ANIMAL HUSBANDRY

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REGISTRATION OF SEXUAL DIMORPHISM OF LINEAR AND ANGULAR PARAMETERS OF THE FINE STRUCTURE OF THE REMEX VANE OF PADOVANA CHICKENS

Research article

Abstract

Electron microscopic examination of the fine structure of the primary remiges in a male and a female of Padovana chicken revealed signs of sexual dimorphism by four morphometric parameters (elongation index, curvature index, the angle of displacement of the tip of the ventral ridge, the angle of curvature) in five topographic sites of the cross section of the ramus of the pennaceous barb. For this purpose, based on arithmetic means in the Python program using the NumPy library, two data arrays containing 20 elements for each sex were created. The difference found between the elements of the arrays of male and female showed that in 11 cases (55%) there is a dominance of the indicators of the male over the indicators of the female, while in 9 cases (45%) there is a dominance of the parameters of the female over the parameters of the male. No cases of sexual parity have been identified.

Keywords: The Padovana breed of chicken (*Gallus domesticus*), scanning electron microscopy, sexual dimorphism, feather morphology, descriptive statistics, programming.

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РЕГИСТРАЦИЯ ПОЛОВОГО ДИМОРФИЗМА ЛИНЕЙНЫХ И УГЛОВЫХ ПАРАМЕТРОВ ТОНКОЙ СТРУКТУРЫ ОПАХАЛА МАХОВОГО ПЕРА ПАДУАНСКИХ КУР

Научная статья

Аннотация

Электронно-микроскопическое исследование тонкой структуры первостепенных маховых перьев у самца и самки падуанской курицы позволило выявить признаки полового диморфизма по четырем морфометрическим параметрам (индекс удлиненности, индекс изогнутости, угол смещения вершины вентрального гребня, угол изогнутости) в пяти топографических участках поперечного среза стволика бородки первого порядка контурной части опахала. Для этой цели на основе средних арифметических показателей в программе Python с использованием библиотеки NumPy было создано два массива данных, содержащих по 20 элементов для каждого пола. Разница, обнаруженная между элементами массивов самца и самки, показала, что в 11 случаях (55%) наблюдается превосходство показателей самца над показателями самки, при этом в 9 случаях (45%) отмечается превалирование параметров самки над параметрами самца. Случаев полового паритета не выявлено.

Ключевые слова: падуанские куры (*Gallus domesticus*), сканирующая электронная микроскопия, половой диморфизм, морфология перьев, дескриптивная статистика, программирование.

1. Introduction

Modern poultry science is increasingly relying on biological patterns that allow increasing the productivity of domestic bird [1]. One of the most important factors determining the habitus and physiological parameters of individuals is sexual dimorphism, which requires not only a deeper study from a biological point of view, but also a correct quantitative analysis based on the laws of biostatistics and bioinformatics [2].

The Padovana chickens chosen as the object of research belong to decorative breeds of chickens, but recently scientific studies have been conducted related to the assessment of their meat qualities [3], [4]. There are various color forms of the plumage of Padovana chickens, while the relationship between the plumage color and body weight before puberty has been revealed [3]. The revealed high precocity of males in comparison with females allows us to claim not only about sexual dimorphism of Padovana chickens, but also about intrabreed heterochrony [5], which is important to take into account when planning the slaughter of these birds [3], [4].

In this regard, the purpose of our study is to registration sexual dimorphism, while morphometric parameters of the fine structure of the remix in opposite-sex individuals were selected as criteria for intersexual differences in Padovana chickens.

2. Materials and methods

The feathers of Padovana chickens (*Gallus domesticus*) were kindly provided by Dr. V.A. Ponomarev (Ivanovo State Agricultural Academy named after D.K. Belyaev).

Anatomical and microscopic terminology devoted to various parts of the feather is given according to the monograph by Lucas and Stettenheim (1972) [6]. The feathers were viewed and photographed using a scanning electron microscope of the brand "JEOL-840A" (Japan). In the ImageJ program (National Institutes of Health, USA), measurements of the fine structure of the primary remex vane in a male and a female of Padovana chicken were carried out using electronic microphotographs [7].

In particular, the following linear and angular parameters of the cross section of the ramus of the pennaceous barb were studied:

1) elongation index is the ratio of the width of the cross-section to the length of the cross-section, expressed as a percentage;

2) curvature index is the ratio of the distance between the tips of the dorsal and ventral ridges to the length of the cross-section, expressed as a percentage;

3) the angle of displacement of the tip of the ventral ridge α is the angle between the central longitudinal axis of the cross section of the ramus and the tip of the ventral ridge, measured from the separation point at the base of ventral part of the ramus (in degrees);

4) the angle of curvature β is the angle between the central longitudinal axes of the dorsal and ventral parts of the ramus (in degrees) [8].

Measurements and calculation of these parameters were carried out for five topographic sites, while rounding the data to 0,01 (Table 1 and Table 2).

Statistical data processing was carried out in the program "STATISTICA 10" (StatSoft, USA). The number of measurements (*n*) is sufficient to obtain representative descriptive statistics presented in the form of arithmetic mean (*M*) and arithmetic mean error (*m*), that is, $M \pm m$ (Table 1 and Table 2). The program code that allows you to determine the frequency of occurrence of male or female dominance, as well as sexual parity based on the given the morphometric parameters of the fine structure of chicken feathers, is written in the Python program (Python Software Foundation, USA).

3. Results and discussion

The study of linear and angular parameters of the fine structure of the cross section of the ramus revealed signs of sexual dimorphism in adult opposite-sex individuals of Padovana chickens (Table 1 and Table 2).

Table 1 – Morphometric parameters of the cross section of the ramus of the primary remex pennaceous barb in a male Padovana chicken

Topographic sites	*n*	Elongation index, %	Curvature index, %	The angle α, °	The angle β, °
The basal part of the barb:					
The proximal section	10	9,04 ± 0,06	97,62 ± 1,02	5,27 ± 1,43	177,70 ± 0,71
The medial section	10	7,34 ± 0,13	98,25 ± 0,09	13,92 ± 0,87	162,35 ± 1,62
The distal section	11	20,32 ± 0,56	97,30 ± 0,90	32,10 ± 1,52	156,27 ± 0,56
The medial part of the barb	11	49,38 ± 0,48	77,90 ± 2,16	43,31 ± 0,54	119,28 ± 0,57
The distal part of the barb	14	47,71 ± 2,65	85,49 ± 0,51	39,54 ± 0,53	133,57 ± 0,50

Table 2 – Morphometric parameters of the cross section of the ramus of the primary remex pennaceous barb in a female Padovana chicken

Topographic sites	*n*	Elongation index, %	Curvature index, %	The angle α, °	The angle β, °
The basal part of the barb:					
The proximal section	10	6,25 ± 0,59	99,30 ± 0,43	2,32 ± 0,05	176,49 ± 2,99
The medial section	10	5,94 ± 0,28	92,98 ± 2,73	14,54 ± 0,56	153,50 ± 0,51
The distal section	11	11,60 ± 0,93	98,82 ± 0,42	18,01 ± 1,01	165,89 ± 0,47
The medial part of the barb	11	47,27 ± 0,55	82,98 ± 2,88	43,27 ± 0,55	132,28 ± 0,54
The distal part of the barb	11	57,47 ± 0,55	80,59 ± 0,58	51,59 ± 0,50	135,35 ± 0,52

Automation of registration of the frequency of occurrence of sexual dimorphism requires the use of programming methods. For this purpose, using the NumPy library in the Python program, two arrays of data were created on arithmetic means of morphometric parameters of the fine structure of the remex in opposite-sex individuals of Padovana chickens

(Table 1 and Table 2). Each array contains 20 elements, which is achieved due to four parameters defined for five topographic sites. Sexual dimorphism is registered as a result of subtracting the mean value of the male from the mean value of the female, while when a positive difference is obtained, we can talk about male dominance over female, a negative result indicates female dominance over male, a zero-difference value indicates sexual parity due to the equality of the mean values of male and female. However, such a case does not occur among the available data (Table 1 and Table 2). The proposed code algorithm has the following form:

```ipython3
.. code:: ipython3

import numpy as np

.. code:: ipython3

male_Padovana_chicken = np.array(
    [
        [9.04, 97.62, 5.27, 177.70],
        [7.34, 98.25, 13.92, 162.35],
        [20.32, 97.30, 32.10, 156.27],
        [49.38, 77.90, 43.31, 119.28],
        [47.71, 85.49, 39.54, 133.57]
    ])
male_Padovana_chicken
```

```
.. parsed-literal::

array([[  9.04,  97.62,   5.27, 177.7 ],
       [  7.34,  98.25,  13.92, 162.35],
       [ 20.32,  97.3 ,  32.1 , 156.27],
       [ 49.38,  77.9 ,  43.31, 119.28],
       [ 47.71,  85.49,  39.54, 133.57]])
```

```ipython3
.. code:: ipython3

female_Padovana_chicken = np.array(
    [
        [6.25, 99.30, 2.32, 176.49],
        [5.94, 92.98, 14.54, 153.50],
        [11.60, 98.82, 18.01, 165.89],
        [47.27, 82.98, 43.27, 132.28],
        [57.47, 80.59, 51.59, 135.35]
    ])
female_Padovana_chicken
```

```
.. parsed-literal::

array([[  6.25,  99.3 ,   2.32, 176.49],
       [  5.94,  92.98,  14.54, 153.5 ],
       [ 11.6 ,  98.82,  18.01, 165.89],
       [ 47.27,  82.98,  43.27, 132.28],
       [ 57.47,  80.59,  51.59, 135.35]])
```

```ipython3
.. code:: ipython3

Sexual_dimorphism = male_Padovana_chicken - female_Padovana_chicken
Sexual_dimorphism
```

```
.. parsed-literal::

array([[  2.79,  -1.68,   2.95,   1.21],
       [  1.4 ,   5.27,  -0.62,   8.85],
       [  8.72,  -1.52,  14.09,  -9.62],
       [  2.11,  -5.08,   0.04, -13.  ],
       [ -9.76,   4.9 , -12.05,  -1.78]])
```

```ipython3
.. code:: ipython3
```

```
for el in (male_Padovana_chicken - female_Padovana_chicken).flat:
    if el == 0:
        print("Sexual parity (el = 0)")
    elif el > 0:
        print("Dominance of male Padovana chicken (el > 0)")
    elif el < 0:
        print("Dominance of female Padovana chicken (el < 0)")

    .. parsed-literal::
```

Dominance of male Padovana chicken (el > 0)
Dominance of female Padovana chicken (el < 0)
Dominance of male Padovana chicken (el > 0)
Dominance of male Padovana chicken (el > 0)
Dominance of male Padovana chicken (el > 0)
Dominance of male Padovana chicken (el > 0)
Dominance of female Padovana chicken (el < 0)
Dominance of male Padovana chicken (el > 0)
Dominance of male Padovana chicken (el > 0)
Dominance of female Padovana chicken (el < 0)
Dominance of male Padovana chicken (el > 0)
Dominance of female Padovana chicken (el < 0)
Dominance of male Padovana chicken (el > 0)
Dominance of female Padovana chicken (el < 0)
Dominance of male Padovana chicken (el > 0)
Dominance of female Padovana chicken (el < 0)
Dominance of female Padovana chicken (el < 0)
Dominance of male Padovana chicken (el > 0)
Dominance of female Padovana chicken (el < 0)
Dominance of female Padovana chicken (el < 0)

It should be noted that this algorithm was previously used by us to determine the sexual dimorphism of the histochemical activity of phosphatases in the skin glands of laboratory rats [9]. The use of this approach for assessing intersexual differences in morphometric parameters of the microstructure of the feather indicates the universality of this algorithm, which is also advisable to use in electron and light microscopic studies [8], [10].

The results obtained indicate a certain dominance of the parameters of the male over the parameters of the female according to morphometric indicators associated with the fine structure of the remex vane of Padovana chickens. It was found that in 11 cases the dominance of morphometric parameters in the male over the female was observed, in 9 cases the dominance of morphometric parameters in the female over the male was revealed. In relative terms, these values are 55% in favor of male parameters and 45% in favor of female parameters. Sexual parity for this breed of chickens has not been identified.

We believe that the introduction of the bioinformatic approach [11] will make it possible to repeatedly intensify the process of analyzing a variety of indicators and traits in various animals, to conduct a comparative analysis by many criteria through the use of data arrays. The above code is quite universal, since arrays can be expanded and narrowed within the framework of the data available to the researcher.

4. Conclusion

Thus, using a number of quantitative methods based on the use of the basics of descriptive statistics and programming, it becomes possible to study in more detail the signs of sexual dimorphism on the example of the fine structure of the feather of Padovana chickens. The use of programming methods in the field of morphology is relevant for various aspects of evaluating comparable parameters of macro- and microstructure, physiological indicators and other objective data obtained during the experiment. Obviously, such a presentation of data in a grouped form will also be useful in taxonomic studies.

Conflict of Interest	**Конфликт интересов**
None declared.	Не указан.

References in English
1. Scanes C.G. Poultry Science / C.G. Scanes, K.D. Christensen. – 5th ed. – Long Grove: Waveland Press, Inc., 2020
2. Lovich J.E. A review of techniques for quantifying sexual dimorphism / J.E. Lovich, J.W. Gibbons // Growth, Development and Aging. – 1992. – Vol. 56. – pp. 269–281
3. Rizzi C. Plumage colour in Padovana chicken breed: growth performance and carcass quality / C. Rizzi // Italian Journal of Animal Science. – 2018. – Vol. 17(3). – pp. 797–803. DOI: 10.1080/1828051X.2017.1413598
4. Rizzi C. Growth and slaughtering performance, carcase fleshiness and meat quality according to the plumage colour in Padovana male chickens slaughtered at 18 weeks of age / C. Rizzi // Italian Journal of Animal Science. – 2019. – Vol. 18(1). – pp. 450–459. DOI: 10.1080/1828051X.2018.1532823

5. Chernova O.F. Heterochrony as the basis for inter-and intraspecific diversity of skin in Vertebrates / O.F. Chernova, A.B. Kiladze // Biology Bulletin Reviews. – 2019. – Vol. 9(2). – pp. 174–189. DOI: 10.1134/S207908641902004X

6. Lucas A.M. Avian Anatomy Integument / A.M. Lucas, P.R. Stettenheim. – Washington: Publ. US Dept. Agricul., 1972

7. Abràmoff M.D. Image processing with ImageJ / M.D. Abràmoff, P.J. Magalhães, S.J. Ram // Biophotonics International. – 2004. – Vol. 11(7). – pp. 36–42.

8. Fadeeva E.O. Features of the architectonics of the microstructure of the primary remex of Owls (Strigiformes) due to the specifics of the flight / E.O. Fadeeva // Proceedings of the National Academy of Sciences of Belarus. Biological series. – 2021. – Vol. 66(2). – pp. 232–246. DOI: 10.29235/1029–8940–2021–66–2–232–246

9. Kiladze A.B. Bioinformatics of sexual dimorphism of histoenzymatic activity in the skin glands of laboratory rats / A.B. Kiladze, N.K. Dzhemukhadze // JP Journal of Biostatistics. – 2021. – Vol. 18(3). – pp. 429–436. DOI: 10.17654/BS018030429

10. Silaeva O.L. The Current State of Identification Ptilology in Russia / O.L. Silaeva, O.F. Chernova // Biology Bulletin Reviews. – 2022. – Vol. 12(2). – pp. 149–163. DOI: 10.1134/S2079086422020098

11. Ekmekci B. An Introduction to Programming for Bioscientists: A Python-Based Primer / B. Ekmekci, C.E. McAnany, C. Mura // PLOS Computational Biology. – 2016. – Vol. 12(6). – e1004867. DOI: 10.1371/journal.pcbi.1004867