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Yayla Koşullarında Nitelikli Sığır Eti Üretmek İçin Oluşturulan Sığırlarda Karkas ve Kesim Özellikleri Arasındaki İlişkinin Kanonik Korelasyon Analizi

Sadrettin YÜKSEL[1*]

[1]Atatürk Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, 25240, Erzurum

[1]https://orcid.org/0009 0001 0948 0800
*Sorumlu yazar: syuksel@atauni.edu.tr

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ÖZ

Bu çalışmanın amacı, Doğu Anadolu Kırmızı ırkını üretim zincirine entegre etmek amacıyla, genç sığırların kesim özellikleri (besi sonu ağırlık (BSA), sıcak karkas randımanı (SKR), baş+ayak+deri ağırlığı (BADA), pelvik yağ+böbrek ağırlığı (PBYA), karkas uzunluğu (KU)) ve seçilen karkas kalite değerleri (pişirme kaybı (PK), Longissimus dorsi kabuk yağı kalınlığı (LDYK), Longissimus dorsi alanı (LDA), mermerleşme skoru (MS), karkas konformasyon skoru (KKS)) arasındaki çok değişkenli ilişkileri incelenmiştir. Çalışmada, Brown Swiss × Doğu Anadolu Kırmızısı (BSDAK), Holstein Friesian × Doğu Anadolu Kırmızısı (HFDAK) ve Brown Swiss × Holstein Friesian (BSHF) melezlerinden oluşan 36 genç sığırın verileri kullanılmıştır. Cinsiyet ve ırka göre kesim özellikleri (Predictor set, U) ve karkas kalite değerleri (Criterion set, V) arasındaki korelasyonları belirlemek için iki veri seti oluşturulmuştur. İstatistik analizlerde beş kanonik boyut çiftinden ilk ikisi, U1V1 ve U2V2, anlamlı bulunmuştur (P<0,01). Standartlaştırılmış kanonik katsayılar analizinde, ana faktörler olarak kabul edilen BSA, SKR ve KU, erkeklerde ortaya çıkan diğer kriter değişkenlerinden anlamlı derecede daha yüksek etkiye sahip bulunmuştur (P<0,01). Kanonik yükleme analizi, SKR, BSA ve BADA'nın, erkeklerde ölçülen U1'i belirlemede en etkili özellikler olduğunu ve kaliteli sığır eti üretimi için bir seçim kriterinin temelini oluşturabileceğini göstermiştir. Çapraz yüklemeler, SKR, BSA ve BADA'nin erkeklerde U1'i belirlemede diğer özelliklerden daha etkili olduğunu göstermiştir. İki değişken setinin (U1 ve V1) birbirine göre değişiminin fazlalık derecesi, erkekler için sırasıyla %94,1 ve %60,6, dişiler için ise %80,9 ve %34,8 olarak bulunmuştur. Sonuç olarak, bu bulgular, nitelikli sığır eti üretimi için erkek ve dişi sığırlara yönelik kanonik korelasyon analizine dayalı seçim kriterlerinin geliştirilmesi ve EAR ırkının üretim zincirine entegrasyonu için lojistik destek sağlayacaktır.

A Canonical Correlation Analysis of the Relation between Carcass and Slaughter Traits in Cattle Formed to Produce Qualified Beef in the Plateau Condition

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ABSTRACT

The aim of this study was to explore the multivariate relationships among the slaughter characteristics (final weight (FW), hot carcass dressing (HDrs), head+feets+hide weight (HFHW), pelvic fat+kidney weight (PFW), carcass length (CL) and selected carcass quality values (cooking loss (COL), fat thickness on Longissimus dorsi (FTL), Longissimus dorsi area (LDA), marbling score (MS), carcass conformation score (CCS) of young cattle in order to integrate the EAR breed into the production chain. The data of 36 young cattle were used that consisted of Brown Swiss × Eastern Anatolian Red, BSEAR; Holstein Friesian × Eastern Anatolian Red, HFEAR and Brown Swiss × Hostein

Logistics support

Friesian, BSHF. Two data sets were created to determine the correlations between based on sex and breed slaughter characteristics (Predictor set, U) and carcass quality values (Criterion set, V). The first two viz., U1V1 and U2V2 of the five pairs of canonical sizes were significant (P<0.01). In the standardised canonical coefficients analysis, FW, HDrs and CL, which were considered as main factors, have significantly higher effect than the other criterion variables emerging in males (P<0.01). Canonical loading analysis showed that HDrs, FW and PFW were the most influential traits in determining U1 measured in males that could form the basis of a selection criterion for producing quality beef. The cross-loadings showed that HDrs, FW and HFHW were more effective than other traits in determining U1 in males. The degree of of redundancy of change of the two sets of variables (U1 and V1) over each other was found to be 94.1% and 60.6% for males and 80.9% and 34.8% for females, respectively. In conclusion, these findings might enable the development of selection criteria based on canonical correlation analysis for male and female cattle for quality beef production.

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1. Introduction

In the beef production sector, almost all characteristics of carcasses are of great importance due to their close relationship with beef products and production systems. The carcass characteristics and measurements allow comparisons to be made between animal breeds, final weights and ages, feeding systems and correlations with other measurements that make up the carcass and support confirmation of its characteristics (Silva and Pires, 2000). Therefore, for meat production suitable for demands, the applicable solution in performing measurements belonging to individuals in the cattle population can be to use information obtained from carcass traits associated with meat traits and easily measured. Thus, it will be possible to weed out or cull cattle that do not meet the the specified standarts.

Multivariate data analysis techniques have been effectively used to examine the interaction values between the measures under consideration. When conditions require the integration of a large amount of information obtained from an experimental study, multivariate analysis techniques have been shown to be an effective method for identifying biological events based on a matrix composed of fundamental variables for the evaluation of experimental findings (Dillon and Goldstein, 1984; Takma et al., 2017). As carcass evaluation studies are generally done considering a large number of characteristics (Barbosa et al., 2005; Pardo et al., 2024).

In this context, canonical correlation analysis (Bae et al., 2020) has been used as a technique to objectify the percentage of common variance for two groups as well as to determine the interrelationship between two sets of variables. The first from groups is considered to be established by U character and the second by V character. The number of canonical correlations is equal to the smallest number of traits that make up one of the matrix (U or V) and their extent changes with the order in which these are determined. To our knowledge, there is limited information regarding canonical correlation analysis focusing on the possible relationship between slaughter and carcass characteristics of the genotype including DAK breed. This study aims to investigate the multivariate relationships between slaughter characteristics (final weight (FW), hot carcass dressing (HDrs), head+feets+hide weight (HFHW), pelvic fat+kidney

weight (PFW), and carcass length (CL)) and selected carcass characteristics (cooking loss (COL), fat thickness on Longissimus dorsi (FTL), Longissimus dorsi area (LDA), marbling score (MS), carcass conformation score (CCS)) of male and female cattle, considered as key factors for high-quality beef production under plateau conditions, within the genotypes including the Eastern Anatolian Red (EAR) to be local breed of the region, and to provide logistical support in this area.

2. Materials and Methods

2.1. Study Area

The data used in this study were derived from three genetic groups of young cattle fed on plateau condition in the Eastern Anatolian Agriculture Research Institute (39° 55′ 15.49′ N, 41° 17′ 12.90 E and at an altitude of 1,821 m above sea level) in east of Türkiye.

2.2. Material of Study, Feeding Style

The genetic groups including 12 heads F1 (6 male, 6 female) Brown Swiss × Eastern Anatolian Red (BSEAR), 12 heads F1 (6 male, 6 female), Holstein Friesian × Eastern Anatolian Red (HFEAR) and 12 heads F_1 (6 male, 6 female), Brown Swiss × Holstein Friesian (BSHF) were used in the study. The calves were fed (NRC, 1994) with milk at 10% of birth weight, concentrate-I (dry matter (DM) 88.0%, crude protein (CP) 18.0%, ash 7.1%) and *ad libitum*, a dried meadow grass (DM 92.26%; CP 10.13%; Acid Detergent Fiber (ADF) 39.55%; Neutral Detergent Fiber (NDF) 62.4%; ash 10.4%). The claves were weaned at 63 days of age and were bred under similar conditions in calf boxes individually throughout six months. The animals were fed (NRC, 1994) 2 kg/day concentrate-II (DM 88.0%; CP 17%; ash 7.7%), ad libitum dry hay and oat (DM 30.0%; CP 11.30%; ADF 37.82%; NDF 54.0%; ash 8.98%) in equal mix to 180 days from 63 days. Then the plateau conditions feeding regime was adopted, and the animals were fed a ration consisting of dry hay, oat, fresh mowed green hay and concentrate. They were fed (NRC, 1994) 4 kg/day/head concentrate-III (DM 90.25%; CP 16.45%; ash 9.00%) and *ad libitum* dry hay and oat until at the age of 16 months as a group. Until 20 months of age, animals were fed with 4 kg/day/head concentrate-III, 2 kg/day/head dry oat and ad libitum fresh mowed green hay (DM 24.95%; CP 17.00%; ether extract (EE) 3.65%; ash 10.62%). The male and female animals were stocked as a group in the paddocks which was size of 8 × 21 and 8 × 15 m, respectively. All animals were slaughtered at the age of 20 months in an official abattoir.

2.3. Processing of Samples

It was taken values of the all animal FW at 4 h before slaughter, and HDrs, HFHW immediately after slaughter, and PFW, CL, COL, FTL, LDA, MS, CCS at 24 h after slaughter (Yüksel et al., 2012). After a chill period at 4 °C for 24 h, the carcasses were split between the 12th and 13th ribs. The evaluate committee consisting of two experts graded and scored the carcasses (USDA, 1989). The area of Longissimus dorsi (LD) muscle crossection, the depth of the fat at three equally spaced locations over the Longissimus dorsi

muscle, and a marbling score were determined at the ribbing site. The scale used for marbling evaluation ranged from 1 to 6 (1 = slight, 2 = small, 3 = modest, 4 = moderate, 5 = slightly abundant, 6 = abundant). The scale used for conformation (1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = extremely) evaluation ranged from 1 to 5 (USDA, 1989). To evaluate the cooking loss, raw meat samples were cooked in a plastic bag, in a water bath at 90 ºC until they reached an internal temperature of 70 ºC. The cooked meat was then proportioned to the raw meat sample (Kopuzlu et al., 2018).

2.4. Statistical Analysis

The U and V letters referred to the canonical variables. The canonical correlation analysis was carried out to determine the correlation between slaughter traits viz., FW, HDrs, HFHW, PFW, CL (predictor set, U) and carcass traits such as COL, FTL, LDA, MS, CCS (criterion set, V). The multivariate normality and outliers were examined before the analysis. The following equations was used for the hypothesis and canonical correlation calculations in the study (Johnson and Wichern, 2002).

The following hypothesis for canonical coefficients was used:

$H0 = rc1 = rc1 = \ldots = rcr = 0$ (1)

$H1 \neq rci = 0$ at least one i= 1, 2,…k

The Wilk's Lambda (Λ) test for to test the null and alternative hypotheses was:

$\Lambda m = \Pi m\ i = 1(1-\lambda i)$ (2)

where Λm= Wilk's Lambda test statistic

λi= squared canonical correlation

m = canonical correlation numbers.

The following is the Chi-square test for the significance of canonical correlations (Sharma, 1996):

$X^2 = -(N - 1 - (\frac{(kx+ky+1)}{2}))\ln \Lambda m$ (3)

where; N = case numbers,

Kx = the variable numbers in the U (Predictor) set,

Ky = the variable numbers in the V (Criterion) set

Scores estimated for canonical variables (U and V) were:

$U = ZuBu$ (4)

$V = ZvBv$ (5)

where; Zu, Zv = standardized scores and Bu, Bv = canonical coefficients

Use of matrix loadings and canonical coefficients for estimated of correlation matrices among variables were:

$Au = RuuBu, Av = RvvBv$ (6)

$pv_{xc} = \sum_{i=1}^{kx}. a^2\ ixc/kx$ (7)

$pu_{yc} = \sum_{i=1}^{ky}. a^2\ iyc/ky$ (8)

$rd = (pv)(r^2c)$ (9)

where; pvcx was the average variance in the variables U explained by the canonical variable Vi, kx was the number of features in the specified canonical variables, rd = redundancy

In this study, the predictor slaughter traits set and independent carcass traits set consisted of 5 characters each. Thusly, these combinations that was the number of the pairs being equal to the smaller of numbers of set variable were coupled in the pairs of canonical variaties (Uk the first set, Vk the secont set). Each of these couples (Uk, Vk) independently represents the relationship of Xi and Yj, and so that the mutual canonical correlation of (Ul, Vl) was the highest, that of sequential calculation of U2, V2 being the second highest. All variables were standardized (Z-scores) before the analysis and the analysis was performed using the correlation matrix. It was used Pearson's correlation analysis to define the linear correlation between characteristics. Pearson correlation analysis was performed to support and interpret the relationships defined by canonical functions. Furthermore, the purpose of Pearson's analysis after CCA was not stated as Pearson correlation analysis was performed to support and interpret the relationships defined by canonical functions. Data were analyzed using the MANOVA (Multivariate Analysis of Variance) procedure in SPSS version 25.0. To ensure the validity of the results, assumptions of normality and homogeneity of variance-covariance matrices were tested prior to the main analysis (SPSS, 2021). A cut-off value of $|r_s| \geq 0.30$ was adopted for the interpretation of canonical loadings (Hair et al., 2010).

3. Results

There were significantly high positive correlation between FW and PFW, HDrs and HFHW, CL and LDA in males and a significantly high negative correlation between FW and MS, HDrs and PFW, MS and LDA in females of the BSEAR breed. Thus, it was observed that FW that was independent variable had a positive correlation effect on carcass traits that dependent variables in males and a negative correlation effect in females (Table 1).

Table 1. Bivariate correlation coefficients among the carcass and slaughter traits for BSEAR breed at female (below the diagonal) and male (above the diagonal)

	FW	**HDrs**	**HFHW**	**PFW**	**CL**	**COL**	**FTL**	**LDA**	**MS**	**CCS**
FW	1	0.525	0.574	0.924**	0.311	-0.242	0.054	0.361	0.168	-0.088
HDrs	0.202	1	0.889*	0.441	-0.428	-0.151	-0.099	-0.354	-0.262	-0.758
HFHW	0.512	0.560	1	0.451	-0.067	-0.365	-0.468	-0.094	0.184	-0.708
PFW	0.209	-0.815*	-0.348	1	0.231	-0.484	0.000	0.127	0.196	-0.040
CL	0.635	-0.168	0.492	0.584	1	-0.231	-0.307	0.856*	0.777	0.642
COL	-0.334	0.155	-0.183	0.123	0.139	1	0.339	0.254	-0.673	0.154
FTL	-0.364	-0.481	-0.067	-0.040	-0.305	-0.310	1	0.064	-0.806	0.316
LDA	0.299	0.387	0.277	-0.011	0.114	0.287	-0.510	1	0.440	0.574
MS	-0.867*	-0.198	-0.445	-0.371	-0.751	-0.128	0.656	-0.588	1	0.187
CCS	0.285	-0.033	-0.304	0.283	-0.112	0.055	-0.377	0.741	-0.447	1

FW: final weight, HDrs: hot carcass dressing, HFHW: head+feets+hide weight, PFW: pelvic fat+kidney weight, CL: carcass length, COL: cooking loss, FTL: fat thickness on LD, LDA: LD area, MS: marbling score, CCS: carcass conformation score. *: $P < 0.05$, **: $P < 0.01$

The independent five canonical correlation coefficients were calculated for determining relationships between slaughter traits and carcass quality values. It was obtained different canonical correlation coefficients between two different canonical variable pairs (Table 2). When the Wilk's Lambda values and

the significance test of the canonical correlation coefficients were examined, it was found that the first and second canonical correlation coefficient calculated between the first canonical variable pair for males in BSEAR were statistically significant (P<0.01; Table 2). In all breeds for both males (0.987; 0.948; 0.991; 0.980 and 0.090; 0.036, respectively) and females (0.991; 0.065; 0.991; 0.980 and 0.990; 0.936, respectively), the first and second canonical correlation coefficient value were found, statistically, significant (P<0.01; Table 2, Table 4). These results revealed an association between the slaughter traits and carcass quality in experiment animals.

Table 2. Results of the canonical correlation analysis for male in breeds

Pair of Canonical Variables	Canonical Correlation	Eigenvalue	DF1	DF2	Wilks Statistic	Probability Pr>F
			BSEAR			
	0.987	225.179	25.00	1.50	0.001	0.000
	0.948	127.943	16.00	3.69	0.001	0.000
	0.928	6.194	9.00	5.01	0.033	0.290
	0.861	2.858	4.00	6.00	0.240	0.298
	0.271	0.079	1.00	4.00	0.927	0.604
			HFEAR			
U1V1	0.998	102.456	16.00	6.74	0.002	0.000
U2V2	0.971	16.419	9.00	7.45	0.018	0.050
U3V3	0.769	1.450	4.00	8.00	0.308	0.263
U4V4	0.496	0.327	1.00	5.00	0.754	0.257
U5V5	0.401	0.087	1.00	3.01	0.844	0.370
			BSHF			
	0.991	55.554	16.00	6.74	0.002	0.002
	0.909	4.748	9.00	7.45	0.087	0.019
	0.703	0.975	4.00	8.00	0.500	0.543
	0.112	0.013	1.00	5.00	0.987	0.811
	0.102	0.003	1.00	3.82	0.993	0.741

The bivariate correlation coefficient indicating the relationship between the slaughter traits and carcass quality were shown for males and females in HFEAR on Table 3.

Table 3. Bivariate correlation coefficients among the carcass and slaughter traits for HFEAR breed at female (below the diagonal) and male (above the diagonal)

	FW	HDrs	HFHW	PFW	CL	COL	FTL	LDA	MS	CCS
FW	1	0.998**	0.955**	0.859**	0.997**	-0.108	-0.118	0.965**	0.998**	0.930**
HDrs	-0.533	1	0.945**	0.856**	0.996**	-0.147	-0.070	0.962**	0.994**	0.913**
HFHW	-0.251	-0.374	1	0.691*	0.941**	-0.068	-0.224	0.872**	0.944**	0.994**
PFW	0.553	-0.499	-0.597	1	0.859**	-0.054	-0.148	0.882**	0.870**	0.666*
CL	0.937**	-0.648	-0.060	0.491	1	-0.103	-0.072	0.978**	0.998**	0.911**
COL	0.315	-0.303	0.451	-0.225	0.187	1	-0.466	-0.054	-0.081	-0.017
FTL	-0.646	0.386	0.373	-0.672	-0.667	-0.160	1	-0.049	-0.110	-0.301
LDA	0.207	-0.365	0.022	0.238	0.318	-0.456	0.273	1	0.973**	0.835**
MS	0.029	-0.463	0.647	-0.242	-0.024	0.661	0.487	0.199	1	0.920**
CCS	0.967**	-0.533	-0.154	0.444	0.885*	0.373	-0.432	0.335	0.226	1

FW: final weight, HDrs: hot carcass dressing, HFHW: head+feets+hide weight, PFW: pelvic fat+kidney weight, CL: carcass length, COL: cooking loss, FTL: fat thickness on LD, LDA: LD area, MS: marbling score, CCS: carcass conformation score, **: P < 0.01

For males, carcass quality values were highly and positively significant (P<0.05; P<0.01) correlated with slaughter traits (except COL and FTL), an indication of close relationship between the characteristics (Table 3).

Table 4. Results of the canonical correlation analysis for female in breeds

Pair of Canonical Variables	Canonical Correlation	Eigenvalue	DF1	DF2	Wilks Statistic	Probability Pr>F
			BSEAR			
	0.991	951.790	16.00	6.74	0.001	0.000
	0.965	13.558	9.00	7.45	0.052	0.015
	0.485	0.308	4.00	8.00	0.753	0.867
	0.125	0.016	1.00	5.00	0.984	0.790
	0.085	0.003	1.00	4.08	0.991	0.901
			HFEAR			
U1V1	0.991	637.208	16.00	12.85	0.001	0.000
U2V2	0.980	24.173	9.00	12.31	0.020	0.004
U3V3	0.679	0.853	4.00	12.00	0.516	0.369
U4V4	0.211	0.046	1.00	7.00	0.956	0.586
U5V5	0.088	0.006	1.00	3.30	0.980	0.881
			BSHF			
	0.990	204.709	9.00	12.31	0.001	0.000
	0.936	7.012	4.00	12.00	0.105	0.014
	0.383	0.172	1.00	7.00	0.839	0.888
	0.131	0.017	9.00	12.31	0.983	0.737
	0.032	0.011	4.00	9.319	0.985	0.786

When the Wilk's Lambda values and significance test of the canonical correlation coefficients (Table 4) were examined, it was shown that the first and second canonical correlation coefficient calculated between the canonical variable pairs for females in BSEAR, HFEAR and BSHF breeds were found statistically significant (P<0.05; P<0.01). HDrs was highly and positively significantly (P<0.05) correlated with CL in males, whereas FW was highly and positively significantly (P<0.05) correlated with CL and LDA in females (Table 5). Different U and V linear components were constructed by using the standardized canonical coefficients of the canonical variable pairs (Table 6). For the same result, HDrs, PFW, COL and FTL provided negative contribution in HFEAR males while all traits supplied negative contribute in BSHF males (Table 6).

Table 5. Bivariate correlation coefficients among the carcass and slaughter traits for BSHF breed at female (below the diagonal) and male (above the diagonal)

	FW	HDrs	HFHW	PFW	CL	COL	FTL	LDA	MS	CCS
FW	1	-0.167	-0.009	-0.002	0.344	0.442	0.263	0.002	-0.486	-0.095
HDrs	0.366	1	0.547	-0.084	0.822*	-0.285	-0.607	-0.273	-0.240	-0.183
HFHW	0.608	0.707	1	0.224	0.553	0.554	-.620	-0.126	-0.385	-0.350
PFW	-0.505	0.000	-0.358	1	-0.239	0.272	-0.621	-0.119	0.651	0.558
CL	0.839*	0.173	0.377	-0.717	1	0.090	-0.256	-0.406	-0.587	-0.499
COL	-0.293	0.189	-0.186	0.732	-0.229	1	-0.127	-0.208	-0.300	-0.441
FTL	0.785	-0.044	0.590	-0.579	0.621	-0.349	1	-0.100	-0.223	-0.433
LDA	0.899*	0.687	0.790	-0.252	0.598	-0.111	0.616	1	-0.215	0.546
MS	0.587	0.652	0.620	-0.593	0.761	-0.005	0.257	0.589	1	0.569
CCS	0.401	0.174	-0.003	0.521	0.000	0.263	0.128	0.498	0-.250	1

FW: final weight, HDrs: hot carcass dressing, HFHW: head+feets+hide weight, PFW: pelvic fat+kidney weight, CL: carcass length, COL: cooking loss, FTL: fat thickness on LD, LDA: LD area, MS: marbling score, CCS: carcass conformation score

The standardized canonical coefficients for canonical variates in female were given in Table 7. It was revealed that the biggest contributor on the U1 canonical variate was HFHW followed by HDrs and PFW for Predictor variable set in BSEAR breed, while the biggest contributor on the V1 canonical variate was MS, followed by CCS and COL.

It was determined that the biggest contributor on the U1 canonical variate was PFW and CL for Predictor variable set in HFEAR breed, while the biggest contributor on the V1canonical variate was COL and CCS.

Table 6. Standardized canonical coefficients for canonical variables in breeds

		Predictor set, U				
		FW	**HDrs**	**HFHW**	**PFW**	**CL**
				Male		
	a	-0.266	0.960	-0.085	0.125	0.264
	b	1.493	-1.234	0.764	-0.029	0.421
U1	c	-0.151	2.338	-0.552	-2.596	2.841
				Female		
	a	-0.266	2.240	4.495	1.307	0.421
	b	-0.013	-0.100	-0.353	1.337	0.121
	c	1.398	1.211	-3.315	1.696	1.001
		Criterion set, V				
		COL	**FTL**	**LDA**	**MS**	**CCS**
				Male		
	a	0.000	0.000	-0.066	1.025	0.046
	b	-0.004	-0.003	0.206	0.821	0.201
V1	c	-0.361	-0.146	-0.845	-0.235	-0.205
				Female		
	a	-0.001	-0.034	-1.882	1.037	0.021
	b	8.791	-1.737	-0.288	-5.916	0.110
	c	0.001	1.293	-0.203	-0.115	-0.005

a: Brown Swiss × Eastern Anatolian Red, BSEAR; b: Holstein Friesian × Eastern Anatolian Red, HFEAR, c: Brown Swiss × Hostein Friesian, BSHF, FW: final weight, HDrs: hot carcass dressing, HFHW: head+feets+hide weight, PFW: pelvic fat+kidney weight, CL: carcass length, COL: cooking loss, FTL: fat thickness on LD, LDA: LD area, MS: marbling score, CCS: carcass conformation score

This study indicated that there were positive correlations in terms of canonical loadings between the traits, except for COL and FTL for males in BSEAR and HFEAR breeds (Table 7). In BSHF males also, canonical loading values between all variables except COL were negative (Table 7). The loadings for the predictor set suggested that the HDrs and PFW were more influential than other characters in forming U1, whereas LDA and MS were more influential than other characters in forming V1 at criterion set for males in BSEAR (Table 7). In terms of this result, HDrs was effective for U1 and COL was effective for V1 in male BSHF breed. On the other hand, it was seen that HFHW was effective in the predictor set and MS was effective in the criterion set for males in the HFEAR breed. In females, FW and MS features came to the forefront (Table 7). Variables such as FW and MS showed strong representation with loadings exceeding 0.90, whereas COL was identified as having a non-dominant role in characterizing the sets, as its values (-0.29 and 0.01) remained below the specified threshold. Table 8 indicated the loadings of Predictor and Criterion set variables on the canonical sizes composed by cross-loadings that represent the correlations between the opposite canonical variables and the variables in U1 and V1.

Table 7. Canonical loading for original variables with their canonical variables in breeds

		Predictor set, U				
		FW	**HDrs**	**HFHW**	**PFW**	**CL**
				Male		
	a	0.974	0.999	0.947	0.995	0.951
	b	0.962	0.949	0.996	0.950	0.963
U1	c	-0.958	-0.889	-0.891	-0.941	-0.901
				Female		
	a	-0.932	-0.947	-0.760	-0.945	-0.931
	b	0.871	0.821	0.868	0.842	0.834
	c	0.991	0.971	0.969	0.975	0.959
		Criterion set, V				
		COL	**FTL**	**LDA**	**MS**	**CCS**
				Male		
	a	-0.294	-0.584	0.958	0.999	0.827
	b	-0.028	-0.258	0.892	0.994	0.691
V1	c	0.109	-0.222	-0.946	-0.886	-0.787
				Female		
	a	0.015	-0.202	-0.920	-0.711	-0.801
	b	-0.028	-0.258	0.892	0.994	0.691
	c	0.033	0.143	0.833	0.979	0.871

a: Brown Swiss × Eastern Anatolian Red, BSEAR; b. Holstein Friesian × Eastern Anatolian Red, HFEAR, c: Brown Swiss × Hostein Friesian, BSHF, FW: final weight, HDrs: hot carcass dressing, HFHW: head+feets+hide weight, PFW: pelvic fat+kidney weight, CL: carcass length, COL: cooking loss, FTL: fat thickness on LD, LDA: LD area, MS: marbling score, CCS: carcass conformation score

According to the cross-loading, HDrs, PFW, and FW in the male BSEAR were more effective in U1 determination, whereas LDA and MS were more effective in V1 determination (Table 8). Thus, HFHW and CL were more effective in U1 determination, while MS and LDA were effective in V1 determination in the male HFEAR. The male BSHF group followed a different course from result of the other groups among the variables for both sets (Table 8). For females, the BSEAR, FW was most effective on U1 detection, LDA on V1 detection; in the HFEAR, FW on U1 detection, MS on V1 detection; and in the BSHF, FW on U1 detection, FTL on V1 detection (Table 8).

In this study found that the canonical variables, U1 and V1, explained 94% of the total variation of the slaughter traits measured in the male BSEAR that had most values. On the other hand, U1 and V1 variables explained 60% of the total variation in carcass traits measured at the same breed and sex (Table 9). These determinations are 80% and 34% for females according to the same ranking. In female, BSHF had most values (Table 9).

Table 8. Cross loadings of the original variables with opposite canonical variables in breeds

		Predictor set, U				
		FW	**HDrs**	**HFHW**	**PFW**	**CL**
				Male		
	a	0.974[a]	0.999[a]	0.947[a]	0.935[a]	0.995[a]
	b	0.962[b]	0.949[b]	0.996[b]	0.950[b]	0.972[b]
U1	c	-0.949[c]	-0.881[c]	-0.883[c]	-0.932[c]	-0.876[c]
				Female		
	a	-0.932[a]	-0.947[a]	-0.760[a]	-0.945[a]	-0.891[a]
	b	0.874[b]	0.821[b]	0.868[b]	0.842[b]	0.871[b]
	c	0.991[c]	0.971[c]	0.969[c]	0.975[c]	0.973[c]
		Criterion set, V				
		COL	**FTL**	**LDA**	**MS**	**CCS**
				Male		
	a	-0.294[a]	-0.584[a]	0.958[a]	0.998[a]	0.827[a]
	b	-0.028[b]	-0.258[b]	0.892[b]	0.994[b]	0.604[b]
V1	c	0.108[c]	-0.220[c]	-0.937[c]	-0.878[c]	-0.836[c]
				Female		
	a	0.015[a]	-0.202[a]	-0.920[a]	-0.711[a]	-0.721
	b	0.033[b]	0.143[b]	0.833[b]	0.979[b]	0.674[b]
	c	0.004[c]	0.999[c]	0.936[c]	0.887[c]	0.833[c]

a: Brown Swiss × Eastern Anatolian Red, BSEAR; b. Holstein Friesian × Eastern Anatolian Red, HFEAR, c: Brown Swiss × Hostein Friesian, BSHF, FW: final weight, HDrs: hot carcass dressing, HFHW: head+feets+hide weight, PFW: pelvic fat+kidney weight, CL: carcass length, COL: cooking loss, FTL: fat thickness on LD, LDA: LD area, MS: marbling score, CCS: carcass conformation score

Tablo 9. The explained total variation ratio by canonical variables for the variable sets

Predictor set, U				**Criterion set, V**			
	Variance extracted		Redundancy		Variance extracted		Redundancy
				Male			
	0.941[a]		0.941[a]		0.606[a]		0.606[a]
U1	0.930[b]	V1	0.930[b]	V1	0.462[b]	U1	0.462[b]
	0.847[c]		0.832[c]		0.435[c]		0.427[c]
				Female			
	0.809[a]		0.809[a]		0.348[a]		0.348[a]
U1	0.724[b]	V1	0.724[b]	V1	0.418[b]	U1	0.418[b]
	0.954[c]		0.954[c]		0.665[c]		0.665[c]

a: Brown Swiss × Eastern Anatolian Red, BSEAR; b. Holstein Friesian × Eastern Anatolian Red, HFEAR, c: Brown Swiss × Hostein Friesian, BSHF

4. Discussion

The limited literature on multiple relationships between carcass and slaughter traits for breed and sex in cattle forced to refer data of other species while discussing the results. Since the number of observations in this study was limited, interpretation focused on structural coefficients and redundancy indices rather than standardized canonical coefficients, which are sensitive to sampling fluctuations. The FW values of both sexes of BSEAR breed had the highest Pearson correlation coefficient with PFW (male) and MS (female) from carcass traits. However, it were not observed similar results between the FW and slaughter traits. Ventura et al. (2011) reported that were low correlation coefficient between live weight and slaughter traits for pigs. These results indicated that there were not a linear relationship between live weight and slaughter traits. On the other hand, Yaprak et al. (2008) reported a positive moderate

correlation between birth weight and loin eye muscle area in the Morkaraman sheep breed. This declaration supported that might have, in line with our results, a close relationship between live weight and carcass traits in selecting for determining fattening strategy.

It is necessary to use the canonical correlation analysis to explain the interactions between the analysed variable sets while interpreting the relationships among the traits belonging to weights or carcass, as a difficulty could arise in explaining the relationship between morphological traits in a detailed way in practice (Fourie et al., 2002). Thus, in this study to better explain the relationship between two sets of variables by finding linear combinations of variables that maximally correlate, five pair of canonical variates in which each of them was orthogonal to the other canonical variates, were constituted.

In canonical correlation analysis, it were found the first and second (U1V1, U2V2) the pairs of canonical variables were statistically significant ($P<0.05$) in males and females of each three breed. In this regard, different findings have been reported in the literature. Cankaya et al. (2008) was applied canonical correlation analysis to determine the multiple interraction between five different morphologic traits measured at birth and at 6 month age for 56 calves of Holstein Friesian. Only first of estimated five different canonical correlation coefficients between the pairs of canonical variables was found statistically significant ($P<0.05$). This result was different from our results in terms of evaluating the size of the interaction between the canonical variables of the considered sets. Thus, researchers reported that the size of the canonical variable pairs of the same characters in different periods might be more limited (Cankaya et al., 2008). Alıç Ural and Barıtçı (2013) reproted non-significant ($P=0.752$) canonical correlation between some udder (X set) and body traits (Y set) of Holstein Friesian cows. This result was different from the results of our study in terms of effect on Criterion set of Predictor set. In this study, the bivariate correlations that belonged to slaugehter and carcass traits in males of HFEAR had high values and, were, statistically, important; however, the authors determined that in females, the correlation coefficients were lower, ranging from these results (Table 3). Most likely the reason why this low bivariate correlation in females of HFEAR was second later from males to in the value might be due to nature of these meats (Arenas de Moreno et al., 2021) and narrower range of data characteristic present in these carcasses derived from Holstein Friesian crossbreed. Cankaya et al. (2008) reported significant bivariate correlations between body weight and body measurements in Holstein Friesian calves while Alıç Ural and Barıtçı (2013) found that some udder was not very strongly correlated with body traits of Holstein cows. The bivariete correlation values between slaughter and carcass traits in males and females of BSHF was relatively weaker than that of the males and females other breeds (Table 5). These detection was supported with declared analysis results for live weights for different periods of Baladi, Shami and Hybrid goats by Al-Atiyat and Al-Dawood, (2021).

The standardized canonical coefficient of the first pair explains the contribution of each pair to the correlated variable (Keskin and Özsoy, 2004). According to the canonical correlation analysis results, there was in different scale evidence to assume that there was a standardized association between slaughter and carcass traits. Considering the FW; one standard deviation increase in FW in male HFEAR

caused to a 1.49 standard deviation increase in the score on the first canonical variate (U1) for Predictor variable set, while one standard deviation increase in FW at female HFEAR caused to a 8.79 standard deviation increase in the score on the first canonical variate (V1) for Criterion variable set provided that other variables remain constant. The results obtained in our study could comparable with those of Cankaya et al. (2008), who reported that live weight were the most substantial contributors to the standardized canonical coefficients in estimating of relationship between some body measurements at the birth and 6 month periods of Holstein Friesian calves. On the other hand, in the U1 canonical variable, the largest contribution was indicated to be live weight, followed by withers height and tail width for the X variable set, while in the V1 canonical variable, the largest contribution was indicated to be live weight, followed by withers height and chest depth (Ozen et al., 2021).

In this study, as there were multicollinearity in the data set structural correlations (loadings) were calculated as well as the standardized coefficients. Because, canonical loadings declare the correlation coefficients between canonical variables and the original variables in that set (Sharma, 1996). The loadings for the male abd female BSHF suggested that the FW was more influential than other characters in forming U1, while LDA and MS were more influential than other characters in forming V1. The loadings for the live weight of birth and 6 month-old animals, obtained U1 and V1, were more influential than other traits in Holstein calves (Cankaya et al., 2008) and in Karayaka lambs (Tahtalı et al., 2012). The findings of in current study showed that canonical loadings were based on breeds and sexes large which shown both of the canonical variates (U1 and V1) could be considered as a general measure of Predictor and Criterion variable sets, respectively (Cankaya et al., 2008).

According to cross loading values, the FW trait measured from the male BSEAR, following HDrs and CL provided the most contribute to canonical variate U1, while, LDA and MS traits measured from the males of each three breed provided the most contribute to canonical variate V1. For females, HDrs in BSEAR and FW in HFEAR and BSHF were found to contribute the most to U1. When this situation was evaluated in terms of V1, it was observed that LDA, MS and FTL traits were the most contribute for BSEAR, HFEAR and BSHF breeds, respectively. Cankaya et al. (2008) reported that U1 gave chance more determine of V1 of live weight and chest girth traits provided from Holstein calves and provide more complete validation of existing body weight value. According to results of the cross loadings, weaning weigh and withers height in Bafra lambs (Ozen et al., 2021) and live weight and rump width in Chios lambs (Atac and Altincekic, 2023) contributed the most to canonical variates V1 and U1, respectively. The reported results supported the our detection that could be a realtionship between Predictor and Criterion variables.

In the present study, it was clarified that 94.1% of total variation in the slaughter traits set for male BSEAR and male HFEAR, respectively was explained by first canonical variables U1, while the redundancy value of 0.941 for the first canonical variable determined that 94.1% of this ratio was explained, each two breeds by canonical variable V1. It was determined that 84.7% of total variation in the slaughter traits set for male BSHF was explained by first canonical variables U1, while the

redundancy value of 0.832 for the first canonical variable determined that 83.2% of the ratio was clarified by canonical variable V1. For total variation in females, breeds had the same proportions in terms of U1 and V1.

5. Conclusion

Primarily, the results were interpreted cautiously, highlighting exploratory multivariate relationships. Although the canonical correlations observed were high (P>0.98), these values reflect the inherent biological synergy between multiple strongly correlated growth measurements rather than independent predictive success. The redundancy index (ratio of explained variance) further demonstrates the true explanatory power of these relationships. In this context, the findings should be interpreted as a description of a common biological growth factor governing slaughter and carcass traits in young BSEAR, HFEAR, and BSHF breeds. This study adds to the literature by identifying how these integrated traits can inform rearing strategies and breeding practices, providing a biological basis for selecting fitting animals in plateau conditions. On the other that, slaughter characteristics can serve as supporting indicators for evaluating carcass quality of cattle raised under highland conditions, however it cannot completely replace direct carcass measurements.

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Ethical Statement

This study does not have a methodology that requires ethics committee approval.

Conflicts of Interest

The article is single author.

References

Al-Atiyat R., Al-Dawood A. Power of body live weights in differentiation physiological growth of goat breeds. Turkish Journal of Veterinary and Animal Sciences 2021; 45(3): 492-500. doi:10.3906/vet-2010-15.

Alıç Ural D., Barıtçı İ. Determination of relationship between some udder and body traits of Holstein cows by canonical correlation analysis. Kocatepe Veterinary Journal 2013; 6(1): 11-17. doi: 10.5578/kvj.5476.

Arenas de Moreno L., Jerez-Timaure N., Huerta-Leidenz N., Giuffrida-Mendoza M., Mendoza-Vera E., Uzcátegui-Bracho S. Multivariate relationships among carcass traits and proximate composition,

lipid profile, and mineral content of Longissimus lumborum of grass-fed male cattle produced under tropical conditions. Foods 2021; 10(6): 1364. doi: 10.3390/foods10061364.

Atac FE., Altincekic SO. The relationship between live weight and body measurements of Chios lambs at different periods. South African Journal of Animal Science 2023; 53(5): 696-705.

Bae E., Hur JH., Kim J., Kwon JS., Lee J., Lee SH., Lim CY. Multi-group analysis using generalized additive kernel canonical correlation analysis. Scientific Reports 2020; 10: 12624. doi.org/10.1038/s41598-020-69575-x

Barbosa LT., Lopes PS., Regazzi AJ., Guimarães SEF., Torres RA. Evaluation of swine carcass traits using principal components. Revista Brasileira de Zootecnia 2005; 34(6): 2217. doi: 10.1590/S1516-35982005000700007.

Cankaya S., Yazgan E., Kayaalp GT., Göçmez Z., Serbester U. Canonical correlation analysis for estimation of relationship between some body measurements at the birth and 6 month periods in Holstein Friesian calves. Joumal of Animal and Veterinary Advances 2008; 7(8): 953-958.

Dillon WR., Goldstein M. Multivariate analysis: Methods and Applications (2a ed., p: 462), NY: John Wiley, 1984, New York, USA.

Fourie PJ., Neser FWC., Olivier JJ., Van Der C. Relationship between production performance, visual appraisal and body measurements of young Dorper rams. South Africian Journal of Animal Science 2002; 32(4): 256-262.

Hair JF., Black WC., Babin BJ., Anderson RE. Multivariate data analysis. Upper Saddle River, NJ, USA: Pearson Prentice Hall; 2010.

Keskin S., Özsoy AN. Canonical correlation analysis and its an application. Journal of Agricultural Science 2004; 10(1): 67-71.

Kopuzlu S., Esenbuga N., Onenc A., Macit M., Yanar M., Yuksel S., Ozluturk A., Unlu N. Effects of slaughter age and muscle type on meat quality characteristics of Eastern Anatolian Red bulls. Archive Animal Breeding 2018; 61: 497-504, doi: 10.5194/aab-61-497-2018.

Ozen D., Kocakaya A., Ozbeyaz C. Estimating relationship between live body weight and type traits at weaning and six months of age in Bafra lambs using canonical correlatıon analysis. Journal of Animal & Plant Sciences 2021; 31(2): 386-393. doi: 10.36899/JAPS.2021.2.0226.

Johnson RA., Wichern DW. Applied multivariate statistical analysis. Prentice Hill, 2002.

Pardo JIS., Ariza AG., González FJN., Jurado JML., Ruiz ED., Bermejo JVD., Vallejo MEC. Discriminant canonical analysis as a tool for genotype traceability testing based on turkey meat and carcass traits. Frontiers in Veterinary Science 2004; 11: 1326519.

Sharma S. Applied multivariate techniques: Canonical Corelation, 391-418. John Willey and Sons Inc 1996, USA.

Silva LF., Pires CC. Avaliações quantitativas e predição das proporções de osso, músculo e gordura da carcaça em ovinos. Revista Brasileira de Zootecnia 2000; 29(4): 1253-1260. doi.org/10.1590/S1516-35982000000400040.

SPSS. IBM Corp. Released, IBM SPSS Statistics for Windows, Version 25.0. Armonk NY: IBM Corp. 2021.

Tahtalı Y., Çankaya S., Ulutaş Z. Canonical correlation analysis for estimation of relationships between some traits measured at birth and weaning time in Karayaka lambs. Kafkas Universitesi Veteriner Fakültesi Dergisi 2012; 18(5): 839-844. doi:10.9775/kvfd.2012.6578.

Takma Ç., Gevrekçi Y., Özsoy AN., Çevik Mİ. Canonical correlation analysis on egg production traits of quails. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi 2017; 12(1): 92-99.

USDA. Official United States standards for grades of carcass beef. Agricultural Marketing Service. (USDA, Washington DC). 1989.

Ventura HT., Lopes PS., Peloso JV., Guimarães SEF., Carneiro APS., Carneiro PLS. A canonical correlation analysis of the association between carcass and ham traits in pigs used to produce dry-cured ham. Genetics and Molecular Biology 2011; 34(3): 451-455. doi: 10.1590/S1415-47572011000300014.

Yaprak M., Koycegiz F., Kutluca M., Emsen E., Ockerman HW. Canonical correlation analysis of body measurements, growth performance and carcass traits of Red Karaman Lambs. Joumal of Animal and Veterinary Advances 2008; 7(2): 130-136.

Yüksel S., Yanar M., Aksu Mİ., Kopuzlu S., Kaban G., Sezgin E., Oz F. Effects of different finishing systems on carcass traits, fatty acid composition, and beef quality characteristics of young Eastern Anatolian Red bulls. Tropical Animal Health and Production 2012; 44(7): 1521-1528. doi 10.1007/s11250-012-0098-0.