African Journal of Agricultural Research Vol. 7(6), pp. 964-969, 12 February, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1210
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Determination of relationship between nutrient and milk yield components of German fawn × hair crossbred by canonical correlation analysis

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Accepted 3 September, 2011

Canonical correlations among nutrient intake (energy, protein, Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF) and dry matter intake (DMI)) and body weight, milk yield (MY) and milk component in 36 German Fawn x Hair Crossbred goats under different feeding systems were estimated. Canonical correlation coefficient between the first (0.91) pair of canonical variables was significant (P<0.01). There was an important relationship between milk yield and nutrient based on Pearson correlation. The highest contribution for the explanatory capacity of X variable sets was DMI and MY. DMI (most impressing) and MY (most responded) during the last lactation period appear to be a determining factor for estimating performance of German Fawn x Hair Crossbred goats.

Key words: Multivariate statistics, canonical correlation, multi dimension correlation, energy protein source.

INTRODUCTION

The main aim of the multivariate analysis techniques, like other branches of statistics, is to use, summarize, interpret and make decision of the numerical scientific results. Scientific studies deal with events that are usually under the influence of many factors and in addition they are related objects if monitored. Therefore, in applications a large number of variables are encountered. To give valid and reliable statistics, all aspects of the studied factors need to be evaluated. Therefore, the researcher is usually left with multivariate data and their analysis. Canonical correlation analysis is one of the statistics to evaluate the multiple factors and their relationships. As compared to other statistical methods, canonical correlation analysis method is based on fewer assumptions. Even though theoretical background of the model was known, rapid development of computer technology has recently activated the wide use of the model. Fyfe and Leen (2006) interpreted research data using two methods of canonical correlation. First is the use one data set as a target for the current estimate of the other, and then formulation of the Gaussian process regression in the opposite direction is used.

Secondly, Gaussian models canonical correlation analysis, described by Gaussian probability models, used Dirichlet method. Canonical correlation can be used in a wide range in studies of animal breeding and nutrition. For example, Gürbüz (1998) conducted a study with lambs comparing various body parts' weights before and after the slaughter using canonical correlation analysis method and the correlation coefficient between the first canonical variable was significant. The study also explored the possibilities of prediction of the linear combinations of variables, with the help of any other variable group. Similarly, Kocabaş et al. (1998), collected different body sizes of 3-month old Kilis goats and using canonical correlation analysis, examined the relationships between variables first of which was a set of variables

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(withers height, elbow height and shoulder height of the tip width) compared to paddles behind the chest, front chest width, rump width of the front, middle rump width, rump width last, the width of the head and the width of ear set using two canonical correlation coefficients. Akbaş and Takma (2005), implemented canonical correlation analysis to predict the relationship between age at sexual maturity, egg production and body weight, egg weight data. They also suggested that canonical correlations between the estimates from the first and second canonical variables in the analysis were significant.

Çankaya and Kayaalp (2007), conducted a study at German Friesian x hair crossbred goats and measured 8 different morphological features. The resulting data indicated that maximum contributions to the variation in the body weights in different periods were from chest depth and chest compared with other body measurements. Similarly, Kaya and Doğan (2010) determined the relationship between the blood parameters and performance parameters of a set of variable sets using the canonical correlations. The aim of this study, in mid-lactating German Friesian × Hair crossbred goats, the relationships among variables of basic food consumption items and body weight; milk yield and milk contents were estimated using canonical correlation analyses (CCA).

MATERIALS AND METHODS

To determine the different feed consumption rates (dry matter, energy, protein, Acid Detergent Fiber - ADF and Neutral Detergent Fiber - NDF) and body weights, milk yield and content at the end of the trials 36 German Friesian x Hair crossbred goats were fed with different feeding systems. Those measured sets of data were the main values of the study. Feed type and consumption variables were assumed to be one set of data and the other set of data composed of body weight, milk yield and milk content variables. The relationship between those two sets of data was analyzed with CCA. Phenotypic and CCA analysis of feed variables and milk yield and nutrient content variables were carried out with Statistica 7.0 statistical package.

With canonical correlation analysis, maximum correlations of linear functions of the set of chance variables is determined. The linear components of each variable are reduced to a single canonical variable. Therefore, the correlation of the canonical variables between two groups is calculated. In other words, random group of variables of each variable, the maximum correlation and linear unit variance components are obtained. Then the second canonical pair is determined. This is done as long as all possible pairs of variables are obtained (Bilodeau and Brenner, 1999). This process will continue till an equal number of pair of canonical variables of random variable of the group is reached. Canonical correlation analysis is also a data reduction technique. Because p variable of X set and q variable of Y set will have pxq correlations matrices.

Instead of the correlation between two variables, a set of linear combinations of the smallest variables could be tested with canonical correlation model. Because, a high number of correlation coefficients are difficult to interpret individually. Canonical correlation analysis aims to reduce the number of correlation coefficients. Therefore, linear components of the first and second data sets are matched to give the highest correlations. Data sets of the linear components are defined as:

$$U = a'X^{(1)}$$

$$V = b'X^{(2)}$$

And for the coefficient vectors a and b aforestated are obtained with:

$$Var(U) = a'Cov(X^{(1)})a = a'\Sigma_{11}a$$

$$Var(V) = b'Cov(X^{(2)})b = b'\Sigma_{22}b$$

$$Cov(U,V) = a'Cov(X^{(1)}, X^{(2)})b = a'\Sigma_{12}b$$

Thus, for vectors a and b, the highest correlation coefficient could be obtained with:

$$Corr(U,V) = \frac{a'\Sigma_{12}b}{\sqrt{a'\Sigma_{11}a}\sqrt{b'\Sigma_{22}b}}$$

When P number of predicted variables of first variables set was shown with $X^{(1)}$ and q number of the second variables set were shown with $X^{(2)}$, the U-linear components turn out to be:

$$U_1 = a_1X_{11}^{(1)} + a_2X_{12}^{(1)} + ... + a_pX_{1p}^{(1)}$$

$$U_2 = a_1X_{21}^{(1)} + a_2X_{22}^{(1)} + ... + a_pX_{2p}^{(1)}$$

$$U_N = a_1X_{N1}^{(1)} + a_2X_{N2}^{(1)} + ... + a_pX_{Np}^{(1)}$$

And V linear components are shown as follows (Oktay and Cinar, 2002):

$$V_1 = b_1X_{11}^{(2)} + b_2X_{12}^{(2)} + ... + b_qX_{1q}^{(2)}$$

$$V_2 = b_1X_{21}^{(2)} + b_2X_{22}^{(2)} + ... + b_qX_{2q}^{(2)}$$

$$V_N = b_1X_{N1}^{(2)} + b_2X_{N2}^{(2)} + ... + b_qX_{Nq}^{(2)}$$

The aim is to ensure the maximum correlation between the variables U and V (Tatlidil, 1996). U_1 is linear combinations, V_1 is the maximum correlation with unit variance, while U_2 is the linear combinations, and V_2 is maximum correlation difference than first components with unit variance. The first canonical variable pair has the highest covariance. Under the assumption of $p \leq q$ that $X^{(1)}$ and $X^{(2)}$ covariance of random vectors are assumed to be:

$$Cov(X^{(1)}) = \underbrace{\Sigma_{11}}_{(pxp)}$$

$$Cov(X^{(2)}) = \underbrace{\Sigma_{22}}_{(qxq)}$$

$$Cov(X^{(1)}, X^{(2)}) = \underbrace{\Sigma_{12}}_{(pxq)}$$

Full rank in the formula is shown with Σ. For coefficient of linear combinations of vectors of a and b, linear combinations turn out to be $U = a'X^{(1)}$ and $V = b'X^{(2)}$. Then linear combinations (the first canonical variable pair) are described by the high correlation as $U_1 = \underbrace{e_1'\Sigma_{11}^{1/2}}_{a_1'} X^{(1)}$ and $V_1 = \underbrace{f_1'\Sigma_{22}^{1/2}}_{b_1'} X^{(2)}$ are determined which describes the maximum correlation as $\max_{a.b} Corr(U,V) = \rho_1^*$. 1, 2, ..., K-1th canonical variables are linear combinations of the unbound from the kth pair of canonical variables of the k = 2, 3, ..., p, $U_k = e_k'\Sigma_{11}^{-1/2} X^{(1)}$ and $V_k = f_k'\Sigma_{11}^{-1/2} X^{(2)}$ and the maximum correlation pair is described as $Corr(U_k, V_k) = \rho_k^*$. Independent combinations mentioned earlier gives 1, 2, ..., K-1 canonical variables. The eigenvalues of $\Sigma_{11}^{-1/2}\Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}\Sigma_{11}^{-1/2}$ are values of $\rho_1^{*2} \geq \rho_2^{*2} \geq ... \geq \rho_p^{*2}$. $e_1, e_2, ..., e_p$ on the other hand are associated with (Px1) vectors. Likewise, $\rho_1^{*2} \geq \rho_2^{*2} \geq ... \geq \rho_p^{*2}$ values with $\Sigma_{11}^{-1/2}\Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}\Sigma_{11}^{-1/2}$ corresponding matrix of (qx1) number of $f_1, f_2, ..., f_p$ values are eigenvalues of the largest pieces of vectors. Each f_i value is ratio to $\Sigma_{22}^{-1/2}\Sigma_{21}\Sigma_{11}^{-1/2} e_i$. Assuming that canonical variables are k = 1, 2,..., P.

$$Var(U_k) = Var(V_k) = 1$$

$$Cov(U_k, U_l) = Corr(U_k, U_l) = 0 \quad k \neq l$$

$$Cov(U_k, V_l) = Cor(V_k, V_l) = 0 \qquad k \neq l$$

$$Cov(U_k, V_l) = Corr(U_k, V_l) = 0 \quad k \neq l$$

If the original variables are standardized:

$$Z^{(1)} = \left[Z_1^{(1)}, Z_2^{(1)}, ..., Z_p^{(1)}\right]'$$ and

$$Z^{(2)} = \left[Z_1^{(2)}, Z_2^{(2)}, ..., Z_q^{(2)}\right]'$$

Then canonical variables are expressed in the form of:

$$U_k = a_k'Z^{(1)} = e_k'\rho_{11}^{-1/2} Z^{(1)}$$

$$V_k = b_k'Z^{(2)} = f_k'\rho_{22}^{-1/2} Z^{(2)}$$

Here, while $Cov(Z^{(1)}) = \rho_{11}$, $Cov(Z^{(2)}) = \rho_{22}$, $Cov(Z^{(1)}, Z^{(2)}) = \rho_{12} = \rho_{21}'$, e_k and f_k values are eigenvalues vectors of $\rho_{11}^{-1/2}\rho_{12}\rho_{22}^{-1}\rho_{21}\rho_{11}^{-1/2}$ and $\rho_{22}^{-1/2}\rho_{21}\rho_{11}^{-1}\rho_{12}\rho_{22}^{-1/2}$. Canonical correlation ρ_k^*, provides the conditions $Corr(U_k, V_k) = \rho_k^*, k = 1, 2, ..., p$. Here, the linear component of the U_1 generated $X^{(1)}$ of the first canonical variable, V_1 is the linear component of the $X^{(2)}$' which is called the first canonical variable. Additionally, the relationship between U_1 and V_1, the first canonical correlation, the square of the first canonical correlation is named the first eigenvalue. The values of generated variable pair coefficients (U, V) can be calculated with a and b coefficients. Relationship between U and V pair results depend on the coefficients a and b. For this reason, the a and b coefficients could be selected for canonical correlation analysis of the maximum relationship values between U and V.

As a result, the first canonical correlation makes it possible for the highest relationship created between components. In general, this process continues with the creation of other canonical variable pairs. The purpose of the canonical correlation purpose is to make the maximum determination of linear combinations between U_i and V_j pairs through determination of a_i and b_j coefficients. In this case, a simple correlation between two linear combinations is described as:

$$r_{(u,v)} = \frac{Cov(u,v)}{\sqrt{Var(u)Var(v)}}$$

$$r_{(u,v)} = \frac{a'S_{12}b}{\sqrt{(a'S_{11}a)(b'S_{22}b)}}$$

It could be assumed that canonical correlation coefficients have most of the features of simple correlation coefficients. Simple correlation value ranges between -1 and 1 while canonical correlation coefficients vary between 0 and 1. At first this may seem as a contradiction to the definition of the canonical correlation but canonical correlation coefficients could be taken as negative making no difference between them (Oktay and Cinar, 2002).

Correlation between canonical and original variables

The correlation between $X^{(1)}$ of U_i canonical variable and original variables could be calculated with;

$$Corr(U_i, X^{(1)}) = \frac{Cov(U_i, X^{(1)})}{\sqrt{\left[Diag(Var(U_i))\right]\left[Diag(Var(X^{(1)}))\right]}} = \frac{a_i'\Sigma_{11}}{\sqrt{Diag(\Sigma_{11})}}$$

Likewise, the correlation between canonical variable Vi and $X^{(1)}$ original variables:

$$Corr(V_i, X^{(1)}) = \frac{b_i'\Sigma_{21}}{\sqrt{Diag(\Sigma_{11})}}$$

Table 1. Names and abbreviations of the analyzed variables sets.

One set of variables	Second set of variables
X1 = ME - Metabolizable energy	X6 = BW - Body weight
X2 = CP – Crude protein	X7 = MC - Milk casein
X3 = ADF - Acid detergent fiber	X8 = TN - Total N
X4 = NDF - Neutral detergent fiber	X9 = MF - Milk fat
X5 = DM – Dry Matter	X10 = MDM - Milk Dry Matter
	X11= NPN - Milk Non-protein nitrogen
	X12 = MY - Milk Yield

Table 2. Correlation matrix between two variables sets.

Variable	X6 (BW)	X7(MC)	X8(T N)	X9(MF)	X10(MDM)	X11(NPN)	X12 (MY)
X1(ME)	0.408*	-0.198	0.206	-0.143	0.325	-0.081	0.759**
X2(CP)	0.266	-0.542**	0.092	0.007	0.357	0.322	0.720**
X3(ADF)	0.271	-0.522**	0.055	0.017	0.403*	0.190	0.615**
X4(NDF)	0.159	-0.400*	0.347	-0.319	0.412*	0.014	0.439*
X5(DM)	0.350	-0.321	0.247	-0.168	0.392*	-0.016	0.738**

* : P<0.05, ** : P<0.01.

Similarly, the correlation between U_i canonical variable and $X^{(2)}$ original variables can be calculated with the following formula;

$$Corr(U_i, X^{(2)}) = \frac{a_i^{'}\Sigma_{12}}{\sqrt{Diag(\Sigma_{22})}}$$

Significance test of canonical correlation coefficients

At the end of the canonical correlation analysis, it is important to determine how many pairs of canonical variables are significantly different. Namely there is need to decide how many of the relationship between the variable groups is significant (Tatlidil, 1996). With Wilk's lambda approach, the hypothesis that all canonical correlation coefficients are equal to zero is tested against the alternative hypothesis shown as follows.

H_0: $\Sigma_{12} = 0$ or $r_1 = r_2 = \ldots r_p = 0$

H_A: at least $r_i \neq 0$

In the case of rejection of H_0 hypothesis, the value of the biggest coefficient is taken out and the operation is repeated until the acceptance of the H_0 hypothesis. Wilk's lambda test statistic is obtained as follows.

$$\wedge = \prod_{i=1}^{k}(1 - r_i^2)$$

Using the coefficient aforestated χ^2 test statistical value is calculated with:

$$\chi^2 = -\left[(n-1) - \frac{(p+q+1)}{2}\right]\log(\wedge)$$

in this equation, n is the sample size, p is the value of first variable's set, q is the value of the second variable's set, r_i is canonical correlations, and k specifies the number of the canonical correlation (Ozdamar, 2002). The calculated test statistic value χ^2 with $\chi^2_{pxq;\alpha}$ is compared with the Chi-square critical value. When χ^2 > $\chi^2_{pxq;\alpha}$ H_0 hypothesis is rejected. That is the first canonical correlation is significant (Kaya and Dogan, 2010).

RESULTS

Phenotypic correlations of variables in the study are presented in Table 2. The highest correlations of first variables set were determined between milk yields. Milk casein has been inversely proportional to CP, ADF and NDF consumption (P <0.05). Milk dry matter was positively influenced by ADF, NDF and DM (P<0.05). CCA of only the first and second variable pairs derived from 5 different CCA were significant (P<0.05). Here, we focus on the first CCA coefficients (U_1V_1) full-linearity. Using U_1V_1 components, canonical variable coefficient were calculated as follows:

$U_1 = -1.86X1 + 0.036X2 + 0.43X3 - 1.39X4 + 3.41X5$ $V_1 = -0.06X6 - 0.32X7 - 0.06X8 + 0.29X9 + 0.38X10 - 0.20X11 + 0.85X12$

According to linear relationship between the U_1V_1 components, CP, ADF and DM independent variables increase were in parallel with milk fat, milk dry matter and

Table 3. Canonical correlation analysis results of variables sets.

Parameter	First variables set	Second variables set
Extracted variance (%)	100.00	72.55
Total redundancy (%)	73.45	41. 37
Variables	5	7
	X1	X6
	X2	X7
	X3	X8
	X4	X9
	X5	X10
		X11
		X12
Canonical correlation coefficient R: 0.92 (N=24)	Chi-square (35)=67.05 (P=0.001)	

milk yield. In addition, the decrease in ME and NDF reduced body weight, milk casein, total N and milk NPN. 73.5% of the total variation of the first variables set was explained by second variables set and 41.4% of variation in the second set of variables had been explained by the first set of variables (Table 3). As seen in Table 3, the highest correlation was found between the first variables set and milk yield followed by milk casein (P<0.01). Five different five variable canonical correlation coefficients of the pair are derived from the canonical correlations between pairs of canonical correlation coefficients, only the first canonical variable was highly significant (P<0.01). Canonical correlation coefficients between pairs of the second canonical variable was statistically significant (P<0.05). Other canonical correlation coefficients were not significant. Significance of canonical correlation coefficients were determined using the chi square values Wilks' Lambda values. First two variable pairs of U_1V_1 and U_2V_2, which indicated that U_1V_1 had strong linear while U_2V_2 had a weak linear relation. Since first and second canonical variable pairs were significant, only their linear components were used to calculate canonical variable coefficients with the equations as follows:

$$U_1 = -1.86X1 + 0.037X2 + 0.43X3 - 1.40X4 + 3.42X5$$

$$V_1 = -0.07X6 - 0.33X7 - 0.06X8 + 0.29X9 + 0.39X10 - 0.20X11 + 0.85X12$$

$$U_2 = 0.72X1 - 2.08X2 + 2.88X3 - 1.89X4 - 0.11X5$$

$$V_2 = 0.22X6 + 0.33X7 - 0.44X8 + 0.59X9 - 0.25X10 - 0.36X11 + 0.16X12$$

Regarding the relationship between linear components of U_1V_1 (similar comments can also be made about U_2V_2). Any increase in the first set of variables CP, ADF, and DM resulted in increase in the second variables set of milk fat, milk dry matter, and milk yield. Also, decrease in ME and NDF variables caused reduced variables such as body weight, milk casein, total N, and milk NPN. Factor structure coefficients of absolute value of the named variables are placed in order of magnitude. In this way, canonical correlation and canonical variables the most contributing to the original variables is determined.

Both in the set of first and second variables, CP and milk yield were the most contributing to U_1 and V_1 respectively. HP, DM, ADF, NDF, and ME had the most contribution to the formation of U_1. While, in the formation of V_1 the most contribution were from the milk yield, milk casein, milk dry matter, body weights, milk NPN, milk fat, and total N. Canonical correlations and their statistics from the biggest to the lowest values are given in Table 4: The first (0.92) and second (0.80). Canonical correlation coefficients were found to be significantly. The canonical correlation analysis summary results are presented in Table 5. As seen in Table 3; 73% of first variables set variation was clearly explained by canonical variables (V1, V2, V3, V4, and V5). On the other hand 41% of variation in second variables set was explained by canonical variables (U1, U2, U3, U4, U5, U6 and U7).

DISCUSSION

In this study the relationship between milk yield and nutrient content of the German Friesian x Hair Crossbred Goats has been evaluated with phenotypic correlation and canonical correlation analysis. As a result of canonical correlation analysis, which examined the relationship specifications, which were reduced to 5 dimensional space and the high phenotypic relationships between variables were found among ME, CP, ADF, and DM and milk yield. In addition, relationship between the CP and ADF and milk casein was found significant.

Table 4. Five different canonical correlation coefficients.

S/N	Canonic correlation coefficient	Square of canonic correlation coefficient	Chi-Square	Degrees of freedom	P	Lambda
1	0.92	0.84	67.05	35	0.01	0.01
2	0.80	0.65	38.57	24	0.03	0.08
3	0.72	0.51	22.41	15	0.10	0.24
4	0.57	0.33	11.29	8	0.19	0.48
5	0.53	0.28	5.12	3	0.16	0.72

Table 5. The most contributing first pair of canonical variables and canonical correlation to the original variables.

First variables set of first canonical variable (U_1) correlation coefficients	Second variables set of first canonical variable (V_1) correlation coefficients
0.928 (X2)	0.852 (X12)
0.870 (X5)	0.448 (X7)
0.867 (X3)	0.375 (X10)
0.838 (X1)	0.369 (X6)
0.582 (X4)	0.184 (X11)
	0.159 (X9)
	0.002 (X8)

Higher correlations were determined with newly created first canonical variable pairs (0.92) and second (0.80) between pairs of canonical variables.

In addition, it was shown that the relationships between variables could be expressed in two or even one-dimensional space rather than 5 dimensional spaces. In other words, canonical correlation analysis from the canonical variable calculated from five different pairs revealed that the first canonical correlation was statistically highly significant and the second one was only significant. When U_1V_1 component of the first canonical correlation coefficient was examined; CP, ADF and DM variables had the most important effect on milk fat, milk dry matter and milk yield. Decrease in ME and NDF independent variables caused decrease in body weight, milk casein, and total N and milk NPN dependent variables. As a result, phenotypic effects were more significant with the canonical correlation between sets of coefficients of the 1st variables on the 2nd variables then Pearson correlation coefficients.

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