Asian-Aust. J. Anim. Sci.
Vol. 21, No. 11 : 1576 - 1584
November 2008

www.ajas.info

Canonical Correlation Analysis for Estimation of Relationships between Sexual Maturity and Egg Production Traits upon Availability of Nutrients in Pullets

Soner Cankaya*, Nuh Ocak and Murat Sungu
Ondokuz Mayis University, Faculty of Agriculture, Department of Animal Science
55139, Kurupelit, Samsun, Turkey

ABSTRACT : In this study, canonical correlation analysis (CCA) was applied to estimate the relationship between three different sexual maturity traits (X set: days to first egg (DFE), weight of the first egg (WFE), body weight at first egg (BWFE)) and level of nutrient intake (Y set: energy (EI) and protein intake (PI)) or the egg production traits at two different periods (Z set: number of egg (NE_1 and NE_T) and weight of egg (WE_1 and WE_T) from 22 to 25 (W_{first}) and 22 to 33 wk of age (W_{all}), respectively), which were measured from 64 egg-type pullets (Isa Brown) manipulated for time of access to energy and protein sources to onset of egg production. Partial CCA (PCCA) was used to eliminate the contribution of differences in the levels of nutrient intake to canonical variables for X and Z sets at the first production period. Estimated canonical correlation coefficients between X set and Y set (0.429, p = 0.042), X set and Z set (0.390, p = 0.007 for W_{first}) and within Z set (between W_{first} and W_{all}; 0.780, p<0.001), and partial canonical correlation coefficient between X set and Z set (0.415, p = 0.009) were significant. Canonical weights and loadings from CCA indicated that the BWFE had the largest contribution compared to the DFE and WFE to variation of egg number produced at two different periods. The results from PCCA indicated that the contribution of PI and EI to the degree of the correlation between canonical variables for X and Z sets were unfavourable. In conclusion, the effect of body weight at sexual maturity upon the availability of nutrients can have a higher contribution to variation of egg production in pullets if the contribution of differences in nutrient intakes to onset of egg production were eliminated. (**Key Words :** Canonical Correlation Analysis, Canonical Variable, Sexual Maturity, Nutrient Intake, Egg Production, Layer Pullet)

INTRODUCTION

Management and feeding practices in the starter, grower and/or developer phases can alter the body weight gain, growth curve, early egg weight and sexual maturity of the pullets and consequently egg production. Furthermore, advances in genetic selection make today's pullets quite different from those of only a few years ago (Flock, 1998; Jackson, 2006; Ding et al., 2008). Therefore, information on feeding programs for egg-type pullets to point of lay is still required to today's or improved pullets achieve an adequate sexual maturity in terms of body size at first egg, weight of the first egg and days to first egg, and subsequently the production characteristics of laying hens (Zhong et al., 2007; Sungu, 2007).

It is important to determine the relationship between two or more characters measured at early time and measured hard at or later time, since early selection is one of the modern selection programmes applied for a higher production in animal (Akbas and Takma, 2005; Cankaya and Kayaalp, 2007). If there is a relationship between nutrition and measured characters, multivariate analyses such as canonical correlation analysis (CCA), a technique for describing the relationship between two variable sets simultaneously and to produce both structural and spatial meanings (Thompson, 1984), contribute to layer type hens breeding by providing information based on indirect selection. If examined characters build up three variable sets, instead of CCA, partial canonical correlation analysis (PCCA) is preferred for estimating relationship between the sets. In the PCCA, mainstream is to describe the relationship between the linear combinations estimated from other two variable sets when the effect of one of three sets is eliminated (Timm, 2002).

Application of the CCA in poultry science began to

* Corresponding Author: S. Cankaya. Tel: +90-362-3121919-1389, Fax: +90-362-4576034, E-mail: scankaya@omu.edu.tr
Received February 13, 2008; Accepted August 4, 2008

Table 1. Treatments used in the experiment, and diet, schedule of feeding and duration of feeding of the each treatment

Treatments	Diet	Schedule of feeding	Duration of feeding
Control	Balanced diet	*Ad libitum*	Throughout the daily photoperiod
E60:P40	ES and PS	Sequentially	During 60% and 40% of daily photoperiod, respectively
E40:P60	ES and PS	Sequentially	During 40% and 60% of daily photoperiod, respectively
EPFC	ES and PS	Free choice	Throughout the daily photoperiod

ES = Diet consisted of energy sources in the balanced diet (control), PS = Diet consisted of protein sources in the balanced diet.

increase with the availability of related computer packages (Jaiswal et al., 1995; Akbas and Takma, 2005). Indeed, Akbas and Takma (2005) reported that canonical weights and loadings from the CCA indicated that age at sexual maturity had the largest contribution as compared with body weight and egg weight to variation of the number of egg productions at three different periods. To our knowledge, it is, however, not founded the applications of the CCA for estimating of relationships between egg production traits and some sexual maturity characteristics upon the availability of nutrients in pullets. Accordingly, the objectives of the present study were threefold: firstly, to estimate the interrelationship between three different sexual maturity traits (X set: days to first egg (DFE), weight of the first egg (WFE), body weight at first egg (BWFE)) and level of nutrient intakes (Y set: energy (EI) and protein intakes (PI)) or the egg production traits at two different periods (Z set: number of egg (NE_1 and NE_T) and weight of egg (WE_1 and WE_T) from 22 to 25 and 22 to 33 wk of age, respectively), which were measured from egg-type pullets manipulated time of access to energy and protein sources to onset of egg production, secondly, to determine which variables can be used as early selection criteria for increasing performances of layer type hens using CCA, but the main aim was to determine the contribution of differences in the levels of nutrient intake to canonical variables for X and Z sets.

MATERIALS AND METHODS

Animals and feeding

In this study, we examined DFE, WFE, BWFE, EI, PI, NE_1, NE_2, NE_T, WE_1, WE_2 and WE_T data which were measured from total 64 egg-type pullets (Isa Brown) manipulated time of access to energy and protein sources to onset of egg production (Sungu, 2007). The pullets were housed in a high-rise environmentally controlled house. Each dietary treatment was fed to 16 replicates (16 birds per treatment) from 9 to 21 wk of age. Then, the pullets were individually weighed, and were placed in a deep pit layer house ventilated both naturally and mechanically, and illuminated both artificially and naturally through the windows and fed a commercial layer diets. In the layer house, from 22 to 33 wk of age replicates were equally distributed into upper and lower level cages to minimize effect of cage environment. The lighting program (daily photoperiod) started with 11:00 h of light at the initiation of experiment and was increased by 27.5 min per wk until 14:30 h of light and then, by 30 min per wk until 16:00 h of light was achieved at 21 and 33 wk of age, respectively. Mean ambient temperature during the experimental period ranged between 18°C and 25°C.

Treatments used in the experiment, and diet, schedule of feeding and duration of feeding of the each treatment are presented in Table 1. The dietary regimens were selected with the assumption that regardless of dietary regimen, about 40% of the daily feed intake was consumed during the morning and about 60% during the afternoon (Keshavarz, 1998). All hens received a commercial layer peak diet from 22 (age at 50% production) to 33 (the end of the experiment) wk of age. Birds had free access to water. The control diets contained all the nutrients to satisfy the National Research Council (1994) recommendations for grower (from 9 to 11 wk of age), developer (from 12 to 16 wk of age), pre-layer (from 17 wk of age to the first egg age) and peak layer (from 22 to 33 wk of age).

Data collection

Each bird was weighed at 9, 11, 17 and 21 weeks, and at first egg. Age and body weight at first egg and weight of first egg were used as a measure and characteristics of sexual maturity. Egg counts were recorded daily during 21 to 33 wk of age, and mean egg weight for each pen was recorded daily for three consecutive 28-day periods. Total feed, ES and PS consumptions for each pen was measured separately on a weekly basis throughout the experiment.

Canonical correlation analysis (CCA)

The CCA, developed by Hotelling in 1935, focuses on the correlation between a linear combination of the variables in the sexual maturity variable set (X, px1) -called canonical variable U,- and a linear combination of the variables in the egg production performance variable set (Z, rx1) -called canonical variable W- such that the correlation between the two canonical variables is maximized (Gunderson and Muirhead, 1997). Canonical variables (U and W) which are needed to represent the association between the sexual maturity traits and the egg production traits measured from 64 egg-type pullets are so formed that the first pair has the largest correlation of any linear combination of the original variables. Subsequent pairs also have maximized correlation subject to the constraint that they are uncorrelated with each previous pair (Johnson and Wicherm, 2002). Symbolically, given X_{nxp} and Z_{nxr}, then $W_i = Za_i$ and $U_i = Xb_i$ where a_i and b_i are standardized canonical coefficients that can be used to determine which variables are redundant in interpreting the canonical variables (Cankaya and Kayaalp, 2007). These coefficients are the indication of relative importance of the variable set of the sexual maturity in determining the value of the variable set of the egg production performance, and i = 1,…,min(p,r). But the coefficients can be unstable because of presence of multicolinearity in the data. For this reason, the canonical loadings are considered to provide substantive meaning of each variable for the canonical variables (Akbaş and Takma, 2005). The resulting satisfy, $Corr(U_i,W_j) = 0$, $Corr(U_i,U_j) = 0$, $Corr(W_i,W_j) = 0$ for $i \neq j$ and $Corr(U_i,W_j) = \rho_i$ for i = j (Al-kandari and Jolliffe, 1997).

Canonical correlation coefficient (CCC, ρ_i) is measure of the interrelationship between two variable sets. Put and let $\rho_1^2,...,\rho_r^2$ $(0 \le \rho_r^2 \le ... \le \rho_1^2 \le 1)$ be min(p,r) ordered eigenvalues (λ_i) of the matrix $\sum_{11}^{-1}\sum_{12}\sum_{22}^{-1}\sum_{21}$, where $\Sigma=\begin{bmatrix}\Sigma_{11} & \Sigma_{12}\\ \Sigma_{21} & \Sigma_{22}\end{bmatrix}$ Their positive roots $\rho_1 \cdots \rho_p$ are the population canonical correlation coefficients between U and V.

$$\rho_{U_iW_i} = \sqrt{\lambda_i} = \frac{Cov(U,W)}{\sqrt{Var(U)Var(W)}} = \frac{a'\Sigma_{12}\,b}{\sqrt{(a'\Sigma_{11}\,a)(b'\Sigma_{22}\,b)}},\quad i = 1,...,r$$

Partial canonical correlation analysis (PCCA)

The PCCA focuses on the correlation between a linear combination of the variables in the sexual maturity variable set and a linear combination of the variables in the egg production performance variable set such that the correlation between the two canonical variables is maximized when the effect of nutrient intake variable set (Y, qx1) -called canonical variable V, is eliminated on the other two variable set (Cankaya, 2005). All equations for PCCA are given respectively alike that for CCA.

Partial canonical correlation coefficient (PCCC, ρ_{iY}) which is measure of the interrelationship between the sexual maturity variable set (U) and the egg production performance variable set (W_{first}) when the nutrient intake variable set is pegged. Put and let $\rho_{1Y}^2,...,\rho_{rY}^2$ $(0 \le \rho_{rY}^2 \le ... \le \rho_{1Y}^2 \le 1)$ be min(p,r) ordered eigenvalues (λ_i) of the matrix $\sum_{11.2}^{-1}\sum_{13.2}\sum_{33.2}^{-1}\sum_{31.2}$, where

$\sum_{11.2}^{-1}=\left[\sum_{11}-\sum_{12}\sum_{22}^{-1}\sum_{21}\right]^{-1}$, $\sum_{13.2}=\left[\sum_{13}-\sum_{21}\sum_{22}^{-1}\sum_{23}\right]$,

$\sum_{33.2}^{-1}=\left[\sum_{33}-\sum_{32}\sum_{22}^{-1}\sum_{23}\right]^{-1}$, $\sum_{31.2}=\left[\sum_{31}-\sum_{32}\sum_{22}^{-1}\sum_{21}\right]$.

Their positive roots $\rho_{1,Y},\cdots,\rho_{r,Y}$ are the population canonical correlation coefficients between U and W.

$$\rho_{i.Y} = \frac{a'_{i.2}(\Sigma_{13.2}\Sigma_{33.2}^{-1}\Sigma_{31.2})a_{i.2}}{a'_{i.2}\Sigma_{11.2}\,a_{i.2}};\quad i = 1,...,r$$

Interpretations of CCA and PCCA

The null and alternative hypotheses for assessing the statistical significance of the *CCC* are,

$$H_0 : \rho_1 = \rho_2 = ... = \rho_r = 0$$
$$H_1 : \rho_i \neq 0 \text{ at least one i = 1,2,,...,r}$$

The null and alternative hypotheses for assessing the statistical significance of the P*CCC* are,

$$H_0 : \rho_{1.Y} = \rho_{2.Y} = ... = \rho_{i.Y} = 0$$
$$H_1 : \rho_{i.Y} \neq 0 \text{ at least one i = 1,2,...r}$$

Bartlett test statistics for the statistical significance of ρ_i^2 is

$$\chi^2 = -[(n-1)-(p+r+1)/2]\log_e\left(\prod_{i=1}^{r}(1-\rho_i^2)\right)$$

which is approximately distributed as χ^2 with *pr* degrees of freedom. We reject H_0 if $x_2 \ge x_\alpha^2$. Where, n: the number of cases, log_e: the natural logarithm function, p: the number of variables in X set, r: the number of variables in Z set, ρ_i^2: the eigenvalues of $\sum_{11}^{-1}\sum_{12}\sum_{22}^{-1}\sum_{21}$ or the squared canonical correlations.

Bartlett test statistics for the statistical significance of $\rho_{i,Y}^2$ is

$$\chi^2 = -[(n-q-1)-(p+r+1)/2]\log_e\left(\prod_{i=1}^{r}(1-\rho_{i.Y}^2)\right)$$

where, q: the number of variables in Y set (Cankaya, 2005).

The CCC and/or PCCC do not identify the amount of variance accounted for in one variable set by other variable set. Therefore, it is suggested to calculate the redundancy measure for each canonical correlation to determine how much of the variance in one set of variables is accounted for by the other set of variables (Sharma, 1996). Redundancy measure can be formulated as below

$$RI_{U_iW_i} = OV(Z|W_i).\rho_{uw}^2$$

$$OV(Z|W_i) = \frac{\sum_{i=1}^{p} LZ_{ij}^2}{r}$$

Table 2. Descriptive statistics for examined traits

	N	Mean	Std. deviation	95% CI of the difference	
				Lower	Upper
DFE	64	123.69	5.31	122.36	125.01
BWFE	64	1,817.17	117.18	1,787.90	1,846.44
WFE	64	47.22	7.87	45.26	49.19
EI	64	56.86	9.84	54.41	59.32
PI	64	20.81	7.16	19.03	22.60
NE_1	64	18.60	2.11	18.07	19.13
WE_1	64	61.89	2.52	61.26	62.52
NE_2	64	25.09	1.88	24.62	25.56
WE_2	64	64.52	2.33	63.93	65.10
NE_T	64	67.86	4.24	66.79	68.92
WE_T	64	63.59	1.98	63.10	64.09

DFE = Days to the first egg; WFE = Weight of the first egg; BWFE = Body weight at the first egg; EI = Energy intake; PI = Protein intake.
NE_1 = Number of eggs from 22 to 25 wk of age; WE_1 = Weight of egg from 22 to 25 wk of age.
NE_2 = Number of eggs from 30 to 33 wk of age; WE_2 = Weight of egg from 30 to 33 wk of age.
NE_T = Number of eggs from 22 to 33 wk of age; WE_T = Weight of egg from 22 to 33 wk of age; CI = Confidence interval.

where, $OV(Z|W_i)$: the averaged variance in Z variables that is accounted for by the canonical variate W_i, LY_{ij}: the loading of the j^{th} Z variable on the i^{th} canonical variate; r: the number of traits in canonical variates mentioned.

Applications of CCA and PCCA

While the first three characters were included in the first variable set (X_{nxp}: sexual maturity characters), the latter two characters were included in the second variable set (Y_{nxq}: the level of nutrient intakes) others were included in the third variable set (Z_{nxr}: the egg production traits from 22 to 25 (W_{first}) and from 22 to 33 wk of age (W_{all}) respectively). The descriptive statistics for examined traits are presented in Table 2. All the computational work was performed to examine the relationships between two sets of the traits by means of PROC CONCORR procedure of SAS 6.0 statistical package (SAS, 1989).

RESULTS AND DISCUSSION

Bivariate correlations displaying the relationship among egg production traits and body weight, egg weight and age at sexual maturity of the pullet are presented in Table 3. The highest correlation was predicted between PI and EI (-0.479, $p<0.001$), while the lowest correlation was between NE_2 and WE_2 (-0.005, p = 0.962). There was positive relationship between WFE and EI (0.412, p = 0.001), while there was negative relationship between WFE and PI (-0.218, p = 0.084). Also, the relationship between egg production traits and sexual maturity traits is similar to the result of previous studies (Dunnington and Siegel, 1984; Camci et al., 2002; Akbas and Takma, 2005).

In chicks being raised for eggs, too much feed intake may cause premature sexual maturity, poor egg production, and health problems (Jackson, 2006). In the present study, it was also concluded that sexual maturity traits depend on the availability of nutrient source. Egg numbers and weights change are a frequently recorded variable in poultry research. Also, other measurements such as age, body weight and egg weight at sexual maturity etc. are recorded, as they are important indicators of performance traits in layer hens (Akbas and Takma, 2005). On the other hand, it is dramatically difficult to explain the relationship between the performance traits and other traits as sexual maturity

Table 3. Bivariate correlation for egg production traits and body weight, egg weight and age at sexual maturity of the pullet

	DFE	BWFE	WFE	EI	PI	EN_1	EW_1	EN_2	EW_2
DFE	1.000								
BWFE	-0.032	1.000							
WFE	-0.210	-0.057	1.000						
EI	-0.124	-0.132	0.412**	1.000					
PI	0.122	0.058	-0.218	-0.479**	1.000				
EN_1	-0.147	0.318*	0.103	-0.007	-0.031	1.000			
EW_1	-0.018	0.124	-0.347**	-0.020	0.098	0.166	1.000		
EN_2	-0.271*	0.169	-0.091	-0.274**	0.314*	0.249*	-0.026	1.000	
EW_2	-0.012	-0.048	-0.139	0.060	0.129	0.142	0.423**	-0.005	1.000

* $p<0.05$, ** $p<0.01$. DFE = Days to the first egg; WFE = Weight of the first egg; BWFE = Body weight at the first egg.
EI = Energy intake; PI = protein intake.
NE_1 = Number of eggs from 22 to 25 wk of age; WE_1 = Weight of egg from 22 to 25 wk of age.
NE_2 = Number of eggs from 30 to 33 wk of age; WE_2 = Weight of egg from 30 to 33 wk of age.

Table 4. Summary results for the CCA and PCCA

Canonical variate pair	Canonical R (R_c)	Canonical R^2 (R^2_c)	Eigen values	Degree of freedom	Likelihood ratio	Probability Pr>F
CCA						
For the sexual maturity and the nutrient intake traits						
U_1V_1	0.429	0.184	0.225	6	0.802	0.042
U_2V_2	0.069	0.004	0.004	2	0.996	0.877
For the production performance traits (22 to 25 wk of age-22 to 33 wk of age)						
$W_{first1}W_{all1}$	0.780	0.608	1.554	4	0.213	<0.001
$W_{first2}W_{all2}$	0.675	0.457	0.838	1	0.544	<0.001
For the sexual maturity and the egg production performance traits						
22 to 25 wk of age						
U_1W_{first1}	0.390	0.152	0.280	6	0.567	0.007
U_2W_{first2}	0.347	0.121	0.137	2	1.000	0.021
30 to 33 wk of age						
U_1W_{last1}	0.349	0.122	0.139	6	0.859	0.167
U_2W_{last2}	0.147	0.022	0.022	2	0.978	0.517
22 to 33 wk of age						
U_1W_{all1}	0.390	0.152	0.179	6	0.816	0.058
U_2W_{all2}	0.193	0.037	0.039	2	0.962	0.319
PCCA						
22 to 25 wk of age						
U_1V_1	0.415	0.172	0.208	6	0.741	0.009
U_2V_2	0.323	0.104	0.116	2	0.896	0.044

Canonical R (R_c) = Canonical correlation coefficients. CCA = Canonical correlation analysis.
PCCA = Partial canonical correlation analysis. U_iV_i, $W_{firsti}W_{alli}$ and U_iW_i = The canonical variate/variable pairs for the variable sets.

and nutrient intake as simultaneously. Therefore, instead of interpreting the correlations given in Table 3, we used only two canonical correlations to explain the interrelationship between the studied variable sets, since the number of canonical correlations that needs to be interpreted is minimum number of traits within the performance traits, the nutrient intake or sexual maturity traits. We found that estimated CCCs between sexual maturity and nutrient intake traits (0.429, p = 0.042), sexual maturity and egg production traits (0.390, p = 0.007 for W_{first}) and within performance traits (between W_{first} and W_{all}; 0.780, p<0.001), and PCCC between sexual maturity and performance traits (0.415, p = 0.009) were significant from the likelihood ratio test (Table 4). This finding is lower than those reported by Akbas and Takma (2002) concluding egg production with age at sexual maturity, body weight and egg weight. This discrepancy between the degrees of the coefficients estimated from two studies may result from different in feeding methods. Because balanced fed birds reached sexual maturity significantly earlier than cafeteria fed (Scott and Balnave, 1988; Olver and Malan, 2000; Sungu, 2007), at further studies, feeding schedule of pullets should be taken into consideration to the point of lay. Camci et al. (2002) reported that the positive correlation (r = 0.330) between age at sexual maturity and body weight at sexual maturity shows that late maturation resulted in a heavier body weight in quails, confirming the proposition of the present study.

Standardized canonical coefficients (canonical weights) were given for the first pair of canonical variables in Table 5. Magnitudes of the canonical coefficients signify their relative contributions to the correlated variable. That is, these coefficients indicate the effect of the nutrient intake on the sexual maturity and the sexual maturity on the production performance at different periods, respectively. Accordingly, while the energy intake has a positive effect on the sexual maturity, protein intake has a negative effect on the sexual maturity. That is, if the values of the energy intake increase, the DFE and WFE will decrease and the BWFE will increase. While the DFE, WFE and BWFE have a positive effect on the number of egg, a negative effect on the weight of egg at first period. That is, if the values of these parameters increase, the number of egg will increase and the weight of egg will decrease. But, according to the result of the PCCA, the values of DFE should be move to an earlier time for increasing the egg number. Thus, the negative contribution of BWFE on EW can be reduced (approximately, as 10%). These results support idea that body weight and body fat of birds are important factors as the primary determinant for onset of lay (Brody et al., 1984; Dunnington and Siegel, 1984; Kwakkel et al., 1995). Also, Camci et al. (2002) reported that late sexual maturity caused high sexual maturity weight and lower total hen-day egg production; on the other hand early sexual maturity resulted with increased egg production without any change for egg weight. These results indicate that feeding for high body weight at first egg will potentially result in lower age of sexual maturation. Therefore, the health (Ocak and Erener,

Table 5. Standardized canonical coefficient (canonical weights) for canonical variables with both CCA and PCCA

Y-variable set				X-variable set		
For the sexual maturity and the nutrient intake traits						
	DFE	WFE	BWFE		EI	PI
U_1	-0.11	-0.26	0.93	V_1	0.96	-0.07
For the sexual maturity and the production performance traits (22 to 33 wk of age)						
	DFE	WFE	BWFE		EN_T	EW_T
U_1	-0.26	0.68	0.66	W_{all1}	0.80	-0.60
For the production performance traits (22 to 25 wk of age - 22 to 33 wk of age)						
	EN_T	EW_T			EN_1	EW_1
W_{all1}	0.55	0.84		W_{first1}	0.48	0.80
For the sexual maturity and the production performance traits (22 to 25 wk of age)						
	DFE	WFE	BWFE		EN_1	EW_1
CCA						
U_1	0.01	0.31	0.97	W_{first1}	0.65	-0.87
Partial CCA						
U_1	-0.05	0.35	0.92	W_{first1}	0.76	-0.76
For the sexual maturity and the production performance traits (30 to 33 wk of age)						
	DFE	WFE	BWFE		EN_2	EW_2
CCA						
U_1	-0.86	0.40	-0.48	W_{last1}	0.99	0.17

DFE = Days to the first egg; WFE = Weight of the first egg; BWFE = Body weight at the first egg; EI = Energy intake; PI = Protein intake.
NE_1 = Number of eggs from 22 to 25 wk of age; WE_1 = Weight of egg from 22 to 25 wk of age.
NE_2 = Number of eggs from 30 to 33 wk of age; WE_2 = Weight of egg from 30 to 33 wk of age.
CCA = Canonical correlation analysis; PCCA = Partial canonical correlation analysis.
U_1.V_1, W_{first1} and W_{all1} = The canonical variables for each variable sets.

Table 6. Canonical loadings of the original variables with their canonical variables with both CCA and PCCA

Y-variable set				X-variable set		
For the sexual maturity and the nutrient intake traits						
	DFE	WFE	BWFE		EI	PI
U_1	-0.30	-0.31	0.96	V_1	0.99	-0.54
For the sexual maturity and the production performance traits (22 to 33 wk of age)						
	DFE	WFE	BWFE		EN_T	EW_T
U_1	-0.42	0.65	0.68	W_{all1}	0.80	-0.60
For the production performance traits (22 to 25 wk of age-22 to 33 wk of age)						
	EN_T	EW_T			EN_1	EW_1
W_{all1}	0.55	0.84		W_{first1}	0.62	0.88
For the sexual maturity and the production performance traits (22 to 25 wk of age)						
	DFE	WFE	BWFE		EN_1	EW_1
CCA						
U_1	-0.21	0.26	0.95	W_{first1}	0.51	-0.76
Partial CCA						
U_1	-0.22	0.37	0.94	W_{first1}	0.66	-0.65
For the sexual maturity and the production performance traits (30 to 33 wk of age)						
	DFE	WFE	BWFE		EN_2	EW_2
CCA						
U_1	-0.77	0.45	-0.33	W_{last1}	0.99	0.17

DFE = Days to the first egg; WFE = Weight of the first egg; BWFE = Body weight at the first egg; EI = Energy intake; PI = Protein intake.
NE_1 = Nnumber of eggs from 22 to 25 wk of age; WE_1 = Weight of egg from 22 to 25 wk of age.
NE_2 = Number of eggs from 30 to 33 wk of age; WE_2 = Weight of egg from 30 to 33 wk of age.
CCA = Canonical correlation analysis; PCCA = Partial canonical correlation analysis.
U_1.V_1, W_{first1} and W_{all1} = The canonical variables for each variable sets.

2005) or the determination of breeding values (Sezer, 2007) in poultry may affect negatively.

Variables with larger canonical loadings contributed more to the multivariate relationship among the nutrient intake, the sexual maturity and the production performance (Table 6). The loadings for the sexual maturity suggested that BWFE was more influential compared with DFE and WFE in forming U_1 at all period for both CCA and PCCA. The loadings for energy intake and EN_T were more influential than protein intake and EW_T in forming V_1 and W_{all1}, respectively, expect for at first period. According to cross loadings, BWFE and EI provided the most contribute to canonical variate V_1 and U_1, respectively. The BWFE and EN_T provided the most contribute to canonical variate W_{all1} and U_1, respectively. The contribution of BWFE and EW_1 was found the highest on canonical variate W_{first1} and U_1 for CCA, respectively, while EN_1 provided the most contribute to canonical variate U_1 for PCCA (Table 7). Therefore, the some different results of correlation between bivariate (Table 3) and canonical correlations (Tables 5, 6 and 7) may be explained the fact that Interpretation of the canonical variates in a significant function is based on the premise that variables in each set that contribute heavily to shared variances for these functions are considered to be related to each other (Hair et al., 1998).

The results reported here for the canonical weights and loadings from canonical correlation analysis are not in agreement with those reported by Akbas and Takma (2005). These contradictions in the findings might have been due to differences in the experimental approach followed by them and the system of feeding. The method of feeding in their studies allows birds to intake composed their own diet, according to their actual needs and physiological demands. In the present study, pullets are mainly able to select from the energy and protein sources offered to them.

In the present study, it was also founded that 36.9, 35.3, 33.7, 35.6 and 30.2% of total variation in the sexual maturity variable set was explained by canonical variable U_1 for all period, while the redundancy measure of 0.068 for first canonical variable suggests that about 6.8% of the ratio was explained by canonical variable V_1. The redundancy measure of 0.054 for first canonical variable suggests that about 5.4% of the ratio was explained by canonical variable W_{all1}, while the redundancy measure of 0.051 and 0.061 for first canonical variable suggests that about 5.1 and 6.1% of the ratio was explained by canonical variable W_{first1} for CCA and PCCA, respectively. Besides, the redundancy measure of 0.037 for first canonical variable suggests that about 3.7% of the ratio was explained by canonical variable W_{last1}. Initially, 64.1% of total variation in the nutrient intake variable set was explained by canonical variate V_1, while 11.8% of the ratio was explained by canonical variate U_1. Lastly, 49.8, 42.2, 43.4 and 49.9% of total variation in the production performance

Table 7. Cross loading of the original variables with opposite canonical variables with both CCA and PCCA

Y-variable set				X-variable set		
For the sexual maturity and the nutrient intake traits						
	DFE	WFE	BWFE		EI	PI
V_1	-0.13	-0.13	0.41	U_1	0.43	-0.23
For the sexual maturity and the production performance traits (22 to 33 wk of age)						
	DFE	WFE	BWFE		EN_T	EW_T
W_{all1}	-0.16	0.25	0.27	U_1	0.31	-0.23
For the production performance traits (22 to 25 wk of age - 22 to 33 wk of age)						
	EN_T	EW_T			EN_1	EW_1
W_{first1}	0.43	0.65		W_{all1}	0.48	0.69
For the sexual maturity and the production performance traits (22 to 25 wk of age)						
	DFE	WFE	BWFE		EN_1	EW_1
CCA						
W_{first1}	-0.08	0.10	0.37	U_1	0.20	-0.30
Partial CCA						
W_{first1}	-0.09	0.16	0.39	U_1	0.28	-0.27
For the sexual maturity and the production performance traits (30 to 33 wk of age)						
	DFE	WFE	BWFE		EN_2	EW_2
CCA						
W_{last1}	-0.27	0.16	-0.11	U_1	0.34	0.06

DFE = Days to the first egg; WFE = Weight of the first egg; BWFE = Body weight at the first egg; EI = Energy intake; PI = Protein intake.

NE_1 = Number of eggs from 22 to 25 wk of age; WE_1 = Weight of egg from 22 to 25 wk of age.

NE_2 = Number of eggs from 30 to 33 wk of age; WE_2 = Weight of egg from 30 to 33 wk of age.

CCA = Canonical correlation analysis; PCCA = Partial canonical correlation analysis.

U_1,V_1, W_{first1} and W_{all1} = The canonical variables for each variable sets.

Table 8. The explained total variation ratio by canonical variables for the variable sets with both CCA and PCCA

Y_i-variables set				X_i-variables set			
Variance extracted		Redundancy		Variance extracted		Redundancy	
For the sexual maturity and the nutrient intake traits (CCA)							
U_1	0.369	V_1	0.068	V_1	0.641	U_1	0.118
For the sexual maturity and the production performance traits (22 to 33 wk of age)							
U_1	0.353	W_{all1}	0.054	W_{all1}	0.498	U_1	0.076
For the production performance traits (22 to 25 wk of age - 22 to 33 wk of age)							
W_{all1}	0.502	W_{first1}	0.498	W_{first1}	0.576	W_{all1}	0.351
For the sexual maturity and the production performance traits (22 to 25 wk of age)							
CCA							
U_1	0.337	W_{first1}	0.051	W_{first1}	0.422	U_1	0.642
PCCA							
U_1	0.356	W_{first1}	0.061	W_{first1}	0.434	U_1	0.075
For the sexual maturity and the production performance traits (30 to 33 wk of age)							
CCA							
U_1	0.302	W_{last1}	0.037	W_{last1}	0.499	U_1	0.061

CCA = Canonical correlation analysis; PCCA = Partial canonical correlation analysis.

U_1, V_1, W_{first1} and W_{all1} = The canonical variables for each variable sets.

variable set for all period was explained by canonical variate W_{all1}, W_{first1} for CCA, W_{first1} for PCCA, W_{last1} respectively, while 7.6, 64.2, 7.5 and 6.1% of the ratio was explained by canonical variate U_1 for all periods (Table 8).

In conclusion, canonical coefficients and loadings from CCA indicated that the BWFE had the largest contribution compared to the DFE and WFE to variation of egg number produced at two different periods. The results from PCCA indicated that the contribution of PI and EI to the degree of the correlation between canonical variables for X and Z sets were unfavourable. Therefore, the body weight at sexual maturity upon the availability of nutrients can have a higher contribution to variation of egg production in pullets if the contribution of differences in nutrient intakes to onset of egg production were eliminated. Furthermore, because the relationship between performance traits (W_{first} and W_{all1}, 0.780) was high, the effect of nutrient intake on sexual maturity and subsequent on egg production at first period may be lasted at all periods. Thus, if the body weight at sexual maturity were used as early selection criteria for increasing the egg production of layer, the nutrient intakes of pullets to onset of egg production should be taken into account.

ACKNOWLEDGMENTS

The authors wish to thank M. Berk for his financial support and technical assistance. The study was approved by the local Ethical Committee of Ondokuz Mayis University for Experimental Animals, and ascertained that the experiment is not an unnecessary repetition of previous experiments.

REFERENCES

Akbas, Y. and C. Takma. 2005. Canonical correlation analysis for studying the relationship between egg production traits and body weight, egg weight and age at sexual maturity in layers. Czech J. Anim. Sci. 50:163-168.

Al-kandari, N. and I. T. Jolliffe. 1997. Variable selection and interpretation in canonical correlation analysis. Commun. Statist.-Simula. 26:873-900.

Brody, T., P. B. Siegel and J. A. Cherry. 1984. Age, body weight and body composition requirements for the onset of sexual maturity of dwarf and normal chickens. Br. Poult. Sci. 25:245-252.

Camci, O., C. Erensayin and S. Aktan. 2002. Relations between age at sexual maturity and some production characteristics in quails. Arch. Geflügelk. 66:280-282.

Cankaya, S. 2005. Canonical correlation analysis and its applications. Ph.D. Thesis, University of Cukurova, Adana, Turkey.

Cankaya, S. and G. T. Kayaalp. 2007. Estimation of relationship between live weights and some body measurements in German Farm×Hair crossbred by canonical correlation analysis. J. Anim. Prod. 48:27-32.

Ding, S. T., Y. K. Ko, B. R. Ou, P. H. Wang, C. L. Chen, M. C. Huang, Y. P. Lee, E. C. Lin, C. F. Chen, H. W. Lin and W. T. K. Cheng. 2008. The expression of genes related to egg production in the liver of Taiwan country chickens. Asian-Aust. J. Anim. Sci. 21:19-24.

Dunnington, E. A. and P. B. Siegel. 1984. Age and body weight at sexual maturity in female White Leghorn chickens. Poult. Sci. 63:828-830.

Flock, D. K. 1998. Genetic-economic aspects of feed efficiency in laying hens. World's Poult. Sci. J. 54:225-239.

Gunderson, B. K. and R. J. Muirhead. 1997. On estimating the dimensionality in canonical correlation analysis. J. Multivariate Anal. 62:121-136.

Hair, J. F. Jr., R. E. Anderson, R. L. Tatham and W. C. Black. 1998. Multivariate Data Analysis. 5th edn. Upper Saddle River (NJ): Prentice Hall, Inc.

Jackson, N. 2006. Effect of restricting the energy intake of the laying hen, directly and by dilution of the diet, on egg production and the efficiency of energy utilisation. J. Sci. Food Agr. 23:413-428.

Jaiswal, U. C., J. S. Poonia and J. Kumar. 1995. Canonical correlation analysis for studying relationship among several traits- an example of calculation and interpretation. Ind. J. Anim. Sci. 65(7):765-769.

Johnson, R. A. and D. W. Wichern. 2002. Applied multivariate statistical analysis. 5th edn. Prentice Hall, Inc., Upper Saddle River, New Jersey

Keshavarz, K. 1998. Investigation on the possibility of reducing protein, phosphorus, and calcium requirements of laying hens by manipulation of time of access to these nutrients. Poult. Sci. 77:1320-1332.

Kwakkel, R. P., J. A. W. Vanesch, B. J. Ducro and W. J. Koops. 1995. Onset of lay related to multiphasic growth and body-composition in white leghorn pullets provided ad-libitum and restricted diets. Poult. Sci. 74:821-832.

National Research Council. 1994. Nutrient requirements of poultry. 9th edn., National Academy Press, Washington DC.

Ocak, N. and G. Erener. 2005. The effects of restricted feeding and feed form on growth, carcass characteristics and days to first egg of Japanese quail (Coturnix coturnix japonica). Asian-Aust. J. Anim. Sci. 18:1479-1484.

Olver, M. D. and D. D. Malan. 2000. The effect of choice-feeding from 7 weeks of age on the production characteristics of laying hens. S. Afr. J. Anim. Sci. 30:110-114.

SAS Institute Inc. 1989. SAS/STAT User's Guide: Version 6. 4th edn. SAS Institute Inc., Cary, North Carolina.

Scott, T. A. and D. Balnave. 1988. Comparison between concentrated complete diets and self-selection for feeding sexually-maturing pullets at hot and cold temperatures. Br. Poult. Sci. 29:613-625.

Sezer, M. 2007. Genetic parameters estimated for sexual maturity and weekly live weights of Japanese quail (Coturnix coturnix japonica) Asian-Aust. J. Anim. Sci. 20:19-24.

Sharma, S. 1996. Applied Multivariate Techniques. John Wiley & Sons, Inc. New York.

Sungu, M. 2007. The effect of choice feeding at the stage of pullets of layer hens on some growth traits and egg production. MSc. Thesis, University of Ondokuz Mayis, Samsun.

Thompson, B. 1984. Canonical correlation analysis: Uses and interpretation. Sage Publications, Inc. California.

Timm, N. H. 2002. Applied multivariate analysis. Springer-Verlag, Inc. New York.

Zhong, L. L., J. H. Yao, N. Cheng, Y. J. Sun, Y. R. Liu, Y. J. Wang, X. Q. Sun and H. B. Xi. 2007. Effects of supplementing with single or multiple trace minerals on growth performance, fecal mineral excretion and nutrient utilization in pullets from 1 to 18 weeks of age. Asian-Aust. J. Anim. Sci. 20:976-982.