Int. J. Morphol.,
40(6):1536-1545, 2022.

A Morphometric Study on Skulls of Hasmer and Hasak Sheep Breeds

Un Estudio Morfométrico de Cráneos de Razas de Ovejas Hasmer y Hasak

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CAN, M.; ÖZÜDOGRU, Z. & ILGÜN, R. A Morphometric study on skulls of hasmer and hasak sheep breeds. *Int J. Morphol., 40(6)*:1536-1545, 2022.

SUMMARY: The aim of the study was to investigate the head structures of two domestic sheep breeds (Hasak and Hasmer) in Turkey. Gender neutral eight adult Hasmer sheep of 45-66 kg and eight Hasak sheep breeds of 43-66 kg obtained from Bahri Dag˘das¸ International Agricultural Research Institute were used in this study. Measurements were made using digital caliper from 40 points on the skulls of both species. The skull of Hasmer sheep (265.56 ± 14.08) was longer than the skull of Hasak sheep (262.86 ± 9.65). However, the length of the arcus alveolaris maxillaris (77.01 ± 5.08), the length of the molar teeth (50.81 ± 1.22) and the length of the premolar teeth (26.16 ± 4.62) of Hasak sheep were compared to the Hasmer sheep (71.59, ± 5.25; 47.99 ± 3.64; 24.03 ± 3.76, respectively) was observed to be greater. According to these findings, although the skull length of Hasak sheep was shorter than that of Hasmer sheep and arcus alveolaris maxillaris in which molar and premolar teeth were placed was longer. In Hasmer sheep the values of greatest breadth of the foramen magnum, height of the foramen magnum (basion - opisthion), greatest neurocranium breadth-greatest breadth of the braincase (euryon - euryon) were higher than those of Hasak sheep. The difference between these values was also statistically significant ($p < 0.05$). The lateral length of the premaxilla (nasointermaxillare- prosthion) parameter measured between these two species was statistically very important ($p < 0.01$). In conclusion, in this study craniometric values depending on skull morphology of Hasmer and Hasak sheep which accepted as native breeds of Turkey were tried, to reveal similarities and differences with other sheep breeds in both amongst themselves.

KEY WORDS: Fossa Mandibularis; Morphometrical; Processus Palatinus; Skull Morphology.

INTRODUCTION

In the first place a lot of animal domestication in the world, Turkey's Çatal Höyük, Asıklı Köyü and Asvan Kale settlements, besides Mesopotamia region. It was claimed that there were important archaeological data on the domestication of some animals for the first time in the primitive settlements of approximately 10,000 years ago in Çatalhöyük in Middle Anatolia (Payne, 1985; Pedrosa *et al*., 2005; Zeder, 2006; Meadows *et al*., 2007; Zeder, 2008). Sheep was one of the first animals domesticated by humans. According to the results obtained in the studies conducted so far, it was accepted that the wild sheep, which constitute the origin of the domestic sheep, had been domesticated in three separate regions, namely West Asia, Central Asia and Southern Europe (Akçapınar, 1994).

During the process of domestication of wild animals, some morphological and anatomical changes were observed in the general head and body structure of these animals over time. Particularly, the horns and long bones of these animals decrease in size as well as growth in their general body structures (Ryder, 1981; Zohary *et al*., 1998; De Marinis & Asprea, 2006).

It was reported by archaeo-zoologists that the first signs of the domestication of sheep and goats were generally observed on the horns and cranial bones of these animals (Zeder, 2005).

Data on cranial capacity in ruminants were mostly based on osteometric data and direct measurements (Malik *et al*., 1989; Terai *et al*., 1998; Hoefs, 2000). It has been reported that taking craniometric measurements depending on skull morphology has an important role in determining the morphometric changes and the morphological differences

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Received: 2022-08-19 Accepted: 2022-10-18

between species (Wehausen & Ramey, 2000).

The skull was divided into two parts between itself. One of them was the pars faciei that covers the beginning of the digestive and respiratory systems, the other was the pars cranii, which contains the brain (König *et al*., 2007).

Human beings formed sheep types and later sheep breeds by selecting sheep depending on their various yield aspects and combining them. Today, there are more than two hundred sheep breeds in the world and countless projects are carefully carried out to obtain new ones every day (Kaymakçı & Taskın, 2008).

In Turkey Hasmer sheep breeds were obtained by crossing the German Black Headed, Hampshire and Merino sheep breeds and Hasak sheep were obtained by triple crossbreeding of German Black Headed, Hampshire and Akkaraman sheep breeds (Tekin *et al*., 2005a,b; Kaymakçı & Taskın, 2008). In this study, it is aimed to reveal the similarities and differences both among themselves and with other sheep breeds of the craniometric values depending on the skull morphology of the Hasmer and Hasak sheep breeds which have been accepted as native breeds in Turkey.

MATERIAL AND METHOD

A total of 16 skulls of adult (age 4-5 on average) both Hasmer sheep (n=8) of 45-66 kg and Hasak sheep breeds (n=8) of 43-66 kg obtained from Bahri Dag˘das¸ International Agricultural Research Institute gender neutral were used in the study. After the animals were duly slaughtered, the skulls were subjected to maceration. Measurements were made from 40 points on the skulls of both species using Mitutoyo branded digital caliper (resolution 0.01 mm or 0.0005 inches: accuracy ± 0.03 mm). In the presented study, the measurement points and measurements specified in the literature (Özcan *et al*., 2010; Mohamed *et al*., 2016) were taken as basis for obtaining morphometric measurements. *Nomina Anatomica Veterinaria* (International Committee on Veterinary Gross Anatomical Nomenclature, 2017) was used as the basis for the use of anatomical terms.

Measuring points on skull

Akrokranion (A): the most aboral point on the vertex of the cranium in the median plane,
Basion (B): the orobasal margin of the foramen magnum in the median plane,
Bregma (Br): the median point of the parieto-frontal suture,
Ectorbitale (Ect): the most lateral point of the frontal bone on the occipital side of the orbit,
Entorbitale (Ent): the naso-medial indentation of the orbit that corresponds with the inner angle of the eye in the living animal,
Euryon (Eu): the most lateral point of the braincase,
Infraorbitale (If): the (dorso) aboral point of the foramen infraorbitale,
Nasion (N): the median point of the naso-frontal suture,
Nasointermaxillare (Ni): the most aboral point of the premaxilla on the facial surface
Opisthion (O): the nuchodorsal margin of the foramen magnum in the median plane
Otion (Ot): the most lateral point of the mastoid region
Prosthion (P): the median point of the line joining the most oral points of the premaxillae
Postdentale (Pd): the median point of the line joining the aboral points of the alveoli of the hindmost cheekteeth
Premolare (Pm): the median point of the line joining the oral points of the alveoli of the foremost cheekteeth
Palatinoorale (Po): the median point of the palatine-maxillary suture
Rhinion (Rh): the median point of the line joining the most oral points of the nasals
Supraorbitale (Sp): the median point of the line joining the aboral margins of the supraorbital foramina (Von den Driesch, 1976).

The following measurements by using definitions of measuring points (Onar & Pazvant, 2001; Özcan *et al*., 2010; Dalga *et al*., 2018; Özkan *et al*., 2019; Gündemir *et al*., 2020) on the cranium were made:

1. profile length (akrokranion- prosthion),
2. median frontal length (akrokranion - nasion),
3. akrokranion-bregma,
4. frontal length (bregma - nasion),
5. upper neurocranium length (akrokranion – supraorbitale),
6. facial length (supraorbitale - prosthion),
7. akrokranion-infraorbitale of one side,
8. greatest length of the nasals (nasion-rhinion),
9. short lateral facial length (entorbitale - prosthion),
10. least breadth of parietal: Least breadth between the temporal lines,
11. greatest neurocranium breadth-Greatest breadth of the braincase (euryon - euryon),
12. greatest breadth across the orbit-greatest frontal breadth-greatest breadth of skull (ectorbitale - ectorbitale),
13. least breadth between the orbits (entorbitale - entorbitale),
14. facial breadth (breadth across the facial tuberosities),
15. greatest breadth across the nasals,
16. greatest breadth across the premaxillae,

17. condylobasal length (aboral margin of occipital condyles - prosthion),
18. basal length (basion - prosthion),
19. short skull length (basion premolare),
20. premolare-prosthion,
21. dental length (postdentale - prosthion),
22. oral palatal length (palatinoorale - prosthion),
23. length of the cheektooth row (measured along alveoli),
24. length of the molar row (measured along the alveoli on the buccal side),
25. length of the premolar row (measured along the alveoli on the buccal side),
26. greatest palatal breadth (measured across the outer margins of the alveoli),
27. neurocranium length (basion - nasion),
28. viscerocranium length (nasion - prosthion),
29. greatest length of the lacrimal (most lateral point of the lacrimal - the most oral point of the lacrimo - maxillary suture),
30. from the aboral margin of one occipital condyle to the infraorbitale of the same side,
31. lateral length of the premaxilla (nasointermaxillare - prosthion),
32. greatest inner length of the orbit (ectorbitale - entorbitale),
33. greatest inner height of the orbit (measured in the same way as measurement),
34. greatest mastoid breadth (otion - otion),
35. greatest breadth of the occipital condyles,
36. greatest breadth of the bases of the paraoccipital processes,
37. greatest breadth of the foramen magnum,
38. height of the foramen magnum (basion - opisthion),

Sw: zygomatic width (the distance between two zygomatic arches),

Di: the distance from infraorbital foramen to facial tuberosity.

Craniofacial indices (Özcan *et al*., 2010):

I1. Facial index: zygomatic width × 100 / viscerocranial length,
I2. Nasal index: greatest breadth across the nasals × 100 / greatest length of the nasals,
I3. Neurocranium index: maximum width of the neurocranium × 100 / Neurocranium length,
I4. Basal index: maximum width of neurocranium × 100 / basal length,
I5. Skull index: zygomatic width × 100 / skull length,
I6. Foramen Magnum index: The height of the Foramen Magnum × 100 / the width of the Foramen Magnum,
I7. Orbital index: Greatest inner height of the orbit × 100 / Greatest inner length of the orbit.

Statistical analysis: Data were analyzed with SPSS 22 (SPSS Inc., Chicago, IL, USA) using descriptive statistics including mean values, coefficient of variations (CV= Standart Deviation / mean × 100%), and standard deviation to interpret the findings. The independent samples t-test was used to compare two groups based on genotype $p < 0.05$ was considered statistically significant. For all tests, 2-tailed p-value of < 0.05 was considered statistically significant.

RESULTS

In our study, ossa cranii of Hasmer and Hasak sheep were used in macroanatomical examination. The frontale and temporale bones, which are prominent in the dorsal and the parietale bone, which is broadly located in the lateral, constituted the main parts of the skull. The horizontal and sharp appearance of the linea temporalis, the prominent wide structure of the orbit, and the long and sharp appearance of the arcus zygomaticus in both species were observed as important findings. Although it was more prominent tuber faciale in Hasak sheep than in Hasmer sheep, fossa lacrimalis externa was more hollow in Hasmer sheep. In both species, the sutures between the bones of skull were clearly detected. It was determined that measuring points in Hasmer sheep the foramen magnum was in oval shape surrounded by the condylus occipitalis and the processus jugularis was clearly curved towards the ventral. Hasak sheep had condylus occipitalis on both sides of foramen magnum, which is an oval and large hole. Condylus occipitalis were oval shaped, processus jugularis were long enough to exceed the condylus and slightly curved inward.

While the sutura interfrontalis was not very prominent and the suture disappeared completely in the middle part in Hasmer sheep, the suture was very prominent in Hasak sheep and the caudal part of this suture was notched like a saw tooth and the cranial part was straight.

Both species had a single foramen supraorbitale and a prominent sulcus. However, while this hole had a round shape in Hasmer sheep, it had a notched structure in Hasak sheep. The outer surface of the frontal bone of Hasak sheep had a more convex structure than that of Hasmer sheep.

While fossa mandibularis had a shallower structure in Hasmer sheep than Hasak sheep, facies articularis was more convex in Hasak sheep.

In the investigations, in the ventral it was determined that the sutures of the processus palatinus of the os maxilla took the shape of "V", while the fronto-nasal suture resembled the letter "U" in Hasmer sheep and "V" in Hasak sheep. It was observed that the choana opening was uniform in both species, and processus muscularis were sharp.

In the study, 40 morphometric measurements of the skulls of both species were made. The reference points for these measurements were shown in Figures 1 to 8, the obtained morphometric values were presented in Tables I to IV and the calculated index values were presented in Table V.

It was determined that the skull of Hasmer sheep (265.56 ± 14.08 mm) was longer than the skull of Hasak sheep (262.86 ± 9.65 mm) as seen in Table I. However, the length of the arcus alveolaris maxillaris (77.01 ± 5.08 mm), the length of the molar teeth (50.81 ± 1.22 mm) and the length of the premolar teeth (26.16 ± 4.62 mm) of Hasak sheep were compared to the Hasmer sheep (71.59 ± 5.25 mm; 47.99 ± 3.64 mm; 24.03 ± 3.76 mm) was observed to be greater, respectively. According to these findings, although the skull length of Hasak sheep was shorter than that of Hasmer sheep, it was determined that the arcus

Table I. Craniometric measurements of Hasmer and Hasak sheep (dorsal view).

Measurement No	HASAK (n=8)					HASMER (n=8)					
	Mean	SD	Min	Max	CV	Mean	SD	Min	Max	CV	*p* value
1	262.86	9.65	252.42	274.34	3.67	265.56	14.08	241.59	278.11	5.3	NS
2	230.32	10.12	216.32	241.88	4.39	239.67	12.99	222.39	258.1	5.42	NS
3	216.08	14.31	196.84	235.49	6.62	221.85	13.32	203.18	238.49	6.01	NS
4	156.2	7.67	146.87	163.32	4.91	157.58	8.62	147.76	168.96	5.47	NS
5	61.07	5.97	51.11	67.41	9.77	66.82	4.12	61.33	71.79	6.16	NS
6	125.34	6.07	117.56	135.81	4.84	128.1	9.75	116.83	142.85	7.62	NS
7	135.67	4.56	127.67	141.03	3.36	140.99	6.99	130.01	150.47	4.96	NS
8	127.39	7.57	116.4	139.55	5.94	131.73	8.62	120.11	140.43	6.54	NS
9	51.97	3.52	47.16	56.61	6.78	53.42	3.26	50.38	58.75	6.11	NS
10	87.54	8.22	79.88	102.1	9.39	91.63	8.5	82.35	103.93	9.27	NS
11	99.35	4.84	91.45	105.49	4.87	101.75	7.48	92.25	109.74	7.36	NS
12	123.84	2	121.82	127.18	1.62	126.44	5.82	119.75	134.86	4.6	NS
13	171.1	7.44	163.84	178.93	4.35	178.66	10.25	163.52	191.03	5.74	NS
14	36.4	3.93	31.14	40.61	10.8	39.3	3.49	35.62	43.15	8.87	NS
15	85.2	3.04	81.14	88.04	3.56	89.51	4.92	82	94.66	5.5	NS
16	140.96	7.37	130.38	149.29	5.23	148.31	12.2	134.34	170.08	8.23	NS

Note: 1: Profile length (akrokranion - prosthion), 2: median frontal length (akrokranion - nasion), 3: akrokranion-bregma, 4: frontal length (bregma - nasion), 5: upper neurocranium length (akrokranion – supraorbitale), 6: facial length (supraorbitale - prosthion), 7: akrokranion-infraorbitale of one side, 8: greatest length of the nasals (nasion-rhinion), 9: short lateral facial length (entorbitale - prosthion), 10: least breadth of parietal: Least breadth between the temporal lines, 11: greatest neurocranium breadth-greatest breadth of the braincase (euryon - euryon), 12: greatest breadth across the orbit-greatest frontal breadth-greatest breadth of skull (ectorbitale - ectorbitale), 13: least breadth between the orbits (entorbitale - entorbitale), 14: facial breadth (breadth across the facial tuberosities), 15: greatest breadth across the nasals, 16: greatest breadth across the premaxillae. CV, Coefficient of variations; NS, Not significant; SD, Standard deviation.

Table II. Craniometric measurements of Hasmer and Hasak sheep (ventral view).

Measurement No	HASAK (n=8)					HASMER (n=8)					
	Mean	SD	Min	Max	CV	Mean	SD	Min	Max	CV	*p* value
17	162.24	9.71	150.86	173.18	5.99	166.81	11.03	153.01	180.32	6.61	NS
18	123.63	7.05	111.62	129.47	5.7	130.51	7.38	119.81	139.41	5.66	NS
19	97.2	7.31	86.94	104.45	7.52	103.73	5.13	96.26	110.76	4.94	NS
20	75.66	5.72	68.62	84.62	7.56	85.76	5.15	80.94	95.72	6.01	**
21	77.01	5.08	71.5	83.35	6.59	71.59	5.25	67.11	81.23	7.33	NS
22	50.81	1.22	49.21	52.74	2.4	47.99	3.64	43.88	53.23	7.57	NS
23	26.16	4.62	22.33	32.98	17.66	24.03	3.76	20.5	31.26	15.66	NS
24	41.72	1.47	38.85	43.02	3.52	42.84	1.45	40.84	44.21	3.4	NS
25	38.15	0.87	36.85	39.06	2.27	38.69	1.63	36.91	40.94	4.21	NS
26	70.65	1.16	69.67	72.31	1.64	73.15	4.11	67.95	77.91	5.61	NS

Note: 17: condylobasal length. 18: basal length. 19: short skull length. 20: premolare-prosthion. 21: dental length. 22: oral palatal length. 23: length of the cheektooth row. 24: length of the molar row. 25: length of the premolar row. 26: greatest palatal breadth. CV. Coefficient of variations; NS. Not significant; SD. Standard deviation. **$p < 0.01$

alveolaris maxillaris in which molar and premolar teeth were placed was longer.

In our morphometric examinations, it was observed that the values of greatest breadth of the foramen magnum, height of the foramen magnum (basion - opisthion), greatest neurocranium breadth-greatest breadth of the braincase (euryon - euryon) in Hasmer sheep were higher than those of Hasak sheep. The difference between these values was also statistically significant (p <0.05).

It was determined that the lateral length of the premaxilla (nasointermaxillare - prosthion) parameter measured between these two species was statistically very important (p <0.01).

No statistically significant difference was observed in the craniofacial index of both species (Table V).

Table III. Craniometric measurements of Hasmer and Hasak sheep (lateral view).

Measurement	HASAK (n=8)					HASMER (n=8)					
No	Mean	SD	Min	Max	CV	Mean	SD	Min	Max	CV	*p* value
27	46.67	2.25	42.94	49.31	4.82	47.28	3.1	42.63	50.71	6.56	NS
28	64.88	2.04	61.78	67.1	3.14	68.83	4.93	62.53	74.26	7.16	NS
29	21	1.05	19.95	22.71	5.02	23.04	1.66	21.01	25.55	7.19	*
30	19.35	0.77	18.17	20.3	3.99	20.83	1.11	18.86	21.84	5.33	*
31	47.48	1.98	45.13	50.55	4.18	47.45	1.61	45.25	49.8	3.39	NS
32	65.26	1.61	63.59	67.77	2.47	67.95	1.68	65.82	70.34	2.47	*
33	81.91	2.89	78.54	87.28	3.53	84.91	3.55	80.89	90.66	4.19	NS
Sw	104.46	2.86	100.44	107.35	2.74	107.77	3.24	103.94	112.68	3	NS
Di	25.56	3.17	21.32	29.74	12.4	26.7	2.02	24.42	30.46	7.58	NS

Note: 27: neurocranium length, 28: viscerocranium length, 29: greatest length of the lacrimal, 30: from the aboral margin of one occipital condyle to the infraorbitale of the same side, 31: lateral length of the premaxilla, 32: greatest inner length of the orbit, 33: greatest inner height of the orbit, Sw: zygomatic width (the distance between two zygomatic arches), Di: the distance from infraorbital foramen to facial tuberosity. CV, Coefficient of variations; NS, Not significant; SD, Standard deviation. *p < 0.

Table IV. Craniometric measurements of Hasmer and Hasak sheep (occipital view).

Measurement	HASAK (n=8)					HASMER (n=8)					
No	Mean	SD	Min	Max	CV	Mean	SD	Min	Max	CV	*p* value
34	120.11	3.66	117.35	127.19	3.04	122.86	3.07	118.45	126.89	2.5	NS
35	78.33	3.88	72.17	82.83	4.95	82.23	4.87	77.41	88.91	5.93	NS
36	31.63	2.17	28.93	34.19	6.85	32.92	2.63	29.08	35.85	7.99	NS
37	41.45	1.91	40.02	45.2	4.62	43.41	3.6	40.33	49.25	8.29	NS
38	71.88	1.62	70.17	74.2	2.25	75.32	3.66	70.55	79.28	4.87	NS

Note: 34: greatest mastoid breadth, 35: greatest breadth of the occipital condyles, 36: greatest breadth of the bases of the paraoccipital processes, 37: greatest breadth of the foramen magnum, 38: height of the foramen magnum. CV, Coefficient of variations; NS, Not significant; SD, Standard deviation.

Table V. Craniofacial indices of Hasmer and Hasak sheep.

Measurement	HASAK (n=8)					HASMER (n=8)					
No	Mean	SD	Min	Max	CV (%)	Mean	SD	Min	Max	CV (%)	*p* value
I1	89.73	4.12	85.08	93.98	4.59	87.3	4.32	82.84	94.07	4.95	NS
I2	37.15	2.72	33.81	41.23	7.33	36.83	2.89	32.46	39.87	7.86	NS
I3	52.12	1.62	49.9	54.09	3.11	53.28	3.94	46.71	58.32	7.4	NS
I4	30.32	2.34	27.11	33.8	7.73	30.72	2.01	27.98	33.53	6.53	NS
I5	45.71	1.03	44.33	46.9	2.25	46.36	2.36	43.73	50.62	5.09	NS
I6	109.33	2.23	105.43	111.33	2.04	110.84	4.81	103.52	117.58	4.34	NS
I7	92.21	3.16	86.79	95.75	3.43	90.65	5.31	84.93	98.74	5.86	NS

Note: I1: Facial index. I2: nasal index. I3: neurocranium index. I4: basal index. I5: skull index. I6: orbital index. I7: foramen magnum index. CV. Coefficient of variations; NS. Not significant; SD. Standard deviation.

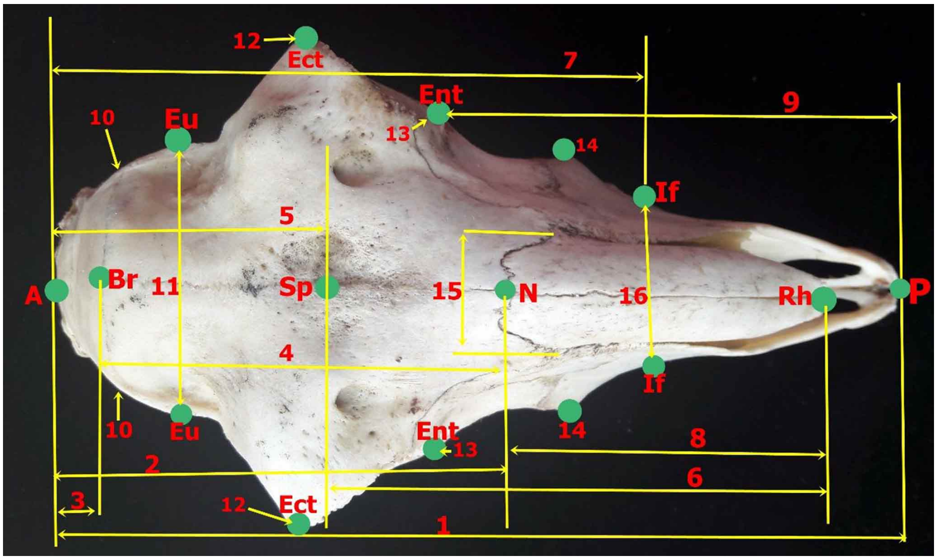

Fig. 1. Measurements of the skull of the Hasmer sheep (dorsal view). A: Akrokranion; Br: Bregma; Ect: Ectorbitale; Ent: Entorbitale; Eu: Euryon; If: Infraorbitale; N: Nasion; P: Prosthion; Rh: Rhinion; Sp: Supraorbitale; 1:profile length; 2:median frontal length; 3:akrokranion-bregma; 4:frontal length; 5:upperneuro cranium length; 6:facial length; 7:akrokranion-infraorbitale of one side; 8:greatest length of nasals; 9:short lateral facial length; 10:least breadth of the parietal; 11:greatest neurocranium breadth; 12:greatest breadth across the orbits; 13:least breadth between the orbits; 14:facial breadth; 15:greatest breadth across the nasals; 16:greatest breadth across the premaxillae.

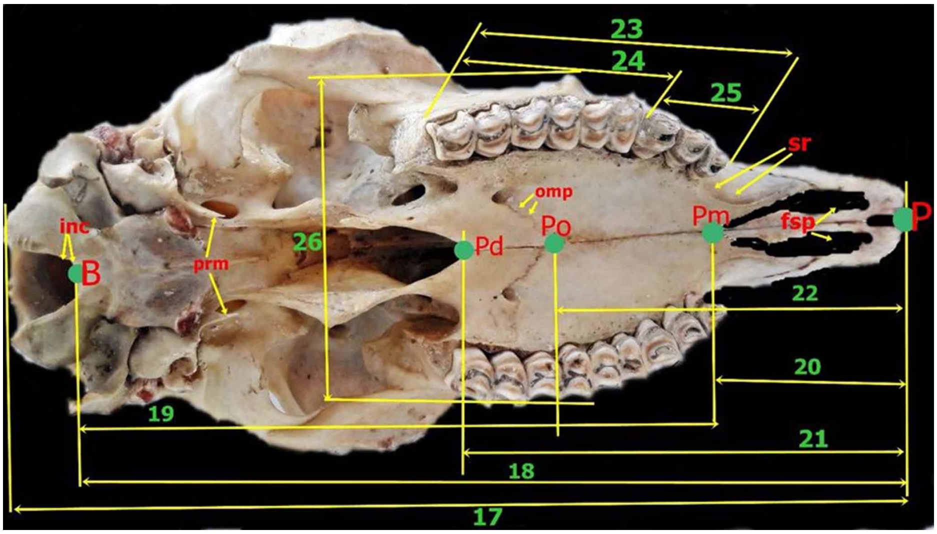

Fig. 2. Measurements of the skull of the Hasmer sheep (ventral view). B: Basion; P: Prosthion; Pd: Postdentale; Pm: Premolare; Po: Palatino orale; sr: Shaperidge; fsp: Fissura palatina; prm: Processus muscularis; inc: Incisura intercondylaris; omp: Processus palatine of the os maxilla; 17: condylo basal length; 18: basal length; 19: short skull length; 20: premolare-prosthion; 21: dental length; 22: oral palatal length; 23: length of the cheek too throw; 24: length of the molarrow; 25: length of the premolarrow; 26: greatest palatal breadth.

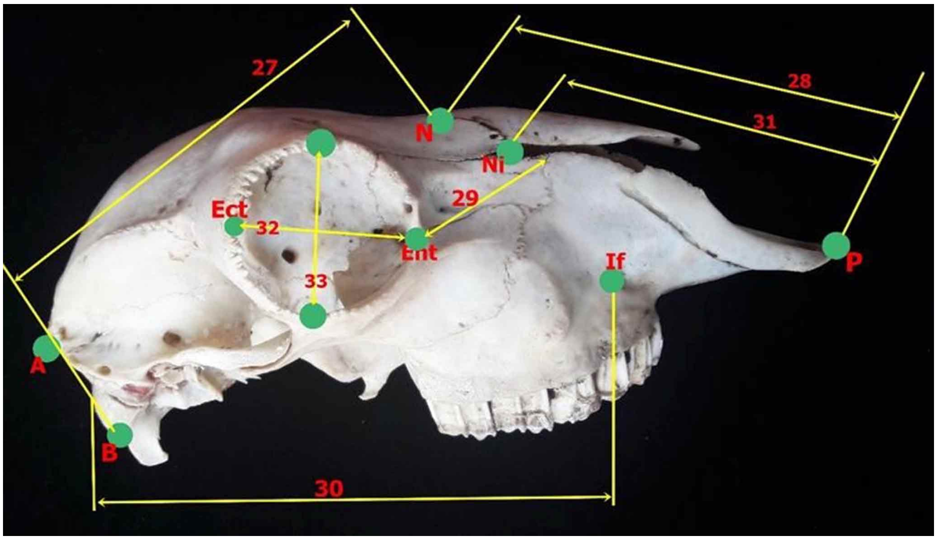

Fig. 3. Measurements of the skull of the Hasmer sheep (lateral view). A: Akrokranion; B: Basion; Ect: Ectorbitale; Ent: Entorbitale; If: Infraorbitale; N: Nasion; Ni: Nasointermaxillare; P: Prosthion; 27: neurocranium length; 28:viscerocranium length; 29:greatest length of the lacrimal; 30:from the aboral margin of one occipital condyle to the infraorbitale of the same side; 31:lateral length of the premaxilla; 32:greatest inner length of the orbit; 33:greatest inner height of the orbit.

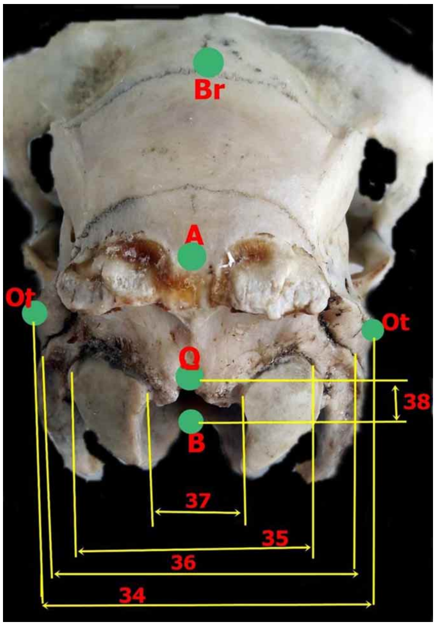

Fig. 4. Measurements of the skull of the Hasmer sheep (occipital view)A: Akrokranion; B: Basion; Br: Bregma; O: Opisthion; Ot: Otion; 34:greatest mastoid breadth; 35:greatest breadth of the occipital condyles; 36:greatest breadth of the bases of the paraoccipital processes; 37:greatest breadth of the foramen magnum; 38:height of the foramen magnum.

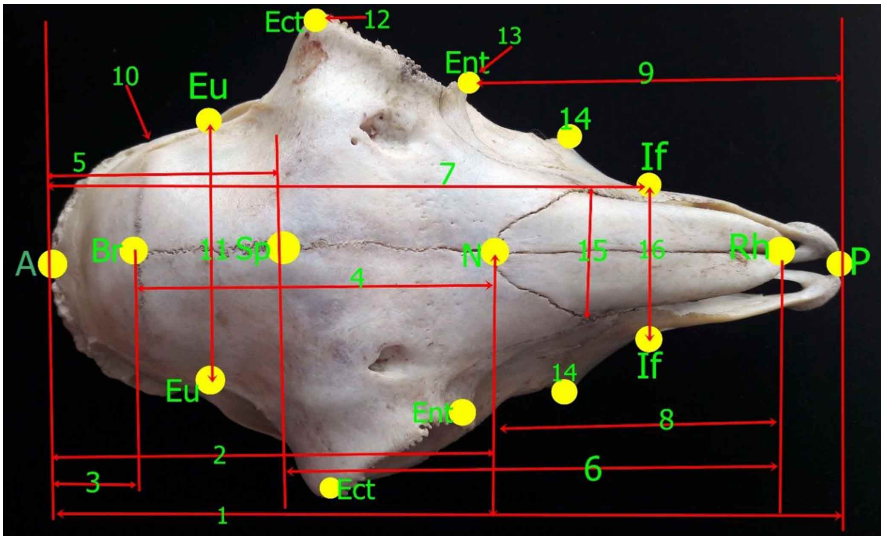

Fig. 5. Measurements of the skull of the Hasak sheep (dorsal view). A: Akrokranion; Br: Bregma; Ect: Ectorbitale; Ent: Entorbitale; Eu: Euryon; If: Infraorbitale; N: Nasion; P: Prosthion; Rh: Rhinion; Sp: Supraorbitale; 1:profile length; 2:median frontal length; 3:akrokranion-bregma; 4:frontal length; 5:upper neurocranium length; 6:facial length; 7:akrokranion-infraorbitale of one side; 8:greatest length of nasals; 9:short lateral facial length; 10:least breadth of the parietal; 11:greatest neurocranium breadth; 12:greatest breadth across the orbits; 13:least breadth between the orbits; 14:facial breadth; 15:greatest breadth across the nasals; 16:greatest breadth across the premaxillae.

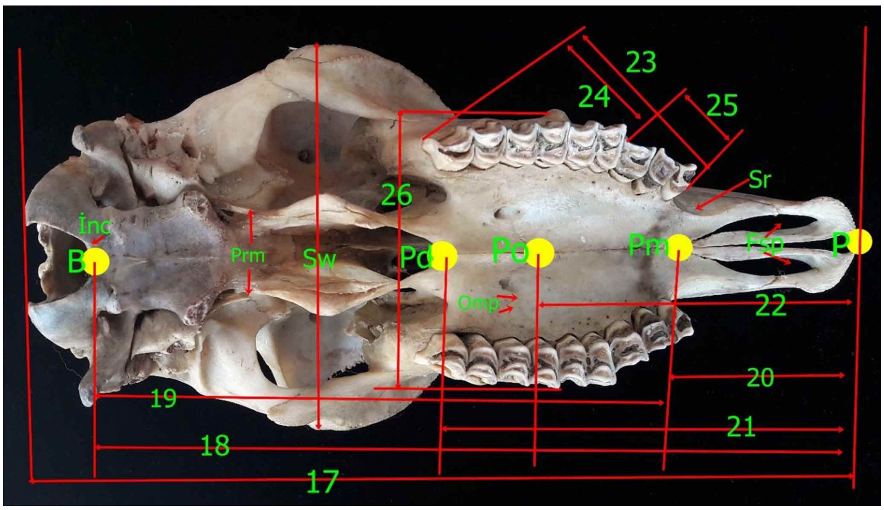

Fig. 6. Measurements of the skull of the Hasak sheep (ventralview). B: Basion; P: Prosthion; Pd: Postdentale; Pm: Premolare; Po: Palatinoorale; Sw: Zygomatic width; sr: Shaperidge; fsp: Fissura palatina; prm: Processus muscularis; inc: Incisura intercondylaris; omp: Processus palatine of the os maxilla; 17: condylo basal length; 18: basal length; 19:short skull length; 20:premolare-prosthion; 21: dental length; 22: oral palatal length; 23: length of the cheek too throw; 24:length of the molarrow; 25: length of the premolarrow; 26: greatest palatal breadth.

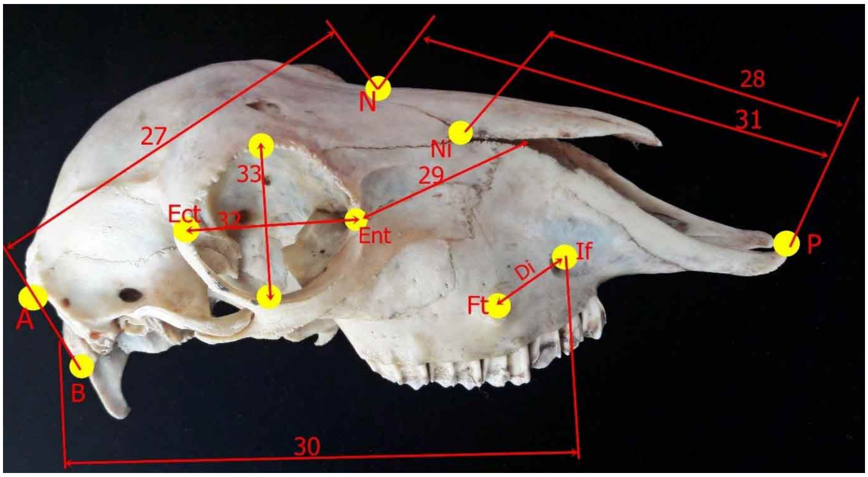

Fig. 7. Measurements of the skull of the Hasak sheep (lateralview). A: Akrokranion; B: Basion; Ect: Ectorbitale; Ent: Entorbitale; If: Infraorbitale; N: Nasion; Ni. Nasointermaxillare; P: Prosthion; Di: The distance from infraorbital foramen to facial tuberosity; 27:neurocranium length; 28:viscerocranium length; 29:greatest length of the lacrimal; 30:from the aboral margin of one occipital condyle to the infraorbitale of the same side; 31:lateral length of the premaxilla; 32:greatest inner length of the orbit; 33:greatest inner height of the orbit.

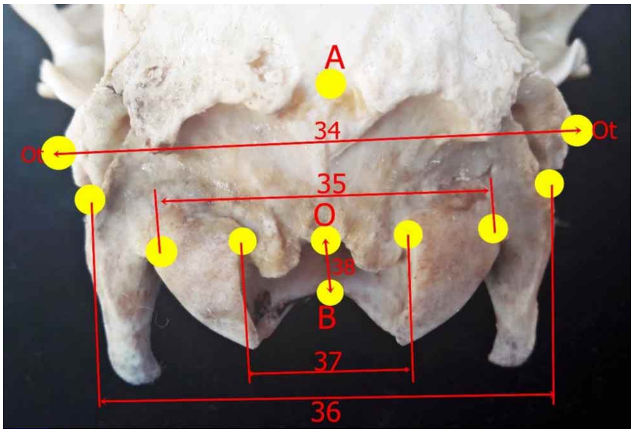

Fig. 8. Measurements of the skull of the Hasak sheep (occipitalview). A: Akrokranion; B: Basion; O: Opisthion; Ot: Otion; 34. Greatest mastoid breadth; 35:greatest breadth of the occipital condyles; 36:greatest breadth of the bases of the paraoccipital processes; 37:greatest breadth of the foramen magnum; 38:height of the foramen magnum.

DISCUSSION

In the study, the skull length was determined as 265.56 ± 14.08 mm in Hasmer sheep and 262.86 ± 9.65 mm in Hasak sheep. This value was found to be 209 ± 4.77 mm in Iranian native sheep (Monfared, 2013), 200.6 ± 0.6 mm in Mehraban sheep (Karimi *et al*., 2011), 246.5 ± 2.16 mm in Barbados Black Belly sheep (Mohamed *et al*., 2016), Tuj sheep (Özcan *et al*., 2010) 198.08 ± 7.69 mm and 204.49 ± 9.71 mm in Morkaraman sheep (Özcan *et al*., 2010), 241.20 ± 25.17 mm in Hemshin sheep (Dalga *et al*., 2018), Suffolk Down sheep (de la Barra *et al*., 2020) 238.3 ± 2.07 mm, Kosovo Bardhoka sheep (Gündemir *et al*., 2020), 245.25 ± 10.24 mm, Zell sheep (Marzban Abbasabadi *et al*., 2020) 196.73 ± 0.60 mm, Yankasa sheep (Shehu *et al*., 2019), 325 ± 0.99 mm, I˙vesi sheep (Yılmaz & Demircioglu, 2020) 241.30 ± 14.01 mm and Xisqueta sheep (Parés I Casanova *et al*., 2010) 265.51 ± 22.24 mm. According to these reported values, the skull length of Hasmer and Hasak sheep was smaller than that of Yankasa sheep, although it was almost equal to Xisqueta sheep and Hasmer sheep, it was observed that they were larger than the Hasak sheep, however, the skulls of these two species used in the study were longer than all other species.

Skull index value was 51.36 ± 0.69 mm in Morkaraman sheep (Özcan *et al*., 2010), 50.42 ± 0.78 mm in Tuj sheep (Özcan *et al*., 2010), 53.57 ± 3.26 mm in Mehraban sheep (Karimi *et al*., 2011), 47.77 ± 3.23 mm in I˙vesi sheep (Yılmaz & Demircioglu, 2020), 44.69 ± 4.29 mm in Xisqueta sheep (Parés I Casanova *et al*., 2010), and 41.69 ± 1.74 mm in Bardhoka sheep of Kosovo (Gündemir *et al*., 2020). This value was measured as 46.36 ± 2.36 mm in Hasmer sheep and 45.19 ± 0.81 mm in Hasak sheep and it was only larger than the Bardhoka sheep of Kosovo and Xisqueta sheep in terms of index.

The distance between two arcus zygomaticus was reported as the widest part of the skull in canine (Onar & Pazvant, 2001), camel (Al-Sagair & El-Mougy, 2002) and Kagani goats (Sarma, 2006). Yılmaz and Demirciog˘lu (2020) and Özcan *et al*. (2010) stated that the widest part of the skull in sheep was the frontal width (ectorbitale - ectorbitale) due to morphological differences. Accordingly, the authors reported that this length was 102.98 ± 2.52 mm in Morkaraman sheep (Özcan *et al*., 2010), 101.66 ± 1.69 mm in Tuj sheep (Özcan *et al*., 2010) and 115.07 ± 7.74 mm in I˙vesi sheep (Yılmaz & Demircioglu, 2020). In this study, similar to what the authors reported in sheep (Özcan *et al*., 2010; Yılmaz & Demirciog˘lu, 2020) it was determined that the frontal width was wider than the distance between two arcus zygomaticus and it was determined that this distance was 122.86 ± 3.07 mm in Hasmer sheep and 120.11 ± 3.66 mm in Hasak sheep. According to these values, it was determined that Hasmer sheep had the largest skull structure among the mentioned sheep above.

The orbital region is a craniofacial structure that can be affected by multiple disorders such as congenital, traumatic, neoplastic, vascular, and endocrine (Acer *et al*., 2009), as it has a fundamental role in the evaluation and recognition of the craniofacial complex (Ji *et al*., 2010). Parés I Casanova *et al*. (2010) reported that the orbital index value was 109.77 ± 10.23 mm in their study on the biometric view of the skull in Spanish Xisqueta sheep. The mentioned orbital index was measured as 112.27 ± 3.50 mm in Ivesi sheep (Yılmaz & Demircioglu, 2020), 93.46 ± 3.48 in Bardhoka sheep of Kosovo (Gündemir *et al*., 2020). In the study, it was determined that the measured value in Hasmer (110.84 ± 4.81 mm) and Hasak sheep (110.49 ± 1.19 mm) was higher than only in Ivesi sheep.

While the sutura interfrontalis was not very prominent in Hasmer sheep and the suture disappeared completely in the middle part, the suture was very prominent and the caudal part was notched like a saw tooth and the cranial part was flat in Hasak sheep, as reported in Bardhoka sheep of Kosovo (Gündemir *et al*., 2020).

Hasak and Hasmer sheep were polled breeds. There was a fossa structure in Hasak and Hasmer sheep in the anterior part of the sutura coronalis, at the level of the os frontale where horn protrusions were found in Anatolian wild sheep (Yalçın & Lök, 2009).

Although it was stated that the fronto-nasal sutura in the Bardhoka breed sheep of Kosovo (Gündemir *et al*., 2020) and Kagani goat (Sarma, 2006) was in the shape of the letter `` V ", the frontal nasal suture of the Hemshin sheep skull (Dalga *et al*., 2018) had the shape of the letter ‘’U ". In present study, it was determined that the fronto-nasal suture resembles the letter "U" in Hasmer sheep like the Hemshin sheep skull and "V" in Hasak sheep as in Bardhoka breed sheep of Kosovo and Kagani goat.

It was reported that although the palato-maxillary suture between the lamina horizontalis of the os palatina and the processus palatine of the os maxilla was in the shape of the letter "U" in Mehraban sheep (Karimi *et al*., 2011), and Bardhoka breed sheep of Kosovo (Gündemir *et al*., 2020) in the form of the letter "V". In the study, it was determined that palato-maxillar suture in Hasmer and Hasak sheep resembles the letter "V" as in Bardhoka breed sheep (Gündemir *et al*., 2020).

Although there was no statistically significant difference between most of the results of the two species compared, there were some differences, possibly due to individual variation. In the studies, it was observed that the values of greatest breadth of the foramen magnum, height of the foramen magnum (basion - opisthion), greatest neurocranium breadth-greatest breadth of the braincase (euryon - euryon) measured in Hasmer sheep were higher than the Hasak sheep (p <0.05).

CONCLUSION

As a result; this study is important because it is the first study about the head structures of Turkey’s domestic two sheep breeds. It is thought that the difference between the skulls of Hasak and Hasmer sheep may be due to the breeds of these sheep. In addition, this research will contribute to the clinical approach, paleontological studies and to the literature on the subject.

CAN, M. ; ÖZÜDOGRU, Z. & ILGÜN, R. Un estudio morfométrico de cráneos de razas de ovejas Hasmer y Hasak. *Int J. Morphol., 40(6)*:1536-1545, 2022.

RESUMEN: El objetivo del estudio fue investigar las estructuras de la cabeza de dos razas de ovejas domésticas (Hasak y Hasmer) de Turquía. En este estudio se utilizaron ocho ovejas Hasmer adultas de género neutral de 45-66 kg y ocho ovejas de raza Hasak de 43-66 kg, obtenidas del Instituto Internacional de Investigación Agrícola Bahri Dagdas. Las mediciones en los cráneos de ambas especies se realizaron con caliper digital de 40 puntos. El cráneo de la oveja Hasmer (265,56 ± 14,08 mm) era más largo que el cráneo que el de la oveja Hasak (262,86 ± 9,65 mm). En las ovejas Hasak la longitud del arcus alveolaris maxillaris fue 77,01 ± 5,08 mm, la longitud de los dientes molares fue 50,81 ± 1,22 mm y la longitud de los dientes premolares fue de 26,16 ± 4,62 mm, en cambio en las ovejas Hasmer fue de 71,59, ± 5,25 mm; 47,99 ± 3,64 mm; 24,03 ± 3,76 mm, respectivamente. Según estos hallazgos, la longitud del cráneo de la oveja Hasak era más corta que la de la oveja Hasmer y el arcus alveolaris maxillaris en el que se colocaron los dientes molares y premolares era más largo. En ovinos Hasmer los valores de mayor amplitud del foramen magnum, altura del foramen magnum (basion - opisthion), mayor amplitud del neurocráneo-mayor amplitud de la caja craneana (euryon - euryon) fueron superiores a los de las ovejas Hasak. La diferencia entre estos valores también fue estadísticamente significativa (p <0,05). El parámetro de longitud lateral del premaxilar (nasointermaxillare-prosthion) medido entre estas dos especies fu estadísticamente significativo (p <0.01). En conclusión, los valores craneométricos en relación a la morfología del cráneo de las ovejas Hasmer y Hasak que se definieron como razas autóctonas de Turquía revelaron similitudes y diferencias con otras razas de ovejas.

PALABRAS CLAVE: Fosa mandibular; Morfometría; Proceso palatino; Morfología del cráneo.

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