

Evaluation for Meat Quality Performance of Broiler Chicken

¹Chaowu Yang, ¹Huarui Du, ¹Xiaocheng Li, ²Qingyun Li,

²Zengrong Zhang, ²Wen Li and ¹Xiaosong Jiang

¹Sichuan Animal Science Academy, ²Sichuan Dahan Poultry Breeding Co. Ltd.,
Chengdu, 610066 Sichuan, P.R. China

Abstract: The goal of this study was to evaluate the meat quality of broiler chicken by defining Meat Quality Index (MQI). Meat quality is a complex trait which consists of several meat quality indicators and is 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 Dahan 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 easy 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 is 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) evaluated 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 lies 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 play an important role in the meat quality of broiler meat. Kralik *et al.* (2001) concluded that abdominal fat weight is an important indicator that was tightly correlated with the meat quality. Kim (2001) applied the microorganism indicators to compare the meat quality of chicken wing and drumstick between Korea

with America. Chen *et al.* (2002) deduced that intramuscular fat and inosinic acid are key factors that influence the flavor of broiler meat quality. The traditional evaluation of meat quality 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 could 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 populations were granted the pureline certificate issued by Sichuan province government) which were developed in form of pureline selection by Sichuan Dahan 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.

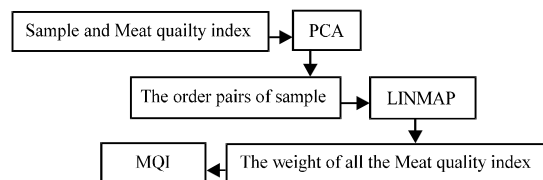


Fig. 1: Schematic diagram of computing program on PCA-LINMAP coupling model

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. Therefore, 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 selction 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

Clusters	Variables	R ²			Proportion explained
		Own cluster	Next closest	1 - R ² ratio	
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

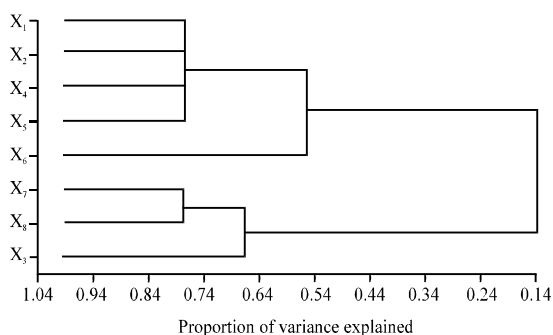


Fig. 2: Clustering tree of eight meat quality traits

Cluster analysis: About eight indicators were classified 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 (\bar{R}_i^2) in the same cluster was calculated, the trait has a highest \bar{R}_i^2 value was chose as the representative indicator each cluster, however, the indicator has a lower R² 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

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
\bar{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

to each characteristic in broiler meat for example as the positive indicator, higher value of CF (X₂) and MFN (X₆) involve soft, fresh and juicy in broiler meat as the negative indicator, higher value of DLR (X₈) means lower capacity of keep water in meat but pH (X₃) is the optimum trait too low or high will involve inferior meat quality. The standardization data of the four indicators show in Table 4.

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 previous. 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, X₂) and Drip Loss (DLR, X₈) and the second largely reflect ultimate pH (pH, X₃) while Muscle Fibre Number (MFN, X₆) 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 ♂ > D99 ♀ > 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:

$$Q = \left\{ (D, C), (D, H), \dots, (D, A) \right\} \\ \left\{ \dots, (B, I), (B, A), (I, A) \right\}$$

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 MQI₁ is equated with MQI₂, 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:

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

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 (x_1 and x_2 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 sicientists 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.

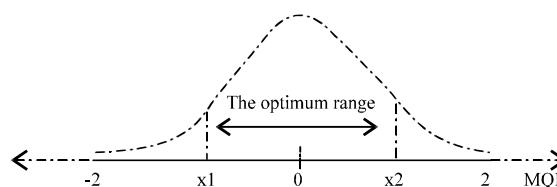


Fig. 3: Normal distribution graphics of the meat quality index in broiler

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. Therefore, 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 reflect 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 evaluation 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.

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