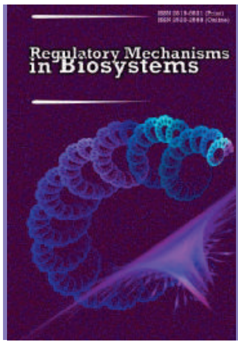

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Morphology and morphometric features of the cerebellum of poultry

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The connection of the cerebellum with the structural parts of the brain and the complex neural system of processing information coming to its cortex make it unique in terms of the variety of functions it performs. The cerebellum is not only the center of coordination of movements and balance but also participates in the regulation of many other functions of the body. The article presents research results into the macro- and microscopic structure and features of the morphometry of the cerebellum of poultry, which belong to the vertebrate subtype, class Aves – birds. For their implementation, the selected material (cerebellum, n = 6) was subjected to fixation in a 10–12% neutral formalin solution, followed by embedding in paraffin. From paraffin blocks, histological sections with no more than 10 μm thickness were made. Staining of tissue preparations with hematoxylin and eosin was used to study cell morphology, conduct morphometric studies, and obtain review histological sections, as well as neurohistological methods of impregnation of nerve tissue with silver nitrate according to Bolshovsky Gros and Ramon-i-Cajal. According to research results, the cerebellum in birds is located between the cerebrum and midbrain, dorsal to the medulla oblongata. The body and two (right and left) lateral ears form the cerebellum. The organ's surface is divided into lobes by numerous furrows; the latter are united into three lobes: front, middle, and back. In the lateral projection, the cerebellum is triangular, with a ventrally elongated apex. In the birds we studied, the cerebellum is characterized by the general principles of its structural organization and morphotopography but differs in its organometallic indicators. According to organometry, the absolute mass of the cerebellum in poultry is different: the largest in turkeys, the smallest in geese, then in ducks, and the smallest in chickens. The relative mass of the cerebellum changes synchronously with the absolute mass and is 0.047% in turkeys, 0.041% in geese, 0.036% in ducks, and 0.023% in chickens. The microscopic structure of the cerebellum of domestic birds has a similar structural organization: gray (cortex) and white matter are differentiated on a cross-section. Molecular, ganglionic, and granular layers form gray matter. It is characterized by a heterogeneous population of neurocytes, which have a determined relationship between the level of the morphofunctional state of the nervous and innervated structures. According to the results of histometry, the thickness of the cerebellar cortex of birds is different: in chickens – 350.7 ± 12.68 μm, in turkeys – 404.25 ± 5.76, in ducks – 376.29 ± 5.34, in geese – 234.85 ± 2,43 μm. The most significant thickness in all birds is characteristic of the granular layer, somewhat smaller – molecular, and the smallest - in the ganglionic layers. According to the cytometry results, the smallest volume of Purkinje cells, characteristic of the cerebellum of the domestic chicken, is somewhat more significant for the domestic duck, followed by geese and turkeys. At the same time, the nuclear-cytoplasmic ratio of Purkinje cells has different values: the highest indicator is found in geese, approximately – in ducks and turkeys, significantly 1.75 times lower – in chickens. The conducted results expand and supplement the information on the macro- and microscopic structure of the cerebellum regarding the species characteristics of domestic birds, which is of relevance for anatomy, histology, comparative anatomy, forensic veterinary medicine, zoology, etc.

Keywords: nervous system; macro- and microscopic structure; organometry; cytometry; Purkinje cells; nuclear-cytoplasmic ratio.

Introduction

As a result of intensive animal husbandry, there was a need for a thorough, comprehensive study of the structure of all organs and body systems (Franco, 2013; Karpenko et al., 2022; Martyshuk et al., 2022; Radzykhovskyi et al., 2022). An urgent issue that requires the attention of scientists – morphologists is the study of the development, growth, and formation of parameters of the structural features of organs and tissues, in particular, organs of the nervous system, which occupies a significant place in the regulation of all vital processes of living organisms (De Moraes et al., 2017). Particular interest in the study of the organs of the nervous system is due to its various properties and functions: perception and conduction of nerve impulses, generation, transformation, storage of energy of different types and information of the external environment, the ability of the nervous system to excite, inhibit, trophic function, etc. (Karpovskiy et al., 2014; Ladle & Hippenmeyer, 2023).

The nervous system ensures the relationship of the organism with the environment (Sokulskyi et al., 2021) is one of the priority integrating systems of the organism, which, together with the endocrine and cardiovascular systems, unites the organism into a single whole, ensuring its communication with the internal and external environment (Grechukha & Otych, 2020). Organs of the nervous system coordinate and regulate blood and lymph circulation and metabolic processes, which, in turn, affect the state of the nervous system (Garman, 2011; Shnurenko et al., 2020). The nervous system of the human and animal body perceives information of various kinds that comes from the external environment and internal organs, analyzes it, and generates signals that provide appropriate reactions adequate to the active stimuli (Dehtyarenko, 2018).

The morphoarchitectonics of the nervous system, in general, and its departments in particular, is determined by the location of animals in the phylogenetic series and the conditions of their living in the environment (Budd, 2015). In evolutionary development, the nervous system regulates, controls, and ensures the vital activity of the organism: development, growth, differentiation of cells and tissues, and interaction between them (Grechukha & Otych, 2020).

Recently, many studies have been conducted on the macro- and microscopic structure and development of the nervous system in vertebrates, particularly the cerebellum in phylogeny (Smaers et al., 2018), ontogenesis (Amore et al., 2021), and experiment (Ramezani et al., 2012; Voogd, 2012; Zhang et al., 2016). At the same time, the histo- and cytometric evaluation of the cerebellum in domestic animals and their comparative characteristics are incompletely covered in the literature.

It is necessary to note evolutionary changes in the organization of the development of the central nervous system and behavior in birds. Compared to reptiles, the brains of birds are more significant, which provides them with a high level of neural activity and behavior (Jarvis et al., 2005). Birds have well-developed senses. This is most clearly manifested concerning the so-called "distant sense organs" – vision and hearing and the corresponding centers in the brain. The complex nature of bird flight is associated with the significant development of the cerebellum, the center of coordination of the motor activity of birds (Wylie et al., 2018). At the same time, its sections play a dominant role in the regulation of movements of various motor apparatuses (Zhu et al., 2004; Zhu & Wang, 2008), functionally connecting them with the muscles of the animal body, ensuring coordination of movements, regulation of balance and muscle tone (Sultan & Glickstein, 2007; Lu et al., 2012). Separate sections of the cortex of each cerebellar hemisphere are connected to other sections of the same hemisphere utilizing bundles of arcuate fibers. These cerebellum associative systems connect adjacent and relatively distant cortical areas of the hemispheres (Lavezzi et al., 2006; Goswami et al., 2014). The cerebellum is connected to almost all parts of the central nervous system by conducting pathways (Zhu et al., 2006; Timmann & Daum, 2007). In addition, the cerebellum is involved in the regulation of visceral functions – the activity of the cardiovascular, respiratory, and immune systems (Cavdar et al., 2001; Zhang et al., 2016) and in the work of cognitive functions – the ability to understand, learn, perceive, realize, process external information (Gottwald et al., 2004; Azevedo et al., 2009; E et al., 2014).

Our work aimed to find out the anatomical and histological structure and morphometric indicators of the cerebellum of domestic poultry belonging to the vertebrate subtype, class Aves – birds (*Gallus gallus* forma *domestica* L., 1758 – domestic chicken, *Meleagris gallopavo* forma *domestica* L., 1758 – turkey, *Anas platyrynchos* forma *domestica* L., 1758 – domestic duck, *Anser caerulescens* forma *domestica* L., 1758 – goose).

Therefore, one of the urgent tasks of neuromorphology today is the study of the structural and functional features of the nervous system in domestic animals, including the cerebellum, which is the center of balance and coordination of movements and ensures the maintenance of muscle tone.

Materials and methods

The research was conducted with the Department of Normal and Pathological Morphology, Hygiene, and Expertise (Polissia National University) and the Department of Zoology, Biological Monitoring and Nature Protection (Zhytomyr Ivan Franko State University). The research was conducted in compliance with the rules of laboratory practice GLP (1981) and the provisions of the "General ethical principles of animal experiments", which were approved by the first National Congress on Bioethics (Kyiv, 2001). Experimental studies were carried out following the requirements of the international principles of the "European Convention for the Protection of Vertebrate Animals Used in Experiments and for Other Scientific Purposes" (Strasbourg, 1986), "Rules for Conducting Work Using Experimental Animals", following the Order of the Ministry of Health No. 281, dated 1 of November 2000 "On measures to further improve organizational forms of work using experimental animals" and the corresponding Law of Ukraine "On the Protection of Animals from Cruelty" (No. 3447-IV dated February 21, 2006, Kyiv) (Nichiporuk et al., 2022). The research material was the cerebellum from clinically healthy, sexually mature domestic animals belonging to the subtype of vertebrates, class Aves – birds (*Gallus gallus* forma *domestica* L., 1758 – domestic chicken, *Meleagris gallopavo* forma *domestica* L., 1758 – turkey, *Anas platyrynchos* forma *domestica* L., 1758 – domestic duck, *Anser caerulescens* forma *domestica* L., 1758 – goose). The selection of experimental animals was carried out taking into account their age (sexually mature animals were used in the comparative anatomical series).

The following methodological approaches were used to perform the work.

Evolutionary. By studying the cerebellum of domestic animals, which differ in phylogenetic age, habitat, and degree of motility, this approach involves forming a holistic view of the main trends and ways of development of the nervous system in general and the cerebellum in particular.

Multi-level. Analysis of the cerebellum at the organ level (linear parameters of various organ structures), tissue level (presence, placement density, and ratio of cells), and cellular level (linear parameters, ratio of cells of different types).

Systemic. Modern interpretation of morphological studies is impossible without the use of a systemic approach, as it includes statistical analysis, which makes it possible to conduct research objectively and make a transition from analytical forms of cognition to synthetic ones, which makes it possible to reveal the regularities of the structural organization of the cerebellum at the tissue and cellular levels in the process their transformations in a comparative aspect, taking into account options for adaptation to specific environmental conditions.

The following methods were used in our work: clinical and anatomical (to characterize the general clinical condition of animals); zootechnical (to determine the body weight of animals and the absolute mass of the cerebellum; histological (to represent the microscopic structure of the cerebellum at the cellular and tissue levels); neurohistological (to detect the neurofibrillary apparatus and basophilic substance in nerve cells); morphometric (to establish the absolute (volumetric and weight) and relative indicators of the body; statistical (for processing digital data to determine the reliability of changes in indicators).

To study the absolute mass of the cerebellum, the organ was prepared and removed from the body (immediately after slaughtering the animals) and was weighed on a Radwag PS-1200 electronic scale with an accuracy of 0.1 g. The cerebellum was measured using a caliper with an accuracy of 0.1 mm.

For microscopic studies, the freshly selected material was fixed in a 10–12% chilled aqueous solution of neutral formalin and Carnoy's fluid, followed by embedding pieces of material in paraffin according to the schemes proposed in the manual (Horalskyi et al., 2019; Horalskyi et al., 2024). Histological sections with a thickness of up to 8–10 µm were made on a sled microtome MC-2.

To study the detailed structure of the cerebellum, the state of its microarchitectonics, cell morphology, histo- and cytometric studies, serial paraffin sections were made, followed by their staining after deparaffinization with hematoxylin (Diapath, Italy, 2021) and eosin (Leica Geosystems, Germany, 2021).

Cytoarchitectonics of the cerebellum in domestic birds, the shape and cellular typing of neurocytes, the state of the neurofibrillary apparatus, and the nature of processes were studied on preparations impregnated with silver nitrate according to Ramon-i-Cahal and Bolshovskyi-Gros (Horalskyi et al., 2019).

Quantitative morphometric research methods were used to obtain objective criteria for the structural organization of the studied cerebellum. An eyepiece micrometer was used to measure the linear parameters of the cerebellum, neurocytes, and their nuclei, and the thickness of the molecular, ganglionic, and granular layers of the cerebellar cortex.

The following formula was used to determine the volume of nerve cells and their nuclei: $V = \pi/6 \times A \times B2$, where V is the volume of cells; π – 3.14; A is the length of cells (nuclei); B is the width of cells (nuclei).

The formula $NUC = V_{nuclei}/(V_{cells} - V_{nuclei})$ determined the nuclear-cytoplasmic ratio.

Statistical analysis of blood parameters was performed using a personal computer and Statistica 7 software (StatSoft Inc., USA). The construction of graphs was carried out using the Statistica 7 program following generally accepted algorithms. The paper gives the average arithmetic values of the values and the error of the average arithmetic value x ± SD (mean ± standard deviation), which are presented in the figures. We used the Tukey test to compare the difference in mean parameters between control and experimental groups, where differences were considered statistically significant at $P < 0.05$ for all data.

Histological specimens were photographed using a CAM V-200 video camera (Inter Med, China, 2017) mounted in a Micros MC-50 microscope (Austria, 2012).

Results

In the poultry we studied, the cerebellum covers a diamond-shaped fossa. The organ is located between the cerebrum and midbrain, above the medulla oblongata. The macroscopic structure of the cerebellum is formed by a massive part (body, vermiform) and two small lateral appendages (poorly developed lateral ears). The surface of the cerebellar body is divided into numerous lobes by transverse furrows.

In chickens, the cerebellum is located between the cerebrum and midbrain, dorsal to the medulla oblongata. The body (vermiform) of the cerebellum is divided by transverse fissures into lobes and hemispheres with tufts and has two pronounced lateral ears (Fig. 1a). The base of the cerebellum is elongated and curved rostrally. From the side, the cerebellum has a rounded appearance and in shape resembles a lump-like structure, greatly expanded near the hemispheres of the cerebrum and significantly narrowed at its border with the medulla oblongata.

In chickens, the cerebellum's ears, which are cone-shaped structures, protrude on both sides of its expanded lower part (Fig. 1a).

Fig. 1. Macroscopic structure of the cerebellum of domestic poultry: *a* – chickens; *b* – turkeys; *c* – ducks; *d* – geese; *1* – hemispheres of the cerebrum; *2* – cerebellum; *3* – body (worm) of the cerebellum; *4* – auricles of the cerebellum; macro drug

The surface of the cerebellum in chickens is divided by slits into leaves (convolutions) that form the lobes, and those, in turn, are the lobes of the cerebellum (Fig. 2a). The turkey cerebellum is between the cerebrum and midbrain, dorsal to the medulla oblongata. Most of it is the middle lobe – a vermiform structure with characteristic transverse furrows. The lateral lobes of the cerebellum are poorly developed and appear as ear-like outgrowths. The cerebellum of sexually mature animals reaches significant sizes, has a rounded shape, and is significantly thickened in the areas where auricle-like growths protrude. It narrows in the caudal direction (Fig. 1b). The surface of the cerebellum has pronounced slits that divide it into lobes (Fig. 2b).

The duck's cerebellum is located dorsal to the medulla oblongata, between the cerebrum and midbrain. It has a developed body and two lateral ears – right and left (Fig. 1c). In the lateral projection, the cerebellum has a triangle shape, with a ventrally elongated apex. The surface of the cerebellum is divided by numerous furrows into ten lobes, which unite into three lobes: anterior, middle, and posterior (Fig. 2c).

In geese, the cerebellum completely covers the rhomboid fossa and occupies the area between the cerebrum and midbrain above the medulla oblongata. The goose cerebellum is built from a massive part – the body (vermiform) and two small lateral appendages in the form of underdeveloped lateral ears (Fig. 1d). The surface of the cerebellar body is divided into numerous lobes by transverse furrows (Fig. 2d). Our organometric studies show that the absolute mass of the cerebellum in poultry has a direct dependence on their species characteristics: the largest is found in turkeys (1.987 g), compared to chickens, the absolute mass of the cerebellum increases reliably (P < 0.001) by 3.80 times. The absolute weight of the cerebellum in geese is 1.409 g, which is significantly (P < 0.001) 1.50 times more than in ducks. At the same time, compared to terrestrial birds, the absolute mass of the goose is 2.73 times greater than that of chickens but is 1.40 times less than that of turkeys (Fig. 3a).

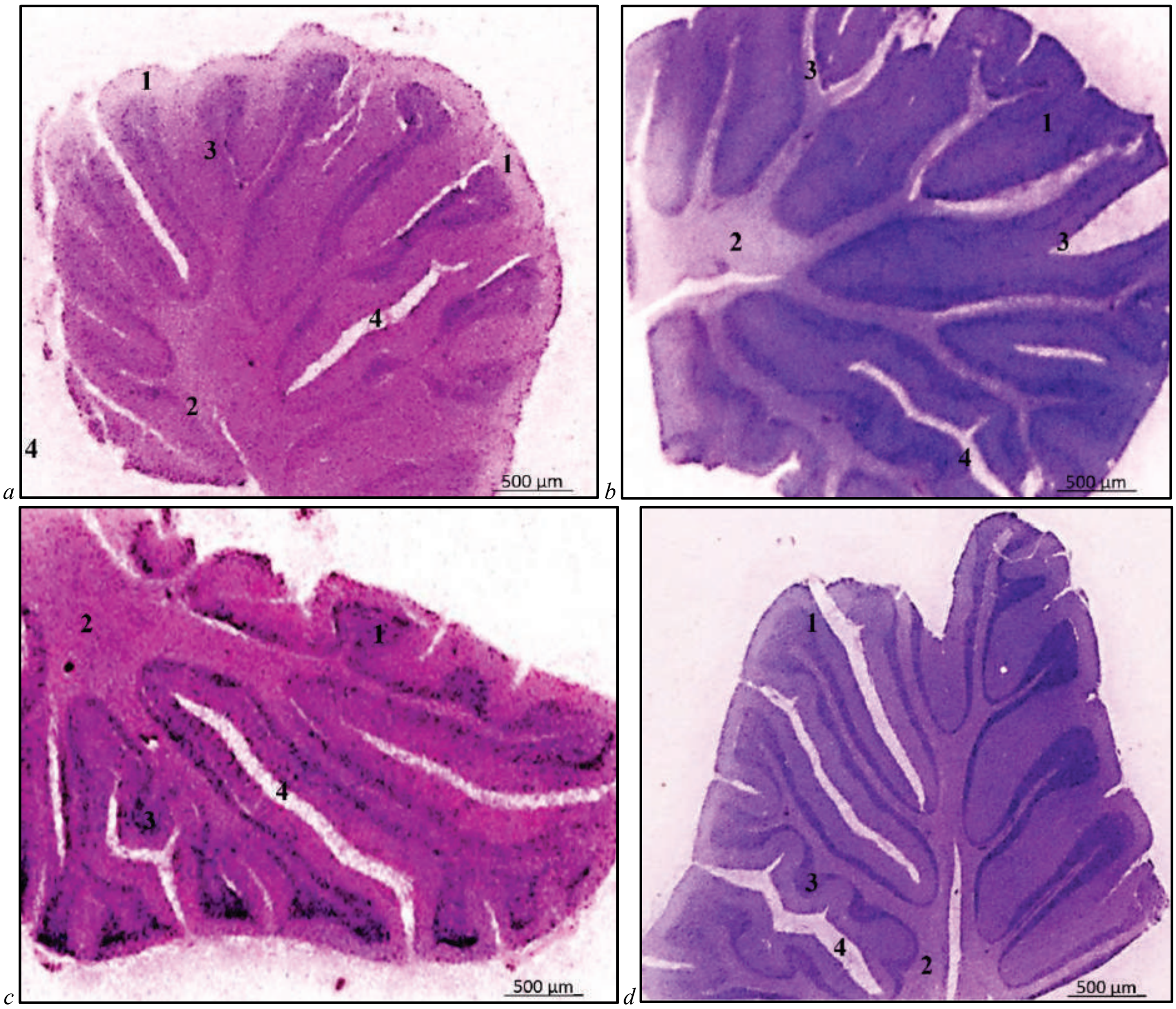

Fig. 2. The microscopic structure of the cerebellum of domestic poultry – frontal section: *a* – chickens; *b* – turkeys; *c* – ducks; *d* – geese; *1* – gray matter; *2* – white matter; *3* – convolutions of gray matter; *4* – slits (grooves) of the cerebellar cortex; hematoxylin and eosin

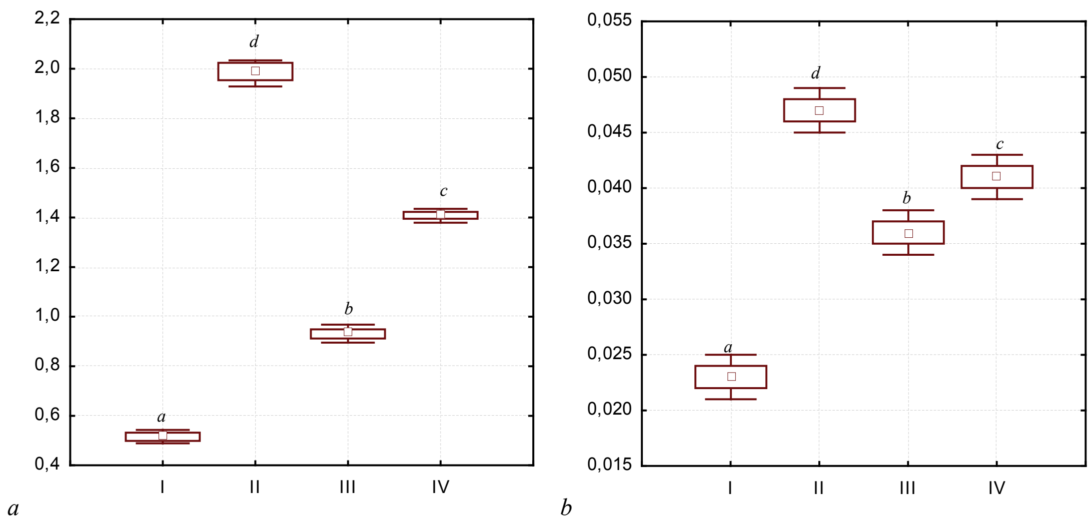

Fig. 3. The absolute and relative mass of the cerebellum of domestic poultry: *a* – absolute mass of the cerebellum (g); *b* – a relative mass of the cerebellum (%, x ± SD, n = 5); groups: I – chicken, II – turkey, III – duck, IV – goose

The relative mass of the cerebellum in the research birds changes synchronously and is directly proportional to the cerebellum's absolute mass and the animals' mass. Thus, according to organometric studies, the relative mass of the cerebellum, as well as its absolute mass, is the largest in turkeys, then somewhat smaller in geese and ducks, and the smallest in chickens (Fig. 4). At the same time, in terrestrial poultry, in turkeys, compared to hens, the relative mass of the cerebellum is significantly ($P < 0.01$) doubled and decreases by 0.047%. The relative mass of the cerebellum in waterfowl, in geese, compared to terrestrial poultry, is 1.15 times inferior to that of turkeys and is probably ($P < 0.01$) 1.80 times greater than that of chickens (Fig. 3b).

Along with ambiguous indicators of the absolute and relative mass of the cerebellum in poultry, there are directly proportional changes in its linear dimensions – length, width, and height, depending on the species characteristics of the studied bird. Thus, the length of the cerebellum of waterfowl, namely geese (15.6 mm), is reliably ($P < 0.01$) 1.26 times smaller than that of ducks and 2.0 mm smaller than that of turkeys, and vice versa, is 0.8 mm larger than that of chickens (Fig. 4a). Characteristic linear features were also detected by us concerning the measurement of the width of the cerebellum, which in geese is 1.34 times reliably greater ($P < 0.01$) than in ducks and equals 12.9 mm. In waterfowl, unlike terrestrial birds, the width of the cerebellum in geese is 6.0 mm greater than that of chickens and 1.15 mm greater than that of turkeys (Fig. 4b). Similar changes were observed concerning linear indicators concerning the height of the cerebellum. Thus, the greatest height of the cerebellum (13.2 mm) was found in geese, the average indicator (11.2 mm) in turkeys, and close (9.6 mm) to the corresponding one in ducks and the smallest (7.4 mm) in chickens (Fig. 4c).

According to the results of histological studies, the cerebellum of the studied birds has a similar structural organization. In cross-section, it is formed by gray and white matter. Its gray matter is located superficially, forming the cerebellum's cortex, and white matter is located in the center of the organ (Fig. 5b). In the gray matter of the cerebellum, three layers are differentiated: outer molecular, middle ganglionic, and inner granular. These layers have similar cytoarchitectonic features characteristic of domestic animals (Fig. 5). Each layer of the cerebellar cortex is represented by clearly defined neurons.

According to our calculations, the volume of Purkinje cells in the ganglionic layer of the goose cerebellum is 1.15 times greater than that of the duck. As regards domestic poultry, there is a decreasing trend for turkey and a probable ($P < 0.01$) increase of 1.8 times for chicken (Fig. 6a). At the same time, the average volume of nuclei in the Purkinje cells of the studied birds does not change significantly (Fig. 6b) and, as a result, affects their nuclear-cytoplasmic ratio, which is the leading morphometric indicator of the level of metabolic processes and cell differentiation in animals, depending on the conditions their existence, and thanks to which it is possible to assess the level of morphofunctional maturity in the species aspect and find out the degree of development of the protein synthesis apparatus.

According to the results of our research, depending on the indicators of the volume of cells and their nuclei, their nuclear-cytoplasmic ratio is different (Fig. 6c). Moreover, the highest nuclear-cytoplasmic ratio is characteristic of goose nerve cells – 0.079 ± 0.013, the approximate value of the nuclear-cytoplasmic ratio is 0.087 ± 0.013 and turkey – 0.083 ± 0.024 and probably ($P < 0.001$) 1.75 times more minor in chicken.

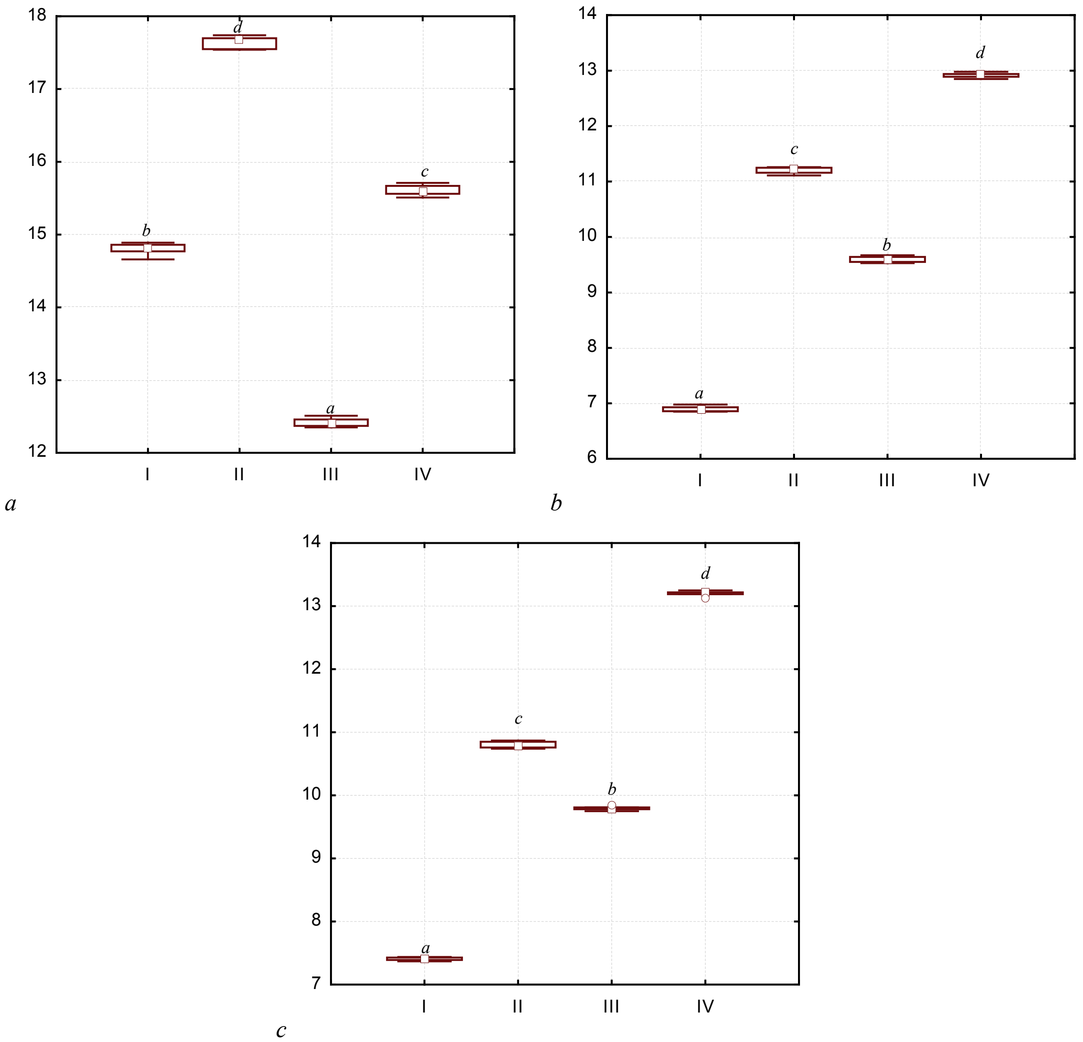

Fig. 4. Organometric parameters of the cerebellum of domestic poultry: *a* – length of the cerebellum (mm); *b* – width of the cerebellum (mm); *c* – thickness of the cerebellum (mm, x ± SD, n = 5); groups: I – chicken, II – turkey, III – duck, IV – goose

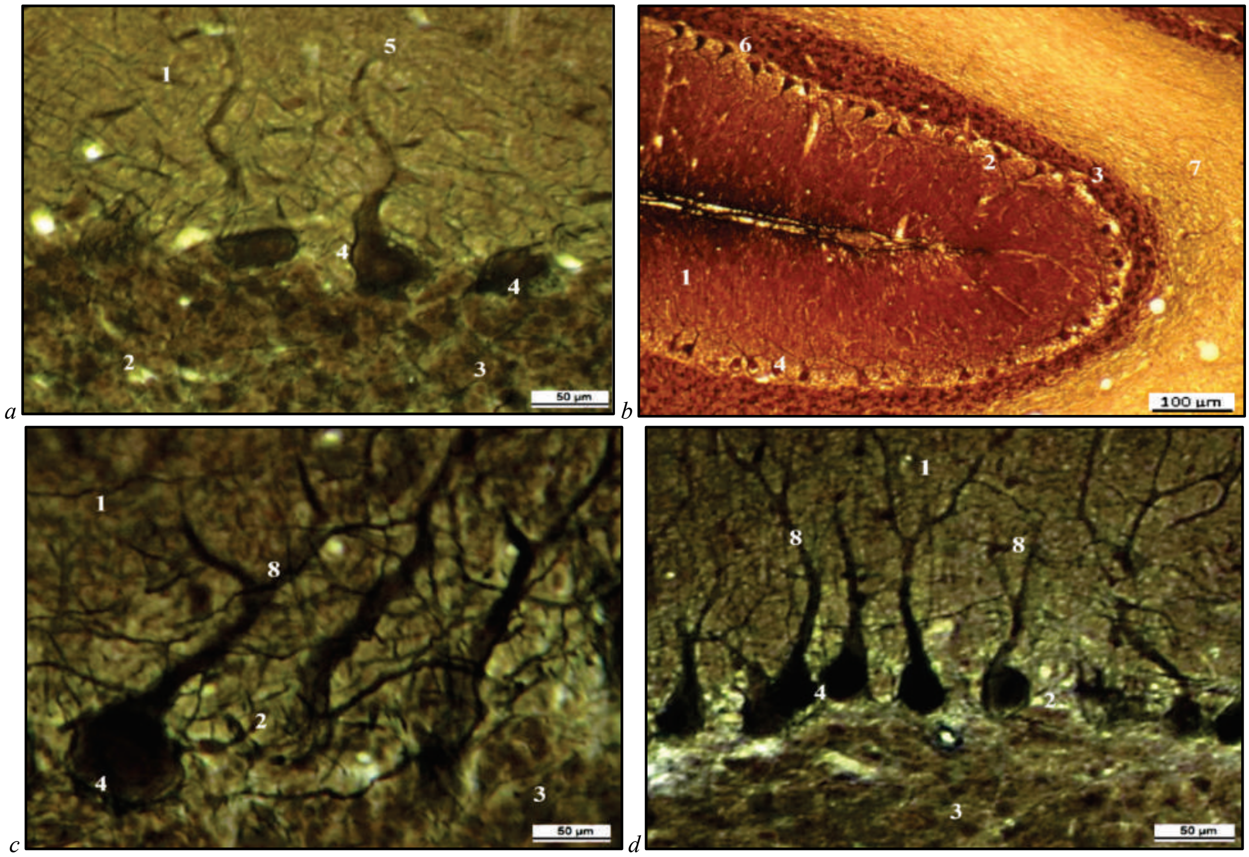

Fig. 5. A fragment of the microscopic structure of the cerebellar cortex of domestic poultry: *a* – chickens; *b* – turkeys; *c* – ducks; *d* – geese; *1* – molecular layer; *2* – ganglionic layer; *3* – granular layer; *4* – Purkinje cells; *5* – dendrite; *6* – gray matter; *7* – white matter; *8* – dendrites of Purkinje cells; Bolshovskyi-Gros

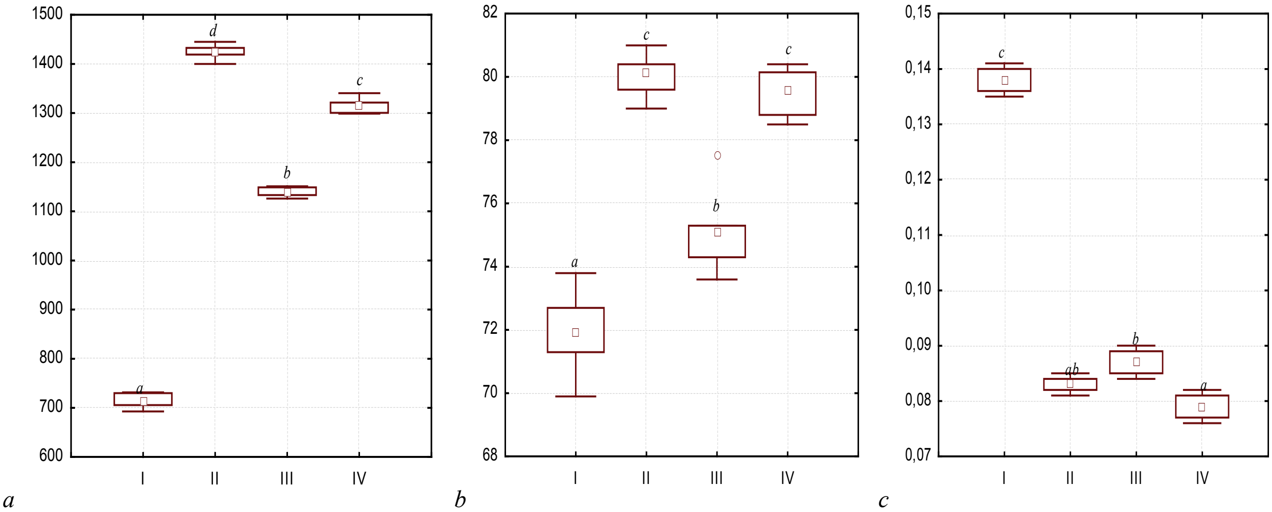

Fig. 6. Cytomorphometric indicators of Purkinje cells of the cerebellum of terrestrial poultry: *a* – volume of perikaryon of nerve cells (μm^3); *b* – the volume of nuclei of Purkinje nerve cells of the cerebellum (μm^3); *c* – nuclear-cytoplasmic ratio of Purkinje cells of the cerebellum (x ± SD, n = 5); groups: I – chicken, II – turkey, III – duck, IV – goose

This is explained by the biological characteristics of birds and indicates the morphofunctional state of nerve cells, the development of their protein synthesis apparatus, the state of metabolic processes, etc., related to the individual and species characteristics of experimental poultry.

It was established that the structural structure of the cerebellar cortex and its histometric parameters of the thickness of the histoarchitectonic layers in waterfowl are similar to the corresponding ones in land birds (Fig. 7). At the same time, the thickness of the cerebellar cortex of the birds studied by us is the largest in turkeys – 404.3 μm, a similar value in geese – 399.7 μm, the average in ducks – 376.3 μm, and the lowest value was recorded in chickens (350.7 μm). Similar changes were observed in the redistribution of tissue components of the histoarchitectonic layers of the organ. Thus, the average thickness of the molecular layer of the cerebellum in the birds studied by us correlates with the thickness of the cerebellar cortex and is the largest in turkeys – 241.9 μm, then somewhat smaller in geese – 234.9 μm, ducks – 178.8 μm, and chickens – 149.8 μm). At the same time, the thickness of the ganglionic layer of the cerebellum in terrestrial poultry and waterfowl was similar. It occupied the least important parameters of all histoarchitectonic layers of the cerebellum (Fig. 7). According to such indicators, changes in thickness parameters were detected in the granular layer of the cerebellar cortex, in the direction of growth in chickens – 174.3 μm, then in ducks – 169.8 μm, and, accordingly, in the direction of decrease in turkeys – 133.7 μm and geese – 137.6 μm, Fig. 7).

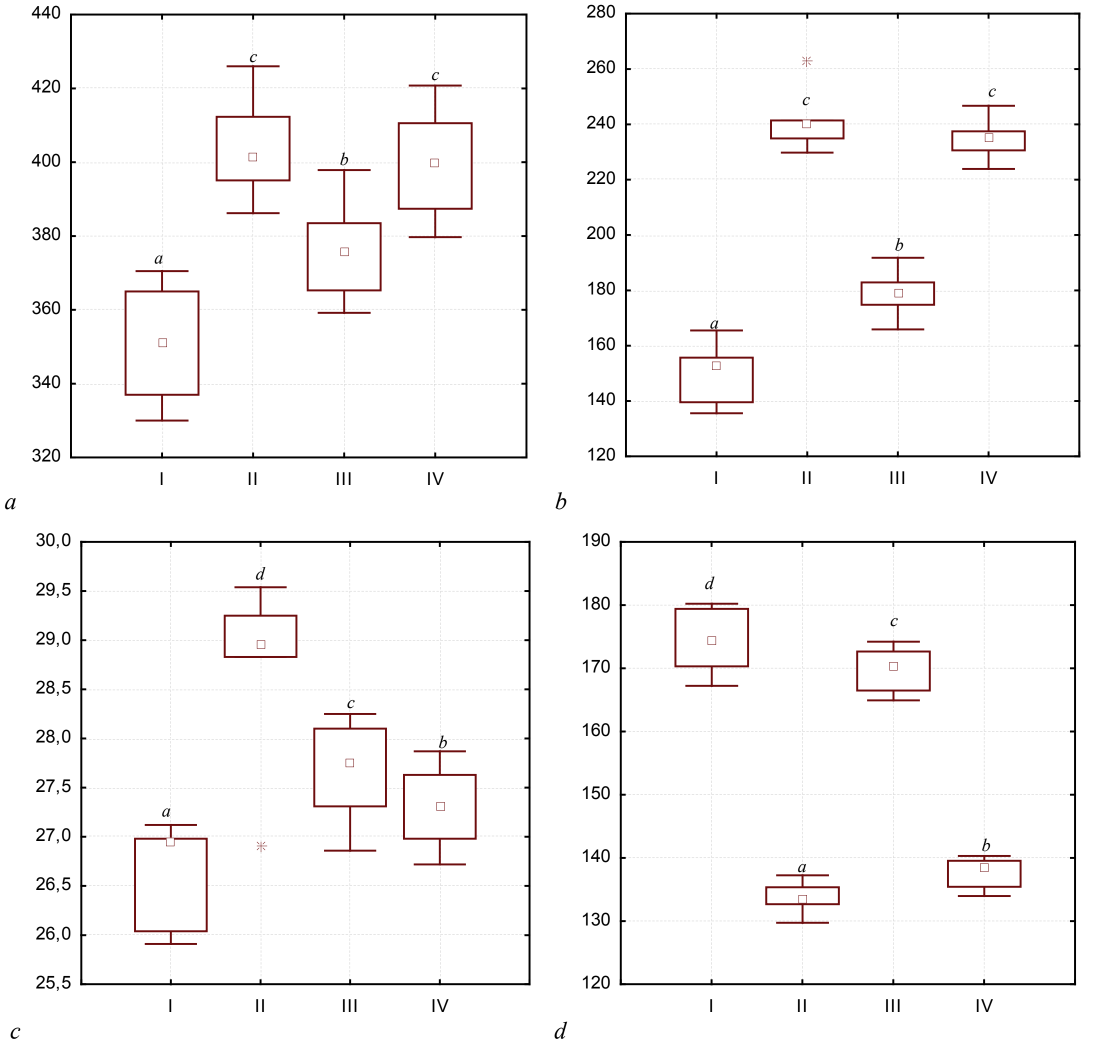

Fig. 7. Histometry of the thickness of the layers of the cerebellum of poultry: *a* – cerebellar cortex (μm); *b* – molecular layer (μm); *c* – ganglionic layer (μm); *d* – granular layer (μm, x ± SD, n = 5); groups: I – chicken, II – turkey, III – duck, IV – goose

Thus, in domestic poultry, there is a significant similarity in the histological structure of the cerebellum. However, fluctuations in the narrow limits of variability of organometric linear parameters of the cerebellum, its cytometric and histometric parameters in representatives of the class of birds, depending on their motor activity and conditions of keeping, were established.

Discussion

To properly control the morpho-functional state of animals in general and the nervous system in particular, it is necessary to know the starting parameters of their characteristics and master the methods of their determination. This requires scientists to conduct research on the organs of the nervous system as one of the essential integrating systems of the body, which determines its integrity and unity and ensures the connection of the body with the environment (Arendt et al., 2019; Gutyj et al., 2019; Sobolev et al., 2020; Dunaievska et al., 2024).

In terms of species, birds are among the most numerous classes of higher vertebrates. They are homoeothermic organisms that acquired the ability to fly by transforming their front limbs into wings.

The adaptation of birds to flight had a substantial impact on the structure of their bodies and vital systems of the body. In evolutionary terms, significant changes have occurred, particularly in the structure of integrating organs. In birds, the nervous system reaches a significantly high degree of development and differentiation (Kang, 2021). The cerebellum of birds, especially parrots and woodpeckers, is considerably larger than that of other vertebrates (Sultan, 2005). Recently, by using a method that allows immunocytochemical identification of neuron nuclei (Herculano-Houzel & Lent, 2005), it was found that for equal brain mass in vertebrates, the number of neurons in the brain of birds is greater than that of mammals. The brain of birds contains almost twice as many neurons as the brain of mammals for the same mass (Olkowicz et al., 2016), and nerve cells in the brain of birds are more densely arranged. By analogy with mammals, birds' brains are divided into large and rhomboid (Watanabe et al., 2021). Unlike reptiles, poultry brains undergo strong development (Marugán-Lobón et al., 2016; Bashchenko et al., 2020).

Organometry is of decisive importance in morphological studies, which allows one to make a careful analysis of quantitative indicators of the structural characteristics of the animal organism in the process of its ontological and phylogenetic development and under the influence of various factors of the external environment on the organism (Krastev, 2007). Qualitative assessment in studies observed by morphologists with the help of modern morphological methods is becoming more and more necessary to analyze the obtained results and justify the studied regularities. Quantitative morphological analysis of the objectively obtained features of structures and their relationships in the body is carried out by morphometry, which allows more adequate and deep studying of the quantitative features of physiological and pathological processes and their logical interpretation (Slaby, 2017).

The molecular layer of the cerebellar cortex in domestic birds contains stellate and basket neurons. Such nerve cells represent a single morphofunctional system that transmits inhibitory nerve impulses to the dendrites and bodies of piriform Purkinje cells. According to the location, the basket neurons are above the ganglion layer's Purkinje cells. Such cells have small sizes and irregular shapes with numerous appendages. Branched dendrites of basket neurons are directed to the top of the cerebellum, and their axons wrap around the perikaryon of Purkinje nerve cells in the form of "baskets," thus forming a synaptic apparatus with them. Star-shaped nerve cells (small and large) are located mainly in the outer two-thirds of the molecular layer. By the number of processes, such cells are multipolar neurons with a rounded perikaryon. Their processes branch in the cerebellar cortex's molecular and granular layers. Such multipolar stellate nerve cells form synapses with the bodies and dendrites of pear-shaped cells – Purkinje.

The ganglionic layer of the cerebellar cortex is formed by large, pear-shaped nerve cells – Purkinje, which are placed in one row, perpendicular to the convolutions of the cerebellum. Therefore, such cells are pear-shaped in the plane through which the dendrites go and spindle-shaped in the vertical plane. Such cells are characterized by a developed tree of dendrites. The latter branch from the apical narrowed surface of pear-shaped neurons and are directed into the molecular layer. From the opposite pole of the cells come neurites that go to the nuclei of the cerebellum. These are the effector neurons of the cerebellum, which, through its nuclei, transmit nerve impulses to the descending pathways connecting the brain with the spinal cord (Kim et al., 2012). Purkinje nerve cells are characterized by a well-defined nucleus and well-defined neuroplasm. They are the largest of the entire population of neurocytes of the cerebellar cortex; their morphofunctional activity and size, placement density, etc., largely depend on the transmission of nerve impulses and are regulated by the coordination of motor processes depending on the species and class of animals (Hoxha et al., 2018).

A different volume of Purkinje cells and their nuclei was established based on cytometric studies and mathematical analysis. At the same time, it was established that their nuclear-cytoplasmic ratio is different, depending on the species characteristics of domestic birds. This is not accidental since the mathematical analysis of the structures of morphological objects has received recognition as a method distinguished by its objectivity and reliability (Rajković et al., 2016).

The study of morphometric criteria for the metabolic activity of neurons (the size of the nuclei and perikaryon of neurons), the density of glial-neuronal contacts, the neuron-glial-capillary index, and the nuclear-cytoplasmic ratio is becoming increasingly relevant in morphological research in normal and pathological conditions. The study of morphometric characteristics, namely the nuclear-cytoplasmic ratio in cells, is a visual indicator sensitive to various pathological processes in cells, which can be used to judge their structure and functional state (Cherniavskyi, 2019).

Morphometric studies, which are often used in morphology (Paruszewska-Achtel et al., 2020), make it possible to clearly and reliably analyze not only quantitative changes at the cellular level but also make it possible to conduct a detailed analysis of the histoarchitectonics of the organism, namely the central nervous system, including the cerebellum in the process of its individual development and phylogeny. That is why our quantitative histometric studies of the cerebellum from the point of view of assessing its plasticity in animals of different levels of the organization, namely representatives of the class birds, with various ecological and functional organization, which are characterized by a moderate degree of activity and their environment (terrestrial, semi-aquatic), made it possible to identify certain regularities, trends, and criteria regarding the structural organization of the cerebellum, its histoarchitectonic layers at the tissue level of organization (Rubinow & Juraska, 2009).

Conclusion

Morphology, variability of organometric weight (absolute and relative mass), linear (length, width, height) values of the cerebellum, its cyto (volume of Purkinje cells), and histometric (thickness of the cerebellar cortex) parameters in representatives of the class birds depend on their motor activity, conditions. It is determined by a specific type of representatives of the class of birds:

– the cerebellum is located dorsal to the medulla oblongata between the cerebrum and midbrain. It is formed by the body and the right and left side ears. On the surface, the cerebellum is divided into lobes by numerous furrows, which unite into three lobes - front, middle, and back. In the lateral projection, the cerebellum of domestic poultry is triangular, with a ventrally elongated apex.

– the absolute mass of the cerebellum of domestic poultry varies: it is greatest in turkeys (1.987 ± 0.009 g), smaller in geese (1.409 ± 0.006 g), smaller still in ducks (0.932 ± 0.004 g), and the smallest in chickens (0.516 ± 0.003 g). The relative mass of the cerebellum changes synchronously with the absolute mass and is, accordingly, equal to: in turkeys – 0.047 ± 0.0002%, in geese – 0.041 ± 0.0002%, in ducks – 0.036 ± 0.0002%, in chickens – 0.023 ± 0.0001%.

The cerebellum of poultry has a similar structural organization. On a cross-section, the cerebellum is formed by gray and white matter. Gray matter is formed by the corresponding histoarchitectonic layers – molecular, ganglionic, and granular – which are characterized by a different population of nerve cells, depending on their structure and species of animals.

The thickness of the cerebellar cortex of the bird class varies: in chickens – 350.7 ± 12.68 µm, turkeys – 404.25 ± 5.76, ducks – 376.29 ± 5.34, and geese – 234.85 ± 2.43 µm. The most significant thickness of its histoarchitectonic layers in all studied animals is characterized by a granular layer, somewhat smaller in the molecular layer and the smallest in the ganglionic layer.

In the comparative anatomical series of poultry, different volumes of Purkinje cell perikaryons were established: the smallest volumes were found in chickens (713.9 ± 68.6 μm^3); somewhat larger were found in ducks (1139.5 ± 88.8 μm^3), geese (1315.2 ± 88.5 μm^3), and turkeys (1423.9 ± 81.6 μm^3).

The nuclear-cytoplasmic ratio of Purkinje cells, which indicates the state of their functional activity, has different values: the most prominent goose indicator is 0.079 ± 0.013, the approximate value in ducks is 0.087 ± 0.013, and turkeys is 0.083 ± 0.024, and it is significantly ($P < 0.001$) less by 1.75 times in chickens.

Prospects for further research include histochemical studies of the cerebellum of domestic poultry.

The authors declare that they have no conflict of interest.

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