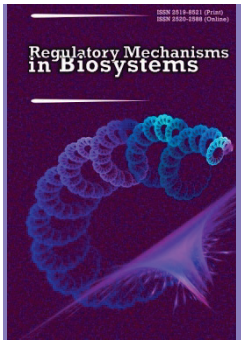

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Effects of gonadectomy on clinical-hematological, metabolic and hormone conditions of cockerels

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Gonadectomy (caponization) of cockerels is an important way of increasing their productivity, improving the quality and taste properties of the meat, and obtaining dietary products. The objective of the study was the influence of gonadectomy of cockerels on their clinical condition, morphological composition of blood, hemoglobin content and anabolism in the tissues, their productivity and chemical content of the muscles. In the experiment, we used 30 Adler silver cockerels aged 4 weeks, which were divided into two groups: control (intact) and experimental (gonadectomized) according to the analogue principle, with 15 individuals in each. The experiment lasted for 185 days, including the main period of 175 days. We determined that the body temperature of cockerels after gonadectomy increased as early as days one and three. In the blood of gonadectomized cockerels, the number of leukocytes decreased by 36.3%, thrombocytes – by 24.7%, while hemoglobin concentration, numbers of heterophils, eosinophils, basophils, monocytes and lymphocytes did not change compared with the intact individuals. On days 20 and 185 of the experiment, the concentration of testosterone in the blood plasma of gonadectomized cockerels was lower respectively by 57.1% and 53.1%, whereas no differences were found prior to gonadectomy and on the third day of the experiment. We determined increase in uric acid concentration and decrease in the level of ionizing calcium in blood plasma of gonadectomized cockerels compared with intact individuals, while the content of cortisol, glucose, total protein, triglycerides, cholesterol, total calcium and inorganic phosphorus, and also activities of alkaline phosphatase, alanine aminotransferase and aspartate aminotransferase did not change. Live weight of gonadectomized cockerels in the period from 45 to 105 days of the raising did not change, and was higher by 10.4–17.0% from day 115 to 145, and further remained not different from the control. Thoracic muscles of gonadectomized cockerels contained 1.8 times more fat, while the levels of moisture, dry matter, protein and ash in thoracic and thigh muscles did not change. The conducted studies have revealed the effect of gonadectomy of roosters on clinical-hematological parameters, metabolic processes, productivity of birds and chemical composition of muscles and may be used to improve the production of chicken meat with high dietary and taste properties.

Keywords: castration; blood; activity of enzymes; cortisol; testosterone.

Introduction

The annually growing demand of consumers for high-quality functional products with improved taste and dietary properties encourages scientists to seek alternative methods to improve the quality of production of poultry farming, production of which is economically beneficial since the demand for it is constantly increasing (Kuźniacka et al., 2017; Sødring et al., 2020).

One of the modern methods of improving food properties of poultry meat, specifically cockerels, is gonadectomy (caponization), carried out surgically (Mahmud et al., 2013; Skade et al., 2021), particularly using laparoscopy (Sirri et al., 2009; Songsee et al., 2020), chemically (Sirri et al., 2009) immunologically (Antunes et al., 2019; Wang et al., 2019; Zeng et al., 2020). Immunological castration is the most successful alternative to the surgical method (Zamaratskaia & Rasmussen, 2015). For this purpose, ovariectomy of chicks is also used, thus affecting not only the concentration of hormones in the organism, but also the metabolic processes, particularly lipid metabolism, gluconeogenesis, energy processes in the tissue of poultry, weight of birds and nutritional value of chicken meat (Calik et al., 2018; Shao et al., 2020).

Gonadectomized (caponized) cockerels were observed to have increases in weight, slaughter yield, weight of gutted carcass and thoracic and thigh muscles, contents of subcutaneous and abdominal fat (Kuźniacka et al., 2017; Kwiecień et al., 2018). Muscles of caponized roosters have better moisture-holdin6g capacity and softness, are characterized by greater content of protein and fat, higher level of poly-saturated and lower concentration of saturated fatty acids (Gesek et al., 2017). Meat of older caponized cockerels (24–28 weeks) is a better source of nutrients than younger ones (Calik et al., 2017). Caponization of some breeds of cockerels decreases the overall content of ash, calcium and phosphorus in the thighs and phosphorus in the legs, and also macro- and microelements in the diaphyseal parts of those same bones, their weight and length (Muszyński et al., 2016) and histological structure of the bones (Kwiecień et al., 2019).

Caponization of cockerels altered the hormone concentrations in blood plasma (Cui et al., 2018), in particular decreased the concentration of testosterone from 1.99 to 0.15 ng/dL^3 (Murawska et al., 2019), hemoglobin, the numbers of erythrocytes and leukocytes in the blood (Mahmud et al., 2013), decreased hematocrit and titer of antibodies after vaccination (Chen et al., 2009), changed the content of triacylglycerols, overall cholesterol, low- and high-density lipoproteins in blood plasma (Zawacka et al., 2016). Scientists indicate that the effect of gonadectomy on processes of lipogenesis is related to the differentiation of adipocytes, increase in the expression of lipid synthesize lipase mRNA (lipoprotein phospholipase) and activation of peroxisome receptors (Guo et al., 2015).

However, a number of researchers found no effect of gonadectomy on increments in live weight or carcass weight of cockerels, chemical compositions of thoracic and thigh muscles, despite changes in the birds' behaviour, improvement of feed consumption, colour and weight of the comb (Decuypere et al., 2005).

The optimum age periods for gonadectomy were determined by surgery, which reduces mortality among birds (Torres et al., 2020). Despite the high number of experiments seeking the most appropriate breeds and cross breeds of birds with high productivity and survival of population, high content of nutrients in meat, the research in this direction continues (Aikpitanyi et al., 2020; Calik et al., 2020).

Moreover, there are a number of unsolved questions regarding the influence of gonadectomy (caponization) of cockerels on clinical condition, morphological composition of blood, content of some hormones, course of metabolic processes in the tissues in the process of their growth, particularly Adler silver cockerels.

Materials and methods

The experiments were carried out according to the requirements of the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes, 1986, and also the Law of Ukraine "On the protection of animals from abuse" as of 21.02.2006 3447-IV as amended on 04.08.2017, confirmed by the Ethics Committee of the National University of Life and Environmental Sciences of Ukraine.

The research was conducted in the clinics of the Department of Veterinary Medicine of the National University of Life and Environmental Sciences of Ukraine. For the experiment, we selected 30 clinically healthy Adler silver cockerels aged four weeks, which according to the principle of group analogues were divided into two groups – control and experimental, with 15 individuals in each. The experiment comprised comparative (10 days) and the main (175 days) periods. Prior to the experiment, the cockerels were immunized by complex polyvalent vaccine Polimun ND IB EDS manufactured by the company BioTestLab (Ukraine). The cockerels of the experimental group were subjected to gonadectomy at the age of 6 weeks. The cockerels of the control and experimental groups were kept separately on unchanged litter on the floor. Density of birds was 7 individuals/m^2. Throughout the experiment, the poultry were fed complete mixed feed provided taking into account the live weight of poultry and the period of growing,their energy requirements, digested protein, fat, cellulose, essential amino acids, macro- and microelements and vitamins. The cockerels had free access to feed and water throughout the day. The air temperature in the premises was maintained at the level of 21–26 °C, rate of air flow was 0.3–0.5 m/s, relative air moisture equaled 40–62%, and the ammonia concentration in the air did not exceed 15 mg/m^3.

In the growing period, cockerels of the control and experimental groups were weighed once every 10 days using electronic scales (Vitek, China) and their temperature was measured using a digital thermometer Flex Temp Smart (Omron Healthcare Co. Ltd., Japan), and also we monitored frequency of cardiac contractions (Color pulse oximeter CMS60C-VET, Contec, China) and the respiratory rate.

Blood samples were taken from the cutaneous ulnar vein of the cockerels according to the rules of aseptic and antiseptics, adding anticoagulant (heparin) (Farmaks-Group, Ukraine). Red blood cell count was determined manually using a hematocymeter. To determine the number of leukocytes, blood smears were stained using Leucodif 200 reagent (Erbo-Lachema, Czech Republic). Differential count of leukocytes was made in blood smears stained according to Pappenheim (Begerman et al., 1972).

Blood plasma of the cockerels was obtained by centrifuging the samples at 3,500 rpm for 15 minutes. The parameters of anabolism in the blood plasma were determined using biochemical semi-automatic analyzer Humalyzer 2000 and reagents manufactured by Human company (Germany).

To determine the cortisol concentration in blood plasma of the cockerels, we employed AccuBind (ELISA Microwetts) manufactured by Monobind Inc. (USA), while the testosterone content was assayed using test system Testosterone, ELISA, manufactured by DRG Instruments GmbH (Germany).

Five cockerels from each of the gonadoectomized and intact groups were slaughtered on day 185 of the experiment by decapitation, and the samples of thoracic and thigh muscles were taken for the studies of chemical composition. In the thoracic and thigh muscles, we assayed the contents of moisture, dry matter, raw ash, protein and fat. Mass content of nitrogen in the muscles was determined using the Kjeldahl method. The samples were mineralized using DK 6 heating digester (Velp Scientifica, Italy). To remove ammonia from the samples, we employed semi-automatic apparatus for steam distillation according to Kjeldahl UDK 129 (Velp Scientifica, Italy). Content of protein in the muscles was estimated according to overall nitrogen, and ash – by burning the samples in Nabertherm L15 muffle furnace (Germany). Fat content was monitored according to the Soxhlet method using SER 148 automatic extractor (Velp Scientifica, Italy).

The results were statistically analyzed using ANOVA software. The data in the tables are presented as x ± SD (mean ± standard deviation). The difference between the groups was considered significan at $P < 0.05$.

Results

The body temperature, pulse and frequency of respiratory moves in cockerels of the experimental group in the preparation period did not differ from the control (Table 1). Behaviour of cockerels of the experimental group in this period also did not differ from the control, and the birds were active, and consumed water and food well. Six weeks-old gonadectomized cockerels of the experimental group were observed to have 1.06 ºC ($P < 0.05$) higher body temperature on the first day and 1.02 ºC ($P < 0.05$) on the third day of the experiment, while having constant values of pulse and respiratory rate compared with the control (Table 1).

It has to be noted that survival of the poultry after gonadectomy and throughout the experiment remained high (100%) and was no different from the control.

Table 1

Parameters of clinical condition of cockerels after gonadectomy (x ± SD, n = 15

Parameter	Groups	
	control	experimental
Prior to gonadectomy		
Body temperature, ºC	41.80 ± 0.08	41.79 ± 0.07
Pulse, beats per minute	112 ± 2	111 ± 4
Respiratory rate per minute	33 ± 1	33 ± 1
After gonadectomy, day		
First		
Body temperatures, ºC	41.83 ± 0.05	42.89 ± 0.06*
Pulse, beats per min.	110 ± 3	113 ± 5
Respiratory rate per min.	33 ± 1	35 ± 1
Third		
Body temperature, ºC	41.86 ± 0.06	42.78 ± 0.08*
Pulse, beats per min.	111 ± 1	115 ± 4
Respiratory rate per min.	33 ± 1	36 ± 1
10		
Body temperatures, ºC	41.78 ± 0.04	41.81 ± 0.05
Pulse, beats per min.	111 ± 1	112 ± 1
Respiratory rate per min.	33 ± 1	33 ± 1
30		
Body temperatures, ºC	41.82 ± 0.06	41.84 ± 0.07
Pulse, beats per min.	111 ± 2	112 ± 2
Respiratory rate per min.	33 ± 1	33 ± 1
185		
Body temperatures, ºC	41.83 ± 0.07	41.85 ± 0.05
Pulse, beats per min.	110 ± 1	110 ± 2
Respiratory rate per min.	33 ± 1	33 ± 1

Note: * – $P < 0.05$ significant difference compared with the control group according to the results of comparison using ANOVA.

On days 10, 30 and 185 of the main period, body temperature, pulse and respiratory rate in gonadectomized cockerels were not significantly different from the control. However, starting from day 30 of the main period, gonadectomized cockerels were observed to have changes in the secondary sexual features, particularly decrease in the size and colour of the comb, decrease in aggression manifestations, and increase in food consumption.

We determined that live weight of cockerels of the experimental group before the gonadectomy was not different from the control and corresponded to the age of poultry of this species in the growing period (Table 2). We found no difference according to this parameter in gonadecto-

mized and intact cockerels aged 55 to 105 days. However, the live weight of gonadectomized cockerels increased by 13.2% ($P < 0.05$) on the 115th day, by 10.4% ($P < 0.05$) on the 125th day, by 13.3% ($P < 0.05$) on the 135th day and by 17.0% ($P < 0.05$) on the 145th day. Later, at the final stage of the raising, from day 155 to 185, the live weight of gonadectomized cockerels was not different from the control (Table 2).

Table 2
Dynamics in weight of cockerels following gonadectomy (g, x ± SD, n = 15)

Age of birds, days	Groups	
	control	experimental
	Preparation period	
45	622.9 ± 11.1	626.6 ± 13.6
	Main period	
55	780.4 ± 15.3	820.6 ± 16.8
65	990.8 ± 13.7	1120.5 ± 12.3
75	1100.5 ± 14.9	1134.3 ± 18.4
85	1400.8 ± 16.1	1460.1 ± 29.9
95	1500.7 ± 12.5	1590.4 ± 22.1
105	1631.5 ± 88.3	1715.5 ± 82.6
115	1814.5 ± 75.9	2053.8 ± 85.2*
125	1998.8 ± 84.9	2206.9 ± 94.5*
135	2092.2 ± 82.7	2371.2 ± 85.2*
145	2109.8 ± 68.4	2467.1 ± 88.7*
155	2345.4 ± 56.8	2471.2 ± 29.9
165	2496.1 ± 27.4	2598.6 ± 29.2
175	2689.6 ± 41.4	2790.6 ± 25.6
185	2920.3 ± 59.2	3108.3 ± 36.8

Note: see Table 1.

Table 3
Morphological composition in blood of cockerels after gonadectomy (x ± SD, n = 5)

Parameter	Prior to gonadectomy		After gonadectomy	
	croups			
	control	experimental	control	experimental
Hemoglobin, g/L	98.2 ± 4.30	107.6 ± 4.38	138.4 ± 3.96	126.38 ± 2.73
Erythrocytes, 10^{12}/L	2.96 ± 0.05	3.0 ± 0.05	3.64 ± 0.14	3.4 ± 0.07
Thrombocytes, 10^9/L	111.2 ± 3.73	98.4 ± 1.25*	127.2 ± 4.03	95.8 ± 5.20*
Leukocytes, 10^9/L	4.34 ± 0.04	5.52 ± 0.32	12.4 ± 0.44	7.9 ± 0.48*
Heterophils, %	32.6 ± 2.36	37.4 ± 1.92	19.8 ± 1.47	23.4 ± 2.63
Eosinophils, %	5.8 ± 0.7	5.4 ± 0.4	2.4 ± 0.4	4.8 ± 1.1
Basophils, %	0.2 ± 0.2	0.4 ± 0.3	0.2 ± 0.2	0.0 ± 0.0
Monocytes, %	4.2 ± 0.7	3.6 ± 0.7	3.4 ± 0.3	3.4 ± 0.4
Lymphocytes, %	57.2 ± 2.81	53.2 ± 1.47	73.8 ± 1.34	68.4 ± 1.48

Note: see Table 1.

During the preparation period, we saw no differences in hemoglobin concentration, numbers of erythrocytes and leukocytes in blood and the leukogram parameters among cockerels of the experimental and control groups (Table 3). However, the number of thrombocytes in the blood of cockerels of the experimental group was 11.5% lower ($P < 0.05$) than in the control. In the blood of gonadectomized cockerels, as compared with the control, leukocytes decreased by 36.3% ($P < 0.05$) and thrombocytes by 24.7% ($P < 0.05$). At the same time, no changes occurred in the hemoglobin concentration and the number of erythrocytes and the ratios of heterophils, eosinophils, basophils, monocytes and lymphocytes in cockerels of the experimental group.

Table 4
Influence of gonadectomy on the content of hormones in blood plasma of cockerels (x ± SD, n = 5)

Study period	Cortisol, ng/dL		Testosterone, μg/mL	
	groups		groups	
	control	experimental	control	experimental
Prior to gonadectomy	1.85 ± 0.22	1.83 ± 0.27	0.90 ± 0.19	1.02 ± 0.26
After gonadectomy,				
day 3	2.00 ± 0.23	1.43 ± 0.14	0.33 ± 0.09	0.36 ± 0.03
day 20	2.34 ± 0.31	1.92 ± 0.36	0.42 ± 0.11	0.18 ± 0.03*
day 185	1.60 ± 0.32	0.92 ± 0.08	10.92 ± 1.61	5.11 ± 0.75*

Note: see Table 1.

We determined that testosterone and cortisol concentrations in blood plasma of cockerels of the experimental and control groups in the preparation period did not differ (Table 4). Testosterone concentration in the blood plasma of gonadectomized cockerels on the third day of the experiment also was not different from the control. Nonetheless, its concentration in the blood plasma decreased by 2.2 times ($P < 0.05$) on day 20, by 2.1 times ($P < 0.05$) on day 185, compared with the control. Cortisol concentration in blood plasma of gonadectomized and intact cockerels did not change on days 3, 20 and 185.

The studies of metabolites, characterized by carbon-protein and mineral metabolisms, specifically the overall protein, and also the concentrations of glucose, triglycerides, cholesterol, total and ionized calcium, inorganic phosphorus, and also activities of alanine aminotransferase and aspartate aminotransferase, alkaline phosphatase in blood plasma, revealed that in gonadectomized cockerels, they were no different from the control group cockerels, according to those parameters (Table 5). We only determined 26.9% ($P < 0.05$) increase in the concentration of uric acid in blood plasma of gonadectomized cockerels, compared with the control.

Table 5
Biochemical parameters of blood plasma of cockerels following gonadectomy (x ± SD, n = 5)

Parameter	Groups	
	control	experimental
Glucose, mmol/L	13.44 ± 0.24	12.41 ± 0.55
Total protein, g/L	46.56 ± 2.60	47.86 ± 2.70
Triglycerides, mmol/L	0.52 ± 0.24	0.50 ± 0.09
Cholesterol, mmol/L	2.98 ± 0.33	2.96 ± 0.44
Uric acid, μmol/L	339.60 ± 6.50	431.00 ± 16.80*
Alkaline phosphatase, U/L	640.00 ± 19.05	634.00 ± 22.06
Alanine aminotransferase (ALT), U/L	0.60 ± 0.27	0.40 ± 0.27
Aspartate aminotransferase (AST), U/L	231.40 ± 22.16	219.60 ± 16.39
Ca (total), mmol/L	2.74 ± 0.06	2.66 ± 0.05
Ca (ion.), mmol/L	1.51 ± 0.01	1.44 ± 0.02*
Inorganic phosphorus mmol/L	1.57 ± 0.12	1.73 ± 0.12

Note: see Table 1.

The studies determined no significant effect of gonadectomized cockerels on the compositions of thoracic and thigh muscles. We determined only 1.8-fold increase in fat content ($P < 0.05$) in thoracic muscles of gonadectomized cockerels compared with the control (Table 6). As compared with the intact poultry, no changes took place in the content of moisture, dry matter, protein, fat and ash in the thoracic and thigh muscles of gonadectomized cockerels.

Table 6
Chemical composition of muscles of cockerels after gonadectomy (%, x ± SD, n = 5)

Parameter	Thoracic muscle		Thigh muscles	
	groups			
	control	experimental	control	experimental
Moisture	74.87 ± 0.50	72.98 ± 0.85	75.79 ± 0.43	72.30 ± 1.78
Dry matter	25.12 ± 0.50	27.02 ± 0.85	24.20 ± 0.43	27.69 ± 1.78
Fat	0.60 ± 0.04	1.08 ± 0.18*	1.99 ± 0.48	2.20 ± 0.04
Protein	23.17 ± 0.20	23.84 ± 0.21	20.32 ± 0.40	20.43 ± 1.14
Ash	1.12 ± 0.01	1.11 ± 0.03	1.11 ± 0.03	1.09 ± 0.03

Note: see Table 1.

Discussion

During the preparation period, we found no differences in the clinical conditions, morphological composition of blood, live weight, concentrations of hormones in blood plasma among cockerels of the experimental and the control groups. At the same time, gonadectomy, as a way of improving the quality and taste of products (Aikpitanyi et al., 2020) by influencing the hormone profile of caponized roosters (Zawacka et al., 2018), is known to increase their weight and slaughter yield, as well as weight of the carcasses (Kuźniacka et al., 2017), and also activate lipogenesis processes (Kwiecień et al., 2018), and therefore meat from such roosters has better moisture-holding ability and softness, contains more fat

and proteins and less connective tissue (Kasperek et al., 2021). Short-term increase in body temperature which was determined in the experiment in cockerels after gonadectomy on the first and the third day was a consequence of surgery, and its value was returning to the norm as the wound healed. Absence of difference in the parameters of temperature and the respiratory rate in gonadectomized and control cockerels in the later periods of the studies, which corresponded to the physiological parameters, indicate optimum health of the birds.

Absence of differences in the weight of gonadectomized and intact birds at the beginning and during 105 days of the main period is likely related to the effects of caponization and growth peculiarities of birds of this breed (Table 2). Positive influence of caponization on weight of cockerels was seen in the period from 115 to 145-days of age. Positive effect of gonadectomy on the weight of roosters was also determined by other researchers (Wang et al., 2019; Hossen et al., 2021), who explain this fact by increased food consumption (Decuypere et al., 2005), and also change in the hormone profile in the organism (Dutta et al., 2020; Songsee et al., 2020). In the later period of growing, particularly from 115 to 185th day, the weight of gonadectomized cockerels was almost the same as in the control, perhaps due to the peculiarities of growth and development of Alder silver cockerels.

The changes we observed in the hormone profile in blood plasma in gonadectomized cockerels, especially the decrease in the concentration of testosterone on days 20 and 185 compared with the control, were the consequences of the removal of the testicles (Table 4). The obtained data on decrease in the testosterone concentration in blood plasma in caponized cockerels corresponded to the results of the studies by other authors (Murawska et al., 2019). Gonadectomy had effects on the functional condition of hematopoietic organs (Mahmud et al., 2013). Decrease in leukocytes and thrombocytes in the blood of gonadectomized cockerels suggests change in morphological composition in blood of cockerels of the experimental group compared with the control (Table 3), though the blood leukogram of cockerels of the experimental group was not different from the control.

Despite the change in the testosterone concentration in blood plasma of roosters of the experimental group, the parameters of carbohydrate-protein and phosphorus-calcium metabolisms, similarly to the activities of alkaline phosphatase, alanine transferase and aspartate transferase remained at the level of the control.

Increase in concentration of uric acid in blood plasma of gonadectomized cockerels likely occurred as a result of intensified reactions of ureogenesis in the liver in response to increased consumption of feed protein (Table 5).

Insignificant increase in the content of fat in thoracic muscles of gonadectomized cockerels compared with the control likely occurred due to intensification of lipogenesis processes in the liver and its deposition under the skin, in the abdominal cavity, and also in the muscles (Table 6). Guo et al. (2015) attribute the increase in the lipogenesis processes in gonadectomized roosters to the intensification of processes of synthesis of fatty acids. Absence of changes in other parameters of chemical composition of thoracic and thigh muscles in gonadectomized roosters compared with the intact roosters are consistent with studies by Mahmud et al. (2013).

Drawing from the analysis and generalization of the results of the studies, we conclude that gonadectomy of roosters – which has an insignificant effect on the clinical condition, morphological composition of blood, thereby decreasing the content of testosterone in blood plasma – is one of the effective ways of increasing the productivity of birds and improving meat quality.

Conclusions

Body temperature of gonadectomized cockerels on the first and third days increased, while pulse and respiratory rate did not change compared with the control. Parameters of the clinical condition of gonadectomized cockerels on the 10th day and further periods of the study corresponded to such in the healthy birds. Gonadectomy of cockerels changed the numbers of leukocytes and thrombocytes in the blood, and also the level of testosterone in the blood plasma, but did not affect the leukogram, concentration of cortisol, glucose, total protein, triglycerols, cholesterol, calcium, phosphorus, activities of alkaline phosphatase, alanine transferase and aspartate aminotransferase. Gonadectomized cockerels had an increased amount of fat in the thoracic muscles, but the content of moisture, dry matter, protein and ash did not change. The results of the study may be used to improve the ways of producing dietary chicken meat of Adler silver cockerels.

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