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Canonical Correlation Analysis of Body Weight, Body Measurement and Carcass Characteristics of Jinghai Yellow Chicken

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Abstract: Canonical correlation analysis of three character sets including 23 variables of Jinghai yellow chicken was performed. Strong significant correlations were obtained between body weight and body measurement characters (0.9153), body weight and carcass characteristics (0.9618) and body measurement and carcass characteristics (0.9618). The coefficients represented 98.46, 98.96 and 92.82% of the total correlation between the two character sets, respectively. Canonical correlation analysis had been able to identify the relevant variables of the three character sets of Jinghai yellow chicken and it would be an appropriate method of analysis to find optimally correlated patterns of chicken body weight, body measurement and carcass characters.

Key words: Canonical Correlation Analysis (CCA,) jinghai yellow chicken, body weight

INTRODUCTION

Canonical Correlation Analysis (CCA) is a multivariate classical analysis method of two variable sets[1,2]; this statistical technique used to assess underlying correlation between two sets of data[3]. It identifies linear relationships that describe a maximum correlation between the two sets. The determination of linear combinations that possess a maximum correlation is important for the analysis of common feature in both data sets[4,5]. CCA plays an important role in multivariate statistics by providing the general theoretical framework for the techniques of factorial discriminate analysis, multivariate regression and correspondence analysis and by establishing the link between their theories[6]. CCA is applicable to evaluate three or more sets of variables[7-11].

CCA has been used extensively in astronomy[12], biochemistry, biophysics[13], financial management[14], agronomy[15], however, it has been little used in the fields of domestic animals and poultry, except for the domestic silkworm[16]. The aim of this study was to investigate the correlation coefficients of the three character sets of Jinghai yellow chicken including body weight, body measurement and carcass characteristics and detailed objectives were to analyze and determine the relationship of 23 relevant variables to the three above mentioned characters.

MATERIALS AND METHODS

Experimental animals: Jinghai yellow chicken is an indigenous yellow-brownish breed with prominent yellow shank. The breed is medium-sized and used as dual purpose, distributed in Haimen, Rugao, Rudong and the outskirt of Nantong, Jiangsu, China. The experiment was conducted at Haimen Integrated Poultry Company and extended for 16 weeks.150 fertilized eggs were collected randomly, assigned and hatched. 101 chicks (50 male, 51 female) were released, wing banded, weighted and transferred to brooding house.

Management and character indices: The experimental stock was raised in semi-intensive system. Feeding and drinking were *Ad. Libitum* according to routine method of layers and routine vaccination program was applied. Chicks were weighted at hatch and subsequently at weekly interval until the age of 16 weeks, body measurements were determined and chicks were slaughtered for carcass characteristics measurement. The 23 variables for the three sets were as follows: birth weight (X_1), body weight at 4 weeks of age (X_2), body weight at 8 weeks of age (X_3), body weight at 12 weeks of age (X_4), body weight at 16 weeks of age (X_5) (concerning body weight characters); body length (X_6), breastbone length (X_7), chest width (X_8), shank length (X_9), shank

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circumference (X_{10}) (concerning body measurement characters); carcass weight (X_{11}), semi-eviscerated weight (X_{12}), eviscerated weight (X_{13}), breast muscle weight (X_{14}), leg muscle weight (X_{15}), heart weight (X_{16}), liver weight (X_{17}), spleen weight (X_{18}), gizzard weight (X_{19}), proventriculus weight (X_{20}), small intestine length (X_{21}), head weight (X_{22}), claw weight (X_{23}) (concerning carcass characteristics).

Statistical methods and data analysis

Principle of CCA:

$$\text{Basic expressions:}\begin{cases}(S_{12}S_{22}^{-1}S_{21}-\lambda_i^2 S_{11})\alpha_i=0\\(S_{12}S_{11}^{-1}S_{21}-\lambda_i^2 S_{22})\beta_i=0\end{cases}$$

S_{11} and S_{22} were the covariance matrix of the first set and of the second set variables respectively, S_{12} and S_{21} were the covariance matrix of the first and second set variables and of the second and first set variables respectively; λ_i^2 was the eigenvalue, α_i and β_i were the corresponding eigenvector respectively. m eigenvalues can be calculated from the above equation, the square root $\sqrt{\lambda_i^2}$ of eigenvalues λ_i^2 was the correlation coefficient of corresponding canonical correlation variables, those m eigenvalues were in accordance to the following array rule:

$$\lambda_1^2 \geq \lambda_2^2 \geq \ldots \geq \lambda_m^2 \geq 0$$

m eigenvalues are corresponding to m eigenvectors, consequently can form m canonical correlation variables:

$$\begin{cases}V_i=\alpha_i x\\W_i=\beta_i y\end{cases}$$

Barlett Chi-square test was used for the significant test of the canonical correlation coefficients[17,18].

CANCORR process of SASv9.0 (Statistical analysis system v9.0) was used for the data analysis[19].

RESULTS

Mean, standard deviation and correlation coefficient: Table 1 showed means and standard deviations of 23 variables of Jinghai yellow chicken, Coefficients of Variability (C.V.) were low (7.77-13.23), medium (10.00-18.93) and high (11.29-31.66) for body measurement, body weight and carcass characteristics, respectively. Correlation coefficients between variables were depicted in Table 2.

Table 2 showed that 188 correlation coefficients were highly significant ($p<0.01$) and 16 were significant ($p<0.05$), from which the correlation coefficient between carcass weight (X_{11}) and semi-eviscerated weight (X_{12}) was the highest (0.996); there was highly significant correlation between birth weight (X_1) and body weight at 4 weeks of age (X_2), but there were no correlation between birth weight (X_1) and any other characters; there was significant correlation between proventriculus weight (X_{20}) and liver weight (X_{17}) and highly significant correlation between proventriculus weight (X_{20}) and gizzard weight (X_{19}), but there were no correlation between gizzard weight (X_{20}) and any other characters.

Canonical correlation coefficients between characters: Canonical correlation coefficients between 3 character sets were depicted in Table 3.

At level 0.01, the canonical correlation coefficients between body weight and body measurement characters, between body weight and carcass characteristics, as well as between body measurement and carcass characteristics were highly significant ($p<0.01$), which were 0.915321, 0.996883 and 0.961838, respectively and they represented 98.46, 98.96 and 92.82% respectively of total correlation between corresponding two character sets. The results also showed that correlation between body weight and carcass characteristics was the highest among the canonical correlation coefficients of the three sets and that between body measurement and carcass characteristics was medium.

Table 1: Mean and standard deviation of 23 variables for Jinghai yellow chicken

Variable	X_1 g^{-1}	X_2 g^{-1}	X_3 g^{-1}	X_4 g^{-1}	X_5 g^{-1}	X_6 cm^{-1}	X_7 cm^{-1}	X_8 cm^{-1}	X_9 cm^{-1}	X_{10} cm^{-1}	X_{11} g^{-1}	X_{12} g^{-1}
Mean	30.69	226.46	638.69	1110.68	1396.14	20.94	11.34	10.05	10.11	3.99	1227.39	1129.76
SD	3.07	37.91	120.90	209.92	231.76	1.64	0.95	1.33	1.24	0.31	208.44	198.46
Variable	X_{13} g^{-1}	X_{14} g^{-1}	X_{15} g^{-1}	X_{16} g^{-1}	X_{17} g^{-1}	X_{18} g^{-1}	X_{19} g^{-1}	X_{20} g^{-1}	X_{21} cm^{-1}	X_{22} g^{-1}	X_{23} g^{-1}	
Mean	955.27	76.18	106.29	7.39	23.14	2.43	25.68	4.68	132.64	56.61	45.93	
SD	170.59	12.83	24.57	2.34	4.42	0.68	4.43	0.86	14.97	17.16	13.37	

Table 2: Correlation coefficient between 23 variables for Jinghai yellow chicken

Variabe	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1	1											
X_2	0.311**	1										
X_3	0.079	0.819**	1									
X_4	0.125	0.717**	0.913**	1								
X_5	0.065	0.644**	0.881**	0.950**	1							
X_6	0.086	0.474**	0.710**	0.796**	0.813**	1						
X_7	0.017	0.401**	0.618**	0.699**	0.708**	0.687**	1					
X_8	0.090	0.483**	0.610**	0.696**	0.691**	0.607**	0.472**	1				
X_9	0.075	0.511**	0.728**	0.853**	0.848**	0.792**	0.723**	0.736**	1			
X_{10}	-0.044	0.313**	0.563**	0.617**	0.638**	0.565**	0.632**	0.401**	0.602**	1		
X_{11}	0.067	0.672**	0.874**	0.940**	0.994**	0.808**	0.704**	0.684**	0.835**	0.712**	1	
X_{12}	0.056	0.666**	0.864**	0.938**	0.990**	0.805**	0.717**	0.686**	0.833**	0.709**	0.996**	1
X_{13}	0.064	0.676**	0.879**	0.937**	0.985**	0.797**	0.695**	0.669**	0.823**	0.697**	0.989**	0.989**
X_{14}	0.049	0.534**	0.707**	0.696**	0.727**	0.658**	0.535**	0.409**	0.628**	0.476**	0.782**	0.767**
X_{15}	0.114	0.630**	0.838**	0.930**	0.947**	0.803**	0.678**	0.688**	0.867**	0.597**	0.949**	0.947**
X_{16}	0.049	0.535**	0.741**	0.848**	0.857**	0.743**	0.653**	0.727**	0.846**	0.579**	0.849**	0.846**
X_{17}	-0.034	0.384**	0.499**	0.547**	0.592**	0.474**	0.476**	0.401**	0.474**	0.458**	0.586**	0.580**
X_{18}	-0.088	0.106	0.286**	0.334**	0.332**	0.202*	0.123	0.213*	0.200*	0.222*	0.256*	0.227
X_{19}	-0.124	0.084	0.323**	0.359**	0.472**	0.372**	0.310**	0.269**	0.318**	0.328**	0.453**	0.469**
X_{20}	-0.005	0.000	0.120	0.036	0.124	0.004	-0.024	0.073	-0.032	0.015	0.207	0.190
X_{21}	0.133	0.178	0.259*	0.281*	0.390**	0.358**	0.325**	0.206	0.330**	0.262*	0.443**	0.418**
X_{22}	0.026	0.495**	0.616**	0.760**	0.753**	0.669**	0.596**	0.683**	0.761**	0.484**	0.740**	0.745**
X_{23}	0.039	0.471**	0.686**	0.816**	0.835**	0.763**	0.687**	0.647**	0.831**	0.677**	0.897**	0.894**

Variabe	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}	X_{23}
X_{13}	1										
X_{14}	0.787**	1									
X_{15}	0.946**	0.717**	1								
X_{16}	0.847**	0.532**	0.852**	1							
X_{17}	0.571**	0.496**	0.555**	0.543**	1						
X_{18}	0.247*	0.267**	0.277**	0.174	0.275**	1					
X_{19}	0.431**	0.305**	0.408**	0.247*	0.347**	0.324**	1				
X_{20}	0.201	0.153	0.058	-0.098	0.203*	0.164	0.366**	1			
X_{21}	0.389**	0.344**	0.324**	0.263*	0.257*	0.207	0.238*	0.143	1		
X_{22}	0.720**	0.480**	0.734**	0.801**	0.386**	0.003	0.224*	-0.175	0.256*	1	
X_{23}	0.890**	0.668**	0.829**	0.743**	0.460**	0.373**	0.363**	-0.085	0.357**	0.685**	1

* Significance at 0.05 level (2-tailed). ** Significance at 0.01 level (2-tailed)

Table 3: Canonical correlation coefficient between 3 character sets

First set	Second set	Canonical correlation coefficient	proportion	Probability value
Body weight character (five variables)	Body measurement characters (five variables)	λ_1=0.915321**	0.9846	0.0001
		λ_2=0.221846	0.0098	0.9936
		λ_3=0.146647	0.0042	0.9921
		λ_4=0.081952	0.0013	0.9745
		λ_5=0.022630	0.0001	0.8525
Body weight character (five variables)	carcass characters (thirteen variables)	λ_1=0.996883**	0.9896	0.0001
		λ_2=0.638438	0.0042	0.1741
		λ_3=0.604118	0.0036	0.3718
		λ_4=0.485113	0.0019	0.7242
		λ_5=0.318186	0.0007	0.8736
Body measurement character (five variables)	Carcass characters (thirteen variables)	λ_1=0.961838**	0.9282	0.0001
		λ_2=0.538819	0.0308	0.3797
		λ_3=0.456968	0.0198	0.6309
		λ_4=0.429840	0.0170	0.7408
		λ_5=0.229597	0.0042	0.9525

* Significance at a=0.05 level. ** Significance at a=0.01 level

Table 4: Formation of canonical variant for significant correlation between characters

Character	Formation of canonical variant
Body weight characters and body measurement characters	$V_1=0.0181x_1+0.6063x_2+0.8651x_3+0.9707x_4+0.9797x_5$
	$W_1=0.9070x_6+0.8041x_7+0.7750x_8+0.9590x_9+0.6991x_{10}$
Body weight character and carcass characters	$V_1=0.0241x_1+0.7201x_2+0.8926x_3+0.9515x_4+0.9997x_5$
	$W_1=0.9976x_{11}+0.9952x_{12}+0.9913x_{13}+0.7965x_{14}+0.9583x_{15}+0.8616x_{16}$ $+0.5371x_{17}+0.2309x_{18}+0.4369x_{19}+0.1730x_{20}+0.3545x_{21}+0.7318x_{22}+0.9101x_{23}$
Body measurement characters and slaughter characters	$V_1=0.8838x_6+0.7698x_7+0.7833x_8+0.9709x_9+0.7546x_{10}$
	$W_1=0.9207x_{11}+0.9201x_{12}+0.9060x_{13}+0.7665x_{14}+0.9213x_{15}+0.8957x_{16}$ $+0.5029x_{17}+0.1449x_{18}+0.3690x_{19}-0.0141x_{20}+0.4045x_{21}+0.8302x_{22}+0.9680x_{23}$

Formation of canonical variants between characters: Formation of canonical variants corresponding to canonical correlation coefficient between characters was listed in Table 4.

For the first pair (V_1, W_1) of canonical variants with significant correlation between body weight and body measurement characters, the coefficients of body weight at 12 weeks of age of (X_4) and at 16 weeks of age (X_5) were higher within V_1, while the coefficient of shank length (X_9) was the highest (0.959) within W_1, which indicated the close correlation of body weight at the 12 weeks of age (X_4) and/or at 16 weeks of age (X_5) and shank length (X_9) and caused the significant correlation between body weight (V_1) and body measurement (W_1) characters.

Significant correlation revealed between body weight and carcass characteristics. Coefficients of body weight at 12 (X_4) and 16 (x_5) weeks of age within V_1 were higher (0.9515) and (0.9997), respectively and within W_1 the coefficient of carcass characteristics was slightly higher (0.9976).

For (V_1, W_1) of canonical variants with significant correlation between body measurement and carcass characteristics, the coefficients of shank length (X_9) and body length (X_6) within V_1 were relatively greater and the coefficient of claw weight (X_{23}) within W_1 was the greatest, demonstrated the close correlation between shank length (X_9) and/or body length (X_6) and claw weight (X_{23}) to elucidate the significant correlation between body measurement characters (V_1) and carcass characteristics (W_1).

DISCUSSION

Canonical correlation analysis demonstrates the main contradiction among the multitudinous correlation variables and it can reflect the correlative essence of two character sets, that could not be settled by the simple correlation. Sometimes, due to the influence of other factors, simple correlation can only reflect the exterior, nonessential correlation.

Several authors reported positive correlation between body weight and body measurement characters in poultry[20-24]. Main characters of body measurement that strongly correlated to the body weight were chest depth, chest width, body length, shank length and breast bone length. The present study was in consistent with previous findings; however the greater effect of body measurement characters on body weight at 12 and 16 weeks of age of Jinghai yellow chicken were for shank length (0.9590) and body length (0.9070), respectively. The correlation coefficient of body weight with body measurement characters elevated steadily with age increased, reached the maximum (0.9797) at 16 weeks of age, it could be attributed to the self-accelerating growth phase.

There was intrinsic relationship between body weight and carcass characteristics in poultry. Highly positive significant correlation among body weight, carcass weight, semi-eviscerated weight, eviscerated weight, breast muscle weight and leg muscle were found[24]. Body weight character was strongly significant correlated with carcass characters[23]. Similarly, canonical correlation between body weight and carcass characters of Jinghai yellow chicken mainly reflected the close correlation of 12 weeks body weight and 16 weeks body weight and carcass weight.

Strong positive correlation between body measurement characters and carcass character was achieved for different chicken breeds[23-25], for Nigerian indigenous fowl, Tibetan chicken and Xiaoshan chicken and Xianju male chicken, respectively. Similar result was obtained in this study, canonical correlation between those two characters could mainly due to close correlation of shank length and body length, obviously shank length and body length had relatively greater influence on carcass characteristics of Jinghai yellow chicken.

Canonical correlation analysis had been able to identify the relevant variables of the three character sets of Jinghai yellow chicken and it would be an appropriate method of analysis to find optimally correlated patterns of chicken body weight, body measurement and carcass characters.

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