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Research Article

A morphometric comparison of the skulls of Akkaraman and Kangal Akkaraman sheep on a three-dimensional model using computed tomography

Hacer Baş Ekici[1], Kamil Beşoluk[1], Nisa Başpınar[2]

[1]Department of Veterinary Anatomy, Faculty of Veterinary Medicine, Selçuk University, Konya, Türkiye.
[2]Department of Radiology, School of Medicine, Sivas Cumhuriyet University, Sivas, Türkiye.

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Correspondence:
H. BAŞ EKİCİ
(vethacer.bas@gmail.com)

ORCID
H. BAŞ EKİCİ : 0000-0003-1941-1830
K. BEŞOLUK : 0000-0001-6968-6272
N. BAŞPINAR : 0000-0003-4240-6001

ABSTRACT

This study was conducted to determine the craniometric characteristics of the skulls of Akkaraman and Kangal Akkaraman sheep, local breeds in Turkey, using computed tomography (CT). The study material comprised two groups of 12 heads of healthy male Akkaraman and Kangal Akkaraman sheep, aged 8-12 months. The heads were scanned with a CT device, then these images were converted into a three-dimensional structure using the 3D Slicer program and morphometric measurements were calculated. A total of 13 parameters and 5 indexes were measured in each skull, and the morphometric differences between the skulls of Akkaraman and Kangal Akkaraman sheep were determined using statistical methods. All the characteristics examined were expressed as mean±SD values. The study results of the craniometric data showed a statistically significant difference in the parameters of skull length, skull width, greatest length of the nasal bone, greatest breadth across the nasal, medial frontal length, cranial width, facial width, height of the foramen magnum, greatest breadth of the foramen magnum, greatest frontal breadth and least breadth between the orbits ($p<0.05$). No statistically significant difference was observed between the breeds in terms of viscerocranium length, greatest inner width of the orbit, and craniofacial indexes ($p>0.05$). These data can be considered useful for veterinarians in the fields of surgery and clinical practice, and for studies in the field of zooarchaeology, and sheep taxonomy.

INTRODUCTION

Sheep farming, which is an important economic area, is widespread in many parts of the world in areas with vast meadows and pastures and dry climatic conditions. Sheep breeding has become the most profitable branch of livestock production due to the structure and ability of sheep to make the best use of areas with large pastures of low quality. Sheep breeding has an important place in Turkey due to the soil structure and the suitability of grazing opportunities. The Akkaraman sheep breed is intensively bred in Turkey, especially in Central Anatolia, and accounts for almost half the current sheep population (Akçapınar, 2000). The Kangal Akkaraman sheep breed, which was previously recognised as a variety within the Akkaraman sheep breed, one of the indigenous breeds of Turkey, was registered as an independent breed with the communiqué number 28384 published in the Official Gazette on August 14, 2012 (Oğrak et al., 2014). Compared to the Akkaraman breed and other breeds, the Kangal Akkaraman sheep has a larger structure and higher productivity and is compatible and resistant to the natural conditions of the region. Moreover, it is a combined breed for both meat and milk production. It is distinguished from the Akkaraman sheep breed and other varieties by black spots around the eyes, on the feet and around the shins, and by the convex nasal area (Örkiz et al., 1984). Skull morphometry is widely used in disciplines such as forensic medicine, taxonomy, and zooarchaeology due to certain differences between breeds and genders (Kobryńczuk et al., 2008; Adebisi, 2009; Onar et al., 2015). Polymorphism is very common in sheep breeds, making purely morphological classification difficult. Therefore, morphometric studies are very important for taxonomy (Kaymakçı & Sönmez, 1996; Soysal et al., 2003). Although there are some studies on Akkaraman sheep, as yet there has been no comprehensive anatomic study investigating the morphometric parameters of the skull in Akkaraman and Kangal Akkaraman sheep. The aim of this study was to determine the craniometric data of Akkaraman and Kangal Akkaraman sheep, which are local breeds in Turkey, and to calculate the indexes obtained using craniometric measurements.

MATERIAL and METHODS

Animals

This study used the skulls of 12 male Akkaraman and 12 male Kangal Akkaraman sheep, each aged between 8 and 12 months old. The research materials were collected from private slaughterhouses in the provinces of Konya and Sivas. This study was performed with the permission of Selçuk University Experimental Animal Breeding and Experimental Research Center Ethics Committee (SÜVDAMEK) (decision no: 2022/20).

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Three-dimensional modelling of the images and performing their craniometric measurements

A 64-slice CT scanner (Toshiba Aquillon CX-Tokio/Japan) was used to scan the sheep skulls, and the images obtained were stored in DICOM format. They were then uploaded to the three-dimensional modeling application, 3D Slicer 5.0.3, where 3D models of the skull were formed and the craniometric measurements were recorded. Craniometric measurements were taken of 13 distinct parameters on the 3D models of the skulls. The morphometric measurements were taken based on the measurement sites described in the literature (Von den Driesch, 1976). Osteometric measurements were used to calculate five distinct indices. The formula for the indices generated using these measurement sites was shown in Table 2. The linear measurement points acquired from the dorsal, ventral and lateral surfaces of the skull were shown in Table 1. The research employed Nomina Anatomica Veterinaria for the nomenclature (Nomina, 2017).

Table1. Studied cranial parameters (cm).

Parameter No	Parameters	Definition
1	Skull length	Akrokranion - Prosthion
2	Greatest length of the nasal bone	Nasion - Rhinion
3	Medial frontal length	Akrokranion - Nasion
4	Greatest breadth across the nasal	Maximum distance across the nasal bones
5	Facial width	Distance between the caudal extents of the orbital rims.
6	Least breadth between the orbits	Entorbitale - Entorbitale
7	Greatest breadth of the Foramen magnum	The maximum distance between the two occipital condyles.
8	Height of the Foramen magnum	Basion - Opisthion
9	Greatest inner length of the orbit	Ectorbitale - Entorbitale
10	Viscerocranium length	Nasion - Prosthion
11	Cranial width	Distance between two external auditory meatus
12	Skull width	Distance between two zygomatic arches
13	Greatest frontal breadth	Ectorbitale - Ectorbitale

Table 2. Indices and formulas of the skulls.

İndex No	Craniofacial İndexes	Formulas
1	Skull index	Skull width/ Skull length× 100
2	Cranial index	Cranial width/ Medial frontal length× 100
3	Nasal index	Greatest breadth across the nasal/ Greatest length of the nasal bone× 100
4	Facial index	Facial width/ Viscerocranium length× 100
5	Foramen magnum index	Height of the Foramen magnum/ Greatest breadth of the Foramen magnum× 100

Statistical analysis

Statistical analyses of craniometric measurements of skull data were performed in SPSS software version 26 (IBM Corp., Armonk, NY, USA). The conformity of the data to normal distribution was determined using the Shapiro-Wilk test and it was confirmed that the data showed normal distribution. Statistical differences between groups were analyzed using the independent samples t test. Results were expressed as mean ± standard deviation (SD) values. A value of $p<0.05$ was considered statistically significant.

RESULT

In this study, the first reports of craniometric measurements of sheep from the Akkaraman and Kangal Akkaraman breeds were presented. Craniometric measurements were used to calculate the cranial-facial indices in both species. A total of 13 different craniometric measurements of the skull were made for the investigation (Figure 1). The mean values, standard deviations, coefficients of variation, maximum and minimum values for each parameter were shown in Table 3, and the derived indexes used in the current investigation on the skull were shown in Table 4.

in only one of the calculated index values, the skull index of the Akkaraman sheep was higher than that of the Kangal Akkaraman sheep.

The mean length and width of the skull were measured as

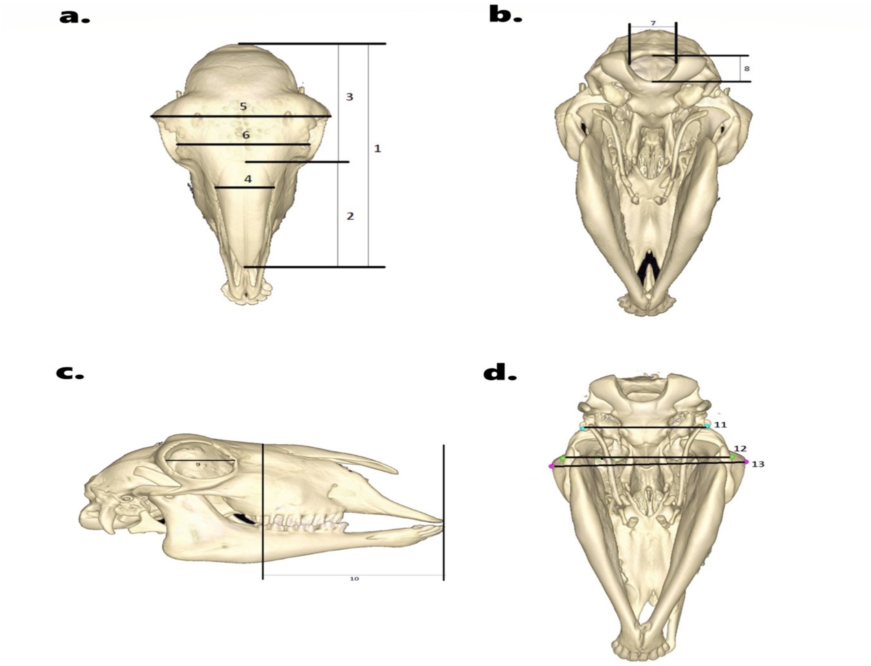

Figure 1. Measurement of the skull of Kangal Akkaraman sheep. (a) Dorsal view, (b,d) Ventral view, (c) Lateral view. 1-Skull length, 2-Greatest length of the nasal bone, 3-Medial frontal length, 4-Greatest breadth across the nasal, 5-Facial width, 6-Least breadth between the orbits, 7-Greatest breadth of the foramen magnum, 8-Height of the foramen magnum, 9-Greatest inner length of the orbit, 10-Viscerocranium length, 11-Cranial width 12-Skull width, 13-Greatest frontal breadth.

All the statistically important data specified in Table 3 should be mentioned in this section in respect of the parameters of skull length, skull width, greatest breadth across the nasal, greatest height of the foramen magnum, greatest frontal breadth, and least breadth between the orbits ($p<0.05$). In terms of the estimated craniofacial indices, the largest inner width of the orbit, and viscerocranium length, no statistically significant difference was determined between the breeds ($p>0.05$) (Table 3 and 4). Based on the metric measurement points, the skull length was found to be the longest measurement, determined as mean 18.37 ± 0.65 cm in Akkaraman sheep and 20.08 ± 0.29 cm in Kangal Akkaraman sheep ($p<0.001$) (Table 3). The foramen magnum height, measured as mean 1.93 ± 0.13 cm in Akkaraman sheep and 2.07 ± 0.16 cm in Kangal Akkaraman sheep ($p=0.039$), was seen to be the smallest measurement. The foramen magnum index had the highest value ($p=0.871$) and the nasal index had the lowest value ($p=0.269$) for the craniofacial index.

DISCUSSION

In this study, 13 craniometric parameters were measured and 5 craniofacial indices were calculated. In all the craniometric measurements, the values of the Akkaraman sheep were lower than those of the Kangal Akkaraman sheep. However,

18.37 ± 0.65 cm and 8.82 ± 0.46 cm, respectively in Akkaraman sheep, and as 20.08 ± 0.29 cm and 9.50 ± 0.34 cm, respectively in Kangal Akkaraman sheep. According to the literature, the skull length of Akkaraman and Kangal Akkaraman sheep was shorter than the skull length of Hasak and Hasmer (Can et al., 2022) Suffolk Down (de la Barra et al., 2020), Morkaraman (Özcan et al., 2010), Xisqueta (Parés Casanova et al., 2010), Awassi (Yılmaz & Demircioğlu, 2020), Bardhoka (Gündemir et al., 2020), Hemshin (Dalga et al., 2018), Hamdani (Dayan et al., 2022), Sharri (Jashari et al., 2022), Iranian Native (Monfared, 2013), and Barbados Black Belly sheep (Mohamed et al., 2016). The skull length of the Akkaraman sheep was shorter than that of the Tuj sheep (Özcan et al., 2010) and longer than that of the Kangal Akkaraman sheep. The skull length of the Kangal Akkaraman sheep was longer than that of male Zell and Mehraban sheep, and the skull length of the Akkaraman sheep was shorter than that of male Zell and Mehraban sheep (Karimi et al., 2011; Marzban Abbasabadi et al., 2020). Moreover, in the current study, it was found that the skull width of Akkaraman and Kangal Akkaraman sheep was lower than Mehraban sheep (Karimi et al., 2011). The skull width of both Akkaraman and Kangal Akkaraman sheep was higher than that of male Zell sheep (Marzban Abbasabadi et al., 2020). It is believed that the differences in skull length and width between breeds of animals are due to the geographical environment in

Table 3. Results of morphometric parameters of the skull of a male Akkaraman sheep and male Kangal Akkaraman sheep determined by 3D reconstruction of CT images.

Parameters (cm)	Groups						P values
	Akkaraman Sheep			Kangal Akkaraman Sheep			
	Mean ± SD	Min-Max	CV	Mean ± SD	Min-Max	CV	
Skull length	18.37 ± 0.65	16.80 - 19.10	3.53	20.08 ± 0.29	19.80 - 20.70	1.42	<0.001
Skull width	8.82 ± 0.46	8.10 - 9.60	5.20	9.50 ± 0.34	9.06 - 10.03	3.62	0.001
Greatest length of the nasal bone	7.62 ± 0.47	6.70 - 8.30	6.20	8.35 ± 0.69	7.10 - 9.80	8.25	0.007
Greatest breadth across the nasal	3.04 ± 0.23	2.80 - 3.40	7.60	3.47 ± 0.18	3.20 - 3.80	5.26	<0.001
Medial frontal length	10.74 ± 0.45	10.10 - 11.40	4.15	11.73 ± 0.67	10.40 - 13.00	5.72	<0.001
Cranial width	5.95 ± 0.36	5.20 - 6.40	6.05	6.61 ± 0.38	6.20 - 7.60	5.75	<0.001
Viscerocranium length	10.03 ± 0.53	9.50 - 11.08	5.32	10.36 ± 1.03	9.50 - 13.30	9.96	0.329
Facial width	10.25 ± 0.37	9.60 - 10.70	3.66	10.77 ± 0.41	10.10 - 11.50	3.84	0.004
Height of the foramen magnum	1.93 ± 0.13	1.70 - 2.20	7.08	2.07 ± 0.16	1.70 - 2.30	8.01	0.039
Greatest breadth of the foramen magnum	2.05 ± 0.13	1.80 - 2.30	6.69	2.21 ± 0.15	2.07 - 2.50	6.87	0.017
Greatest frontal breadth	10.44 ± 0.43	9.80 - 11.30	4.18	11.04 ± 0.33	10.50 - 11.50	3.04	0.001
Greatest inner length of the orbit	3.72 ± 0.15	3.40 - 3.90	4.14	3.80 ± 0.22	3.40 - 4.10	5.91	0.351
Least breadth between the orbits	7.47 ± 0.51	6.40 - 8.10	6.83	7.86 ± 0.31	7.30 - 8.40	3.99	0.034

which they are raised, their care and feeding conditions, the calcium ratio in their feed, and breed-specific characteristics.

The current study showed that the medial frontal length of Akkaraman and Kangal Akkaraman sheep was shorter than that of Xisqueta (Parés Casanova et al., 2010), Mehraban (Karimi et al., 2011), Iranian Native (Monfared, 2013), and Barbados Black Belly sheep (Mohamed et al., 2016), but the medial frontal length of Kangal Akkaraman sheep was almost equal to that of Iranian Native sheep (Monfared, 2013). Although the medial frontal length of Akkaraman sheep and Tuj sheep were the same, the medial frontal length of Kangal Akkaraman sheep was greater than that of Morkaraman and Tuj sheep (Özcan et al., 2010).

In the present study, the greatest breadth across the nasal

Table 4. The results of indexes of skull of male Akkaraman sheep and male Kangal Akkaraman sheep obtained through 3D reconstruction of CT images.

Index (%)	Groups						P values
	Akkaraman Sheep			Kangal Akkaraman Sheep			
	Mean ± SD	Min-Max	CV	Mean ± SD	Min-Max	CV	
Skull index	48.06 ± 2.33	44.92 – 52.17	4.85	47.31 ± 1.86	43.96 – 49.49	3.93	0.391
Cranial index	55.41 ± 3.01	49.56 – 59.43	5.43	56.52 ± 4.05	49.23 – 66.09	7.17	0.455
Nasal index	39.97 ± 3.23	34.57 – 47.76	8.08	41.83 ± 4.66	32.65 – 52.11	11.16	0.269
Facial index	102.46 ± 6.92	93.20 – 111.58	6.76	104.74 ± 10.83	79.70 – 121.05	10.34	0.545
Foramen magnum index	106.92 ± 10.11	94.74 – 122.22	9.46	107.76 ± 14.71	94.09 – 141.18	13.65	0.871

P value is indicated in bold for the parameters with statistical differences in the data analyzed using the independent sample t-test.
Abbreviation: CV, Coefficient of variations.

was greater than that of Mehraban (Karimi et al., 2011), Morkaraman and Tuj sheep (Özcan et al., 2010). Moreover, greatest length of the nasal bone in Akkaraman and Kangal Akkaraman sheep was shorter than that of Xisqueta (Parés Casanova et al., 2010), Sharri (Jashari et al., 2022), Suffolk Down (de la Barra et al., 2020), Iranian Native (Monfared, 2013) and Mehraban sheep (Karimi et al., 2011). Akkaraman and Kangal Akkaraman sheep had higher values than Morkaraman and Tuj sheep (Özcan et al., 2010). The greatest length of the nasal bone of Kangal Akkaraman sheep was longer than that of Barbados Black Belly (Mohamed et al., 2016), Akkaraman and male Zell sheep (Marzban Abbasabadi et al., 2020). However, the greatest value of nasal bone length of Akkaraman sheep was higher than that of male Zell sheep (Marzban Abbasabadi et al., 2020).

Facial width and viscerocranium length were 10.25 ± 0.37 cm and 10.03 ± 0.53 cm, respectively in Akkaraman sheep, and 10.77 ± 0.41 cm and 10.36 ± 1.03 cm, respectively in Kangal Akkaraman sheep. The viscerocranium length of Akkaraman and Kangal Akkaraman sheep was shorter than that of Xisqueta (Parés Casanova et al., 2010), Mehraban (Karimi et al., 2011), Morkaraman, and Tuj sheep (Özcan et al., 2010). These results show that the viscerocranium length of Akkaraman and Kangal Akkaraman sheep was higher than that of male Zell sheep (Marzban Abbasabadi et al., 2020). The facial width was almost the same in Akkaraman, Kangal Akkaraman, and Mehraban sheep (Karimi et al., 2011). However, the value was higher in Akkaraman and Kangal Akkaraman sheep than in Suffolk Down (de la Barra et al., 2020) and male Zell sheep (Marzban Abbasabadi et al., 2020), but lower than in Sharri sheep (Jashari et al., 2022).

The least breadth between the orbits (entorbitale - entorbitale) was measured as mean 7.47 ± 0.51 cm in Akkaraman sheep, and as 7.86 ± 0.31 cm in Kangal Akkaraman sheep. This parameter in both Akkaraman and Kangal Akkaraman sheep was seen to be higher than in Morkaraman sheep and Tuj sheep (Özcan et al., 2010), but lower than in Sharri (Jashari et al., 2022) and Xisqueta sheep (Parés Casanova et al., 2010).

The distance between the two zygomatic areas in dogs and camels has been reported as the largest area of the skull. Due to morphological differences, the largest area of the sheep skull has been shown to be the parameter of the greatest frontal breadth (ectorbitale - ectorbitale). This value in the current study was determined to be mean 10.44 ± 0.43 cm in the Akkaraman sheep and 11.04 ± 0.33 cm in the Kangal Akkaraman sheep. According to previously reported data, the greatest frontal breadth of both the Akkaraman and Kangal Akkaraman sheep was less than that of Xisqueta (Parés Casanova et al., 2010) and Awassi sheep (Yılmaz & Demircioğlu, 2020), but greater than that of Morkaraman and Tuj sheep (Özcan et al., 2010).

The greatest inner length of the orbit, also known as the orbital width, was measured as 3.72 ± 0.15 cm in Akkaraman sheep and 3.80 ± 0.22 cm in Kangal Akkaraman sheep. This value was lower in Akkaraman and Kangal Akkaraman sheep compared to Suffolk Down (de la Barra et al., 2020), Sharri (Jashari et al., 2022), Xisqueta (Parés Casanova et al., 2010), and Mehraban sheep (Karimi et al., 2011), but higher than in male Zell (Marzban Abbasabadi et al., 2020), Morkaraman and Tuj sheep (Özcan et al., 2010).

The height of the foramen magnum and greatest breadth of the foramen magnum were 1.93 ± 0.13 cm and 2.05 ± 0.13 cm, respectively in Akkaraman sheep, and 2.07 ± 0.16 cm and 2.21 ± 0.15 cm, respectively in Kangal Akkaraman sheep. The height and width values of the foramen magnum were greater in Akkaraman and Kangal Akkaraman sheep than in Xisqueta (Parés Casanova et al., 2010), male Zell (Marzban Abbasabadi et al., 2020) and Mehraban sheep (Karimi et al., 2011), but lower than in Awassi sheep (Yılmaz & Demircioğlu, 2020).

The height and width of the foramen magnum were higher in Kangal Akkaraman sheep than in Morkaraman and Tuj sheep (Özcan et al., 2010). However, the height of the foramen magnum in Akkaraman sheep was lower than in Morkaraman sheep and higher than in Tuj sheep (Özcan et al., 2010), whereas the maximum breadth of the foramen magnum was lower in Akkaraman sheep than in Morkaraman and Tuj sheep (Özcan et al., 2010). Based on the values obtained in the study, the height of the foramen magnum was higher in Akkaraman and Kangal Akkaraman sheep than in Sharri (Jashari et al., 2022) and Suffolk Down sheep (de la Barra et al., 2020), but the greatest breadth of the foramen magnum was lower than in Sharri (Jashari et al., 2022) and Suffolk Down sheep (de la Barra et al., 2020).

Skull index values are used in bone deformities and in the evaluation of brain development. The index values of sheep breeds are important in determining the typology of breeds (Kanchan et al., 2014; Onar & Pazvant, 2001). The skull index of the Akkaraman sheep was found to be 48.06 ± 2.33 cm. This index was higher in Akkaraman and Kangal Akkaraman sheep than in Sharri sheep (Jashari et al., 2022), Xisqueta sheep (Parés Casanova et al., 2010), and Awassi sheep (Yılmaz & Demircioğlu, 2020), but lower than in Hemshin sheep (Dalga et al., 2018), Morkaraman and Tuj sheep (Özcan et al., 2010). However, it was determined that the skull index of Akkaraman and Kangal Akkaraman sheep was lower than that of Mehraban sheep (Karimi et al., 2011), Morkaraman, and Tuj sheep (Özcan et al., 2010).

The nasal and facial index values of the Akkaraman and Kangal Akkaraman sheep in this study were higher than those of Morkaraman and Tuj sheep (Özcan et al., 2010). Similarly, the facial index values of the Akkaraman and Kangal Akkaraman sheep were higher than those of the Xisqueta sheep (Parés Casanova et al., 2010), Sharri sheep (Jashari et al., 2022), Hemshin sheep (Dalga et al., 2018), and Mehraban sheep (Karimi et al., 2011).

The value of the foramen magnum index in this study was determined to be mean 106.92 ± 10.11 in Akkaraman sheep and 107.76 ± 14.71 in Kangal Akkaraman sheep, which may be attributed to the fact that the width of the foramen magnum is greater than the height. The differences between these values may be due to breed differences and, in part, to differences in the measurement methods used.

CONCLUSION

In conclusion, it is thought that the results of this study will serve as a reference for science branches such as osteoarchaeology, anatomy, for the creation of a craniometric measurement and index database for Akkaraman and Kangal Akkaraman sheep, and it can also be used for taxonomic classification of species in Turkey and breeding ram determination. Nevertheless, further studies with larger sample sizes could produce more precise results in the measured parameters.

DECLARATIONS

Ethics Approval

This study was performed with the permission of the Selçuk University Experimental Animal Breeding and Experimental Research Center Ethics Committee (SÜVDAMEK) (decision no: 2022/20).

Conflict of Interest

All the authors have read and approved the manuscript. The authors have no conflict of interests to declare.

Consent for Publication

Not applicable

Author contributions

Idea, concept, and design: HBE, KB, NB

Data collection and analysis: HBE

Drafting of the manuscript: HBE, KB

Critical review: HBE, KB, NB

Data Availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1.Adebisi, S. (2009). Forensic anthropology in perspective: The current trend. The Internet Journal of Forensic Science, 4(1).

2.Akçapınar, H. (2000). Koyun yetiştiriciliği. İsmat Matbaacılık.

3.Can, M., Özüdogru, Z., & Ilgün, R. (2022). A Morphometric Study on Skulls of Hasmer and Hasak Sheep Breeds. International Journal of Morphology, 40(6).

4.Dalga, S., Aslan, K., & Akbulut, Y. (2018). A morphometric study on the skull of the adult Hemshin sheep. Van Veterinary Journal, 29(3), 125-129.

5.Dayan, M. O., Demircioğlu, İ., Koçyiğit, A., Güzel, B. C., & Karaavci, F. A. (2022). Morphometric analysis of the skull of Hamdani sheep via Three-Dimensional modelling. Anatomia, Histologia, Embryologia. https://doi.org/10.1111/ahe.12873.

6.de la Barra, R., Carvajal, A. M., & Martínez, M. E. (2020). Variability of cranial morphometrical traits in Suffolk Down Sheep. Austral journal of veterinary sciences, 52(1), 25-31.

7.Gündemir, O., Duro, S., Jashari, T., Kahvecioğlu, O., Demircioğlu, İ., & Mehmeti, H. (2020). A study on morphology and morphometric parameters on skull of the Bardhoka autochthonous sheep breed in Kosovo. Anatomia, Histologia, Embryologia, 49(3), 365-371. https://doi.org/10.1111/ahe.12538.

8.Jashari, T., Duro, S., Gündemir, O., Szara, T., Ilieski, V., Mamuti, D., & Choudhary, O. P. (2022). Morphology, morphometry and some aspects of clinical anatomy in the skull and mandible of Sharri sheep. Biologia, 77(2), 423-433.

https://doi.org/10.1007/s11756-021-00955-y

9.Kanchan, T., Krishan, K., Gupta, A., & Acharya, J. (2014). A study of cranial variations based on craniometric indices in a South Indian population. Journal of Craniofacial Surgery, 25(5), 1645-1649. https://doi.org/10.1097/SCS.0000000000001210

10.Karimi, I., Onar, V., Pazvant, G., Hadipour, M., & Mazaheri, Y. (2011). The cranial morphometric and morphologic characteristics of Mehraban sheep in Western Iran. Global Veterinaria, 6(2), 111-117.

11.Kaymakçı, M., & Sönmez, R. (1996). İleri koyun yetiştiriciliği. Ege Üniversitesi Basım Evi, Bornova-İzmir.

12.Kobryńczuk, F., Krasińska, M., & Szara, T. (2008). Sexual dimorphism in skulls of the lowland European bison, Bison bonasus bonasus. Annales Zoologici Fennici. https://doi.org/10.5735/086.045.0415

13.Marzban Abbasabadi, B., Hajian, O., & Rahmati, S. (2020). Investigating the morphometric characteristics of male and female zell sheep skulls for sexual dimorphism. Anatomical Sciences Journal, 17(1), 13-20.

14.Mohamed, R., Driscoll, M., & Mootoo, N. (2016). Clinical anatomy of the skull of the Barbados Black Belly sheep in Trinidad. International Journal of Current Research Medical Sciences, 2(8), 8-19. http://s-o-i.org/1.15/ijcrms-2016-2-8-2

15.Monfared, A. (2013). Clinical anatomy of the skull of Iranian native sheep. Global Veterinaria, 10(3), 271-275. https://doi.org/10.5829/idosi.gv.2013.10.3.7253.

16.Nomina, N. A. V. (2017). Nomina anatomica veterinária. In: International Committee on Veterinary Gross Anatomical Nomenclature, World.

17.Oğrak, Y. Z., Tuzcu, N., & Ocak, B. E. (2014). İyi Yetiştiricilik Uygulamalarının Kangal Akkaraman Irkı Koyunlarda Brusellozis Görülme Oranlarına Etkileri. Türk Tarım-Gıda Bilim ve Teknoloji dergisi, 2(3), 150-153.

18.Onar, V., Pazvant, G., Pasicka, E., Armutak, A., & Alpak, H. (2015). Byzantine horse skeletons of Theodosius Harbour: 2. Withers height estimation. Revue de médecine vétérinaire, 166, 30-42.

19.Onar, V., & Pazvant, S. (2001). Skull typology of adult male Kangal dogs. Anatomia, Histologia, Embryologia, 30(1), 41-48. https://doi.org/ 10.1046/j.1439-0264.2001.00292.x.

20.Örkiz, M., Kaya, F., & Çalta, H. (1984). Kangal Tipi Akkaraman Koyunlarının Bazı Önemli Verim Özellikleri. Lalahan hayvancılık araştırma enstitüsü dergisi, 24(1-4), 15-33.

21.Özcan, S., Aksoy, G., Kürtül, I., Aslan, K., & Özüdogru, Z. (2010). A comparative morphometric study on the skull of the Tuj and Morkaraman sheep. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 16(1), 111-114. https://doi.org/10.9775/kvfd.2009.518.

22.Parés Casanova, P.-M., Sarma, K., & Jordana i Vidal, J. (2010). On biometrical aspects of the cephalic anatomy of Xisqueta sheep (Catalunya, Spain). International Journal of Morphology, 2010, vol. 28, num. 2, p. 347-351. https://doi.org/ 10.4067/S0717-95022010000200001.

23.Soysal, M., Özkan, E., & Gürcan, E. (2003). The status of native farm animal genetic diversity in Türkiye and in the world. Trakia Journal of Sciences, 1(3), 1-12.

24.Von den Driesch, A. (1976). A guide to the measurement of animal bones from archaeological sites (Vol. 1). Peabody Museum Press.

25.Yılmaz, B., & Demircioğlu, İ. (2020). Morphometric Analysis of the Skull in the Awassi Sheep (Ovis aries), Fırat Üniversitesi Sağlık Bilimleri Veteriner Dergisi, 34(1), 01-06.