Comparative Study on Muscle Nutritional Composition between Bashang Long-tail Chickens and Hy-Line Brown Chickens (Postprint)

Authors: Duan Lingxin, Chang Li, Li Xianglong, Peng Yongdong, Zhang Chuansheng, He Ying, Lu Chunxiang, Deng Ying, Dai Haoyang

Date: 2017-10-10T00:00:00+00:00

Abstract

The Bashang Long-tail Chicken is the only local poultry breed from Hebei Province listed in the China Animal Genetic Resources. To better protect and utilize the Bashang Long-tail Chicken resources, this experiment selected 180 birds each of this breed and Hy-Line Brown Chickens at 200 days of age under the same feeding and management conditions, with each group randomly divided into 5 replicates of 36 birds each. Under the same conditions, they were raised conventionally, and at 230 days of age, 10 chickens were selected from each group for slaughter, and a comparative analysis of the main nutritional components in muscle was conducted. The results showed: 1) The crude protein and crude fat contents in the muscle of Bashang Long-tail Chickens showed no significant difference compared with those of Hy-Line Brown Chickens ($P > 0.05$). 2) The essential amino acid contents in breast and leg muscles showed no significant difference between the two breeds ($P > 0.05$); the flavor amino acids (glutamic acid, aspartic acid, glycine, and alanine) in the muscle of Bashang Long-tail Chickens were significantly higher than those of Hy-Line Brown Chickens ($P < 0.05$), while the content of the bitter-tasting amino acid phenylalanine in leg muscle was significantly lower than that of Hy-Line Brown Chickens ($P < 0.05$). 3) The contents of unsaturated fatty acids, saturated fatty acids, and total fatty acids in the leg muscle of Bashang Long-tail Chickens were significantly lower than those of Hy-Line Brown Chickens ($P < 0.05$); the contents of arachidonic acid and docosahexaenoic acid in the leg muscle of Bashang Long-tail Chickens were significantly higher than those of Hy-Line Brown Chickens ($P < 0.05$). 4) The contents of magnesium ($P < 0.01$) and iron ($P < 0.05$) in the breast muscle of Bashang Long-tail Chickens were significantly higher than those of Hy-Line Brown Chickens, and the contents of sodium ($P < 0.05$), magnesium ($P < 0.01$), and iron ($P < 0.05$) in the leg muscle were significantly higher than those of Hy-Line Brown Chickens. Thus, both chicken breeds exhibited excellent muscle

quality, and the muscle quality of Bashang Long-tail Chickens was superior to that of Hy-Line Brown Chickens.

Full Text

Comparative Study on Muscle Nutritional Components Between Bashang Long-tail Chicken and Hy-Line Brown Chicken

Duan Lingxin[1], Chang Li[2,3]*, Li Xianglong[1], Peng Yongdong[1], Zhang Chuansheng[1], He Ying[1], Lu Chunxiang[1], Deng Ying[1], Dai Haoyang[1]

[1]College of Animal Science and Technology, Hebei Normal University of Science & Technology, Qinhuangdao 066004, China
[2]College of Animal Science and Technology, Agricultural University of Hebei, Baoding 071000, China
[3]Agriculture Bureau of Qinhuangdao, Qinhuangdao 066004, China

Abstract: Bashang long-tail chicken is the only local poultry breed from Hebei Province included in the *Animal Genetic Resources in China*. To better protect and develop this resource, 180 Bashang long-tail chickens and 180 Hy-Line brown chickens at 200 days of age were selected under identical feeding and management conditions, randomly divided into 5 replicates with 36 birds each. After conventional feeding, 10 chickens from each group were slaughtered at 230 days of age for comparative analysis of main muscle nutrients. The results showed: (1) No significant differences in crude protein and crude fat contents between the two breeds ($P>0.05$). (2) Essential amino acid contents in breast and leg muscles showed no significant differences between breeds ($P>0.05$); however, flavor amino acids (glutamic acid, aspartic acid, glycine, and alanine) were significantly higher in Bashang long-tail chicken ($P<0.05$), while bitter amino acid phenylalanine in leg muscle was significantly lower ($P<0.05$). (3) Unsaturated fatty acids, saturated fatty acids, and total fatty acids in leg muscle were significantly lower in Bashang long-tail chicken ($P<0.05$), while arachidonic acid and docosahexaenoic acid (DHA) were significantly higher ($P<0.05$). (4) Magnesium ($P<0.01$) and iron ($P<0.05$) in breast muscle, and sodium ($P<0.05$), magnesium ($P<0.01$), and iron ($P<0.05$) in leg muscle were significantly higher in Bashang long-tail chicken. These findings indicate that both breeds possess good meat quality, with Bashang long-tail chicken showing superior muscle quality compared to Hy-Line brown chicken.

Keywords: Bashang long-tail chicken; Hy-Line brown chicken; amino acid; fatty acid; mineral element

Introduction

Bashang long-tail chicken is an excellent local breed resource in China, primarily an egg-type dual-purpose breed distributed in the Bashang region of

Chengde and Zhangjiakou in northern Hebei Province. Characterized by cold resistance, coarse feed tolerance, and strong adaptability, it is the only local poultry breed from Hebei included in the *Animal Genetic Resources in China: Poultry* (2011). Previous research has investigated breed resource surveys and growth-development measurements, but no studies have reported on meat quality determination. Therefore, this study randomly selected 200-day-old Bashang long-tail hens under identical caged feeding conditions, using same-age Hy-Line brown layers as controls, to determine meat quality and nutritional components, providing data for conservation, breeding, and development of this local breed.

1. Materials and Methods

1.1 Experimental Materials

Muscle samples were obtained from Bashang long-tail chickens at the Bashang Long-tail Chicken Conservation Base of Zhangjiakai Jingxingyuan Ecological Agriculture Co., Ltd., with Hy-Line brown chickens under the same feeding management conditions serving as controls.

1.2 Main Instruments

Gas chromatograph (Shimadzu GC-2010, Japan), high-performance liquid chromatograph (Shimadzu LC-20AB, Japan), amino acid analyzer (Hitachi L-8900), atomic absorption spectrophotometer, Kjeldahl nitrogen analyzer, Soxhlet fat extractor, muffle furnace, and meat grinder (Joyoung JYS-A950).

1.3 Experimental Groups

One hundred eighty 200-day-old Bashang long-tail chickens and 180 Hy-Line brown chickens were randomly divided into 5 replicates of 36 birds each. Both breeds were fed the same peak-layer complete feed and housed in a semi-open three-tier cage system. Dry mash was provided three times daily with ad libitum access to feed and water. Daily lighting duration was 16 hours. Basal diet composition and nutrient levels are shown in Table 1 .

Table 1 Basal diet composition and nutrient levels (air-dry basis), %

Ingredients	Content	Nutrient levels[2]	Content
Corn		Metabolic energy (MJ/kg)	
Soybean meal		Crude protein (CP)	
CaHPO		Calcium (Ca)	
Limestone		Total phosphorus (TP)	
Premix[1]		Available phosphorus (AP)	
Total			

[1]Premix provided per kilogram of diet: VA 10,000 IU, VD 3,500 IU, VE 20 IU,

VK 2 mg, thiamine 1 mg, riboflavin 5 mg, calcium pantothenate 6 mg, nicotinic acid 30 mg, pyridoxine 6 mg, biotin 1.5 mg, folic acid 2.5 mg, VB 2 mg, choline 500 mg, Mn 65 mg, I 0.8 mg, Fe 60 mg, Cu 8 mg, Zn 80 mg, Se 0.3 mg.

[2]Metabolic energy was calculated, while others were measured values.

After 30 days of feeding, 10 birds were randomly selected from each group and slaughtered at 230 days of age. Following bleeding and evisceration, 200 g of left and right breast and leg muscles were collected, placed in plastic ziplock bags, and frozen at -20°C. Muscle chemical composition was determined in our laboratory, while other indices were analyzed by the Beijing Institute of Nutritional Resources.

1.4 Determination Methods

1.4.1 Muscle Chemical Composition Determination Breast and leg muscle samples were ground three times using a meat grinder. Moisture, crude protein, and crude fat contents were determined according to GB/T 9695.15—2008, GB/T 9695.11—2008, and GB/T 9695.7—2008, respectively. Each sample was analyzed in triplicate, with arithmetic means used as final values.

1.4.2 Amino Acid and Fatty Acid Content Determination Sample pretreatment: Frozen muscle samples were thawed at 4°C, ground uniformly, and approximately 100 mg was used for analysis. Seventeen amino acids were determined according to GB/T 5009.124—2003. Tryptophan was hydrolyzed with 4.2 mol/L NaOH, while other amino acids were hydrolyzed with 6 mol/L HCl, then analyzed using a Hitachi L-8900 amino acid analyzer. Fatty acids were analyzed by gas chromatography according to GB/T 22223—2008.

1.4.3 Muscle Cholesterol Determination Analyzed by high-performance liquid chromatography according to GB/T 22220—2008.

1.4.4 Muscle Mineral Element Determination Analyzed by atomic absorption spectrophotometry: Cu (GB/T 5009.13—2003), Zn (GB/T 5009.14—2003), Mg, Fe, Mn (GB/T 5009.90—2003), K, Na (GB/T 5009.91—2003), and Ca (GB/T 5009.92—2003).

1.5 Statistical Analysis

Data were analyzed by sample t-test using SPSS 13.0 and expressed as mean ± standard deviation.

2. Results

2.1 Muscle Chemical Composition of Bashang Long-tail and Hy-Line Brown Chickens

As shown in Table 2 , no significant differences were observed in crude protein and crude fat contents between breeds (P>0.05). Between muscle parts, crude protein in breast muscle was significantly higher than in leg muscle (P<0.05), while crude fat in breast muscle was extremely significantly lower than in leg muscle (P<0.01).

Table 2 Muscle chemical component of Bashang long-tail and Hy-Line brown chickens, %

Items	Breast muscle		Leg muscle	
	Bashang long-tail	Hy-Line brown	Bashang long-tail	Hy-Line brown
Dry matter	24.70±0.46	24.9524±0.4125±0.27		24.28±0.60
Crude protein	23.17±0.77	23.4220±0.4538±0.46		19.30±0.90
Crude fat	1.71±0.49	2.75±4.0328±0.32		5.03±1.54

Between different breeds, values in the same row with adjacent lowercase letter superscripts indicate significant difference (P<0.05), alternate lowercase letters indicate extremely significant difference (P<0.01), and same letters or no letters indicate no significant difference (P>0.05). Between different muscle parts of the same breed, values in the same row with adjacent uppercase letter superscripts indicate significant difference (P<0.05), alternate uppercase letters indicate extremely significant difference (P<0.01), and same letters or no letters indicate no significant difference (P>0.05). The same as below.

2.2 Muscle Amino Acid Content of Bashang Long-tail and Hy-Line Brown Chickens

As shown in Table 3 , breed comparison revealed that leucine (P<0.01), threonine (P<0.01), serine (P<0.01), aspartic acid (P<0.01), glutamic acid (P<0.05), and alanine (P<0.01) in breast muscle were significantly or extremely significantly higher in Bashang long-tail chicken, while valine (P<0.01), tyrosine (P<0.01), and proline (P<0.05) were significantly or extremely significantly lower compared to Hy-Line brown chicken; other amino acids showed no significant differences (P>0.05). In leg muscle, leucine (P<0.05), serine (P<0.05), aspartic acid (P<0.01), and alanine (P<0.01) were significantly or extremely significantly higher in Bashang long-tail chicken, while phenylalanine (P<0.05) and tyrosine (P<0.01) were significantly or extremely significantly lower; remaining amino acids showed no significant differences (P>0.05).

Between muscle parts, phenylalanine in Bashang long-tail breast muscle was extremely significantly higher than in leg muscle (P<0.01), while tryptophan (P<0.01), isoleucine (P<0.05), valine (P<0.01), histidine (P<0.01), tyrosine (P<0.05), aspartic acid (P<0.05), and alanine (P<0.01) were significantly or extremely significantly lower in breast muscle. In Hy-Line brown chicken, leucine (P<0.05), valine (P<0.01), threonine (P<0.01), lysine (P<0.05), histidine (P<0.01), aspartic acid (P<0.05), and alanine (P<0.01) were significantly or extremely significantly lower in breast muscle, with total amino acids also extremely significantly lower (P<0.01).

Table 3 Amino acid contents in muscle of Bashang long-tail and Hy-Line brown chickens, %

Items	Breast muscle		Leg muscle	
	Bashang long-tail	Hy-Line brown	Bashang long-tail	Hy-Line brown
Tryptophan	0.17±0.05	0.18±0.203±0.01		0.21±0.06
Isoleucine	0.83±0.04	0.86±0.904±0.06		0.89±0.04
Leucine	1.80±0.08	1.58±1.924±0.13		1.69±0.07
Valine	0.90±0.05	1.01±1.062±0.04		1.12±0.07
Threonine	0.90±0.04	0.84±0.961±0.05		0.90±0.04
Lysine	1.80±0.09	1.75±1.925±0.12		1.87±0.07
Phenylalanine	0.83±0.03	0.80±0.751±0.04		0.87±0.08
Methionine	0.57±0.03	0.58±0.602±0.04		0.60±0.04
Histidine	0.59±0.05	0.59±1.023±0.03		0.94±0.19
Tyrosine	0.03±0.01	0.64±0.041±0.00		0.67±0.05
Arginine	1.30±0.06	1.26±1.307±0.10		1.31±0.09
Serine	0.84±0.04	0.76±0.803±0.04		0.78±0.02
Glycine	0.89±0.06	0.87±0.912±0.03		0.92±0.08
Aspartic acid	2.03±0.09	1.82±2.206±0.10		1.97±0.10
Glutamic acid	3.46±0.15	3.20±3.379±0.32		3.20±0.20
Alanine	1.37±0.06	1.12±1.533±0.09		1.20±0.04
Proline	0.58±0.03	0.66±0.577±0.06		0.71±0.13
Total	18.87±0.78	18.52±20.123±1.13		19.83±0.77

2.3 Muscle Fatty Acid and Cholesterol Content of Bashang Long-tail and Hy-Line Brown Chickens

Breed comparison: As shown in Table 4 , no significant differences were observed in essential and non-essential fatty acids between breeds in breast muscle (P>0.05), except for -linolenic acid. However, palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid, arachidonic acid, and docosahexaenoic acid (DHA) were lower in Bashang long-tail chicken. In leg muscle, myristic acid (P<0.05), palmitic acid (P<0.01), linoleic acid (P<0.01), and -linolenic acid (P<0.01) were significantly or extremely significantly lower in Bashang long-tail chicken, while arachidonic acid and DHA were significantly higher (P<0.05). Palmitoleic acid, stearic acid, and oleic acid showed no significant differences between breeds in either muscle type (P>0.05), though values were lower in Bashang long-tail chicken. These results demonstrate breed effects on fatty acid content and composition. As shown in Table 5 , no significant difference in muscle cholesterol content was observed between breeds (P>0.05).

Muscle part comparison: Table 4 shows that palmitic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid, and arachidonic acid were significantly or extremely significantly higher in leg muscle than breast muscle for both breeds (P<0.05 or P<0.01). DHA content showed no significant difference between breast and leg muscle in Bashang long-tail chicken (P>0.05), but was significantly higher in breast muscle of Hy-Line brown chicken (P<0.05). Table 5 indicates no significant difference in cholesterol content between breast and leg muscle in Hy-Line brown chicken (P>0.05), while an extremely significant difference was observed in Bashang long-tail chicken (P<0.01).

Table 4 Fatty acid contents in muscle of Bashang long-tail and Hy-Line brown chickens, g/100g

Items	Breast muscle		Leg muscle	
	Bashang long-tail	Hy-Line brown	Bashang long-tail	Hy-Line brown
Myristic acid (C14:0)	<0.01	0.02±00.031±0.00		
Palmitic acid (C16:0)	0.26±0.06	0.44±0.677±0.14		0.94±0.16
Margaric acid (C17:0)	<0.01	<0.01	<0.01	
Stearic acid (C18:0)	0.13±0.03	0.18±0.307±0.04		0.36±0.05
Arachidic acid (C20:0)	<0.01	<0.01		
Behenic acid (C22:0)	<0.01	<0.01		
Palmitoleic acid (C16:1)	0.02±0.01	0.03±0.092±0.02		0.10±0.02
Oleic acid (C18:1)	0.35±0.10	0.61±1.030±0.26		1.49±0.30
Eicosenoic acid (C20:1)	<0.01	0.01±0.010±0.00		<0.01

Items	Breast muscle		Leg muscle	
Nervonic acid (C24:1)	<0.01	0.01±0.00	<0.01	
Linoleic acid (C18:2)	0.20±0.04	0.49±0.35	0.63±0.17	1.19±0.28
-Linolenic acid (C18:3)	<0.01	0.01±0.00	0.01±0.00	
-Linolenic acid (C18:3)	0.00±0.01	0.01±0.01	0.01±0.01	0.04±0.01
Eicosadienoic acid (C20:2)	<0.01	0.01±0.00	<0.01	
Dihomo- -linolenic acid (C20:3)	<0.01	<0.01	0.01±0.00	<0.01
Arachidonic acid (C20:4)	0.11±0.02	0.12±0.02	0.17±0.01	0.14±0.02
DHA (C22:6)	0.01±0.01	0.02±0.01	0.02±0.01	0.01±0.00
Saturated fatty acids (SFA)	0.39±0.09	0.63±0.25	1.02±0.18	1.34±0.21
Monounsaturated fatty acids (MUFA)	0.37±0.11	0.65±0.32	1.23±0.28	1.60±0.32
Polyunsaturated fatty acids (PUFA)	0.33±0.06	0.64±0.37	0.93±0.17	1.40±0.30
Unsaturated fatty acids (UFA)	0.70±0.16	1.29±0.68	2.16±0.44	3.00±0.58
Total fatty acids (TFA)	1.09±1.25	1.92±0.93	3.19±0.60	4.34±0.78

ND: Not detected.

Table 5 Cholesterol content in muscle of Bashang long-tail and Hy-Line brown chickens, mg/100g

	Breast muscle	Leg muscle
	Bashang long-tail	Hy-Line brown
Cholesterol	35.34±4.23	40.64±10.01

2.4 Muscle Mineral Element Content of Bashang Long-tail and Hy-Line Brown Chickens

Breed comparison: As shown in Table 6 , magnesium ($P<0.01$) and iron ($P<0.05$) in breast muscle, and sodium ($P<0.05$), magnesium ($P<0.01$), and iron ($P<0.05$) in leg muscle were significantly or extremely significantly higher in Bashang long-tail chicken compared to Hy-Line brown chicken.

Muscle part comparison: Table 6 shows that sodium ($P<0.01$), calcium ($P<0.05$), iron ($P<0.01$), and zinc ($P<0.05$) in Bashang long-tail breast muscle were significantly or extremely significantly lower than in leg muscle, while magnesium was extremely significantly higher ($P<0.01$). In Hy-Line brown chicken, sodium ($P<0.01$), iron ($P<0.01$), and zinc ($P<0.05$) in breast muscle were significantly or extremely significantly lower than in leg muscle, while magnesium was extremely significantly higher ($P<0.01$).

Table 6 Mineral element contents in muscle of Bashang long-tail and Hy-Line brown chickens, mg/100g

Items	Breast muscle		Leg muscle	
	Bashang long-tail	Hy-Line brown	Bashang long-tail	Hy-Line brown
Sodium (Na)	339.43±32.97	303.78±30.09	286.56±44.50	308.25±24.74
Calcium (Ca)	45.94±5.58	47.06±3.78	77.18±5.03	68.11±2.93
Magnesium (Mg)	3.72±0.39	3.53±0.63	4.53±0.42	4.13±0.64
Iron (Fe)	35.86±0.88	31.55±1.58	28.43±0.43	25.38±0.59
Zinc (Zn)	0.67±0.05	0.57±0.04	1.67±0.04	1.49±0.14
Manganese (Mn)	0.56±0.02	0.53±0.04	2.63±0.26	2.50±0.56
Copper (Cu)	<0.01	<0.01	<0.01	<0.01
	0.01±0.00	0.02±0.01	<0.01	<0.01

3. Discussion

3.1 Muscle Chemical Composition

Intramuscular fat content affects chicken tenderness, juiciness, and flavor, serving as an important consumer selection criterion. Optimal eating quality occurs when intramuscular fat reaches 3.0%-7.5%, producing smooth, fatty-but-not-greasy meat; values below 2.5% result in dry, tough texture. The average fat content in Bashang long-tail muscle approaches 3.0%, indicating optimal eating quality. Breast muscle fat content of 1.75% accounts for 18%-20% of whole carcass weight, which may be perceived as poor texture by consumers preferring breast meat, though this does not negate the overall quality of Bashang long-tail chicken. This study found lower crude fat contents in both breast and leg muscles of 33-week-old Bashang long-tail chickens compared to Hy-Line brown chickens, possibly due to age and breed effects on fat deposition. Regarding crude protein, both breeds showed significantly higher contents in breast muscle than leg muscle, indicating superior protein nutrition in breast meat.

3.2 Muscle Amino Acid and Fatty Acid Content

Essential amino acids are primary indicators for evaluating muscle nutritional value. The proportions of eight essential amino acids to total amino acids were 41.34% and 41.51% in Bashang long-tail breast and leg muscles, and 41.04% and 41.10% in Hy-Line brown muscles, respectively—all meeting the FAO/WHO requirement of 40% for ideal protein. The essential-to-non-essential amino acid ratios also exceeded the FAO/WHO requirement of 60%.

Meat palatability depends largely on flavor amino acid composition. Among four flavor amino acids, glutamic acid (Glu) and aspartic acid (Asp) are characteristic umami amino acids (with Glu being the strongest), while glycine (Gly) and alanine (Ala) are characteristic sweet amino acids. Average flavor amino acid contents were 7.75% and 8.01% in Bashang long-tail breast and leg muscles, significantly higher than 7.01% and 7.29% in Hy-Line brown chicken. Phenylalanine, a bitter amino acid, was significantly lower in Bashang long-tail leg muscle. Based on essential amino acid proportion and flavor/bitter amino acid composition, Bashang long-tail chicken demonstrates superior amino acid nutritional value.

Regarding fatty acids, most fatty acids including linoleic acid, palmitic acid, saturated fatty acids, polyunsaturated fatty acids, and total fatty acids were significantly lower in Bashang long-tail leg muscle. Low polyunsaturated fatty acid intake affects blood lipid health, suggesting that regular consumers of Bashang long-tail chicken should supplement through other sources. Fatty acid content is a primary factor affecting muscle flavor and represents the first choice for health-conscious consumers seeking low-fat diets. Essential fatty acids are necessary components for cell membrane synthesis and indispensable for nutritional evaluation. Arachidonic acid, one of three essential fatty acids, serves as a precursor for various bioactive substances, participating in hematopoiesis and immune regulation with important roles in disease pathophysiology. DHA, known as "brain gold," is a structural membrane component comprising up to 20% of human cerebral cortex and 50% of retinal tissue, crucial for brain and retinal health. This study found significantly higher arachidonic acid and DHA in Bashang long-tail leg muscle, demonstrating clear advantages in these fatty acids. In vivo, arachidonic acid is derived from linoleic acid via enzymatic conversion, while DHA is synthesized from -linolenic acid through carbon chain elongation and desaturation. Interestingly, the precursors linoleic acid and -linolenic acid were significantly lower in Bashang long-tail chicken, suggesting stronger conversion capacity to arachidonic acid and DHA in leg muscle.

3.3 Muscle Mineral Element Content

Mineral elements are one of six essential nutrients for normal human growth and development. Though required in small amounts, they perform vital physiological functions. Iron is a hemoglobin component maintaining oxygen transport; zinc is a component of dozens of enzymes related to brain development and intelligence, and maintains epithelial and mucosal integrity. Among eight measured mineral elements, Bashang long-tail chicken showed higher average values than Hy-Line brown chicken for most elements, particularly magnesium and iron in both muscle types. For populations with magnesium deficiency due to high meat and low vegetable consumption, Bashang long-tail chicken offers both meat satisfaction and magnesium supplementation. For urban and rural residents commonly deficient in iron, zinc, and calcium, Bashang long-tail chicken represents an excellent dietary choice.

As a precious poultry genetic resource in Hebei Province, Bashang long-tail chicken exhibits not only excellent egg production value, strong adaptability, and ornamental qualities, but also significantly higher contents of essential amino acids, flavor amino acids, arachidonic acid, DHA, and minerals compared to the widely raised Hy-Line brown chicken, establishing it as a high-quality local breed.

References

[1] Chen Guohong. *Poultry Genetic Resources in China* [M]. Shanghai: Shanghai Scientific & Technical Publishers, 2004: 39-41.

[2] Liu Xiaohui, Li Xianglong, Zhou Rongyan, et al. Investigation report on Bashang long-tail chicken breed resources [J]. *China Animal Husbandry & Veterinary Medicine*, 2014, 41(6): 182-187.

[3] Liu Xiaohui, Li Xianglong, Zhou Rongyan, et al. Study on growth and development patterns of Bashang long-tail chicken during brooding period [J]. *Jilin Agricultural Sciences*, 2015, 40(1): 76-81.

[4] Liu Xiaohui, Li Xianglong, Zhou Rongyan, et al. Study on growth and development patterns of Bashang long-tail chicken during growing period [J]. *Hubei Agricultural Sciences*, 2016, 55(2): 418-421, 424.

[5] Xi Pengbin, Jiang Zongyong, Lin Yingcai, et al. Research progress on chicken meat quality evaluation methods [J]. *Chinese Journal of Animal Nutrition*, 2006, 18(Suppl.): 347-352.

[6] Kerry J, Kerry J, Ledward D. *Modern Meat Processing and Quality Control* [M]. Translated by Ren Fazheng. Beijing: China Agricultural University Press, 2006: 24.

[7] Ma Chuang. World meat production and consumption trends [J]. *China Poultry Industry Herald*, 2010, 27(5): 2-7.

[8] Zeng Guangzhi. Amino acid taste and sweeteners [J]. *Chemistry Bulletin*, 1990(8): 1-9.

[9] Jiang Ying, Xu Ying, Zhu Gengbo. Human taste and amino acid flavor [J]. *Amino Acids and Biotic Resources*, 2002, 24(4): 70.

[10] Lang Liwei, Wang Hongyun, Hu Bei, et al. Research progress on polyunsaturated fatty acids in cancer and inflammatory diseases [J]. *Chinese Journal of Biochemical Pharmaceutics*, 2014, 34(1): 153-155, 158.

[11] Cao Wanxin, Meng Ju, Tian Yuxia. Research progress on physiological functions and applications of DHA [J]. *China Oils and Fats*, 2011, 36(3): 1-4.

[12] Baucells MD, Crespo N, Barroeta AC, et al. Incorporation of different polyunsaturated fatty acids into eggs [J]. *Poultry Science*, 2000, 79(1): 51-59.

[13] Ma Fengxi. Eating refined foods may cause magnesium deficiency [N]. *China Women' s News*, 2006-11-21(2).

[14] Yu Xiaodong, Chai Weizhong. Report on China' s fortified food industry development [C]// *China Nutrition Industry Development Report (2006).* Beijing: Public Nutrition and Development Center, 2006.

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