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Research Article

Evaluation of Cold Carcasses of Kıvırcık and Romanov Lambs by Geometric Morphometric Method

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Abstract

Carcass discrimination is a very important issue in the evaluation of different sheep breeds as lamb meat for the red meat sector and the study aims to determine the carcass differences of Romanov and Kıvırcık lambs up to 6 months old by 2D geometric analysis. In this study was carried out with six months old 13 Kıvırcık and 16 Romanov lamb cold carcasses. Principal components (PC) that describe the most variation in shape were determined for all samples. A discriminant analysis was performed for the mean shapes of two different breeds. In terms of size (centroid size), Romanov's results were higher. The difference in shape (procrustes distance) was statistically significant for the whole carcass. The shape variations were pretty close for the top view of the whole carcass. It was observed that this analysis was not effective in the differentiation of breeds. The most significant analysis between the two feedings was in the side view of the whole carcass. A total of 26 PCs were obtained from the side view of the whole carcass, 25 PCs from the inside view of half carcass, and 12 PCs from the shape analysis made from the top view of the whole carcass as a result of PCA analysis. PC1 was found to describe for more than 40% shape variation for each view. The lower border of Romanov's rib cage was more ventral according to the results. Also, Kıvırcık had a straighter thoracal and lumbar vertebrae arrangement, while Romanov's was curved. Geometric morphometry can be a useful method for carcass separation.

Keywords: Geometric morphometrics, Principal component analysis, Sheep, Shape analysis, Taxonomy

Introduction

Sheep-breeding in Turkey is carried out by natural methods, and it is traditionally run by small family-type businesses that have great importance in terms of nutrition, income and culture of the rural population [1]. One of the primary incomes in sheep husbandry in Türkiye is lamb as reported and also a preferred protein source for consumers [2]. For this reason, there are many breeds of sheep such as Kıvırcık, Dağlıç, Merino, and Avesi are produced in Türkiye. In addition to these breeds, there are also various imported sheep breeds such as Romanov sheep, Dorper and Suffolk [3]. Among these breeds, some have very important roles in the red meat sector such as Romanov breed, which was raised with the ability to produce multiple offspring, and the Kıvırcık breed, which was raised in terms of meat quality [4]. In Türkiye, it is reported that some of the studies on meat production are carried out in the field of sheep breeding [5].

Unlike traditional morphometric analysis, geometric morphometric (GM) analysis is used to detect shape differences. Shape differences within and between groups can be revealed by statistical methods via GM analysis.

Additionally, GM analysis methods do not deal with size or dimension. GM analysis concentrates on the concept of shape. Anatomical points, curves and contours are used as data sources in GM [6]. Two or three dimension visual data sources which are obtained above mentioned regions can be used for the analyses. The points required for shape analysis from these regions so called landmarks can be 3 types [7]. Type 1 landmarks are landmarks used in anatomical regions that are easy to define. Type 2 landmarks are those used in the most recessed or protruding part of the shape. Type 3 landmarks, on the other hand, are landmarks placed along the curve, also called semi-landmarks.

There are publications stating that breeds and sex discrimination on biological samples have been successfully made and positive results have been obtained in shape analysis with the GM analysis method in recent years [8-12]. It can be revealed whether the shapes are statistically different from each other by GM analysis. Although breeds differences can be demonstrated morphometrically in carcass separation in slaughterhouses, meat warehouses and integrated facilities, this distinction is quite difficult in terms of between breeds differences. Especially the differences between breeds can be reduced to a level that cannot be observed with the naked eye with some corrections made on the carcass. These practices, which allow for unfair profit in the commercial sense, can also cause many unwarranted reservations about meat quality. Shaving body fat, reducing tail fat, reducing shell fat are examples can be given for such negative practices. It is important to overcome this problem with an objective systematic evaluation. For this purpose, it has been tried to understand whether breeds discrimination can be made by GM analysis method on cold carcasses of Kıvırcık and Romanov lambs. It is stated that various researchers conducted studies on cold carcass yields in lambs as our study carried on [5]. Carcass discrimination is a very important issue in the evaluation of different sheep breeds as lamb meat for the red meat sector and the study aims to determine the carcass differences of Romanov and Kıvırcık lambs up to 6 months old by 2D geometric analysis.

Material and Methods

Ethical Statement

The study did not require ethical approval.

Animals

The study was carried out with six months old 13 Kıvırcık and 16 Romanov lamb cold carcasses, obtained from Faculty of Veterinary Medicine, Istanbul University-Cerrahpaşa. After slaughter, the carcasses were kept in +4 cooler for 24 h. Photographs of the rested carcasses were taken from 3 different angles. Inspection of carcasses during slaughter was carried out by the veterinarian. There was no pathological finding on the carcasses.

Geometric Morphometry

Images of the carcass from 3 different angles were used for geometric morphometry;

1- Side view of the whole carcass *(Fig. 1)*

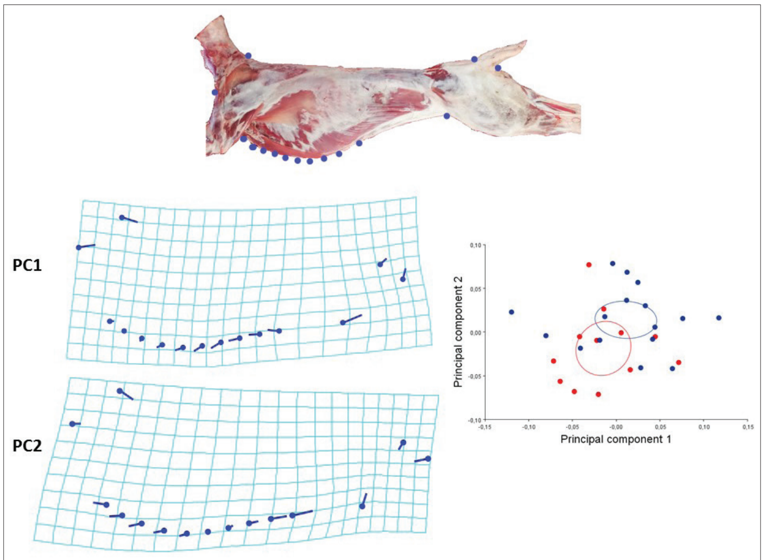

Fig 1. The landmarks used for the side view of the whole carcass (top left), transformation grids for PC1 and PC2 (below left), the distribution of samples according to PC1 and PC2 (right). The points represent the mean shape and the extensions on the dots represent the positive change of the PC value in transformation grids. (Red: Kıvırcık sheep; Blue: Romanov sheep, confidence ellipses for means)

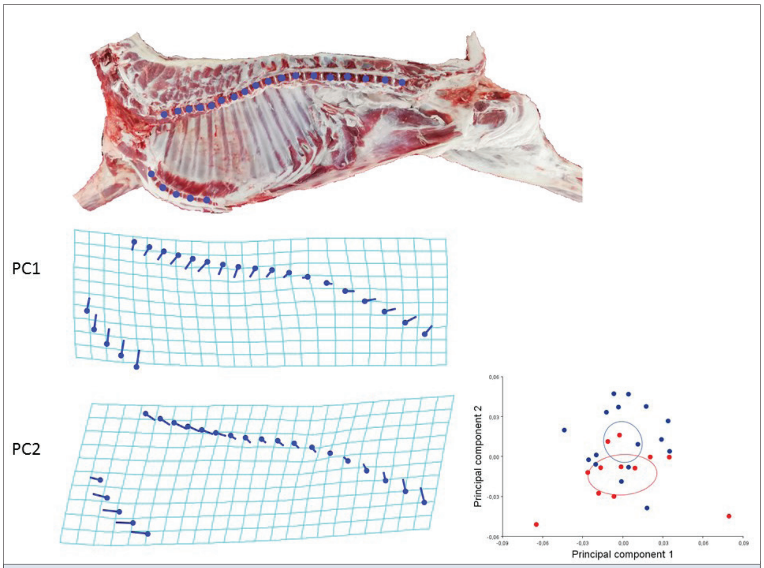

Fig 2. The landmarks used for the inside view of the half carcass (top left), transformation grids for PC1 and PC2 (below left), the distribution of samples according to PC1 and PC2 (right). The points represent the mean shape and the extensions on the dots represent the positive change of the PC value in transformation grids. (Red: Kıvırcık sheep; Blue: Romanov sheep, confidence ellipses for means)

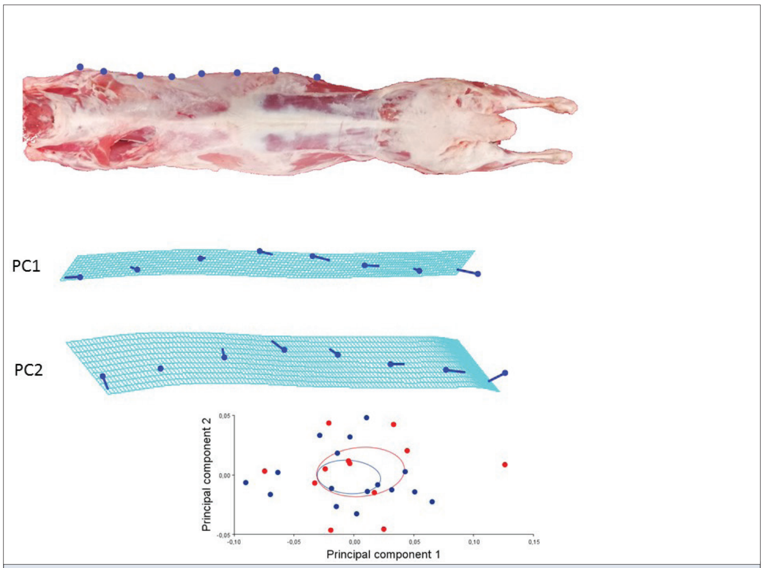

Fig 3. The landmarks used for the top view of the whole carcass (top left), transformation grids for PC1 and PC2 (below left), the distribution of samples according to PC1 and PC2 (right). The points represent the mean shape and the extensions on the dots represent the positive change of the PC value in transformation grids. (Red: Kıvırcık sheep; Blue: Romanov sheep, confidence ellipses for means)

2- Inside view of half carcass *(Fig. 2)*

3- Top view of the whole carcass *(Fig. 3)*

Images were taken by the same person at the same distance (1 meter) for the homogeneity of the analysis. Images were taken via Canon 500D camera and transferred to the computer environment. Photos taken in "jpeg" format were first converted to "tps" format using tpsUtil (version 1.76) [13]. Afterwards, landmarks were used on the shapes using tpsDig2 [14]. The landmarks used in the study are given in *Fig. 1*, *Fig. 2*, and *Fig. 3*. First, points were placed from the initial level of the arm muscles to the lower and upper parts of the neck for the side view of the whole carcass *(Fig. 1)*. Landmarks (Type 1) were placed on the border of the hindlimb with the trunk and the initial upper and lower border of the tail for the rear part. Ten semi-landmarks (Type 2) were used on the lower border of the thorax. Semi-landmarks were used on the center of the trunks of the 13 thoracic vertebrae, the first 5 lumbar vertebrae, and 5 sternums for the inside view of half

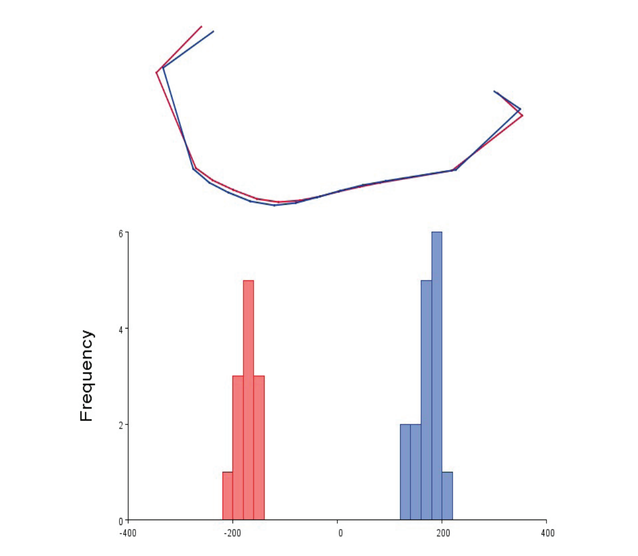

Fig 4. Average shapes for Kıvırcık sheep and Romanov sheep for whole carcass view (above), distinctive scores and frequency for Romanov sheep and Kıvırcık sheep (below). (Red: Kıvırcık sheep; Blue: Romanov sheep)

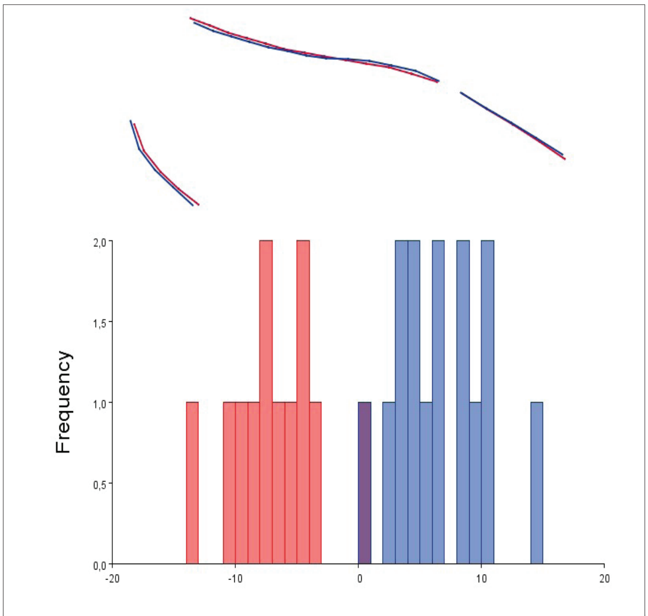

Fig 5. Average shapes of Kıvırcık and Romanov ewes (top), distinctive scores and density of Romanov and Kıvırcık ewes (bottom) for side view of half carcass

carcass *(Fig. 2)*. Finally, 8 semi-landmarks were used to examine the lateral borders of the thoracic cavity in terms of shape for the top view of the whole carcass *(Fig. 3)*.

Statistical Analysis

For the statistical analysis of the study, the morphoJ statistical program was used. First, procrustes analysis was performed to eliminate position and size differences. Then, the average shape and shape variations for all samples used in the study were revealed by principal component analysis (PCA). Principal components (PC) that describes the most variation in shape were determined for all samples. A discriminant analysis was performed for the mean shapes of two different breeds. It was examined whether Kıvırcık and Romanov sheep were distinguished from each other in terms of shape with the discriminant analysis. Procrustes distance and centroid size averages and p values of the breeds were obtained.

Results

A total of 26 PCs were obtained from the side view of the whole carcass, 25 PCs from the inside view of half carcass, and 12 PCs from the shape analysis made from the top view of the whole carcass as a result of PCA analysis. PC1 was found to describe for more than 40% shape variation for each view. The highest PC1 value belonged to the top view of the whole carcass.

PCA analysis results for the side view of the whole carcass are given in *Fig. 1*. The points used for the transformation grids for PC1 and PC2 in *Fig. 1* belong to the mean figure. The extensions of the dots represent how much and in which direction the shape variations of the positive value PCs are. The positive change for PC1 represented a neck structure closer to the chest. The points on the tail and hindlimbs were more distant in shape than the chest. The most important change was in the tail and hindlimb region in terms of PC2. The origin of the tail was thinner in shape and the hindlimb was closer to the origin in increasing PC2. In addition, the increased PC2 value had a wider lower rib cage border in shape. It was seen that Romanov lambs had wider PC1 variation in the distribution of samples according to PC1 and PC2. Conversely, the Kıvırcık lamb had wider shape variation for PC2. Although the difference was not much for PC1, Romanov's mean values for PC2 were higher than for Kıvırcık lamb.

PCA analysis results for analysis of half carcass are given in *Figure 2*. The points used for the transformation grids for PC1 and PC2 in *Fig. 2* belong to the mean figure. The extensions of the dots represent how much and in which direction the shape variations of the positive value PCs are. The positive change for PC1 represented a narrower rib cage. In addition, the lumbar vertebrae were more dorsal with increasing PC1 value. Shape variations were close to each other between Romanov and Kıvırcık sheep in PC1. The increased value for PC2 represented a more anterior sternum line in shape. In addition, the lumbar vertebrae were more dorsal in increasing PC2. Romanov sheep had a high PC2 value, while Kıvırcık sheep had lower.

The PCA results for the top view of the whole carcass are given in *Fig. 3*. The points used for the transformation grids for PC1 and PC2 in *Fig. 3* belong to the mean figure. The extensions of the dots represent how much and in

Table 1. *PCA analysis results. Top 3 PCs describing the highest variation*

Principal Components	Side View of the Whole Carcass (Fig. 1)		Inside View of Half Carcass (Fig. 2)		Top View of the Whole Carcass (Fig. 3)	
	Eigenvalues	% Variance	Eigenvalues	% Variance	Eigenvalues	% Variance
PC1	0.00274632	41.755	0.00084016	40.042	0.00216748	46.805
PC2	0.00146299	22.243	0.00052845	25.186	0.00065114	14.061
PC3	0.00084454	12.840	0.00023674	11.283	0.00059618	12.874
Total PC	26 PC		25 PC		12 PC	

PCA: Principal Component Analysis; PC: Principal Components

Table 2. *Results of CS and shape*

View	Effect	SS	MS	df	F	P
Side view of the whole carcass	CS	53407.501005	53407.501005	1	0.16	0.6898
	Shape	0.01547913	0.0005953510	26	2.35	0.0002
Inside view of half carcass	CS	5661.371481	5661.371481	1	0.03	0.8719
	Shape	0.01259594	0.0002999033	42	1.08	0.3374
Top view of the whole carcass	CS	201676.707297	201676.707297	1	4.57	0.0421
	Shape	0.00197158	0.0001642985	12	0.43	0.9528

CS: Centroid Size; SS: Sum of Squares; MS: Mean Squares; df: Degrees of Freedom

Table 3. *The distribution of the samples as a result of the discriminant analysis*

Samples	Side View of the Whole Carcass (Fig. 1)		Inside View of Half Carcass (Fig. 2)		Top View of the Whole Carcass *(Fig. 3)*	
	Kıvırcık	Romanov	Kıvırcık	Romanov	Kıvırcık	Romanov
Kıvırcık	12	0	11	1	12	0
Romanov	0	16	0	16	3	13

which direction the shape variations of the positive value PCs are. For the top view, the variation changes for the Romanov and Kıvırcık sheep were very close to each other. Top view analysis of the whole carcass was less successful in distinguishing the two breeds than analyses for other views of the carcass.

Centroid size (CS) and shape averages and standard deviations are given in *Table 2*. In terms of size (CS), Romanov's results were higher. This difference was statistically different for top view, but statistically insignificant for other analyses. The difference in shape (procrustes distance) was statistically significant for the whole carcass. For other analyses, the difference was statistically insignificant.

The distribution of the samples as a result of the discriminant analysis is given in *Table 3*. According to these results, the two breeds were completely separated from each other with the side view of the full carcass. In the analysis of half carcass, 1 Kıvırcık showed Romanov carcass shape features. In the analysis of the carcass images from the top, the distribution was correct for the Kıvırcık sheep carcass samples, but 3 Romanov sheep samples showed shape characteristics of Kıvırcık sheep carcass.

The average shapes of Kıvırcık sheep and Romanov sheep carcass for the side view of the whole carcass are given in *Fig. 4*. According to these results, the forelimb of the Kıvırcık sheep was more anterior and lower than the Romanov sheep. Also, the tail border of the Kıvırcık sheep was observed lower and backwards. The border below the chest was lower in shape in Romanov sheep.

The average shapes of Kıvırcık and Romanov sheep for the inside view of the half carcass are given in *Fig. 5*. According to the results, the lower border of the rib cage of the Romanov sheep was still in the abdomen. Also, the Curly sheep had a flatter thoracic and lumbar arrangement, while the Romanov sheep had a curved arrangement.

Discussion

Various studies have reported that carcasses of animals raised with different feeds and diets change many factors such as carcass, meat quality, meat color, and meat flavor [15-17]. It has been reported that information on other yield characteristics such as carcass yield and meat quality characteristics of the Romanov sheep breed should be completed [18], and in this study has brought a different perspective to the subject and revealed the shape differences between Kıvırcık and Romanov cold carcasses comparatively. Priolo et al.[19] reported the evaluation of carcass structures in animals fed with different feeds and feeding techniques by means of a visual evaluation method. It was also observed that the width of the carcass was wider in the barn-fed ones. Ekiz et al.[20] reported that carcass quality is an important factor in breeds. When the shape differences were examined in our study, it was seen that there were differences between the studied breeds when the PC1 and PC2 analyzes were examined depending on the breeds and different variables. Cameron found that there was a high positive correlation between arm dissection and the amount of meat, fat, and bone in the whole carcass [21]. In another study, it was reported that leg and arm dissections gave effective results in determining the meat, fat, and bone ratios of the carcass [22]. Wilson et al.[23] reported that there is a positive correlation between carcass size and large body limb bones in ruminants. Demir reported a high correlation between the thigh for total meat estimate and the waist region for total fat in Kıvırcık sheep [5]. Manuta et al.[24] reported that cows, sheep, and horses have higher PC1 values compared to horses in their studies on olecranon, and the tuberosity of olecranon is wider. In this study, the view of the carcass shape from different angles was studied. The increased PC1 value in the whole carcass view gives the ventral view of the thorax. Half carcass, Ascending PC1 gives a narrow appearance. The increase in the lumbar vertebrae affects the carcass width and causes changes in PC1 and PC2 values. In studies, it was seen that the positive growth effect of the bone on the carcass was also observed in our studies. Akçapınar [25] determined that the correlations of thigh and arm meat amount of Kıvırcık sheep showed a high positive correlation with whole body meat amount. In this study, it was observed that the effect of the amount of leg and arm meat on the whole carcass changed according to PC1 and PC2 analyses.

While geometric morphometry reveals the differences between the races, it also reveals the structural and anatomical differences between the breeds. Manuta et al.[26] reported that the increase in PC1 and PC2 values varies in different anatomical structures. For example, PC1 increase indicates narrow acetabulum whereas PC2 increase indicates margin of acetabulum. In the study of Hadžiomerovic et al.[10] with ear ossicles, increased PC1 was seen in the caput mallei of malleus, while PC2 increased in the caput mallei of malleus. Szara et al.[27] know that in his study on Japanese Quails, PC1, PC2 and PC3 increase and decrease in the same and different anatomical structures reveal differences. In this study, the PC1 and PC2 increase, for example, the change in the sternum of the carcass, was found to be equivalent to other studies in the study conducted with 3 different appearances of the carcasses. It is known that the statistical difference between breeds and sex in the studies performed on Centroid size reveals the closeness of the central figure to the central figure, which increases the quality of the studies. Parés-Casanova and Xènia reported that in comparison of the sphenoid bone of sheep and goats, sheep were larger in shape, and the statistical difference in centroid size and shape was quite significant ($P<0.001$) [28]. When we compared Romanov and curly carcasses in this study, it was revealed that the Romanov was larger in shape. Manuta et al.[26] reported on crossbred cats, stated that the difference between the pelvis and the female male was statistically insignificant ($P>0.05$). Manuta et al.[24] found that Shape and centroid size were statistically significant in horses, sheep and cows in their study on Calcaneus ($P<0.001$). Gündemir et al. reported that there was no statistical difference in dorsal and lateral view centroid size in their study among cat breeds, but the dorsal and lateral statistical difference between cat breeds in shape was quite significant ($P<0.001$) [29]. Ojanguren-Affilastro et al.[30] found that Centroid size and shape were statistically significant in their study on scorpions. In this study, while the whole carcass centroid size of Romanov and Kıvırcık sheep is statistically significant ($P<0.05$), it is highly significant in terms of shape ($P<0.001$). The centroid size of the top view was statistically significant ($P<0.05$). If there is a statistical difference in centroid size and shape between breeds in the studies conducted, the data we have obtained shows that there is a statistical difference like other studies.

Gürbüz and Demiraslan [31], in their study on the incus of horses and donkeys, looked at canonical variance analysis and revealed the differences in anatomical structures between the two breeds. They reported that the corpus inducus was flatter and the top of the crus longum was wider in donkeys. Manuta et al.[26] reported that the line terminalis is wider in females in their study in the cat pelvis. He also determined that the linea terminalis was more prominent on its dorsal side as a specific difference. Casanova and Miquel reported that gender discrimination can be made in geometric morphometric examinations of the dorsal skulls of White Rasquera goats and that the sagittal points of the viscerocranium provide the greatest contribution to this distinction [32]. Yaprak et al.[33] The skulls of Hair, Honamlı, Kilis and Saanen goats were examined geometrically morphometrically and it was seen that it was possible to distinguish between goat breeds. The most prominent points of deformation are the caudo-oral corner of the margo alveolaris of the III molar in females and the meatus acusticus externus in males. Dörtbudak et al. reported that two different fish breeds had anatomical differences in their study on otoliths of fish [34]. As in other studies conducted in this study, anatomical differences were observed between breeds. For example, in the whole carcass, the front part of the Kıvırcık sheep is seen lower and behind compared to the Romanov sheep. Anatomical differences were also seen in the data obtained in top view and half carcass.

In conclusion, this study is the first new in this field. It aimed to add a new breath with the contributions of the departments of anatomy and food by presenting the multidisciplinary contributions of different scientific fields. It was examined that it was not possible to make a separation between the two breeds by using the photographic method. The shape variations were pretty close for the top view of the whole carcass. It was observed that this analysis was not effective in the differentiation of breeds. The most significant analysis between the two feedings was in the side view of the whole carcass. This difference was also statistically significant in the ANOVA results. After the shape variations, a discriminant function was performed for the two breeds. In these results, the side view of the whole carcass image was distinctive for the two feedings. In the analysis made for the top view within the discriminant function, the error was high in classification. Geometric morphometry can be a useful method for carcass separation.

Availability of Data and Materials

The data presented in this study are available on request from the corresponding author (O. P. Choudhary).

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Ethical Statement

The study did not require ethical approval.

Competing Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, M.G.G and A.E.Y, methodology, B.C.G; M.G.G and A.D software, M.G.G; B.C.G and A.E.Y.; validation, M.G.G, formal analysis, M.G.G and B.C.G, investigation, S.K.B, resources, K.M; data curation, E.O. and M.G.G, writing original draft preparation, B.C.G and M.G.G; writing-review and editing, M.G.G; B.C.G and O.P.C; visualization, M.G.G and B.C.G; funding acquisition, O.P.C. All authors have read and agreed to the published version of the manuscript.

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