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Canonical Correlation Analysis for Estimation of Relationships Between Some Characteristics and Color of Broiler Meat

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Abstract: *In this study, canonical correlation analysis (CCA) was applied to estimate the relationships between two sets (X – Y, water holding capacity (WHC) and pH-lightness (L^*), redness (a^*), yellowness (b^*) values, respectively). Canonical correlation analysis was applied to data obtained from thigh and breast meats of 30 male Ross 308 broilers. Two canonical variable pairs were constituted as U and W. The first canonical correlation between U and W canonical variable pairs (U_1W_1) was found 0.481(p=0.020), while the second canonical correlation (U_2W_2) was 0.108(p=0.722). According to results of this analysis, relationship between the two canonical variable pairs was determined as 48.1%. In conclusion, the decrease of pH caused to increase in W_1 and as a result of this b^* value increased. So, the reduction of WHC and pH caused to decrease in L^* and a^* values and increase of b^* value.*

Keywords: *Canonical correlation, canonical variable, meat quality, water-holding capacity, meat color*

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I. Introduction

Broiler meat is mostly preferred with the reasons like low fat-high protein content, rich vitamin and mineral content, easy preparing, usability in a wide variety of dishes and being cheaper than red meat [1]. Poultry meat is delicious, easy to digest and have nutrients to meet the daily requirements for human [2]. However, increased level of prosperity and consciousness to healthy nutrition leads to an increase in more attentive consumers with quality demands.

The quality of poultry meat is a complex issue that may be evaluated from various standpoints. Carcass yields, appropriate carcass scores, good aesthetics, sensory and nutritional parameters are all desirable traits from a consumer and marketting perspective [3]. Pale, soft and exudative meat (PSE) is an increasing problem in the poultry industry. Properties of PSE meat are low water-holding capacity (WHC), paleness and soft gel formation [4,5]. This imperfect meat is the result of postmortem metabolism resulting in a sudden pH decline while meat temperature is still relatively high [6]. Meat color including lightness, redness, and yellowness values, L^*, a^*, and b^*, respectively, is another important characteristic affecting the consumer preference. The L^* value of the broiler meat is closely related to total antioxidant capacity due to the relationship between meat brightness and phospholipase A_2 activity, which oxidases the phospholipids in meat [7,8]. Meat color, WHC and pH can be influenced by environmental factors such as temperature prior to slaughter [9]. Feed formulation manipulations, access to outdoor and breed are the other factors affecting the meat color and WHC.

Researchers still care about the WHC, pH and meat color parameters while exploring the effects of different supplements on performance, health or another feature of broilers. Measuring L^*, a^* and b^* values needs a high technology equipment called color-meter, calculating WHC is a time consuming, long-period process by centrifuging. In this study, it was aimed to determine the relationships among pH, WHC, L^*, a^* and b^* values of broiler meats by using canonical correlation analysis. Therefore, it may be possible to evaluate some of the relations as an indicator of meat quality and prevent time loss and create an easier method to compare and discuss about the broiler meat quality.

II. Material and Methods

All procedures for animal handling and sample collection were applied according to the advices of the company, producing the genotypes.

Experimental diet was a typical corn-soybean based, which was formulated to meet all nutrient requirements reported in the Ross rearing guidelines [10] and any performance enhancers were not used. A total of 30 male birds were fed 42 days in 2 periods (Starter 0-21, Finisher 22-42). Breast and thighs of the birds were collected during the slaughter. The breast and thighs were separated with their skin on. The color values of breast and thighs were determined according to the CIELAB method using Minolta CR-400 (USA) colorimeter apparatus. Lightness, redness, and yellowness values, L^*, a^* and b^*, respectively, were represented according to this method. Water-holding capacity was calculated by the centrifuging method [11].

The canonical correlation analysis is a method used to reveal the correlations between the two data sets (*X* and *Y*), which contain $p > 1$, $q > 1$ number. Canonical correlation analysis is a multivariate method evaluating the relationship between sets through linear components. In the canonical correlation analysis, the magnitude of the relationship between the *X* data matrix, which contains the p-variable, and the data matrix Y which contains a number of factors, are found. In order to determine the direction and importance of the relationship, the correlation between the canonical variables which are the linear components of the X and Y matrices and the correlation between these two variables are calculated.

In canonical correlation analysis we want to maximize correlations between objects that are represented with two data sets. These data sets are;
$(X' = [X_1 X_2 \cdots X])$ and $(Y' = [Y_1 Y_2 \cdots Y])$
dimensions of *X* and *Y* is $m \times p$ and $m \times q$, respectively. The canonical variables were obtained from the *X* and *Y* variable data sets, U_i and W_i, respectively.
$U_i = a_i' X, W_i = b_i' Y$

Canonical correlation between U and W canonical variables, we can obtain,

$$\sigma_{Ui}^2 = \alpha_i' \sum_{XX} \alpha_i, \sigma_{Wi}^2 = b_i' \sum_{YY} b_i, \sigma_{UiWi}^2 = \alpha_i' \sum_{XY} b_i$$

and

$$Corr = \frac{\alpha_i' \sum_{XY} b_i}{\sqrt{\alpha_i' \sum_{XX} \alpha_i} \sqrt{b_i' \sum_{YY} b_i}} \quad (1)$$

To maximize correlation between *U* and *W* canonical variables *α* and *b* the coefficient of correlation where the coefficients are maximum must be calculated. The maximum correlation is possible between the *U* and *W* canonical variable pairs with unit variance as shown in eq. 2

$$\sigma_{Ui}^2 = \alpha_i' \sum\nolimits_{XX} \alpha_i = 1 \sigma_{Wi}^2 = b_i' \sum\nolimits_{YY} b_i = 1 \quad (2)$$

Let the maximization problem of eq. 1 write in a Lagrangian form (eq. 2), Lagrange function for *U* and *W* variables,

$$L = \alpha_i' \sum\nolimits_{XY} b_i - \frac{1}{2} \lambda_X (\alpha_i' \sum\nolimits_{XX} \alpha_i - 1) - \frac{1}{2} \lambda_Y (b_i' \sum\nolimits_{YY} b_i - 1) \quad (3)$$

To maximize the eq. (3), after taking derivatives *L* function with respect to a and b with the constraint $\lambda_X = \lambda_Y = \lambda$ given eq. (2) and (3). So, canonical correlations are calculated from the maximum one to minimum one ($\lambda_1 \geq \lambda_2 \geq \cdots \lambda_P$). [12, 13, 14, 15].

The null and alternative hypotheses for assessing the statistical significance of the canonical correlation

$$H_0 = p_1 = p_2 = \cdots = p_p$$

$H_0 = p_i \neq 0$ at least one $i=1,2, ..., p$

Bartlett test is common used to determine the statistical significance of canonical correlation [16].

$$\chi^2 = -[n - 1 - (p + q + 1)/2] \ln \left[\prod_{i=1}^{p} 1 - r_i^2 \right]$$

which is approximately distributed χ^2 as with $p * q$ degrees of freedom. We reject if $H_0 \chi^2 \geq \chi^2_\alpha$. Where, *n*: the number of cases, ln: the natural logarithm function, *p*: the number of variables in X set, *q*: the number of variables in Y set, r_i^2: the squared canonical correlations [17].

III. Results and Discussion

The descriptive statistics for examined traits are showed in Table 1. All the computational work was provided to study the relationships between two data sets of the traits by means of SPSS 21 statistical package. Pearson correlation coefficients for traits are showed Table 2. The highest correlation was predicted between b^* and a^* (0.568, p<0.001), while the lowest correlation was between a value and pH (-0.009, p=0.947). There was positive relationship between WHC and L^* value (0.303, p=0.020), while there was negative relationship between WHC and a^* value (-0.129, p=0.330).

Table 1. Descriptive statistics for studied traits

Parameters	Mean	Std. Dev.	Min.	Max.
WHC	58.6947	4.3486	48.96	69.49
pH	6.3846	0.1735	6.05	6.77
*L**	70.8571	3.9851	62.92	77.93
*a**	2.9964	0.3380	-0.9	11.17
*b**	7.6163	3.4575	1.81	16.90

Table 2. Pearson correlation coefficient for traits in two sets

	WHC	pH	L^*	a^*	b^*
WHC	1				
pH	0.284^*	1			
L^*	0.303^*	0.352^{**}	1		
a^*	-0.129	-0.009	-0.067	1	
b^*	-0.212	-0.169	-0.010	0.568^{**}	1

WHC: Water-holding capacity, L^*: Lightness, a^*: Redness, b^*: Yellowness, *: P<0.05; **: P<0.01.

However, some researchers have reported the relationship among broiler meat L^* value and pH and meat quality, low pH or high L^* value was reported to be associated low WHC [18, 19]. Low or high L^* values cause a decrease in WHC [20]. There is a positive relationship between pH and a^* value of broiler meat, while there was a negative relationship among pH and L^*, b^* values [18, 21, 22, 19].

It was found that early content of products was also proportional with water holding capacity and high fat products had lower water holding capacity [23]. This situation means higher water holding capacity is related with low fat and high pH. [24] have reported that PSE meats contained more protein and less fat than normal meats. Pale, soft and exudative (PSE) meat is a meat quality problem that affects important meat physical characteristics, such as WHC and pH [25].

In this study, X and Y variable sets have $p = 3$ and $q = 2$ variables, respectively. Hence, two canonical variable or variate pairs (U_i,W_i) can be potentially ensured and canonical correlations between pairs were calculated by using eq. (1). These canonical correlations are presented in Table 3.

As seen in Table 3, the first canonical correlation between *U* and *W* canonical variate pairs was found statistically significant (P<0.05). Therefore, only the first pair canonical variate was considered in the next calculations. By the first canonical variate pairs (U_1W_1), the canonical correlation is found 48.1% (rU_1W_1 = 0.481). This result noticed that study of the relationships between (WHC, pH) and meat color traits in broilers by using first canonical variates (U_1W_1) will be equal to original variables. So, 23.13 ($r^2U_1W_1 = (0.481)^2$) this percent of the variation will be expressed by only U_1-W_1 canonical pairs.

Table 3. Canonical correlation coefficients

Canonical					
Variables	Correlations	P value	Wilk's Lambda	DF	Chi-SQ
U_1W_1	0.481	0.020	0.760	6	15.090
U_2W_2	0.108	0.722	0.988	2	0.651

The standardized canonical coefficients are observed in Table 3. In canonical correlation analysis, standardized canonical coefficients indicate the alteration in canonical variable with regard to their standard deviation when original variable changes one standard deviation [15]. Indeed, these coefficients indicate the effect of original variables on the canonical variates. These coefficients and variable-variate correlations or canonical loadings were showed in Table 4.

According to U_1 canonical variate, L^* (-0.865) had the highest negative coefficient and b^* (0.618) had the highest positive coefficient in *X* data set in eq.6. For the W_1 canonical variate, pH (-0.688) had the highest coefficient in *Y* data set in eq.7. If there is multicollinearity in the data and the sample size is small, the standardized canonical coefficients may be unstable. In such cases, the use of loading and structural correlation has been proposed [26]. So, loadings for first canonical variates were showed in Table 4.

Table 4. Standardized canonical coefficients and canonical loadings for the first canonical variate pairs

Parameters	Standardized Canonical Coefficients	Variable –Variate Correlations	
		U_1	W_1
WHC	-0.556	-0.751	-0.660
pH	-0.688	-0.846	0.533
L*	-0.865	-0.855	0.079
a*	-0.247	0.162	0.987
b*	0.618	0.487	0.505

The U_1 and W_1 canonical variate pairs are expressed as standardized canonical coefficients in the eq.6 and eq,7.

$$U_1 = -0.865L - 0.247a + 0.618b \quad (6)$$

$$W_1 = -0.556WHC - 0.688pH \quad (7)$$

All loadings in *X* set, except b^*, were found negatively correlated with U_1 and W_1. On the other hand all loadings in *Y* set were found negatively correlated with U_1 and W_1. In spite of canonical coefficient of a^* was positive, canonical load of this variable was found positive in Table 4. When the original variables loadings in *X* set are examined, L^* value had the negative and highest value with (-0.855) and this followed by b^* value with 0.487, a^* value with (0.162). Besides, in *Y* set, WHC was highly and negative correlated with (-0.660) W_1 canonical variate while the pH was found (0.533).

To get high value for U_1, all parameters, except L^* value should be high value. Likewise, in order to get high value for W_1, WHC should be low values.

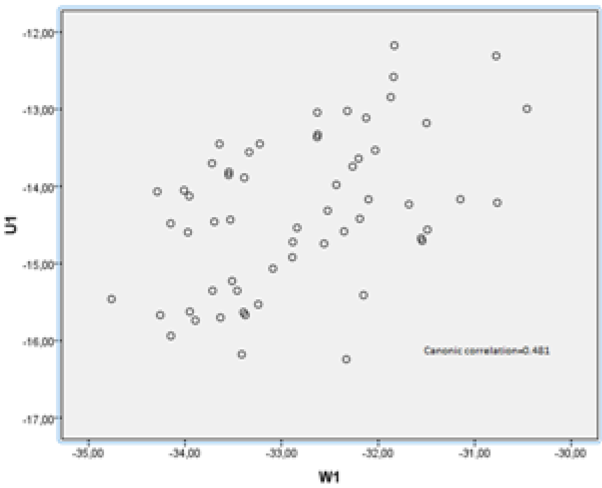

Figure. 1. Scater plot of canonical variates U_1 and W_1.

IV. Conclusion

Canonical correlation analysis was used for definition the relationships between (WHC, pH) and color traits. According to results of analysis, relationship between the two set has been found as 48.1% in fig. 1.

Hence, it can be expected that when WHC and pH traits have high values, color traits also will be high. The U_1 will be increased when W_1 increased because the canonical coefficient between U_1 and W_1 canonical variables is positive. According to this, the decrease of pH will cause to the increase of W_1 and as a result of this, b^* value will increase. In conclusion, the reduction of WHC and pH caused to decrease in L^* and a^* value and increase of b^* value.

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