RESEARCH ARTICLE

MORPHOMETRIC STUDY OF NEUROCRANIUM IN DIFFERENT MALE CHICKEN BREEDS RAISED IN TÜRKIYE

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Original Submission: 25 March 2024
Revised Submission:18 April 2024
Accepted: 22 April 2024

How to cite this article: Duro S, Ünal B, Manuta N, Çakar B, Güzel BC, Korkmazcan A. 2024. Morphometric study of neurocranium in different male chicken breeds raised in Türkiye. Veterinaria, 73(1), 44-52.

ABSTRACT

In the poultry industry, male chicks serve various purposes, depending on the specific production system and market demands, mostly for meat production. In the systems where male chicks are raised for meat production, they may be slaughtered when about six to nine weeks old. The aim of this study was to assess the male neurocranium of different chicken breeds through linear morphometric parameters. The morphometric study was undertaken on 70 skulls of the chicken breeds: 12 Ataks (AT), 12 Sasso (SS), 12 Lohmann Brown (LB), 12 Broiler (BR) and 10 Leghorn (LG) raised in Türkiye. In total, eight linear measurements were determined in accordance with the anatomical structure of the chicken skulls, and two skull indices were calculated. The data revealed that the length and width of the neurocranium of five laying hen breeds are quite similar and longerthan for the Broiler breed (BR). The longest and widest skull belong to the (SS) breed with 43.01±4.05mm and 29.12±2.61mm, respectively. The smallest skull belongs to (BR) breed with length and width of 32.07±3.38mm and 22.44±2.44mm, respectively. The cranial length (Cl) in the (AT) breed is statistically different from the (BR) breed, $p<0.001$ and (LG) breed, $p<0.05$. The maximum width of the cranium in all breeds is statistically different, $p<0.001$ from the (BR) breed, and the (SS) is statistically different from the (BR), $p<0.001$ and (LG) breed, $p<0.01$. In conclusion, the data from this study can serve for further research in the similar fields and for the comparative studies on galliform species.

Keywords: Cranium, chicken breed, linear parameters, male chicken

doi.org/10.51607/22331360.2024.73.1.44

INTRODUCTION

The domestic chicken (*Gallus gallus domesticus*) has been selectively bred for many years, and hundreds of breeds have been developed and crossed with other breeds. In Türkiye, some of these breeds are bred mainly for egg production, like Leghorn, Lohman Brown meat production, like Broiler as well as double-purpose breeds, for eggs and meat, like Sasso breed (Yıldırım and Kaya, 2017; Tutkun et al., 2018).

In the poultry industry, male chicks, also known as cockerels, serve various purposes, depending on the specific production system and market demands, mostly for meat production, but also for breeding programs, pet food, by-products, research and education.

In the systems where male chicks are raised for meat production, they may be slaughtered when about six to nine weeks old, depending on the growth rate and market demands, but usually after eight weeks of age.

The bones of the head skeleton consist of the thin plates, which are extensively pneumatised (Baumel, 1993; Bahadir, 2002; Feduccia, 1975). This is facilitated by the fusion of these bones in the relatively early stages of growth (Plateau and Foth, 2021). The boundaries between the bones of the avian neurocranium are almost indistinguishable (Koch, 1973; Baumel, 1993). The avian skull consists of two parts, the cranium (neurocranium) and the facial skeleton (viscerocranium). The skull of an avian has several adaptations to be light and aerodynamic to facilitate flight, or to ensure food intake and its swallowing (King AS, McLelland, 1975; Nickel et al., 1977; König et al., 2016).

Chicken neurocranium is the structure very well ossified, which protects the brain and makes connection with the vertebral column. Especially, the neurocranium structures have a great importance in taxonomy, evolutionary science and the comparative anatomy studies (Marugán -Lobon J, Buscalioni, 2009). Different morphological and morphometric studies are made on the avian head skeleton (Markos et al., 2024; Sridevi et al., 2020; Gündemir et al., 2020b; Verdiglione and Rizzi, 2018; Ilgun et al., 2016; Degrange and Picasso, 2010; Acosta Hospitaleche, 2009; Acosta Hospitaleche et al., 2009; Acosta Hospitaleche and Tambussi, 2006; Cakir, 2001). Other studies are focused on evolutionary and functional avian anatomy (Tokita et al., 2017; Marugán-Lobón and Buscalioni, 2006; Gussekloo et al., 2001). Additional studies are focused on the comparation and diversity (Pecsics, 2023; Zusi, 1993), or the detection of the sexual dimporphism, even if the birds do not show such clear sexual dimorphism as mammals (Szara et al., 2022a; Szara et al., 2022b; Pazvant et al., 2022; Gündemir et al., 2020a; Verdiglione and Rizzi, 2018; Rathert et al., 2017; Dillon, 2014).

Craniometry performed through different linear measurements of the head skeleton is a method that is commonly used in taxonomic studies of vertebrates, comparative anatomy, zooarchaeology, etc. (Jashari et al., 2022; Duro et al., 2021; Gündemir, 2019; Avdić et al., 2013; Bärmann et al., 2013).

For very long times, chickens have been used as a model organism for the study of the vertebrate development. The comparative morphology and morphometry of the juvenile avian skulls are poorly known, and the literature is limited. Ever since the different studies wereundertaken, their morphological variability and morphometry has never been quantified in detail for different chicken breeds.

The aim of this study was to assess the male neurocranium of different chicken breeds through linear morphometric parameters.

MATERIALS AND METHODS

Samples

The morphometrical study was undertaken on 70 skulls of six different chicken breeds: 12 Ataks (AT), 12 Sasso (SS), 12 Lohmann Brown (LB), 12 Broiler (BR) and 10 Leghorn (LG), raised in Türkiye. The skulls of two-month old male chicken were received in the slaughterhouse after they had been slaughtered. Samples with pathological morphological disorders were excluded from the study. All collected skull samples were sent to the Animal Anatomy lab and were subjected to maceration to remove the skin, muscles and soft tissues. The skulls were then boiled for 30 minutes and soaked in 35% hydrogen peroxide for 10 minutes to remove fatty, soft tissues and the splanchnocranium parts, and, finally, the clean neurocraniums were allowed to dry for 10 days at room temperature.

The eight linear measurements were determined in accordance with the anatomical structure of the chicken skulls, as described by Baumel (1993), Ino et al. (2008), Gusselkoo et al. (2001), Hall et al. (2009), Onar et al. (1997), Singh et al. (2015) and also the Nomina Anatomica Avium (NAA) (Baumel et al., 1993). The measurement points defined on the chicken neurocranium are shown in Figure 1 and 2. All linear measurements were taken in millimeters with a digital calliper (±0.2 mm). The photographs of the samples were made with a Samsung photo camera NX210 20.3 MP. The linear measurements are:

1. Cranial length (Cl): Length between Prominentia cerebellaris and the middle point of Frontonasal suture.
2. Maximum width of neurocranium (Mwn): Width between the bases of the Postorbital processes.
3. Maximum width of the neurocranium base (Mwnb): Width between the lateral edges of the Paraoccipital processes.
4. Nuchal surface height (Nsh): Height between the ventral margin of Foramen magnum and Crista nuchalis transversus in the midline.
5. Foramen magnum height (Fmh): Height between the middle of dorsal and ventral margins of Foramen magnum.
6. Foramen magnum width (Fmw): Maximum width of Foramen magnum.
7. Occipital condyle height of (Och): Height between the middle of dorsal and ventral margins of occipital condyle.
8. Occipital condyle width (Ocw): Maximum width of occipital condyle.

From these measurements were calculated also the cranial and Foramen magnum index according to the formulas:

Cranial index (CrI)= Maximum width of neurocranium x 100 /Cranial length

Foramen magnum index (FmI)= Foramen magnum height x 100 /Foramen magnum width

Statistical analysis

The statistical analysis was performed using the SPSS 22 package program, which calculated the mean values, standard deviations, minimum, maximum and P values for all measurements. ANOVA was used for comparison between groups.

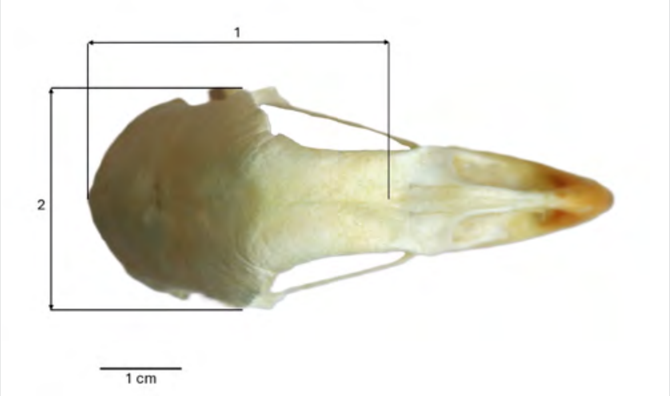

Figure 1 Linear measurements on the chicken skull (dorsal surface). Cranial length (Cl), 2. Maximum width of neurocranium (Mwn)

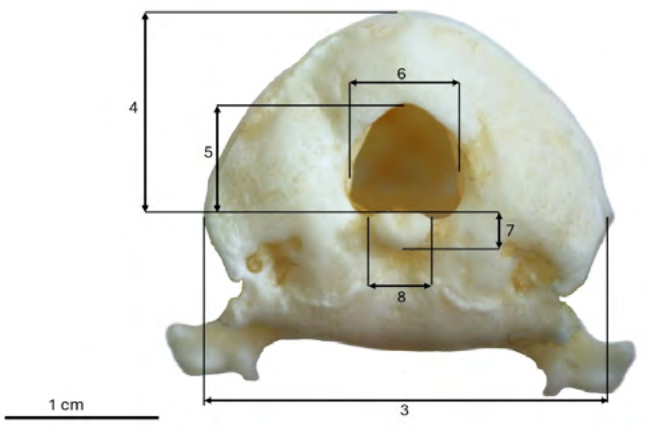

Figure 2 Linear measurements on the chicken skull (nuchal surface). Maximum width of the neurocranium base (Mwnb), 4. Nuchal surface height (Nsh), 5. Foramen magnum height (Fmh), 6. Foramen magnum width (Fmw), 7. Occipital condyle height of (Och), 8. Occipital condyle width (Ocw)

RESULTS

The linear measurements of the neurocranium for six breeds of male chicken are presented in Table 1 as mean, standard deviation and minimum and maximum values.

Table 1 Morphometric linear parameters in male skulls of different breeds of chicken

Measure-ments	Data	AT	LB	SD	SS	BR	LG
(mm)	**N**	**12**	**12**	**12**	**12**	**12**	**10**
	Min	38.21	40.86	35.19	39.04	26.62	36.49
Cl	Max	45.95	44.56	44.55	53.79	39.63	39.56
	Mean	41.88	42.26	39.21	43.01	32.07	38.11
	Stand. dev	2.39	1.20	2.61	4.05	3.38	1.05
	Min	26.30	26.87	26.31	26.80	17.86	23.29
Mwn	Max	28.54	28.87	29.22	35.89	27.28	28.81
	Mean	27.29	27.80	27.48	29.12	22.44	26.46
	Stand. dev	0.69	0.62	0.93	2.61	2.44	1.51
	Min	26.40	27.17	25.50	26.51	24.14	25.83
Mwnb	Max	28.18	28.81	29.30	34.99	28.75	28.12
	Mean	27.55	27.77	27.22	28.68	25.75	26.85
	Stand. dev	0.58	0.51	1.22	2.47	1.34	0.70
	Min	10.80	12.66	13.01	12.47	10.11	11.40
Nsh	Max	13.16	14.23	13.96	29.23	14.46	13.30
	Mean	11.78	13.40	13.36	15.36	11.83	12.34
	Stand. dev	0.64	0.48	0.30	4.69	1.19	0.66
	Min	6.86	6.96	6.88	7.44	6.17	3.58
Fmh	Max	8.03	8.34	8.53	8.99	8.24	7.43
	Mean	7.43	7.51	7.52	8.11	7.01	6.23
	Stand. dev	0.42	0.40	0.53	0.44	0.59	1.06

	Min	7.85	8.18	7.19	7.76	6.99	5.85
Fmw	Max	9.92	10.38	9.03	9.23	8.53	8.14
	Mean	8.80	8.87	8.60	8.71	7.61	7.42
	Stand. dev	0.52	0.64	0.57	0.45	0.43	0.62
	Min	2.41	2.71	2.20	2.82	2.07	2.63
Och	Max	3.52	3.51	3.22	3.46	3.93	4.05
	Mean	3.02	2.93	2.84	3.05	2.85	3.05
	Stand. dev	0.30	0.24	0.30	0.18	0.51	0.43
	Min	3.37	3.63	3.57	3.85	4.10	3.67
Ocw	Max	4.82	4.64	4.74	5.66	5.29	4.23
	Mean	4.14	4.19	4.19	4.44	4.79	3.93
	Stand. dev	0.42	0.26	0.36	0.46	0.31	0.17

The data show that the length and width of the neurocranium of five laying hen breeds are quite similar and longer for the broiler breed (BR).

The other linear measurements show less differences between the breeds. The longest and widest skull belong to the (SS) breed with 43.01±4.05mm and 29.12±2.61mm, respectively. The smallest skull belongs to (BR) breed with the length and width of 32.07±3.38mm and 22.44±2.44mm, respectively.

Table 2 shows the ANOVA results of comparisons of the neurocranium linear parameters between the chicken breeds.

Table 2 ANOVA results of linear morphometric parameters in male skulls of different chicken breeds

Measurements	Breeds	LB	SD	SS	BR	LG
	AT	0.9994	0.1652	0.9103	p<0.001	p<0.05
Cl	**LB**		0.07778	0.9838	p<0.001	p<0.001
	SD			p<0.05	p<0.001	0.9332
	SS				p<0.001	p<0.001
	BR					p<0.001
Mwn	**AT**	0.9743	0.9998	0.09256	p<0.001	0.8585
	LB		0.9969	0.3929	p<0.001	0.4312
	SD			0.1693	p<0.001	0.7185
	SS				p<0.001	p<0.01
Mwnb	**BR**					p<0.001
	AT	0.9985	0.9901	0.318	p<0.05	0.8275
	LB		0.9096	0.5658	p<0.01	0.5966
	SD			0.09458	0.09228	0.988
Nsh	**SS**				p<0.001	p<0.05
	BR					0.3963
	AT	0.3901	0.4238	p<0.01	1	0.9884

	LB		1	0.1986	0.425	0.8275
Fmh	**SD**			0.1775	0.4599	0.853
	SS				p<0.01	p<0.05
	BR					0.9924
	AT	0.9996	0.9994	0.07374	0.5081	p<0.001
Fmw	**LB**		1	0.1524	0.3171	p<0.001
	SD			0.159	0.3064	p<0.001
	SS				p<0.001	p<0.001
	BR					p<0.05
Och	**AT**	0.9996	0.9427	0.9982	p<0.001	p<0.001
	LB		0.8234	0.9763	p<0.001	p<0.001
	SD			0.9966	p<0.001	p<0.001
	SS				p<0.001	p<0.001
Ocw	**BR**					0.9697
	AT	0.984	0.7756	0.9999	0.8077	1
Cl	**LB**		0.9877	0.9468	0.9921	0.9566
	SD			0.6452	1	0.6906
	SS				0.683	1
	BR					0.7254
Mwn	**AT**	0.9997	0.9993	0.3326	p<0.001	0.7299
	LB		1	0.5118	p<0.01	0.5493
	SD			0.5431	p<0.01	0.5195
	SS				0.147	p<0.05
	BR					p<0.001

The cranial length (Cl) in the (AT) breed is statistically different from (BR) breed, p<0.001 and (LG) breed, p<0.05, but the (SS) breed is statistically different from the (LB) breed, p<0.001, (BR) breed, p<0.001 and (LG) breed, p<0.001.

The maximum width of the cranium of all breeds is statistically different, p<0.001 from the (BR) breed, and the (SS) is statistically different from the (BR), p< 0.001 and (LG) breed, p<0.01.

No statistical differences are shown in the Occipital condyle height of (Och).

The parameters for the BR and LG breeds are the most statistically different from all other breeds in this study.

Based on the cranial index (Table 3), the (AT) and (LB) breeds have the longest skulls compared to the (SD), (BR) and (LG) breeds, which were more quadrate in shape.

Table 3 Skull indices

Indices	**Breeds**					
	AT	**LB**	**SD**	**SS**	**BR**	**LG**
Cranial Index	65.14	65.79	70.08	67.71	69.97	69.43
Foramen magnum Index	84.43	84.66	87.38	93.15	92.11	83.94

From the data of the Foramen magnum index, the (SS) and (BR) breed have Foramen magnum more circular than the others, while the (LG) breed had the shortest parameters of Foramen magnum, and its shape was more triangular.

DISCUSSION AND CONCLUSION

The chicken neurocranium is small, compact and very well-ossified structure with the very smooth external surface (Baumel, 1993; Nickel et al., 1977; König et al., 2016; Süzer et al., 2018). Based on the study of Plateau and Foth (2021), the neurocranium of the chicken is fully mature in the first months of their life, which is demonstrated by the invisibility of the sutures between the bones, especially in the nuchal and frontal areas.

For decades, chickens have been used as a model organism for the study of vertebrate development, but their morphological and morphometric variability has never been quantified, and the skull anatomy of the breeds in comparison to fowl has never been described (Davey and Tickle, 2007).

The linear parameters based on well- defined structures of the chicken neurocranium have great importance in assessing the skull dimensions, their shape and type in order to compare it among the breeds, or to compare it with other avian species.

The results of this study present some crucial linear parameters of the neurocranium in six different breeds of male chicken which can help to assess the skull dimensions, predict the growth dynamic and also be used in the taxonomic studies.

In general, the shape and size of the male chicken neurocranium measured in this study show that the larger skull belongs to the double production-breeds like Sasso (SS) and the smallest, the Broiler breed, and this is significantly affected bythe genotype also in all studied linear parameters (Verdiglione and Rizzi, 2018).

There is not much information in the literature about the morphometrical parameters of the poultry species skulls in general, and the comparisons with other poultry species are limited.

The study shows full ossification skulls with the invisible sutures in all six chicken breeds.

Foramen magnum, in almost a triangular shape was positioned in the centre of the nuchal surface, and its width ranged from 27.64% in LG to 31.95% in AT, LB and 29.53% in BR. This demonstrates a big difference between laying hens and broilers, which means the opening for the spinal cord is larger in egg-producing chicken in compare to the broilers. The data from this study on male chicken are a bit different in comparison with those of *Amazona aestiva* species, which represents 22.6% of the skull maximum caudal width, and of *Diopsittaca nobilis* species with 20.2% (Souza et al., 2017).

Based on the measurements of the length and maximum width of the neurocranium of the male chickens for the egg-producing part of the study, which ranged from 26.46 mm to 29.12 mm, we can say that the data are quite comparable with Padovana chicken weighing 1798 g, and the skull weight was 26.3 mm (Verdiglione and Rizzi, 2018). This is potentially another argument in favor of full ossifications of the skull in the age of about eight to ninth weeks. These data can support the similarities among the avian neurocraniums, mostly in domesticated species, which can be explained by the domestication process (Stange at al., 2018).

In conclusion, the data from this study can serve for further research in the similar fields and for the comparative studies on galliform species.

CONFLICTS OF INTEREST

The authors do not have any conflicts of interest to declare.

CONTRIBUTIONS

Concept – SD, NM; Design – SD, BU, BC; Supervision – SD, BCC; Resources –BU, NM, BC; Materials – AK, BC; Data Collection and Processing – BU, NM; Analysis and Interpretation – BCC, BU, NM; Literature Search – BC, BCC, AK; Writing Manuscript – SD, BCC; Critical Review – BU, NM, BC.

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MORFOMETRIJSKA STUDIJA NEUROKRANIJUMA KOD RAZLIČITIH SOJEVA MUŠKIH PILIĆA UZGOJENIH U TURSKOJ

SAŽETAK

U peradarstvu se muški pilići koriste u različite svrhe u ovisnosti od specifičnog sistema proizvodnje i zahtjeva tržišta, uglavnom za proizvodnju mesa. U sistemima u kojima se muški pilići uzgajaju zbog proizvodnje mesa, pilići se mogu klati u uzrastu od šest do devet sedmica. Cilj našeg istraživanja je procijeniti neurokranijume muških pilića različitih sojeva korištenjem linearnih morfometrijskih parametara. Proveli smo morfometrijsko istraživanje na 70 lubanja različitih sojeva pilića: 12 Ataka (AT), 12 Sasso (SS), 12 Lohmann Brown (LB), 12 Broiler (BR) i 10 Leghorn (LG) pilića uzgojenih u Turskoj. Obavljeno je ukupno osam linearnih mjerenja prema anatomskoj strukturi pilećih lubanja, pri čemu su izračunata po dva lubanjska indeksa. Podaci su pokazali da su dužina i širina neurokranijuma kod pet vrsta pilića dosta slični međusobno i da su veći nego kod soja Broiler (BR). Najduža i najšira lubanja pripadaju soju SS i iznose 43.01±4.05 mm, odnosno 29.12±2.61 mm. Najmanja lubanja pripada soju BR sa dužinom i širinom od 32.07±3.38 mm, odnosno 22.44±2.44 mm. Kranijalna dužina (Cl) kod soja AT se statistički signifikantno razlikuje u odnosu na soj BR, $p<0.001$ i soj LG, $p<0.05$. Maksimalna širina kranijuma kod svih sojeva se statistički signifikantno razlikuje, $p<0.001$, u odnosu na soj BR sa statističkom signifikantnošću od $p<0.001$ za sojeve SS i BR i $p<0.01$ za LG. Možemo zaključiti da podaci iz ovog istraživanja mogu biti korišteni za daljnja istraživanja u sličnim poljima, kao i za komparativne studije galiformnih vrsta.

Ključne riječi: Kranijum, linearni parametri, muški pilići, vrsta pilića