Journal of Zhejiang University-SCIENCE B (Biomedicine & Biotechnology)
ISSN 1673-1581 (Print); ISSN 1862-1783 (Online)
www.zju.edu.cn/jzus; www.springerlink.com
E-mail: jzus@zju.edu.cn

Meat quality traits of four Chinese indigenous chicken breeds and one commercial broiler stock*

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Received June 16, 2013; Revision accepted Aug. 9, 2013; Crosschecked Sept. 24, 2013

Abstract: Meat quality traits of four genotypes of Chinese indigenous chicken [Ninghai chicken (NC), frizzle chicken (FC), Ninghai xiang chicken (XC), and Zhenning loquat chicken (LC)] and one genotype of commercial broiler [Arbor Acres plus broiler (AAB)] were analyzed. The indigenous chickens were raised before the commercial chickens in order to achieve the same final processed days. Indigenous chickens of NC, FC, XC, and LC showed significantly higher inosine-5′-monophosphate (IMP) content, shorter fiber diameter, and lower shear force than those of AAB (P<0.05). In the indigenous genotypes, NC and FC had significantly shorter fiber diameters and lower shear forces than XC and LC (P<0.05), and NC and XC had a higher IMP content than FC and LC (P<0.05). Moreover, the indigenous genotype of LC significantly displayed the highest protein content (P<0.05) in the five genotypes of birds, and no significant differences of protein content were found between the other genotypes of NC, FC, XC, and AAB (P>0.05). The indigenous chickens from FC displayed the highest total lipid content in the five bird genotypes (P<0.05). Significant differences of pH, color values of L* and a*, and drip loss for the five genotypes of birds were also observed. In conclusion, there were significant differences in the meat quality traits of the bird breeds selected in this study, and the indigenous chickens, especially the NC genotype, produced better quality meat as far as the IMP content, fiber diameters, and shear forces were concerned.

Key words: Indigenous chicken, Commercial broiler, Meat quality, Fiber diameter, Inosine-5′-monophosphate
doi:10.1631/jzus.B1300163 **Document code:** A **CLC number:** S831

1 Introduction

In China, indigenous chickens are the main chickens that are marketed live, making up 20% of the poultry market, and the indigenous chicken market is rapidly developing by a rate of 5% to 10% per year (Tang *et al.*, 2009). In recent years, a large number of indigenous chicken breeds are bred in Ningbo (Zhejiang, China). The breed of Ninghai chicken (NC), one of the indigenous chicken genotypes with high meat quality (Li *et al.*, 2009), is the cross between a Ninghai indigenous chicken breed and one Chinese broiler stock. It was bred successfully by Zhejiang University (Hangzhou, China) and Ningbo Zhenning Animal Husbandry Co., Ltd. after six years of breeding. The frizzle chicken (FC) breed is bred in Ningbo Zhenning Animal Husbandry Co., Ltd., due to a genetic mutation which causes the feathers to curl

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* Project supported by the Zhejiang Provincial Public Technology Application Research Project (No. 2012C22052), the Hangzhou Science and Technology Development Project (Nos. 20120232B72 and 20101032B18), and the General Administration of Quality Supervision, Inspection and Quarantine of China (No. 201310120)

up. The first frizzle mutants appeared in the Pacific Rim in the 1500s and were used as both layer and meat birds. The Ninghai xiang chicken (XC) breed was introduced through the Qiandongnan xiaoxiang chicken (one high-quality indigenous chicken in Guizhou Province, China) and is stocked in the Chinese bayberry forest at an elevation above 500 m, commonly known as the "bayberry chicken". The Zhenning loquat chicken (LC) breed is produced in the hometown of Ninghai, and due to its appearance, it looks like the white loquat, so it is named the loquat chicken.

The Arbor Acres plus broiler (AAB) stock is imported from the American Arbor Acres Poultry Breeding Co., Ltd. Nowadays, AAB is largely raised by Chinese poultry breeding companies, and has become the main meat chicken in Chinese markets. It is one of the typically fast-growing broiler breed. However, it may has the negative influence on the sensory and functional qualities of meat due to the fast growth and high yield (Dransfield and Sosnicki, 1999), pushing muscle fibers to their maximum functional size constraints (MacRae *et al.*, 2006).

There are many factors that affect meat quality, such as genetics, nutrition, environment, and additives. Specially, genetics is one of the most important factors. Meat quality traits of poultry include chemical (proteins, total lipids, etc.) and physical traits (pH, color, water holding capacity, texture, sarcomere length, etc.) (Petracci and Baeza, 2011). Chinese consumers often prefer indigenous chicken breeds over commercial breeds due to their meat qualities (Sheng *et al.*, 2013). The meat quality traits of indigenous chickens and broilers have been widely researched in literature (Fanatico *et al.*, 2007; Lu *et al.*, 2007; Tang *et al*., 2009; Sirri *et al.*, 2010; 2011). However, the meat quality differences of indigenous chicken breeds in Zhejiang and AAB have not been reported. Therefore, the objective of this study was to compare the meat quality traits of male indigenous chicken genotypes of NC, FC, XC, and LC to each other, and also with those of the male broiler stock of AAB at their respective market ages.

2 Materials and methods

2.1 Birds

All birds of the five genotypes of NC, FC, XC, LC, and AAB were hatched at the hatchery of Ningbo Zhenning Animal Husbandry Co., Ltd. (Ningbo, Zhejiang, China), and 450 1-d male chicks of NC, FC, XC, LC, and AAB were randomly distributed into pens in a conventional indoor facility. The indigenous chickens of NC, FC, XC, and LC are slow-growing genotypes, while the broiler breed of AAB belongs to a fast-growing genotype. Therefore, the indigenous chickens were raised before the commercial chickens to achieve the same final processed days, namely the commercially available days. After 21 d, the indigenous genotypes of NC, FC, XC, and LC were raised in a mountainous field (about 2 000 m^2) where there were a variety of weeds and seedlings and vegetation, and the daylight and winds were considered to be sufficient for breeding. The mountainous field was subdivided into 12 separate yards. Each of the genotype birds was randomly separated into three groups of 30 birds each, and then indigenous chickens of the four genotypes were stocked in the yards randomly until 110 d. All indigenous chickens were supplemented with the same multiphase diets every day (Table 1). The broiler genotype of AAB was also divided into three groups of 30 birds each, and raised in the indoor facility for 42 d. The facility contained fans to ventilate and cool the pens. Each indoor pen was the size of 1.8 m×1.8 m and contained wood shavings, water bowls, and hanging tube feeders. The chicken bred indoor pens were supplied with a constant photoperiod of 24 h. The diets supplied for the AAB are displayed in Table 1.

2.2 Slaughter and meat sample collection

Thirty birds of each genotype chicken were collected from one separate group. A total of 90 birds of each genotype chicken were used for this experiment. They were placed in plastic coops and transported to the processing facility in Hangzhou. Before slaughter, the feed was withheld for 12 h, including the lairage time at the processing plant of 2 h and the transport time of 3 h. The birds of each group were individually processed under commercial conditions using electrical stunning (120 V, 200 Hz) and were soft-scalded at 53 °C for 120 s. Carcasses were pre-chilled at 12 °C for 15 min and then chilled by immersing in 1 °C cold water for 1 h. After chilling, the breast and thigh samples were collected, stored at 4 °C for 24 h and then used for subsequent meat

Table 1 Nutrient composition for indigenous chickens and AAB and ingredient composition of diets for AAB

Ingredient	AAB		Indigenous chicken		
	1–21 d	22–42 d	0–28 d	29–56 d	57–110 d
Nutrient level (%, w/w)					
ME (MJ/kg)	12.42	12.67	11.91	12.20	12.53
Crude protein	20.47	19.27	20.55	18.78	17.02
Calcium	0.97	0.90	0.90	0.85	0.80
Available phosphorus	0.45	0.40	0.45	0.42	0.40
Met	0.50	0.40			
Lys	1.15	1.03			
NaCl			0.15	0.15	0.15
Crude fiber			3.00	3.00	3.00
Ingredient (%, w/w)					
Corn	58.00	62.09			
Soybean meal	31.75	27.00			
Corn protein meal	3.90	5.00			
$CaHPO_4$	1.90	1.60			
Limestone	1.20	1.20			
Soybean oil	2.00	2.00			
NaCl	0.37	0.37			
Lys	0.23	0.18			
Met	0.15	0.06			
Premix	0.50	0.50			
Total	100	100			

ME: metabolizable energy; Lys: lysine; Met: methionine

quality evaluation. All meat samples were deboned and trimmed of skin and visible fat before the test. Breast fillets were used to evaluate drip loss, shear force, color, protein, total lipid content, and inosine-5′-monophosphate (IMP). The pH values and fiber diameters of the pectoralis major and biceps femoris were both tested. Fifteen of the muscle fillets were randomly selected from the breast or thigh fillets of each group, namely, a total of 45 muscle fillets were selected from each genotype chicken and used for testing the physical traits (body live weight, pH, fiber diameter, drip loss, shear force, and color) and were individually examined (within one day). As soon as samples of the physical traits were gathered, the rest of the pectoralis major muscles were ground, frozen and stored at −80 °C until protein, total lipid, and IMP were analyzed (within one week). All of samples in each genotype chicken were tested for 10 times.

2.3 pH measurement

The pH values of the chicken meat were measured according to Jeacocke (1977) with some modification. Approximately, 5 g of muscle for each pectoralis major and biceps femoris muscle, respectively, were minced by hand and homogenized with 45 ml of 5 mmol/L iodoacetate solution with 150 mmol/L of potassiumchloride for 30 s. The supernatant was used for pH determination using a pH meter (PHS-3C, Yuefeng, Shanghai, China).

2.4 Fiber diameter

Pieces (0.2 cm×0.2 cm×0.5 cm) were excised from the central part of the pectoralis major muscle and biceps femoris muscle. They were immersed in 20% nitric acid solution for 24 h, and then approximately 1 mm×1 mm×1 mm sections were sampled. These sections were placed onto a glass slide in which two drops of glycerin were added before placing, and then they were separated by hand using a dissecting needle to make the fibers separate and be distributed uniformly. Fibers were coated with a cover glass slide. An electron microscope was used to examine the fiber diameters, and imaging program and Image-Pro-Plus (IPP) software (Eastman Kodak Company, New Haven, CT, USA) were used for muscle fiber diameter measurement. One-hundred-fiber diameters of each sample were recorded, and the mean values of them were used to present the fiber diameter.

2.5 Drip loss

Drip loss was measured on intact fillets of the right side of the pectoralis major muscle (5 cm×3 cm ×2 cm) and packaged in plastic bags, and then hung on wooden supports at 4 °C for 24 h, and calculations were made as a percentage of weight loss during storage.

2.6 Shear force

Breast fillets were cooked on racks in aluminum-lined, covered pans in a preheated convection oven to an internal temperature of 76 °C for 10 min. A Meullenet-Owens razor shear (MORS) method was used to evaluate the shear force of the cooked breast fillets. Shear force was determined on intact fillets using a texture analyzer (TA-XT2i; Scarsdale, NY, USA) and using a razor blade (24 mm in height and 8.9 mm in width) with a 5-kg load cell set to 20-mm

penetration depth. Crosshead speed was triggered by a 10-g of contact force with 5 mm/s. Breasts were punctured across muscle fibers (Fanatico *et al.*, 2007).

2.7 Color measurement

The complete International Commission on Illumination (CIE) system color profile of light (L*), redness-greenness (a*), and yellowness-blueness (b*) was performed by a TC-PIIG colorimeter (Beijing Optical Instrument Factory, China) with illuminant source D65, 0°/diffuse illuminating and viewing type geometry relative to 10° visual field under dark background, with a spectral range of 380–780 nm. Color measurements were taken on the dorsal surface of each breast fillet (bone side) in an area free of obvious color defects (bruises, discolorations, hemorrhages, full blood vessels or any other condition that may have affected uniform color reading).

2.8 Chemical trait measurement

Protein content and lipid content were measured on the raw pectoralis major patties by the Association of Official Analytical Chemists (AOAC) methods. The IMP content of each of the pectoralis major patties from each genotype was determined by the method of Tang *et al.* (2009). The nucleotide contents were tested using high-performance liquid chromatography (HPLC) (Agilent 1100 Series Systems, with UV detector). The HPLC conditions were as follows: ZORBXSB-C18 column (4.6 mm×150 mm i.d., 5-μm particle), 18-min mobile phase gradient of 0.1 mol/L phosphate buffer (pH 6.0) and methanol (70:30) in 0.1 mol/L phosphate buffer pH 6.0, 1 ml/min flow rate, injection volume of 20 μl, and measurement of eluent absorbance at 254 nm. The peaks of the individual nucleotides were identified using the retention time for standards and the concentration of IMP was calculated using the area for each peak. Assays for protein, total lipid, and IMP were individually performed in triplicate.

2.9 Data analysis

A completely randomized design was used in this study. Data were evaluated statistically as one-way analysis of variance (ANOVA) using SPSS (SPSS Inc., Chicago, IL, USA), and were expressed as mean±standard deviation (SD). Significant differences in mean values were determined by the Student Newman Keuls test ($P<0.05$) procedure of the statistical analysis system (Sirri *et al.*, 2010).

3 Results and discussion

3.1 Physical traits of bird meats

The body live weights of these birds are presented in Table 2. Even if the AAB was bred only 42 d, it had the heaviest weight of (1 921.31±201.06) g. The body live weights of the NC, FC, LC, and XC which were bred for 110 d were significantly lower than that of the AAB. It may be caused by the differences of the diets (Table 1). The diets of these birds were different in this experiment, because the indigenous chicken and broiler were bred in different conditions and had different growing speeds. However, the indigenous chickens with the same diets also had different body live weights. Therefore, it might be concluded that genotype also had an influence on the body live weight.

The pH value of the pectoralis major muscle of NC was the lowest in the five genotypes followed by FC, LC, XC, and AAB (5.49, 5.57, 5.67, 5.76, and 5.78; Table 2). The similar tendency of pH values in biceps femoris muscle was observed, while the pH value in biceps femoris muscle was higher than that of in the pectoralis major. It can be seen that the NC and FC of the pectoralis major and NC, FC, and LC of the biceps femoris had a significantly lower pH value than that of AAB. However, in the pectoralis major muscle, the pH values of XC and LC were significantly higher than those of NC and FC, and no significant differences were found between XC, LC, and AAB, and in the biceps femoris muscle, XC had a significantly higher pH value than NC, FC, and LC, and no significant differences were observed between XC and AAB.

Different fiber diameters of the chicken's white meat have been reported variously as 32.6 μm (Smith *et al.*, 1993), 38–46 μm (Smith and Fletcher, 1988), and 68.2 μm (Kiessling, 1977). In this study, the breast and leg fiber diameters of AAB were (45.67 ±2.03) and (48.31±1.25) μm, respectively (Table 2). The FC had the shortest fiber diameter in the pectoralis major muscle in these birds, followed by NC, and no significant differences were noted between them. The fiber diameter in the biceps femoris muscle

Table 2 Physical traits of pH, fiber diameter, water loss, and color of muscles of the five genotypes of chicken

Genotype	Body live weight (g)	pH		Fiber diameter (μm)		Breast shear force (N)	Breast drip loss (%)	Breast color		
		Breast	Leg	Breast	Leg			L*	a*	b*
NC	1 398.39^{c}	5.49^{b}	5.90^{b}	36.52^{c}	36.24^{c}	69.83^{d}	1.02^{c}	50.53^{b}	4.47^{c}	8.24^{a}
	±113.63	±0.17	±0.16	±2.19	±0.44	±3.96	±0.18	±1.86	±2.35	±5.44
FC	1 298.33^{c}	5.57^{b}	5.97^{b}	35.88^{c}	37.90^{c}	81.37^{c}	1.35^{b}	52.51^{b}	5.61^{a}	9.55^{a}
	±108.54	±0.05	±0.17	±2.37	±0.30	±8.20	±0.16	±2.59	±0.17	±1.48
XC	1 509.23^{b}	5.76^{a}	6.26^{a}	38.10^{b}	39.14^{b}	121.30^{b}	1.16^{c}	47.67^{c}	4.58^{bc}	8.44^{a}
	±181.35	±0.07	±0.09	±2.98	±0.79	±2.42	±0.29	±4.55	±2.96	±1.59
LC	1 685.21^{b}	5.67^{ab}	6.07^{b}	40.28^{b}	41.95^{b}	126.00^{b}	1.02^{c}	54.59^{a}	4.89^{b}	13.84^{a}
	±197.61	±0.08	±0.06	±2.14	±0.65	±5.97	±0.38	±1.30	±0.55	±2.0
AAB	1 921.31^{a}	5.78^{a}	6.25^{a}	45.67^{a}	48.31^{a}	138.25^{a}	1.52^{a}	48.28^{c}	5.09^{b}	10.68^{a}
	±201.06	±0.12	±0.08	±2.03	±1.25	±4.15	±0.37	±3.07	±1.64	±2.61

Data were expressed as mean±SD (n=45). Different superscripts (a–d) after the mean in the same column show significiant difference (P<0.05). NC: Ninghai chicken; FC: frizzle chicken; XC: Ninghai xiang chicken; LC: Zhenning loquat chicken; AAB: Arbor Acres plus broiler

of NC was the shortest, followed by FC, and no significant differences were observed between NC and FC. Fiber diameter of the indigenous chickens was shorter than that of AAB, significantly both in the pectoralis major muscle and the biceps femoris muscle (P<0.05; Table 2). Results suggest that the fast-growing genotype of AAB had the larger fiber diameter than the slow-growing chicken genotypes of NC, FC, XC, and LC. Similar results were reported by Dransfield and Sosnicki (1999). The differences in the fiber diameters may be due to the differences in the genotype, age, production system, diet, and so on.

Shear force is used to assess meat tenderness, and higher shear force means tougher meat quality (Cavitt *et al.*, 2004). The shear force of the breast fillets of NC was the lowest in these genotypes, followed by FC, XC, LC, and AAB, which had the highest shear force in the five genotypes of chicken (P<0.05; Table 2), and this can be explained by the differences in the muscle fiber size. It was shown that the muscle fiber diameters of the pectoralis major muscle and the biceps femoris muscle of the AAB were greater than those of the indigenous chickens of NC, FC, XC, and LC. Mahon (1999) reported a similar result that fast-growing lines of chickens have longer fiber diameters than slow-growing lines and longer fiber diameters are often associated with higher shear force and meat toughening. Tang *et al.* (2009) explained that the difference in shear force may be due to the ages of the birds.

The water-holding capacity (WHC) is important in whole meat and further processed meat products and can be measured by drip loss. The drip loss of pectoralis major muscle in the five genotypes of birds is shown in Table 2. AAB had the higher drip loss than the others (P<0.05). NC, XC, and LC had a significantly lower drip loss value than FC (P<0.05).

Color is one of the first traits noticed by consumers and thus an indicator of meat quality (Owens *et al.*, 2000; Woelfel *et al.*, 2002). The color measurement results of the five genotypes of birds are provided in Table 2. The L* value of LC was higher than those of NC and FC (P<0.05), which were higher than XC and AAB (P<0.05). There was no significant differences between NC and FC, or between XC and AAB for the L* value. The a* value of FC was the highest in the five genotypes (P<0.05), followed by AAB, XC, LC, and NC. No significant differences were found between the five genotypes in the b* value (P>0.05). However, in this study, it is difficult to evaluate the meat quality if you just depend on the color. Different results of the genotype with color were also reported in various literature. Gordon and Charles (2002) found that slow-growing birds have a redder meat color than fast-growing birds because the slow-growing birds are typically older, while Fanatico *et al*. (2007) observed that the slow-growing birds were less red (lower a*) than the fast-growing birds (P<0.05).

3.2 Chemical traits of bird meats

The chemical traits of protein, total lipid, and IMP of the five genotypes of birds are shown in Table 3. Both protein content and total lipid content in

pectoralis major muscle were significantly influenced by the genotypes of the birds (P<0.05). Protein content of LC was the highest in the five genotypes of birds, calculated at 24.25%. Higher protein content of the breast chicken muscle was also observed by Sirri *et al*. (2010) who reported that the protein content of slow-growing chicken genotypes was 24.6%. The indigenous genotypes of LC, XC, NC, and FC showed a higher content of protein than the broiler genotype of AAB (P>0.05). Protein content of AAB was the lowest, which was 17.24%. The genotype of LC had significantly higher protein content than other genotypes, but no significant differences were found between XC, NC, FC, and AAB (P>0.05). Similar results had been reported by Fanatico *et al.* (2007) who found that the slow-growing birds had higher protein than the fast-growing ones.

Table 3 Chemical traits of protein, total lipid, and IMP of leg muscles of the five genotypes of chicken

Genotype	Protein (%)	Total lipid (%)	IMP (mg/kg)
NC	19.08^{b}±1.00	3.73^{b}±0.63	$2\,482.69^{a}$±29.25
FC	17.96^{b}±0.61	5.72^{a}±0.84	$2\,390.33^{b}$±17.62
XC	20.86^{b}±2.68	2.82^{b}±0.82	$2\,510.05^{a}$±17.71
LC	24.25^{a}±1.96	3.82^{b}±0.81	$2\,108.07^{c}$±15.27
AAB	17.24^{b}±0.86	3.74^{b}±0.70	$1\,897.21^{d}$±19.89

Data were expressed as mean±SD (n=10). Different superscripts (a–d) after the mean in the same column show significiant difference (P<0.05). NC: Ninghai chicken; FC: frizzle chicken; XC: Ninghai xiang chicken; LC: Zhenning loquat chicken; AAB: Arbor Acres plus broiler; IMP: inosine-5′-monophosphate. The pectoralis major muscle was used for determination

The FC had the highest total lipid content in the five genotypes (P<0.05). Other genotypes had no significant differences in the total lipid content. In this paper, the indigenous chickens of NC, FC, XC, and LC were slow-growing genotypes, and AAB was a fast-growing genotype. Differences in the total lipid content in this study were different from Sirri *et al.* (2010; 2011) and Fanatico *et al.*, (2007) who reported that the fast-growing birds had higher lipid content than the slow-growing birds. It may be due to the differences in genotype, age, production system, and diet of the birds selected in these studies.

The chemical trait of IMP is a flavor precursor and its degradation results in formation of ribose in meat (Kawai *et al.*, 2002). In the five genotypes, XC had the highest IMP content followed by NC, and they were significantly higher than the other genotypes, but no significant difference was found between them. The IMP content of FC was higher than those of LC and AAB, that of AAB was the lowest, and all of them had significant differences (P<0.05). In the current study, the indigenous chickens (NC, FC, XC, and LC) had higher IMP content than AAB (P<0.05). Similar results were also reported by Tang *et al*. (2009).

4 Conclusions

In summary, significant differences in meat quality traits of indigenous genotypes of chicken and commercial broiler stock were observed. There were significant differences in body live weight, pH, fiber diameter, shear force, drip loss, and color values of L* and a* for the five genotypes of birds in this study. A shorter fiber diameter and lower shear force of the indigenous chickens were identified when compared to those of AAB, and NC had the shortest fiber diameter and the lowest shear force. The IMP content of the four genotypes of indigenous chickens used in this study was significantly higher than that of the AAB. The NC and XC displayed higher IMP content when compared with the other genotypes. LC and FC had the highest protein content and total lipid content, respectively, in the five genotypes of chicken, and no significant differences were found in protein content or total lipid content of the other genotypes, including the broiler stock. In conclusion, the indigenous chickens, especially the NC breed showed better quality meat than the broiler breed, as far as the IMP content and texture were concerned.

Acknowledgements

We would like to thank You-jin TU, Xi-hang CHEN, and Miao-ying TU from Ningbo Zhenning Animal Husbandry Co., Ltd. (China) for providing materials for this research.

Compliance with ethics guidelines

Rong-fa GUAN, Fei LYU, Xiao-qiang CHEN, Jie-qing MA, Han JIANG, and Chao-geng XIAO declare that they have no conflict of interest.

All institutional and national guidelines for the care and use of laboratory animals were followed.

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