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Canonical Correlation Analysis of Body Measurements, Growth Performance and Carcass Traits of Red Karaman Lambs

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Abstract: Three body measurements including Height at Wither (HTW), Heart Girth Circumference (HGC) and Body Length (BL) were obtained from 14 Red Karaman fat tailed male lambs at birth and were organized in a set of body measurements at birth. All lambs were allowed to grazing on pasture after weaning and fattened during the last 75 days before slaughter. Measurements of Birth Weight (BW), Weaning Weight (WW), Post Grazing Weight (PGW) and Average Daily Gain (ADG) were recorded and set as a growth by arranging set of variables. Cold Carcass Weight (CCW), Dressing Percentage (DP), loin Eye Muscle Area (EMA) and Tail Fat weight (TF) were recorded and arranged as a carcass traits set of variables. Two different canonical correlation analyses were performed to identify the associations between body measurements at birth and also growth performances with carcass traits. The first analysis used 3 body measurements (HTW, HGC, BL) as one set of independent variables, the second analysis used 4 growth performance measurements (BW, WW, PGW, ADG) as independent variables. Both analyses used four carcass traits (CCW, DP, EMA, TF) as the dependent set of variables. The second and following sequential canonical correlations were higher in the analysis using growth records (0.99-0.86) than in those using measurements at birth (0.94-0.72) while first canonical correlations were similar (0.99) in both analyses. Two indexes are suggested by this study. The size at birth index emphasizes size and large lambs that consume large amount of feed have dependent higher carcass traits. The independent growth performances index, emphasizes weight and heavier lambs have higher carcass traits. High and statistically significant canonical correlations were found from the general framework of relationship between body measurements, growth performances and important carcass traits in Red Karaman male lambs.

Key words: Canonic correlation, linear measurements, carcass, body, lamb, growth performance

INTRODUCTION

Approximately 87% of Turkey's sheep population (30.3 million heads) is fat tailed breeds. Sheep meat (133,000 t) is an important contributor to the red meat production amounting for 26% of the total meat production (512,000 t) in Turkey (Anonymus, 2000). The present meat production performances of native sheep breeds are far from optimal. Larger birth size, growth rate of lambs and better feed conversion efficiency are among the factors that need to be improved to produce economical sheep meat.

There are several studies utilizing correlations to express the relationship between variables of body measurements and/or growth performance with carcass traits. Development of technologies enabling the view of in vivo prediction of carcass composition, utilizing linear measurement (shoulder weight, heart girth, body length) and/or growth rate to evaluate or predict body composition in sheep has been reported by several researchers (Cuthbertson *et al*., 1984; Edwards *et al*., 1989; Cunnigham *et al*., 1967). As outlined by Butterfield (1988) tissues within the body follow predictable patterns of development from birth to maturity. Additionally in vivo techniques commonly use live weight as the standard to which other predictors of body composition are compared (Kempster, 1984; Kempster *et al*., 1986; Simm, 1992).

Multivariate data analysis techniques have been used effectively to study latent relationships among measurements (Hair *et al*., 1995; Johnson and Wichern, 1988). Canonical Correlation Analysis (CCA), one of the most direct ways of analyzing relationships between sets of variables, has been used for analyzing multivariate data regarding various morphological and physiological characters of livestock (Compton, 1972; Miguel, 1972; Desmoulin *et al*., 1977; Brown, 1978, Johnson *et al*., 1980; Gurbuz, 1989). Specifically, this analysis allows

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investigation of the relationship between two sets of variables which one representing a set of independent (predictor) variables and another a set of dependent (criterion) variables. CCA has the ability to deal with 2 sets of variables simultaneously and to produce both structural and spatial inference. Because CCA allows the researcher to examine the effects of multiple predictor variables on multiple criterion variables, multidimensional measurements of body predictor variables or weight measurements in different periods of growth can be compared to carcass traits as criterion variables simultaneously. This procedure addresses the question of whether the same forces influence multiple measurements and their relative contribution in explaining these measurements. Moreover, CCA reduces the probability of Type I error that might occur with the computation and comparison of more than one multiple regression analysis in modeling multiple criterion variables (Thompson, 1991). Thus, the use of CCA is more advisable than the calculation and comparison of results of separate regression equations for different dependent measurements. CCA is particularly appropriate when one seeks not an explanation of each of the criterion variables but rather the set of criterion variables taken together (Levine, 1977). As such, CCA enables investigators to address the question of whether or not carcass traits share some common variance with each other as well as with a set of predictor variables. This last feature makes CCA particularly appropriate for understanding underlying relationships between body measurements and growth performances with carcass traits and meets multivariate assumptions. In other words, CCA is most useful in explaining multidimensional relationship between predictor body measurements or growth performances with a dependent set carcass traits, to which the researcher attempts to generalize.

Therefore, the objective of this research was to use a multivariate statistical technique, canonical correlation analysis, to identify the associations between 2 independent sets of variables, body measurements and growth performance with carcass traits utilizing Red Karaman male lambs. Additionally, the present study results enable the researchers to select the appropriate multi variables as selection criteria for carcass traits in threshold studies.

MATERIALS AND METHODS

Data were obtained from 14 Red Karaman male lambs at the Research and Application Farm of College of Agriculture, Ataturk University, Erzurum, Turkey. References, analysis, writing and editing of the research were conducted at The Ohio State University, Columbus, Ohio, USA. The lambs were born in March 2000 and kept with their dams until approximately 2.5 months of age. Three body measurements at birth were obtained from the newborn lambs with steel tape and caliper. Birth measurements were taken and included Height at Wither (HTW), Heart Girth Circumference (HGC) and Body Length from point of shoulder to pin Bone (BL). Growth measurements were also determined from birth and weaning (at the beginning of grazing season) weights. After weaning the lambs were allowed to graze on pasture and additional growth measurements of Post Grazing Weight (PGW) was also recorded. The primary forage plants of the pasture were *Festuca ovina*, *Koleleria cristata*, *Bromus tomentalus*, *Medicago* sp. and *Onobrychis* sp. At 8 month of age, the animals were fed with concentrate basic diet (Table 1) for 75 days before slaughter. Average Daily Gains (ADG) were calculated from lambs weighted biweekly during the fattening period. Lambs (n = 14) were slaughtered for obtaining the measurements of carcass traits. The carcasses were chilled at +4°C for 24 h, before dissecting and Cold Carcass Weights (CCW) were taken on the intact cold carcasses (Kempster *et al*., 1982). After dissecting, Dressing Percentage (DP), loin Eye Muscle Area (EMA) and Tail Fat Weight (TFW) measurements were obtained as a set of carcass traits.

Table 1: Composition of concentrate (%) utilized in this research

Ingredients	Ration (%)
Barley	42.00
Corn	24.00
Soy bean	10.00
Sun flower seed	8.00
Molasses	8.00
Wheat bran	4.00
Limestone	3.00
Salt	0.95
Premix(*)	0.05

*: Basic diet contains 7,000,000 I.U. Vitamin A, 1,000,000 I.U. Vitamin D3, 30,000 mg Vitamin E, 50,000 mg Mn, 50,000 mg Zn, 50,000 mg Fe, 10,000 mg Cu, 8,000 mg I, 200 mg Co, 150 mg Se 100 mg Mg per kg

Canonic correlation analysis: CCA was used to examine dependencies that exist between important carcass traits of Red Karaman lambs and their body and growth performance measurements. Developed by Hotelling (1935, 1936), as a generalization of multiple regression analysis, CCA seeks to identify and quantify the associations between 2 sets of variables where each set consists of at least two variables (Kshirsagar, 1972). CCA focuses on the correlation between a linear combination of the variables in one set and another linear combination of the variables in the other set. The idea is to determine the pairs of linear combinations having the large correlation among all of the orthogonal pairs of linear combinations. The pairs of linear combinations are called the canonical variates and their correlations are called canonical correlations or characteristic roots. The maximum number of canonical variates that can be extracted from the sets of variables equals the number of variables in the smaller set of variables. Thus, in this research it provides a way of considering overall body measurements or growth performance as a composite evaluation, rather than using one performance trait at a time as is done in traditional regression analysis. The added benefit of canonical correlation comes from taking into account the inter-relationship among dependent variables and providing overall description of association between multiple independent predictor variables and multiple dependent variables simultaneously. CCA consolidates or channels all associations into distinct and manageable pieces of information that might otherwise result in a less cohesive, unwieldy inter-play of correlations between pairs of variables. Table 2 illustrates the classification of variables used in this research.

The independent predictor sets of p variables are represented by Xi and the dependent criterion set of q variables by set Yj. The first pair of linear combinations can be represented by

$$U_k = a_{k1}X_1 + a_{k2}X_2 + \ldots + a_{kp}X_p,\ k = 1, \ldots, \min(p; q) \quad (1)$$

$$V_k = b_{k1}\ Y_1 + b_{k2}\ Y_2 + \ldots + b_{kq}\ Y_q,\ k = 1, \ldots, \min(p, q) \quad (2)$$

sequential CCA provides us new variables, known as canonical variates. The maximum number of canonical variate pairs that can be extracted from the sets of variables equals the number of variables in the smaller set of variables. In this research this would be 3, predictor birth measurements set and 4 in the independent gain variable set. Table 3 shows the organization of variables utilized in this research.

The mathematical analysis includes the separate forming of linear combinations for both Xi and Yj according to Eq. 1 and 2. The combinations thus formed are coupled in the pairs of canonical variaties (Uk the predictor set , Vk the criterion set), the number of the pairs being equal to the smaller of p or q. Each pair (Uk, Vk) independently represents the relationship of Xi and Yj so that the mutual canonical correlation of (U1, V1) is the highest, that of sequential calculation of U2, V2 being the second highest, etc. Generally, all the statistically significant pairs are utilized for more thorough analysis. The correlation between canonical variates r (U1, V1), which is the canonical correlation of first canonical variate

Table 2: Selection of variables for canonical correlation analysis

Analysis	Independent (Predictor) variables	Dependent (Criterion) variables
I	Body Measurements	Carcass Traits
	Height at wither	Dressing percentage
	Body length	Cold carcass weight
	Heart girth circumference	Loin eye muscle area
		Tail fat weight
II	Growth Performance	Carcass Traits
	Birth weight	Dressing percentage
	Weaning weight	Cold carcass weight
	Post grazing weight	Loin eye muscle area
	Average daily gain	Tail fat weight

Table 3: Canonical variates

Analysis	Independent (Predictor) canonical variates	Dependent (Criterion) canonical variates
I	Body Measurements (3 variables)	Carcass Traits (4 variables)
	U1[a,b]	V1[a,b]
	U2[a]	V2[a]
	U3[a,c]	V3[a,c]
II	Growth Performance (4 variables)	Carcass Traits (4 variables)
	U1[a,b]	V1[a,b]
	U2[a]	V2[a]
	U3[a]	V3[a]
	U4[a,c]	V4[a,c]

[a]: Sequential calculation of canonical variates in each analysis. [b]: Mutual canonical correlation in the highest, [c]: Mutual canonical correlation is the lowest

pair. Canonical correlation of r (U1, V1) is the highest, that of r(U2, V2) being the second highest, etc. If sample size is small (14 lambs in this experiment) then only the first canonical variate pair should be considered for further analysis (Barcikowski and Stevens, 1975).

The canonical coefficient aki and bkj represent the effect of the original independent variables on the corresponding canonical varieties, those varieties consequently act as a bridge between the original variables. Lambda prime is a modification of Wilk's lambda describing the unexplained variance. If lambda prime values increases for a variate pair, only those variate pairs which has zero or close to zero are considered for closer exploration. A more detailed description of CCA is given by Hair *et al.* (1995). All the computational work was performed using a SAS for Windows software package (1985).

Data from lambs were subjected to 2 canonical correlation analyses. Analyses I used three body measurements taken at birth for the independent set while analysis II used the four independent growth performances as the independent predictor set of variables (X) and the four dependent (criterion) carcass traits were used as the set of variables (Y) in both analysis.

RESULTS AND DISCUSSION

Means and standard deviations of the variables of Red Karaman male lambs are presented in Table 4. Cold

Table 4: Means, minimum, maximum and standard deviation of growth performances, body measurements and some carcass traits of red karaman male lambs

Measurements	Mean	Minimum	Maximum	S.D.
HTW (cm)	42.4	37	47	2.56
BL (cm)	33.1	30	38.5	2.93
HGC (cm)	42.4	41	45	1.25
Bw (kg)	4.9	3.8	6.6	1.24
W W (kg)	23.3	17.5	26.5	3.56
PGW (kg)	31.0	24.5	33.0	3.58
ADG (kg)	0.232	0.200	0.260	0.02
DP (%)	0.48	0.45	0.52	0.02
CCW (kg)	21.3	19.1	23.5	1.45
E MA (cm^2)	13.1	11.0	14.9	1.03
TWF (kg)	2.1	1.5	3	0.52

HTW: Height at Wither, BL: Body Length from point of shoulder to pin bone, HGC: Heart Girth Circumference BW: Birth Weight, WW: Weaning Weight, PGW: Post Grazing Weight, ADG: Average Daily Gain; DP: Dressing Percentage, CCW: Cold Carcass Weight, EMA: Loin Eye Muscle Area, TFW: Tail Fat Weight

Table 5: Correlation of body measurements and growth performances with carsass traits of red karaman male lambs

Measurements	Dressing (%)	Cold carcass weight	Loin eye muscle area	Tail fat weight
HTW	-0.36	0.14	0.40	0.59*
BL	0.30	0.79*	0.37	0.10
HGC	0.19	0.66*	0.27	0.41
BW	0.17	0.71*	0.56*	0.14
WW	0.67*	0.82*	0.29	-0.01
PGW	0.69*	0.74*	-0.08	0.08
ADG	-0.26	-0.33	0.46	-0.62*

*Marked correlations are significant at p<0.05. HTW: Height at Wither, BL: Body Length from point of shoulder to pin bone, HGC: Heart Girth Circumference; BW: Birth Weight, WW: Weaning Weight, PGW: Post Grazing Weight, ADG: Average Daily Gain

carcass weights obtained in this research were similar to that reported by Macit (1991). Dressing percentage figures were higher than those reported by Geliyi and Ilaslan (1984). But dressing percentage figures in this study are similar with the findings of Macit *et al.* (1997).

The traditional correlations of independent body measurements at birth and independent growth performances with dependent carcass traits of Red Karaman lambs are given in Table 5. A significant ($p<0.05$) correlation of Body Length (BL) and Heart Girt Circumference (HGC) with Cold Carcass Weight (CCW) was observed while Height at Wither (HTW) was significantly correlated with Tail Weight (TW). The correlation of body measurements and carcass traits were higher than the findings obtained by Durecko and Botto (1973) and Stoyanov (1977). As expected, Weaning Weight (WW) and Post Grazing Weight (PGW) had high positive correlation ($p<0.05$) with Cold Carcass Weight (CCW) and Dressing Percentage (DP). Meanwhile, birth weight was highly correlated ($p<0.05$) with (BW) Cold Carcass Weight (CCW) and loin Eye Muscle Area (EMA). Average Daily Gain (ADG) was highly correlated with fat Tail Weight (TW).

Canonical correlation analysis: Table 6 shows F tests for the successive canonical variate pairs and the inherent canonical correlations. The canonical variate is a linear combination of a set of variables in which the within-set correlation has been controlled (that is, variance of each variable accounted for by other variables in the set has been removed). In analysis I, first, second and third variate pairs were significant at the level 1 and 5%, respectively and the first, second and third canonical variate pairs were significant at the 1% level in analysis II. While the first canonical correlations were the same (0.99) in both analysis, the second and third canonical correlations were higher in the analysis using independent growth records (0.99, 0.86) than in those using independent body measurements (0.94, 0.72). However, another characteristic, lambda prime, which is a modification of Wilk's lambda describing the unexplained variance, increases considerably after the second variate pairs in both analysis and this suggest that only those first and second pairs in both analysis should be considered for closer exploration. However, the first 2 and first 3 canonical correlations in analysis I and II, respectively were higher than the highest correlation found between body measurements, growth performances and carcass traits utilizing the traditional correlation. In this research, only the first canonical correlations in both analyses should be considered because of the small sample size (Barcikowski and Stevens, 1975).

Because canonical correlations are made maximal by definition, a large and significant canonic correlation estimate does not imply that a strong correlation exists among the original variables themselves. After the finding of the statistically significance, the extent to which the pair of canonical variates and their associated variables contribute to the multivariate relationship was interpreted. Canonical loadings were used for the substantive interpretation of naming constructs for the canonical variates and to link multivariate relationships across a pair of canonical variates. A canonical loading gives the product-moment correlation between the original variable and its corresponding canonical variate. It reflects the degree to which a variable is represented by a canonical variate. As such, predictor and dependent variables with larger loadings on their corresponding canonical variates contribute more to the naming of their within-set variate and to the multivariate relationship between predictor and dependent variables.

Because a dependent variable and a predictor variable are generally linked on the basis of, respectively higher loadings on their respective canonical variate and not on any direct measure of correlation between them, the relationship between a variable in one set and another

Table 6: Statistical characteristics of canonical variate pairs

Canonical variate pair	Canonical R	Standard error	Canonical R^2	Lambda prime	Significance
Analysis I (Height at wither, body length, heart girth circumference)					
1[a,b]	0.999	0.000	0.999	0.000	0.000**
2[a]	0.948	0.027	0.899	0.048	0.000**
3[a,c]	0.720	0.133	0.519	0.480	0.036*
Analysis II (Birth weight, weaning weight, post grazing weight, average daily gain)					
1[a,b]	0.999	0.000	0.999	0.000	0.000**
2[a]	0.999	0.000	0.999	0.000	0.000**
3[a]	0.866	0.068	0.751	0.169	0.004**
4[a,c]	0.563	0.189	0.316	0.683	0.071

** Significant ($p<0.01$), * significant ($p<0.05$). Canonical R: Canonical correlation, Canonical R^2: Percent of dependent canonical variate accounted for independent canonical variate, Lambda prime: Modification of Wilk's lambda describing unexplained variance, Significance: F test, [a]: Sequential calculation of canonical variates in each analysis, [b]: Mutual canonical correlation in the highest, [c]: Mutual canonical correlation is the lowest

Table 7: Canonical loadings (internal correlation and significance of a variable with its canonical variates) of the original variables with canonical variate pairs in analysis I

Variables		U1	U2	U3
SET 1[a]	Htw	0.79	0.59	-0.13
	BL	0.61	0.46	0.63
	HGC	0.53	0.73	0.41
		V1	V2	V3
SET 2[b]	DP	0.80	0.10	-0.55
	CCW	0.93	0.31	0.14
	EMA	0.07	-0.11	0.83
	TFW	-0.49	0.85	0.08
	CC	0.99	0.99	0.86

HTW: Height at Wither, BL: Body Length from point of shoulder to pin bone, HGC: Heart Girth Circumference; DP: Dressing Percentage, CCW: Cold Carcass Weight, EMA: Loin Eye Muscle Area, TFW: Tail Fat Weight and CC: Canonic Correlation, U1, U2, U3: Canonical variates of independent body measurements variables sequentially calculated from highest to lowest, V1, V2, V3: Canonical variates of dependent carcass traits variables sequentially calculated from highest to lowest, [a]: Independent birth body measurements, [b]: Dependent carcass measurements

variable in the other set may be perceived to be higher than it actually is. Because of this, cross loadings tend to provide a more solid basis for interpretation and it is more conservative than the canonical loadings. For a given pair of linear combinations, cross loadings give the relationship between an observed variable from one set with a canonical variate from the other set. The canonical loadings of the variables in relation to the canonical variates are presented in Table 7 and 8. The canonical loadings of a variable in those particular pairs of columns represent the internal correlation and significance of a variable to the canonical variate. The higher the loading the higher the significance of that variable. Variables with loadings of 0.50 or higher are of primary concern and thus their loading level will be selected as the threshold for detailed study. Consequently, in analysis I (Table 7) all body measurements highly dominated U_1 and V_1 was highly dominated by cold carcass weight and dressing percentage. In analysis II (Table 8), birth weight, weaning weight and post grazing wight dominate U_1, while V_1 was highly dominated by cold carcass weight and eye muscle area. Canonical loadings of the variables in relation to the canonical variates were concluded that the first variate pair dominated by all three variables in analysis I (Table 7) and is more efficient for prediction of dressing percentage and cold carcass weight.

Table 8: Canonical loadings (internal correlation and significance of a variable with its canonical variates) of the original variables for four canonical variate pairs in analysis II

Variables		U1	U2	U3	U4
SET 1[a]	BW	0.81	0.13	-0.37	0.42
	WW	0.87	0.19	0.29	0.32
	PGW	0.57	0.41	0.38	0.58
	ADG	-0.04	-0.89	-0.05	-0.44
		V1	V2	V3	V4
SET 2[b]	DP	0.42	0.13	0.82	0.35
	CCW	0.72	0.15	0.15	0.65
	EMA	0.65	-0.42	-0.52	-0.34
	TFW	0.01	0.82	0.36	-0.42
	CC	0.99	0.99	0.86	0.56

BW: Birth Weight, WW: Weaning Weight, PGW: Post Grazing Weight, ADG: Average Daily Gain; DP: Dressing Percentage, CCW: Cold Carcass Weight, EMA: Loin Eye Muscle Area, TFW: Tail Fat Weight and CC: Canonic Correlation, U1, U2, U3, U4: Canonical variates of independent growth performance measurements variables sequentially calculated from highest to lowest, V1, V2, V3, U4: Canonical variates of dependent carcass traits variables sequentially calculated from highest to lowest, [a]: Independent growth measurements, [b]: Dependent carcass measurements

Table 9 illustrates body measurements (I) and growth performances (II) of independent canonical variates with cross loadings between these variates and dependent carcass traits as set of variables. The highest cross loadings that were found were 0.93 and 0.80 between cold carcass weight and dressing percentage from carcass variables with the first canonical variate of body measurements variables in analysis I. In addition, loin eye muscle area, one of the most important carcass characteristics, was positively high correlated (0.65) with canonical variate of growth performances variables in analysis II (Table 9). These positive high cross loadings express that the U_1 index can be used as a selection criteria for breeding, with a statistically high reliability, for cold carcass weight and dressing percentage in analysis I. For example, individuals having higher score on the U_1 index in analysis I are expected to have higher cold carcass weight and dressing percentage because of the positive canonical and cross loadings values. Also, in prediction of dependent loin eye muscle area, using U_1 index of independent growth performance traits (analysis II) can be more reliable than other canonic variate indexes obtained in both analyses.

Table 9: Cross loadings of the original variables with opposite canonical variates

Canonical variate pairs	Dressing percentage	Cold carcass weight	Loin eye muscle area	Tail fat weight
Analysis I (Height at wither, body length, heart girth circumference)				
U_1	0.80	0.93	0.07	-0.49
U_2	0.10	0.30	-0.10	0.81
U_3	-0.40	0.10	0.60	0.05
Index				
U_1 = -1.05 HTW + 1.37 BL - 0.01 HGC				
Analysis II (Birth weight, weaning weight, post grazing weight, average daily gain)				
U_1	0.42	0.72	0.65	0.01
U_2	0.13	0.15	-0.42	0.82
U_3	0.71	0.13	-0.45	-0.31
U_4	0.20	0.36	-0.19	-0.23
Index				
U_1 = 0.15 BW + 1.78 WW - 1.21 PW -0.14 ADG				

U1, U2, U3 in analysis I: Canonical variates of independent body measurements variables sequentially calculated from highest to lowest, U1, U2, U3, U4 in analysis II: Canonical variates of independent growth performance variables sequentially calculated from highest to lowest

CONCLUSION

It was concluded that high and statistically significant canonical correlations clearly were found from the general framework of relationship between body measurements and growth performances, with important carcass traits of Red Karaman male lambs. Relatively rapid and inexpensive in vivo methods such as linear measurements and live weight, which do not harm animal performance, would be applicable for the selection of breeding stock or estimation of market-readiness. Considering all body measurements and growth performances and relating these measurements can provide an accurate method to estimate important carcass traits by explaining their correlation with CCA.

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