acids such as aspartic acid, serine, and histidine (P>0.05).

Table 6 Inosinic acid and amino acid contents in muscle of three chicken breeds

Items	Shouguang chickens	Gushi chickens	Roman layers
IMP	2.73±0.55a	2.56±0.10a	1.99±0.38b
Asp	8.43±0.32	8.48±0.45	8.46±0.32
Glu	13.26±0.33a	13.31±0.21a	12.39±0.45b
Ser	3.56±0.10	3.54±0.12	3.31±0.25
His	3.33±0.58	3.35±0.23	2.84±0.70
Gly	4.18±0.71a	4.12±0.36a	3.63±0.23b
Thr	4.09±0.14	4.06±0.16	3.75±0.36
Ala	5.75±0.27	5.78±0.28	5.12±0.52
Arg	6.17±0.29	6.11±0.13	5.59±0.59
Tyr	3.91±0.20	3.89±0.23	3.60±0.34
Val	4.20±0.22	4.23±0.25	3.79±0.44
Met	2.46±0.11	2.44±0.22	2.24±0.25
Phe	3.90±0.13	3.93±0.18	3.59±0.39
Ile	4.15±0.21a	4.19±0.11a	3.76±0.44b
Leu	7.44±0.33	7.36±0.21	6.76±0.72
Lys	7.97±0.38	7.87±0.24	7.27±0.13
Pro	3.37±0.49	3.32±0.29	3.11±0.29
Cys	0.56±0.22	0.60±0.33	0.67±0.22
Total AA	86.73±2.82	86.58±2.14	79.05±7.73
Flavor AA	37.79±1.02a	37.81±0.65a	35.19±1.14b

Discussion

High-quality eggs and meat are rich in nutrients, offering high nutritional value and market value. This study compared egg quality, meat quality, and nutrient contents in eggs and muscle among Shouguang chickens, Gushi chickens, and Roman layers to identify superior breeds.

Egg quality generally refers to external characteristics (such as weight) and internal contents (such as albumen viscosity, yolk color, yolk ratio, and Haugh unit). Larger eggs contain more contents, and increasing egg weight is an effective measure for improving egg production. Although Roman layers produced heavier eggs, they contained less dry matter and more moisture, indicating that egg weight alone does not guarantee high quality. Egg nutrients and flavor compounds are primarily concentrated in the yolk; therefore, yolk ratio and color depth are associated with nutritional richness and taste. Shouguang chickens had higher yolk ratios, while Gushi chickens exhibited deeper yolk color than other breeds. In intensive production, yolk color can be enhanced through genetic control, lipid supplementation, antioxidants, high calcium, and pharmaceuticals. The Haugh unit measures egg freshness and reflects thick albumen viscosity. Egg quality is typically classified as AA grade (above 72), A grade (60–72), or B grade (below 60), with higher Haugh units indicating better albumen quality and overall egg quality. Both Shouguang and Gushi chickens achieved AA grade Haugh units.

Meat quality comprises a series of comprehensive traits including meat color, water loss rate, drip loss rate, and shear force. Drip loss rate is related to protein solubility in post-slaughter chicken meat. Charged proteins in muscle bind substantial water, and when protein content decreases, drip loss rate increases. In this study, Roman layers exhibited the highest muscle drip loss rate, indicating greater protein dissolution and nutrient loss during cold storage. Meat color reflects comprehensive changes in chicken muscle physiology, biochemistry, and microbiology, with muscle optical density (OD) values positively correlating with crude fat content. Among the three breeds, Roman layers had the lowest meat color OD value, corresponding to their lowest crude fat content. Shear force is positively correlated with meat tenderness; higher crude fat content results in lower shear force, while rapid protein deposition increases myofibrillar degradation enzyme activity, reducing post-slaughter shear force. Shouguang chickens had the highest crude fat and crude protein contents in muscle, corresponding to the lowest shear force, consistent with these findings and indicating superior meat tenderness.

Eggs and meat are rich in Na, Se, Zn, Fe, Ca, Cr, Mn, Cu, and other elements essential for normal human metabolism. Na is the main cation in extracellular fluid, and excessive levels can cause sodium retention and affect osmotic pressure. Se inhibits free radical activity and participates in lipid metabolism. Zn is a component of various metalloenzymes and maintains immune function. Fe is a component of red blood cells and participates in oxygen transport. Cr has therapeutic effects on diabetes, Mn provides anti-aging benefits, and Cu maintains normal bone, blood vessel, and skin function. This study found that Shouguang chickens had the lowest Na content but the highest Se, Zn, Fe, and Ca contents in eggs, followed by Gushi chickens with similar values, while Roman layers had the lowest levels of these elements. No significant differences were observed in Cr, Cu, Fe, Mn, Se, or Zn contents in muscle among the three breeds.

Fat serves as a source of fat-soluble vitamins and essential fatty acids and is the primary site for deposition of aromatic compounds, potentially providing richer flavor and nutrition. Protein plays crucial physiological roles in metabolism and growth, containing essential amino acids that closely match human requirements.

In this study, Shouguang and Gushi chickens had significantly higher fat and protein contents in both eggs and muscle compared to Roman layers, indicating superior egg and meat quality.

The delicious taste of chicken meat is primarily formed through chemical reactions involving flavor precursors such as flavor nucleotides and free amino acids. Inosinic acid is one of the important umami substances in chicken meat. Glycine, alanine, serine, and proline impart sweetness, while aspartic acid and glutamic acid provide umami taste; these six amino acids are considered flavor amino acids. The composition and content of flavor amino acids influence meat palatability. This study found that Shouguang chickens had the highest inosinic acid content in muscle, followed by Gushi chickens, with Roman layers having the lowest. Additionally, Shouguang and Gushi chickens had higher contents of glycine, glutamic acid, and flavor amino acids in muscle. Therefore, Shouguang and Gushi chickens demonstrated better meat quality compared to Roman layers.

Shouguang chickens, Gushi chickens, and Roman layers all maintained good egg and meat quality under the mixed dry-lot feeding and woodland stocking system, though breed had a significant impact on these traits. First, Shouguang and Gushi chickens produced eggs with deep yolk color, large yolk size, excellent albumen height and Haugh units, consistent with their rich nutrient content and high protein and fat levels, indicating superior egg quality. Roman layers produced heavier eggs but with higher albumen ratio, lower albumen height and Haugh units, and higher moisture content, resulting in poorer egg quality compared to Shouguang and Gushi chickens. Second, Roman layers exhibited poorer water holding capacity and shorter shelf life, while Shouguang and Gushi chickens had longer shelf life, juicier meat, higher crude protein and crude fat contents, and greater inosinic acid and flavor amino acid contents, resulting in more tender and nutritious meat. Third, comprehensive comparison revealed that among the three breeds, Shouguang and Gushi chickens exhibited superior egg and meat quality.

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Note: Figure translations are in progress. See original paper for figures.