Journal of Animal and Veterinary Advances 10 (8): 949-954, 2011
ISSN: 1680-5593

Evaluation for Meat Quality Performance of Broiler Chicken

[1]Chaowu Yang, [1]Huarui Du, [1]Xiaocheng Li, [2]Qingyun Li,
[2]Zengrong Zhang, [2]Wen Li and [1]Xiaosong Jiang
[1]Sichuan Animal Science Academy, [2]Sichuan Dahen Poultry Breeding Co. Ltd.,
Chengdu, 610066 Sichuan, P.R. China

Abstract: The goal of this study was to evalaute the meat quality of broiler chicken by defining Meat Quality Index (MQI). Meat quality is a complex trait which is consist of several meat quality indicators and affected by a series of factors. So, evaluation for the meat quality of broiler is indeed a difficult project. In this study, the coupling model of Principal Component Analysis and Linear programming techniques for Multidimensional Analysis of Preferences (PCA-LINMAP) was constructed to evaluate meat quality performance of broiler chicken and 250 chickens both cocks and hens from 5 populations (S01, S02, S03, S05, D99 developed by Dahen Poultry Breeding Company and Sichuan Animal Science Academy) were used as an application case, the eight main meat quality indicators of breast muscle and leg muscle were collected. About 4 representative indicators were selected by cluster analysis, they are crude fat, ultimate pH, muscle fibre number and drip loss. And then the meat quality index was constructed by PCA-LINMAP coupling model, the results show that the meat quality of S01 is the best, S03 came next, D99 came last and meat quality of female is superior to the cock in each line. Finally, the value range of MQI was identified based on its property. The PCA-LINMAP model made the evaluation for meat quality easily and the all main meat quality indicators were gathered to one integrated trait which could be contained in the breeding plan with other traits such as production and reproduction traits of broiler.

Key words: Broiler chicken, high-quality meat chicken, PCA-LINMAP, meat quality evaluation, MQI, breeding

INTRODUCTION

In the past decades, the poultry breeding has achieved exciting progress. For example, broiler chickens have been improved in many traits such as daily weight gain, feed efficiency and resistance to disease. But now, the high selection intensity for growth rate has caused many problems, especially the decreasing trend for meat quality (Rance *et al*., 2002). At present, close attention is being paid to the chicken meat quality and the high-quality meat chicken industry are mushrooming all over the country in China (Shu, 2009). In animal breeding, meat quality is a complex trait, referring to the compositional, visual and sensory traits of a carcass or its retail cuts. Meat quality of chicken is stressed by Chinese consumers which refers to the sensory attributes of cooked product, i.e., tenderness, flavor, juiciness and color (Jiang and Groen, 2000).

Evaluation for meat quality of broiler chicken is all along a difficult problem that puzzles the researchers. Liao (1984) evaluate the meat quality of broiler according to the appearance of Cooked meat, Wu *et al*. (1998) considered that the evaluation for the broiler meat should include the objective and subjective evaluation, the former lie in chemical and physical characters of the meat, the latter means the sensory evaluation, however the method could be very difficult to operate. So, researchers try to construct a easy evaluation system for broiler meat quality in recent decades and obviously, the measure and comparison for the individual meat quality indicator became the hot topic in this area (Xi, 2000). Those researches concerning on the muscle fiber and chemical composition of broiler are most widely reported, Zhang and Yang (1998) evaluated the meat quality by fragrance. Le Bihan-Duval *et al*. (1999) used the ultimate pH, meat color and water holding capacity as the meat quality evaluation indicators. Ding *et al*. (2000) considered that the crude protein, crude fat, moisture content and collagen paly an important role in the meat quality of brolier meat. Kralik *et al*. (2001) concluded that abdominal fat weight is a important indicator that was tightly correlation with the meat quality. Kim (2001) applied the microorganism indicators to compare the meat quality of chicken wing and drumstick between Korea

Corresponding Author: Xiaosong Jiang, Sichuan Animal Science Academy, Niusha Road # 7, Chengdu, 610066 Sichuan, P.R. China

with America. Chen *et al.* (2002) deduced that intramuscular fat and inosinic acid are key fators that influence the flavor of broiler meat quality. The traditional evaluation of meat qualiy obtain some seemingly valid conclusions by comparing difference respectively between a series of indicators in chicken meat such as chemical composition, flavor indicators (Mehaffey *et al.*, 2006; Jukna *et al.*, 2007). However, these meat quality indicators influence each other, meanwhile not all the traits are better or worse to a piece of chicken meat. Therefore, this evaluation of meat quality cannot judge which is superior. Tang (2003) evaluated the broiler meat quality based on judges tasting and obtained a evaluation model by regression analysis but this method has some weak repeatability because of its subjectivity. Yang *et al.* (2007) analysed the function of the main meat quality indicators on meat quality and applied the 1st principal component as the meat quality index to evaluate the broiler meat quality, however actually the 1st principal component cannot represent the whole information of the all meat quality indicators.

At present, the developing high-quality chicken industry needs a unified standard which coluld evaluate the quality of chicken meat accurately in China. The aim of the present study was to evaluate, meat quality performance of broiler chicken by constructing Meat Quality Index (MQI).

MATERIALS AND METHODS

Experimental birds: In this current research, high-quality chicken populations were used including five pure lines (S01, S02, S03, S05, D99, these resource polpulations were granted the pureline certificate issued by Sichuan province government) which were developed in form of pureline selection by Sichuan Dahen Poultry Breeding Company using local breeds in Sichuan province of China. For each population, 50 chickens both cocks and hens were randomly sampled for slaughtering.

Management and phenotypic measurements: High-quality chickens were raised in cages according to the conventional program for commercial broilers. At the age of 90 days, body weight was measured on live birds after 12 h with no access to feed. After slaughter at the same day of age, the eight main meat quality indicators of breast muscle and leg muscle were measured including Crude Protein (CP, X_1), Crude Fat (CF, X_2), ultimate pH (pH, X_3), Intramuscular Fat (IMF, X_4) Inosinic acid (IMP, X_5), Muscle Fibre Number (MFN, X_6), Muscle Fibre Diameter (MFD, X_7) and the Drip Loss (DLR, X_8). These traits were measured according to the standard criterion after processing.

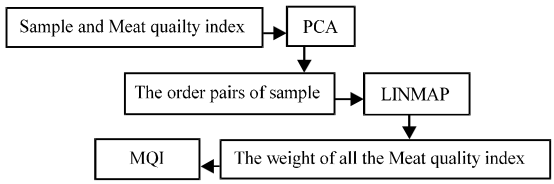

Fig. 1: Schematic diagram of computing program on PCA-LINMAP coupling model

Statistical analysis

Cluster analysis: In this study all the, eight meat quality indicators selected are play an important role in meat quality of broiler, however these index may be interact each other, positive or negative. Therefor, cluster analysis was used to explore the relationship of the eight meat quality traits firstly.

PCA-LINMAP coupling model: PCA-LINMAP coupling model was construct to evaluate the meat quality performance for broiler in the current study. Starting from the basic idea sample to index, the data collection of meat quality order was obtained by Principal Component Analysis (PCA) (Yang *et al.*, 2007) which defined as O, the data collection of meat quality order pairs that came from the comparison of meat quality each other defined as Q could be deduced and then input Q to Linear programming techniques for Multidimensional Analysis of Preferences (LINMAP), the weight of all the main meat quality index output (Fig. 1).

Computing technique: The software involved SAS 9.0 and lingo 9.0 in the current study. Correlation analysis, Cluster analysis and Principal component analysis employed the PROC CORR, PROC VARCLUS and PROC PRINCOMP, respectively by SAS and the LINMAP used simplex method by Lingo.

RESULTS AND DISCUSSION

Correlation analysis: Eight important indicators closed link with meat quality of broiler were used by correlation analysis in current study. CP had significant positive correlation with CF, IMP, IMF nad MFN and had significant oppsite correlation with MFD and DLR. pH had moderate positive correlation with IMP, MFD and DLR. More results wre shown in Table 1.

The main selection indicators could be determined approximately by analysing the character of correlation here, CF, pH, MFN and DLR could be chose as main selection traits, purpose selcetion on the four traits will hopefully ensure the improvement of meat quality of broiler.

Table 1: Corrections among meat quality traits in high quality meat chicken

Traits	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
CP (X_1)	1.00							
CF (X_2)	0.60**	1.00						
pH (X_3)	-0.46**	-0.16	1.00					
IMF (X_4)	0.47**	0.97**	-0.06	1.00				
IMP (X_5)	0.64**	0.58**	0.28*	0.52**	1.00			
MFN (X_6)	-0.03	0.43**	0.27*	0.42**	0.34**	1.00		
MFD (X_7)	-0.10	-0.26*	0.08	-0.27*	-0.22	-0.69**	1.00	
DLR (X_8)	-0.71**	-0.88**	0.31**	-0.85**	-0.59**	-0.51**	0.38**	1.00

*p<0.05, **p<0.01

Table 2: Cluster result of eight meat quality indicators

		R^2			
		----------			Proportion
Clusters	Variables	Own cluster	Next closest	1 - R^2 ratio	explained
1	X_1 (CP)	0.6335	0.2428	0.4841	0.7219
	X_2 (CF)	0.8573	0.4841	0.2766	
	X_4 (IMF)	0.7616	0.4562	0.4384	
	X_5 (IMP)	0.6465	0.2408	0.4656	
2	X_7 (MFD)	0.6785	0.4464	0.5808	0.6785
	X_8 (DLR)	0.6943	0.4285	0.5349	
3	X_6 (MFN)	1.0000	0.5123	0.0000	1.0000
4	X_3 (pH)	1.0000	0.0707	0.0000	1.0000

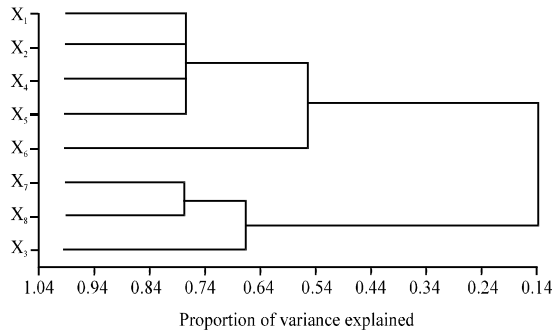

Fig. 2: Clustering tree of eight meat quality traits

Cluster analysis: About eight indicators were classfied into four clusters by cluster analysis, the proportion of explained variance exceed 80% of the total variance (Table 2, Fig. 2). And then, the square of correlation coefficient of each trait with other traits ($\overline{R_i}^2$) in the same cluster was calculated, the trait has a highest $\overline{R_i}^2$ value was chose as the representative indicator each cluster, however, the indicator has a lower R^2 with next closest value should be chose in those clusters have two traits and obviously, there is no alternative for those clusters have only one indicator.

Finally, four representative indicators (CF, pH, MFN and DLR) were chose from each cluster (Table 3). As the representative indicator of the 1st cluster, higher value of CF involve higher value of CP, IMF and IMR, higher value of DLR involve higher value of MFD in the 2nd cluster as the same.

Evaluation for meat quality: Phenotype value of the four representative indicators were standardized according to each characteristic in broiler meat for example as the positive indicator, higher value of CF (X_2) and MFN (X_6) involve soft, fresh and juicy in broiler meat as the negative indicator, higher value of DLR (X_8) means lower capacity of keep water in meat but pH (X_3) is the optimum trait too low or high will involve inferior meat quality. The standardization data of the four indicators show in Table 4.

Table 3: Correlation matrix and representative indicator of the 1st cluster

Variables	X_1 (CP)	X_2 (CF)	X_4 (IMF)	X_5 (IMP)
X_1 (CP)	1.00	0.60	0.47	0.64
X_2 (CF)	0.60	1.00	0.97	0.58
X_4 (IMF)	0.47	0.97	1.00	0.52
X_5 (IMP)	0.64	0.58	0.52	1.00
$\overline{R_i}^2$	0.66	0.88	0.81	0.67

Table 4: Equalization data of four meat quality indicators

Line	Sex	CF (X_2)	pH (X_3)	MFN (X_6)	DLR (X_8)
D99	♂ A	0.7937	1.0141	0.8362	-1.1699
D99	♀ B	0.8058	0.9800	0.9023	-1.1269
S01	♂ C	1.3530	1.0092	1.0368	-0.8765
S01	♀ D	1.2327	1.0141	1.1267	-0.7995
S02	♂ E	0.8118	1.0157	1.0903	-1.0261
S02	♀ F	1.1124	0.9946	1.0387	-0.9013
S03	♂ G	0.9862	0.9833	1.0578	-0.9341
S03	♀ H	1.1846	0.9671	0.9170	-0.8307
S05	♂ J	0.7817	1.0125	0.8907	-1.2106
S05	♀ K	0.9381	1.0092	1.1034	-1.1244

Table 5: Eigen values and total variance explained of four principal components

Principal component	F_1	F_2	F_3	F_4
Eigenvalues	2.2685	1.2408	0.4196	0.0815
Variance (%)	56.8272	30.9320	10.4968	2.0276
Cumulative (%)	57.0257	87.5252	97.9730	100.0000

Principal component analysis was used to evaluate meat quality after the cluster analysis. Four principal components obtained after principal component analysis used the four representative indicators both the cock and female of five pure lines mentioned privious. The eigenvalue and total variance explained of each principal component show in Table 5. The eigen value of 1st principal component is 2.2685, the proportion explained total variance is 56.82%, the eigen value of the 2nd is 1.2408, the proportion explained total variance is 30.93% and the cumulative proportion explained total variance of the 1st two principal components reached 87.52% which reflect the all information of meat quality traits more or less. So, the 1st two principal components

Table 6: Eigenvalues and eigenvectors of the two Selected Principal Components (SPC)

SPC	X_2	X_3	X_6	X_8	Eigen values	Variance (%)
F_1	0.5982	-0.1358	0.4325	0.6537	2.2685	64.6425
F_2	-0.0584	0.8027	0.5348	-0.1358	1.2408	35.3575

Table 7: Principal component score and comprehensive score of meat quality each lines

Line	Sex	F_1	F_2	Total score	Rank
D99	♂ A	-0.0660	1.3737	0.4430	10
	♀ B	0.0025	1.3752	0.4879	8
S01	♂ C	0.5478	1.4046	0.8507	2
	♀ D	0.5644	1.4532	0.8786	1
S02	♂ E	0.1485	1.4903	0.6229	7
	♀ F	0.3033	1.4243	0.6996	5
S03	♂ G	0.4309	1.3103	0.7418	4
	♀ H	0.3904	1.4113	0.7514	3
S05	♂ I	-0.0760	1.4078	0.4486	9
	♀ J	0.1663	1.4981	0.6372	6

were chose to evaluate the meat quality as the comprehensive indicator. The corresponding eigen values and eigen vectors were shown in Table 6. The two selected principal components showed following:

$$F_1 = 0.5982X_2 - 0.1358X_3 + 0.4325X_6 + 0.6537X_8$$

$$F_2 = -0.0584X_2 + 0.8027X_3 + 0.5348X_6 - 0.1358X_8$$

The eigen vector indicate the contribution rate to each principal component, it is absolute value and sign reflect amount and attribute. The 1st principal component is a main reflection of Crude Fat (CF, X_2) and Drip Loss (DLR, X_8) and the second largely reflect ultimate pH (pH, X_3) while Muscle Fibre Number (MFN, X_6) was reflected in that two.

The four selected indicators were summed up in two principal components thus the evaluation for meat quality appeared to be full and simple. The result of evaluation for meat quality both the cock and female in five pure broiler lines shown in Table 7.

The order of meat quality showed as S01♀>S01♂>S03♀>S03♂>S02♀>S05♀> S02♂>D9♀> D99♂>S05♂. Generally, the meat quality of S01 is the best, S03 came next, D99 came last and meat quality of female is superior to the cock in each line.

Construction of Meat Quality Index (MQI): After the principal component analysis were:

$$O = \{D,C,H,G,F,J,E,B,I,A\}$$

was deduced and the:

$$Q = \begin{Bmatrix} (D,C),(D,H),\ldots,(D,A) \\ ,\ldots,(B,I),(B,A),(I,A) \end{Bmatrix}$$

the square of weight of each trait W_j obtained though inputting Q into LINMAP model where:

$$W_j = 0.3660, 0.1960, 0.4686, 0.3746$$

So that the absolute weight value of each trait is:

$$w_j = 0.6050, 0.4428, 0.6845, 0.6120$$

Two kinds of weight obtained after the simplification for the w_j where:

$$w_{j1} = 0.5400, 0.3953, 0.6110 - 0.5463$$

$$w_{j2} = 0.2581, 0.1888, 0.2920, 0.2611$$

And then meat quality index deduced by:

$$MQI = \sum w_j \cdot X_j$$

where, X_j represent the phenotype data of each trait. So:

$$MQI_1 = 0.5400CP + 0.3953pH + 0.6110MFN - 0.5463DLR$$

$$MQI_2 = 0.2581CP + 0.1888pH + 0.2920MFN + 0.2611DLR$$

Actually, the result of MQI_1 is equated with MQI_2, the only difference is that the former employed the standardized data, the latter employed the normalized data. Meat quality is complex trait which was governed by several factors.

Eight meat quality indicators were chose which were regarded as the main traits affecting the meat quality in the current study. Four representative indicators were selected by cluster analysis, they are crude fat, ultimate pH, muscle fibre number and drip loss. And then the meat quality index was constructed by PCA-LINMAP coupling model.

Finally, the evaluation for meat quality become easily and the all main meat quality index were gathered to one integrated trait which could be contained in the breeding plan with other traits such as production and reproduction traits of broiler.

The properties of MQI: As mentioned before:

$$MQI = \sum w_j \cdot X_j$$

Where:

$$\sum w_j = 1 \text{ and } 0 < |X_j| < 2$$

So:

$$-2 \le MQI = \sum w_j \cdot X_j \le 2$$

But despite the representative indicators selected are positive for meat quality, the high phenotypic value does not mean high meat quality in different broiler breeds such as over valuation of pH involve dark meat color and low tenderness so, the high value of MQI does not mean high meat quality and vice versa in different broiler breeds.

However, there is little difference for each meat quality indicator in the same breeds due to the biology restrictions even if for different lines. On the basis of this analysis, the meat quality display statistically normal distribution and have a optimum range that MQI in the optimum range involve high meat quality and out of the optimum range involve low meat quality. As to the critical point (x1and x2 in the Fig. 3).

Effect of sex on the meat quality: The result of evaluation for the meat quality in five lines showed that meat quality of female is superior to the cock in each line which is caused by the physiological differences.

For the cock, the strongly oxidative metabolizing lead to a series of physical changes due to the the secreting of male hormone which result in accelerating of the exhaustion of nutrients and restraining of fat deposition (Lin *et al*., 2000).

The relatively lower of intramuscular fat is the main factor that the meat quality of cock inferior to the female. Aiming at solving the problem, extirpative castration was carried out by some sicentists and marked results were obtained. However, the scheme can hardly be practised for scale raising.

Choice of the meat quality evaluating indicator: The factors affect the meat quality of broiler are complex and the choice of the meat quality evaluating indicators is difficulty. The eight meat quality traits selected in this study were regarded as the main factors that affect the meat quality according to the great number of studies (Groom, 1990) that crude protein, crude fat, intramuscular fat and inosinic acid reflect the nutrition, cuisine and flavor of the meat (Zhang and Sun, 2008), muscle fibre number, muscle fibre diameter and the drip loss reflect the flavor and tenderness (Wu *et al*., 1998; Dranfield and Sosnicki, 1999; Chen and Chen, 2002) and ultimate pH closely related with flavor, tenderness and meat color (Allen *et al*., 1997, 1998; Rathgeber *et al*., 1999; Qiao *et al*., 2001).

To sum up the above arguments, these eight meat quality evaluating indicators could reflect the meat quality perfectly which is representative and feasibility for comprehensive evaluation on meat quality of broiler chicken.

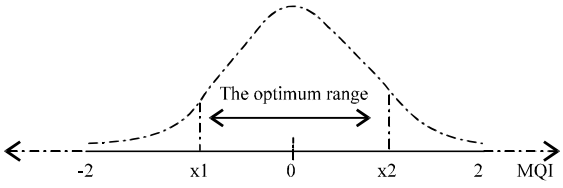

Fig. 3: Normal distribution graphics of the meat quality index in broiler

It is worthwhile to note that those nutrition indicators were significantly positive correlation among crude protein, crude fat, intramuscular fat and inosinic, the reason is that the meat quality indicators phenotype data were derived from the measurement of dry matter which result in that any unknown key matter were measured repeatedly in different meat quality indicators. Therefor, the advise is that avoiding the measurement of dry matter.

PCA-LINMAP coupling model: The principle component analysis is an objective evaluation method but the weight coefficients of evaluating indicator by which is impossible.

The weight coefficients just reflect the variance contribution to each principle component and which only reflcet a part information of the total even the first principle component so, the weight coefficients of each principle component is different from that of each evaluating indicator that formerly some scholars have selected the first principle component as MQI to evaluating the meat is improper (Yang *et al*., 2007).

As a method for deciding objective weight of the indicator according to the objective evluation results (Srinivasan and Shocker, 1973), LINMAP has been being widely applied in the field of economics, engineering and social sciences (Sadi-Nezhad and Akhtari, 2008; Shevchenko *et al*., 2008; Albayrak and Erensal, 2009).

CONCLUSION

In this current study, PCA provide the effective solution to the evaluation for meat quality of broiler chicken and that the process of meat quality evaluation is simplified by the deciding of each meat quality evaluating indicator based on LINMAP.

ACKNOWLEDGEMENTS

The research was financially supported by the Chinese National Natural Science Funds (Grant No. 31072026) and the Chinese National Broiler System of Industrial Techniques (Grant No. nycytx-42-G1-06).

REFERENCES

Albayrak, Y.E. and Y.C. Erensal, 2009. Leveraging technological knowledge transfer by using fuzzy linear programming technique for multiattribute group decision making with fuzzy decision variables. J. Intell. Manuf., 20: 223-231.

Allen, C.D., S.M. Russell and D.L. Fletcher, 1997. The relationship of broiler breast meat colour and pH to shelf life and odor development. Poult. Sci., 76: 1042-1046.

Allen, C.D., D.L. Fletcher, J.K. Northcutt and S.M. Rusell, 1998. The relationship of broiler breast colour to meat quality and shelf life. Poult. Sci., 77: 361-366.

Chen, J.L., G.P. Zhao and M.Q. Zheng, 2002. Comparison of fat deposition and inosinic acid content between the growth-rapid broiler and Chinese native chicken. China Poultry, 24: 16-18.

Chen, K.W. and G.H. Chen, 2002. Study on the relation between muscle fiber and meat quality in broilers. Chinese J. Anim. Sci., 38: 6-7.

Ding, H.B., R.J. Xu and GA. Chen, 2000. Comparison of meat quality between local Chinese chicken and the broilers. Anim. Husbandry Vet. Med., 2: 16-18.

Dranfield, E. and A.A. Sosnicki, 1999. Relationship between muscle growth and poultry meat quality. Poultry Sci., 78: 743-746.

Groom, G.M., 1990. Factors affecting poultry meat quality. Options Mediterraneennes Ser. A, 7: 205-210.

Jiang, X.S. and A.F. Groen, 2000. Chicken breeding with local breeds in China. J. Anim. Sci., 13: 1482-1498.

Jukna, C., V. Jukna, V. Valaitiene and A. Korsukovas, 2007. Comparative evaluation of meat quality of different animal. Vet. Zootech., 37: 786-793.

Kim, C.R., 2001. Microbiological and sensory evaluation of refrigerated chicken in summer. J. Fd. Hyg. Safety, 16: 16-20.

Kralik, G., G. Kusec and S. Ivankovic, 2001. Effect of dietary oils on fatty acids content in chicken meat. Proceedings of the 47th International Congress of Meat Science and Technology, Aug. 26-31, Krakow, Poland, pp: 230-231.

Le Bihan-Duval, E., N. Millet and H. Remignon, 1999. Broiler meat quality: Effect of selection for increased carcass quality and estimates of genetic parameters. Poult. Sci., 78: 822-826.

Liao, X.G., 1984. Suggestions about slaughter test for meat birds. Chinese J. Anim. Sci., 5: 33-35.

Lin, M., Z.Y. Xiao and D.H. He, 2000. Discussion on Influencing factors of meat quality in broiler. Guide Chinese Poultry, 17: 10-11.

Mehaffey, J.M., S.P. Pradhan, J.F. Meullenet, J.L. Emmert, S.R. McKee and C.M. Owens, 2006. Meat quality evaluation of minimally aged broiler breast fillets from five commercial genetic strains. Poult. Sci., 85: 902-908.

Qiao, M., D.L. Fletcher, D.P. Smith and J.K. Northcutt, 2001. The effect of broiler breast meat color on pH, moisture, water-holding capacity and emulsification capacity. Poult. Sci., 80: 676-680.

Rance, K.A., G.M. Mcentee and R.M. Mcdevitt, 2002. Genetic and phenotypic relationships between and within support and demand tissues in a single line of broiler chicken. Br. Poul. Sci., 43: 518-527.

Rathgeber, B.M., J.A. Boles and P.J. Shand, 1999. Rapid postmortem pH decline and delayed chilling reduce quality of turkey breast meat. Poult. Sci., 78: 477-484.

Sadi-Nezhad, S. and P. Akhtari, 2008. Possibilistic programming approach for fuzzy multidimen-sional analysis of preference in group decision making. Applied Soft Comput., 8: 1703-1711.

Shevchenko, G., L. Ustinovichius and A. Andruskevicius, 2008. Multi-attribute analysis of investments risk alternatives in construction. Baltic J. Sustainability, 14: 428-443.

Shu, D.M., 2009. Development strategy of the high quality chicken industry. Guide Chinese Poult., 26: 38-39.

Srinivasan, V. and A.D. Shocker, 1973. Liner programming techniques for multidimensional analysis of preferences. Psychometrika, 38: 337-369.

Tang, H., 2003. Study on meat quality and selection methods on the crossbreeding lines of quality meat-type chicken. Ph.D. Thesis, Animal Genetics at the China Agriculture University.

Wu, X.S., G.H. Chen, K.W. Chen, W. Kehua and C. Hong *et al*., 1998. Comparison on histologic characteristic of muscle and muscle quality in Chinese native chickens. J. Yangzhou Univ. (Agric. Life Sci. Edn.), 19: 52-58.

Xi, Z., 2000. An investigation on the flavor compounds and texture in Chinese chicken meat. Ph.D. Thesis, The Philosophy at the University of Hong Kong.

Yang, C.W., Q. Zhu and X.S. Jiang, 2007. Principal component analysis for the evaluation of meat quality performance in chickens. J. Biomathe., 22: 547-553.

Zhang, D.X. and S. Yang, 1998. Study on the meat quality in the high-meat quality chicken. China Poult., 20: 1-2.

Zhang, Y.M. and X.L. Sun, 2008. Nutritive value and function of chcken meat. Meat Industry, 328: 57-58.