WFL Publisher
Science and Technology

Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.11 (1): 54-58. 2013

www.world-food.net

Comparison of muscle properties and meat quality between Jing Ning chicken and Ling Nan Huang Yu meat chicken

Fengli An [1, 2]*, Xiaohong Kang [1], Lu Zhang [1], Leilei [1], JinbaoWang [1], Baoping Shao [1] and Jianlin Wang [1]*

[1] *School of Life Science, Lanzhou University, Lanzhou 730000, Gansu, China.* [2] *College of Chemistry and Life Science, WeiNan Normal University, Weinan 714000, Shaanxi, China. *e-mail address: jlwang@lzu.edu.cn*

Received 28 October 2012, accepted 27 January 2013.

Abstract

The aim of this study was to observe the effect of breed and sex on muscle structural properties associated with meat quality in different chickens. Two broiler strains were reared: Jing Ning chicken (JN, Chinese native chicken) and Ling Nan Huang Yu meat chicken (HY, commercial crossbred chicken). Results showed that cock had higher (p<0.05) myober diameter, shear force value, water loss rate and lower (p<0.05) myober density when compared with hen; HY chicken presented a higher (p<0.05) myober diameter, shear force value, water loss rate and lower (p<0.05) myober density than JN chicken; pectoralis muscle had a higher (p<0.05) myober density, shear force value, water loss rate and lower (p<0.05) myober diameter than thigh muscle correspond to the same strain. However, there were no significant differences of pH and water drip loss with respect to breed and sex (p>0.05). Shear force value was negatively correlated with myofiber diameter (r = -0.807; p<0.01), thickness of endomysium(r = -0.491; p<0.01) and positively correlated with myofiber density (r = 0.67; p<0.01), water loss rate (r = 0.748; p<0.01), water drip loss (r = 0.148; p>0.05) and pH (r = 0.285; p>0.05). In conclusion, breed and sex showed important effect for muscle properties, which affect meat quality. JN chicken have good meat quality due to its lower shear force value than HY chicken at market time, partly as a result of their superiority in myober diameter, density and water loss rate difference.

Key words: Jing Ning chicken, Ling Nan Huang Yu meat chicken, pH, shear force value, water loss rate.

Introduction

Poultry meat becomes a major protein source in human nutrition. Physical indicators such as color and tenderness are important attributes to which consumers will select [1], while variation in these indicators depends on the characteristic of muscle itself [2]. Muscle is composed of different fiber types, on the one hand, they can be affected by sex, breed, age and so on [3], on the other hand, muscle fiber characteristics can influence meat quality characteristics such as color, water- holding capacity and the texture of meat [4]. Breed and strain differences in myofiber type composition, collagen content and architecture have been reported in chickens [5], but the links between several characteristics at tissue level and meat tenderness had provided inconsistent conclusions [6].

Intensive selection has led to the creation of specialized chicken strains that differ significantly in meat yield and reproduction performance from native strains, but there is still an increased interest in local breeds, one of the reasons is the better quality of their meat compared with commercial breeds [7]. Jing Ning chicken (JN) were raised in remote mountain area of Gansu province, with an average temperature of 7.6°C. Expoursing to temperatures below 14°C caused lower glycolytic potential and lactate concentrations [8], this would be beneficial to improve bird welfare and reduce meat quality defects. As one of the local breeds in China, JN chicken had enjoyed a high reputation for juicy texture and avor of their meat, but owing to the poor growth performance and economic benefits, they were endangered by extinction. They had been included in the national protected species list for autochthonous breeds by the Chinese Government. Ling Nan Huang Yu meat chicken (HY) was a line of hybrid strain with fast-growth. In order to explain why there were an increasing demand on native chicken in the market from consumers, it was necessary to investigate the structure difference between muscle characteristics and meat quality in these two breeds, therefore providing theoretical basis for utilizing the precious resource in animal breeding.

Materials and Methods

Animal and tissue collection: Fertilized eggs were incubated at 37°C in a humidied air incubator and were rotated every two hours each day. After 21-day incubation, a total of 120 birds (60 birds each breed) were obtained from the local hatchery and were raised under standard conditions. The birds were slaughtered when they were approximately 2.0 kg of body weight, with approval from the Institutional Animal Care and Use Committee. Pectoralis muscles, thigh muscles from the same side were used for the same purposes, all of the samples were processed following the same procedure, therefore reducing the number of factors responsible for the observed dierence.

Histology morphometry: Muscle sections were stained with hematoxylin and eosin to observe the morphology of the muscle tissue. Myofiber density was determined by counting the numbers of myofibers in ten randomly selected fields of known size (1 mm^2) in each slide, and myofiber diameter was got by measuring the maximum distance across the lesser diameter of 100 fibers. The thickness of endomysium as measured with the membrane of myofiber.

Analytical methods: The pH value was measured by using a portable pH-meter calibrated at pH 4.0 and 7.0 in muscle homogenate. The water holding capacity was estimated by water drip loss and water loss rate [9].

Determination of water holding capacity: A meat sample with 2.532 cm in diameter was placed on 18 layer filter papers between plexiglass plates and pressed at 35 kg for 5 min, water loss rate was calculated as (initial weight-final weight)/initial weight × 100%. Higher water loss rate percentage is related to decreased WHC.

Determination of water drip loss: Samples were stored in sealed plastic bags under atmospheric pressure at 4°C for 48 h. Drip loss was calculated as a difference between final and initial weight expressed as a percentage of the initial weight.

Shear force measurement: Shear force value was determined according to the trational methods with some modifications [10]. Muscle samples were refrigerated at 4°C for 48 h, vacuum packed in boilable bags and cooked at 80°C in a water bath. After cooling to room temperature, the samples were cut into 1.5 cm cubes and sheared perpendicularly to the longitudinal orientation of the bers using Digital Meat Tenderness Meter (Model C-LM3B, Northeast Agricultural University, Harbin, China).

Statistical analysis: Data were analyzed by SPSS17.0 software. The two-way analysis of variance was conducted to test possible interaction between breed and sex for signicance. Pearson correlation coefficients were generated to evaluate the correlation of fiber diameter, density, pH, water loss rate and water drip loss to shear force value. Least squares means were obtained and Tukey's multiple comparison test was used to compare differences among mean values at the 5% level of signicance.

Results and Discussion

Meat quality can be assessed by measuring biophysical properties, such as water-holding capacity, pH, shear force and fiber properties [11]. Effects of breed, sex and their interaction on muscle characteristics are shown in Tables 1- 4 and Fig. 1.

pH: Usually, pH decreases from 7.0 in the live muscle to pH 5.4 to 6.3 in the meat [12]. In the current study, both the breeds had pH value ranging from 6.1 to 6.6 (Table 1, Fig.1). JN chicken had higher pH values than HY chicken in general, but they did not differ significantly, pH was positively (r = 0.285; p>0.05) correlated with meat shear force value (Table 4). When meat pH is above the isoelectricpoint, water molecules are tightly bound resulting in a darker color in meat, but too lower pH is associated with pale color in turkey meat [13]. The general thought that leg muscle had more lactic acid accumulates because of more sport [14] and pH would be lower than breast muscle, while this study did not support this idea, maybe this was the result of effective enzymatic system in muscle after slaughter. It has been shown that pH decline in muscle is associated with calpain autolysis and degradation of myofibrillar and associated proteins [15], and postmortem desmin degradation was more rapid in breast muscle than in leg muscle and calpain activity was higher in breast than in leg muscle [16]. *In vitro*, caspase-3 reproduced the degradation patterns of titin, nebulin and α-actinin during postmortem storage of meat, but caused little proteolysis of desmin. Meanwhile, caspase-3 also induced the weakening in the I band adjacent to Z-lines, which occurred during postmortem meat ageing [17]. Thus, the pH values in the two breeds were within normal scopes and the positive correlation between pH and shear force value is considered normal for meat.

Fiber diameter and fiber density: Fiber diameter and fiber density of the two breeds are shown in Table 1 and Fig. 1. At a given breed, fiber diameter of pectoralis and thigh muscle had little difference between cock and hen (p>0.05). At a given sex, thigh muscle had larger myober diameter than pectoralis muscle (p<0.01) in both the breeds. Between groups, HY chicken had bigger myober diameter in pectoralis muscle and thigh muscle corresponding to JN chicken. It is well known that muscle is a highly organised tissue composed of individual cells known as bers, structured by connective tissue and the myober number in chickens was established before hatching [18]. Most studies have shown that the smaller the fiber size, the more tender the meat [6]. When compared with fast-growing, slower growing chickens had a lower muscle yield but higher protein content, averages of breast myober density is higher than leg muscle in both the breeds [19]. A Chinese local breed -Beijing You chicken had distinct breast muscle features when compared with Arbor Acres chicken (the genetically improved broiler line) [20]. In another study breed was found related neither to meat quality traits, nor fibre type percent and fibre relative

Table 1. Muscle pH, fiber diameter and fiber density in Ling Nan Huang Yu meat chicken (HY) and Jing Ning chicken (JN).

Group	Index		pH	Ffibre diameter (μm)	Fibre density (number/mm2)
HY	pectoralis	cock	6.55±0.025^{a}	46.92±7.989 ^{a}	487.4±63.98^{a}
		hen	6.18±0.058^{b}	43. 45.13±2.49^{ab}	553.3±24.26^{b}
	thigh	cock	6.22±0.22^{bc}	83.15±21.80^{c}	352.9±24.37^{c}
		hen	6.44±0.01^{ad}	80.61±18.42^{dc}	398.1±31.46^{d}
JN	pectoralis	cock	6.59±0.037^{ae}	41.98±8.22^{eb}	570.2±26.26^{eb}
		hen	6.48±0.02^{adef}	40.10±2.78^{fe}	603.4±16.06^{f}
	thigh	cock	6.47±0.02^{adefg}	81.85±20.24^{gcd}	348.3±23.82^{gc}
		hen	6.53±0.01^{adefgh}	80.05±3.31^{hcdg}	367.21±31.27^{hcdg}

Data were presented as mean±SD; $^{a\text{-}h}$Means within rows with no common letter differ significantly (p<0.05).

Table 2. Shear force, water drip loss and water loss rate in Ling Nan Huang Yu meat chicken (HY) and Jing Ning chicken (JN).

Group	Index		Shear force(N)	waterdrip loss(%)	water loss rate(%)
HY	pectoralis	cock	43.29±0.96^{a}	2.57±0.40	37.82±2.78^{a}
		hen	33.09±0.53^{b}	2.58±0.13	31.41±1.99^{b}
	thigh	cock	28.27±1.27^{bc}	2.28±0.18	35.49±3.62^{ca}
		hen	26.82±0.12^{dc}	2.64 ±0.32	25.52±1.61^{d}
JN	pectoralis	cock	39.65±1.30^{ae}	2.33 ±0.61	34.05±2.55^{bce}
		hen	32.61±5.57^{bcf}	2.49±0.29	36.48±1.62^{afce}
	thigh	cock	27.29±3.85^{gcd}	2.68 ±0.29	29.26±2.38^{gb}
		hen	24.02±4.66^{hgcd}	2.39 ±0.15	21.58±2.28^{h}

Data were presented as mean±SD; $^{a\text{-}h}$Means within rows with no common letter differ significantly (p<0.05).

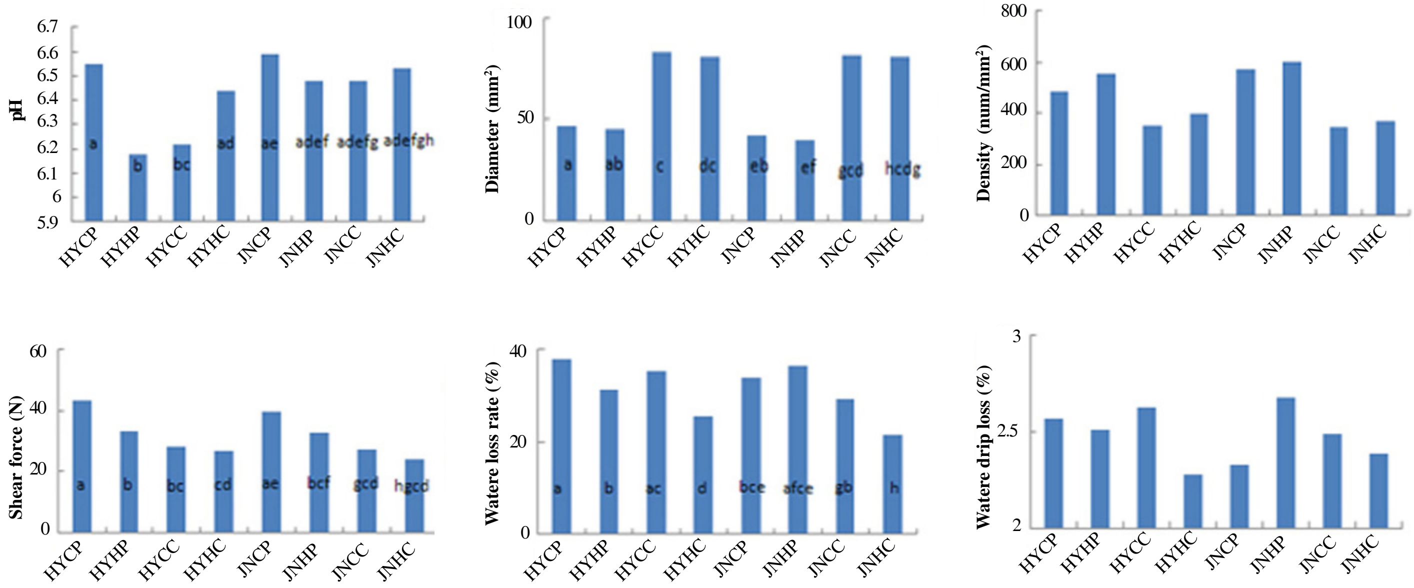

Figure 1. Comparison of pH, fibre diameter, fibre density, shear force, water loss rate and water drip loss of two breeds.
HYCP: huangyu cock pectoralis; HYHP: huangyu hen pectoralis; HYCC: huangyu cock crureus; HYHC: huangyu hen crureus; JNCP: jingning cock pectoralis; JNHP: jingning hen pectoralis; JNCC: jingning cock crureus; JNHC: jingning hen crureus. [a-h]Means in the samples with different letters are significantly different (*p*<0.05).

area, but it affected the size of fibers in pigs [21]. Myober density was positively (r = 0.670, *p*<0.01) and myober diamater negatively (r = -0.807, *p*<0.01) correlated with shear force value (Table 4). Besides fiber diameter, some connective tissue also played an important role in meat tenderness [22]. Endomysium is a network of fine and slightly wavy fibrils, responsible for nutrition supply. When the effect of myofiber was excluded, they also have effect on shear force value (r = -0.491, *p*<0.01) (Table 4, Fig. 2). Native chicken had more chance to get open field activities, but this semi-confined system seemed to have little effect on fiber feature.

Water holding capacity: The distribution and mobility of water in muscle had a profound effect on meat quality like juiciness, tenderness and appearance. Expressible moisture, a good indicator of water holding capacity (WHC), is the percentage of total water in the meat that can be expressed by applied force. So it is an essential quality parameter both for the industry and consumer. In this study, regarding drip loss, no signicant differences were found between the two breeds (Table 2, Fig.1). Within group, cock had higher water loss rate (*p*<0.01) than hen and pectoralis muscles produced higher water loss rate (*p*<0.01) than thigh muscle. Between groups, HY chicken had higher water loss rate of pectoralis muscle (*p*>0.05) and thigh muscle (*p*<0.01) than JN chicken, respectively. Immobilised water accounts for up to 85% of the myowater. It is located within the thick filaments and between the thick and thin filaments of the myofibril [12]. During the conversion of muscle to meat and ageing this water population can be mobilised due to alteration of muscle cell structure and changes in pH [23]. The main factors that affect water holding capacity and drip loss were genotype, calpain activity and proteolysis and ber orientation [24] and so on. Meat juiciness was correlated with the most mobile myowater [25]. Proteins play a critical role in immobilising water in meat. Initially proteolysis improves WHC, but extended proteolysis has the potential to reduce WHC and increase drip loss. As cytoskeletal proteins such as titin comprise approximately 10% of muscle protein [26], there is considerable potential for water to become available as the cytoskeletal protein tertiary structure breaks down. The lower water loss rate was, the higher WHC was. In this study, JN chicken had high WHC showing low drip loss and lower loss rate, and water drip loss and loss rate were negatively correlated with pH (Table 3). These findings clearly suggest that the WHC of muscle is affected by the structural features of the meat.

Table 3. Coefficients of correlation among water drip loss, water loss rate and other measurements index of pH, diameter, density and shear force.

	pH	Diameter	Density	Shear force
Water drip loss	-0.388	-0.254	0.209	0.748**
Water loss rate	-0.091	-0.629**	0.538**	0.148

Correlation is significant at *p<0.05; **p<0.01.

Table 4. Coefficients of correlation between shear force and other measurement indices.

	pH	Diameter	Density	Water Drip loss	Water Loss rate	Thickness of endomysium
Shear force	0.285	-0.807**	0.670**	0.748**	0.148	-0.491**

Correlation is significant at *p<0.05; **p<0.01.

Shear force value: Factors inuencing the tenderness of muscles consisted of genetic stock [27], age, sex and so on. In the present investigation, the mean shear force value for pectoralis, crureus muscle from HY chicken was signicantly higher than in JN chicken, respectively, and this was complied with fiber diameter and density between the two breeds (Table 2, Fig.1). Within group, cock had higher shear force value (*p*<0.01) than hen and pectoralis muscles produced higher shear force value (*p*<0.01) than thigh muscle. Between groups, HY chicken had higher shear force value of pectoralis muscle (*p*>0.05) and thigh muscle (*p*<0.01) than JN chicken, respectively. The shear force value was found to be positively correlated with density of myober (r = 0.670, *p*<0.01), water loss rate (r = 0.748; *p*<0.01), water drip loss (r = 0.148; *p*>0.05) and pH (r = 0.285; *p*>0.05), and

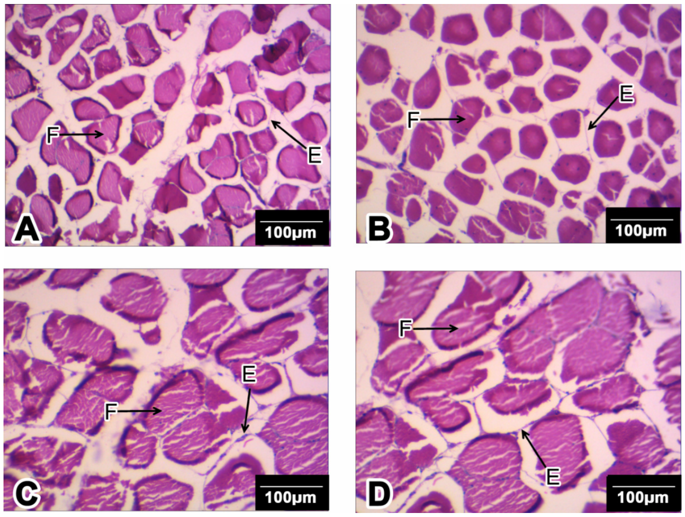

Figure 2. Cross-section of chicken pectoralis and crureus, stained with hematoxylin and eosin: A) cross-section of JN chicken pectoralis, B) cross-section of HY chicken pectoralis, C) cross-section of JN chicken crureus, D) cross-section of HY chicken crureus. The scale bar indicates 100 μm. F fiber, E endomysium.

negatively correlated with myober diameter (r = -0.807, p<0.01) thickness of endomysium (r = -0.491; p<0.01) (Table 4, Fig.2). These agreed with the report that higher breast shear force was found in broiler compared to native chicken [28] and the meat quality of female was superior to the cock in each line [29]. Other than histochemical properties of muscle, different protease activities also might be related to meat tenderness. A number of previous studies indicated that proteolytic degradation of structural proteins, including titin, nebulin, troponin-T, desmin, filamin and vinculin, played central role in the development of meat tenderness [30]. Caspase-3 selective inhibitor inhibited the degradation of muscle skeletal proteins significantly, whereas the activity of calpains was not influenced [31]. Since the rapid increase in tenderness was mainly due to structural weakening of myofibrils, the disintegration of the endomysium and perimysium might contribute to tenderization of pork during extended postmortem aging [32].

Conclusions

The pH, fiber diameter, density and water holding capacity are involved in determining meat quality of the chicken. JN chicken had better meat quality than HY chicken in lower shear force value, that might be due to its unique gene network. These results indicated that we should preserve characteristic phenotypic traits of JN chicken, this would be useful in the production of meat of unique quality and in saving this population from extinction.

Acknowledgements

This work was financially supported by the International Cooperation Program of Gansu province (No.1011WCGA161) and scientific research project of WeiNan Normal University (11YKS023).

References

[1]Miller, M. F., Huffman, K. L., Gilbert, S. Y., Hamman, L. L. and Ramsey, C. B. 1995. Retail consumer acceptance of beef tenderized with calcium chloride. Journal of Animal Science **73**:2308-2314.

[2]Jeong, J. Y., Janardhanan, K. K. and Booren**,** A. M. 2011. Breast meat quality and consumer sensory properties of broiler carcasses chilled by water, air, or evaporative air. Poultry Science **90**:694-700.

[3]Karlsson, A., Enfalt, A. C. and Essen-Gustavsson, B. 1999. Muscle histochemical and biochemical properties in relation to meat quality during selection for increased lean tissue growth rate in pigs. Journal of Animal Science **71**:930-938.

[4]Totland, G. K., Kryvi, H. and Slinde, E. 1988. Composition of muscle fibre types and connective tissue in bovine M. semitendinosus and its relation to tenderness. Meat Science **23**:303-315.

[5]Oshima, I., Iwamoto, H., Tabata, S., Ono, Y., Ishibashi, A. and Shiba, N., 2007. Comparative observation of the growth changes of the histochemical properties and collagen architecture of the iliotibialis lateralis muscle from silky, layer and meat type cockerels. Animal Science Journal **78**:546-559.

[6]Lepetit, J. 2008. Collagen contribution to meat toughness: Theoretical aspects. Meat Science **80**:960-967.

[7]Fujimura, S. 1998. Identification of taste-active components in the meat of Japanese native chicken, Hinai-dori and broiler, and effect of feeding treatments on taste-active components. Bulletin of the Faculty of Agriculture-Niigata University **50**:99-158.

[8]Dadgar, S., Lee, E. S., Leer, T. L. V., Crowe, T. G., Classen, H. L. and Shand, P. J. 2011. Effect of acute cold exposure, age, sex, and lairage on broiler breast meat quality. Poultry Science **90**:444-457.

[9]Honikel, K. O.1998. Reference methods for the assessment of physical characteristics of meat. Meat Science **49**:447-457.

[10]Berry, B. W. and Stiffler, D. M. 1981. Effects of electrical stimulation, boning temperature, formulation and rate of freezing on sensory, cooking and physical properties of ground beef patties. Journal of Food Science **46**:1103-1106.

[11]Somers, C. and Tarrant, P. V., 1984. Evaluation of some objective methods for measuring pork quality. Proc. Scient. Meeting Biophysical PSE-Muscle Analysis, Vienna, 230 p.

[12]Honikel, K. O., Kim, C. J. and Hamm, R. 1986. Sarcomere shortening of prerigor muscles and its influence on drip loss. Meat Science **16**:267-282.

[13]Barbut, S. 1993. Colour measurements for evaluating the pale s-oft exudative (PSE) occurrence in turkey meat. Food Res. Int. **26**:39-43.

[14]Forbes, S. C., Slade, J. M. and Meyer, R. A. 2008. Short-term high-intensity interval training improves phosphocreatine recovery kinetics following moderate-intensity exercise in humans. Applied Physiology Nutrition and Metabolism **33**:1124-1131.

[15]Melody, J. L., Lonergan, S. M. and Rowe, L. J. 2004. Early postmortem biochemical factors influence tenderness and water holding capacity of three porcine muscles. Animal Science **82**:1195-1205.

[16]Chang, Y. S. and Chou, R. G. R. 2010. Postmortem degradation of desmin and calpain in breast and leg and thigh muscles from Taiwan black-feathered country chickens. Journal of the Science of Food and Agriculture **90**:2664-2668.

[17]Huang, M., Huang, F., Xu, X. L. and Zhou, G. H., 2011. The effect of active caspase-3 on degradation of chicken myofibrillar proteins and structure of myofibrils. Food Chemistry **128**:22-27.

[18]Wank,V., Fischer, M. S., Walter, B. and Bauer, R. 2006. Muscle growth and fiber type composition in hind limb muscles during postnatal development in pigs. Cell Tissues Organs **182**:171-181.

[19]Mikulski, D., Celej, J. and Jankowski, J. 2011. Growth performance, carcass traits and meat quality of slower-growing and fast-growing chickens raised with and without outdoor access. Asian Australasian Journal of Animal Science **24**:1407-1416.

[20]Zhao, G. P., Cui, H. X. and Liu, R. R .2011. Comparison of breast muscle meat quality in 2 broiler breeds. Poultry Science **90**:2355-2359.

[21]Orzechowska, B., Wojtysiak, D. and Migdal, W. 2008. Relationships between muscle fibre characteristics and physicochemical properties of longissimus lumborum muscle and growth rate in pig fatteners of three breeds. Animal Science Papers and Reports **26**:277- 285.

[22]Brooks, J. C. and Savell, J. W. 2003. Perimysium thickness as an indicator of beef tenderness. Meat Science **67**:329-334.

[23]Huff-Lonergan, E. and Lonergan, S. M. 2005. Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Science **71**:194-204.

[24]Murray, A. C., Jeremiah, L. E. and Martin, A. H. 1983. Muscle fibre orientation and its effect on measurements of tenderness of bovine longissimus dorsi muscle. Food Science and Technology **18**:607-617.

[25]Bertram, H. C., Straadt, I. K., Jensen, J. A. and Aaslyng, M. D. 2007. Relationship between water mobility and distribution and sensory attributes in pork slaughtered at an age between 90 and 180 days. Meat Science **77**:190-195.

[26]Labeit, S. and Kolmerer, B.1995. Titins: Giant proteins in charge of muscle ultrastructure and elasticity. Science **270**:293-296.

[27]Burke,W. H. and Henry, M. H.,1997. Characteristics of the pectoralis supercialis and semimem-branosus of broiler strain chickens, Bantam chickens, and the reciprocal crosses. Poultry Science **76**:767-773.

[28]Lonergan, S. M., Deeb, N., Fedler, C. A. and Lamont, S. J., 2003. Breast meat quality and composition in unique chicken populations. Poultry Science **82**:1990-1994.

[29]Yang, C. W., Du, H. R., Li, X. C., Li, Q. Y., Zhang, Z. R., Li, W. and Jiang, X. S. 2011. Evaluation for meat quality performance of broiler chicken. Journal of Animal and Veterinary Advances **10**:949-954.

[30]Koohmaraie, M. 1996. Biochemical factors regulating the toughening and tenderization processes of meat. Meat Science **43**:193-201.

[31]Wilhelm, A. E., Maganhini, M. B., Hernandez-Blazquez, F. J., Ida, E. I., Shimokomaki, M. 2010. Protease activity and the ultrastructure of broiler chicken PSE(pale, soft, exudative) meat. Food Chemistry **119**:1201-1204.

[32]Nishimura, T., Fang, S. and Toshiaki, I. 2008. Structural weakening of intramuscular connective tissue during postmortem aging of pork. Animal Science **79**:716-721.