Effect of metallic nanoparticles on exchange of chemical elements in broiler chickens

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Abstract. We studied the effect of chromium (III) oxide nanoparticles of various dosages on the elemental status of the organism. Experimental studies were conducted using 150 heads of broiler chickens "Arbor Aykres". The control groups of birds received the main ration, and the experimental groups received chromium (III) oxide nanoparticles in doses of 50; 100; 200 and 400 µg/kg feed. It was noted that with the introduction of chromium (III) oxide nanoparticles into the diet, an increase in the content of Ca, Zn, Cr, Co in dosages of 100-200 µg/kg occurs. The introduction of chromium nanoparticles into the diet of broiler chickens in dosages of 100–200 µg/kg stimulates exchange of chemical elements, increases Co, Cr, Ca, Zn and depresses Cd, Pb exchange. Depending on the concentration of chromium nanoparticles in the diet, the most active phase is the range of 100–200 µg/kg, at which the active metabolism of the main chemical elements occurs.

1. Introduction

Main source of trace elements for poultry are feed. However, the mineral composition of feed depends on the type of soil, climatic conditions, the type of grain or legumes, agrochemical measures, storage and preparation for feeding, etc. In this regard, in raw materials, there is often shortage of some and excess of other trace elements, which leads to emergence of diseases, decreased productivity, reproductive qualities of chickens and roosters [1-3]. Therefore, the study of the effect of trace elements on the body is one of the central places in research work on the physiology and biochemistry of poultry. The main or essential trace elements are Fe, Cu, Zn, and Cr [4-6]. Chromium is involved in maintenance and regulation of blood glucose levels, in lipid metabolism, in maintaining cholesterol homeostasis, and exhibits antioxidant properties [7]. Prospect of replacing traditional sources of microelements with metal nanoforms is determined by the presence of high specific surface area, greater reactivity and bioavailability of nanoparticles [8, 9]. Thus, the search for alternative forms of trace elements is a necessary tool for managing the process of digestion and increasing the conversion of nutrients in the body.

The aim of our work was to establish changes in mineral status of body of broiler chickens when chromium (III) oxide nanoparticles are added to diet.
2. Materials and methods

150 heads of 7-day-old broiler chickens participated in the experiment. Preparation of rations was based on recommendations All-Russian Research and Technological Institute of Poultry (2004). Chickens drank distilled water. Control for 42 days received a basic ration in which chromium was included as chromium chloride (CrCl3×6H2O) (LLC «Reahim», Russia). Birds of experimental groups during experiment (14-42 days) received chromium oxide NP (III) (LLC «Platina», Russia, d=91 nm). Group I received NPs at a dose of 50 µg/kg of feed, II - 100 µg/kg, III - 200 µg/kg and IV - 400 µg/kg.

Dosages from 50 to 400 µg/kg of feed were selected based on the data of researchers [7].

Determination of the content of chemical elements in biosubstrates was determined by atomic emission spectrometry and mass spectrometry with inductively coupled argon plasma on Optima 2000DV and ELAN 9000 devices (Perkin Elmer, USA) in the laboratory of ANO "Center for Biotic Medicine" (Russia). Statistical processing of the data was carried out using the software package Statistica 10.0 and the software package "MS Excel 2000". Data are presented as: mean (M) ± standard error of the mean (m). Reliable considered the results at P≤0.05.

3. The study of the elemental composition and metabolism in body of broiler chickens when introducing chromium nanoparticles into the diet

As result of the research, we found that the greatest growth rate for the experimental period was observed in III and IV experimental groups, with absolute increase in live weight of 2308.83 and 2304 g. Thus, rates were higher than controls by 12 and 11% (p≥0.05). The level of growth indicators in the I and II experimental groups differed from control values by 5-7% (p≥0.05) (Fig. 1).

Table 1. The concentration of micronutrients in the body of birds, g/kg (M±m, n=30)

| Element | Control | I group | II group | III group | IV group |
|---------|---------|---------|----------|-----------|----------|
| B       | 0.51±0.003 | 0.19±0.01*** | 0.226±0.001*** | 0.171±0.0022*** | 0.487±0.0015* |
| Co      | 0.011±0.0001 | 0.0075±0.0001*** | 0.0213±0.00030*** | 0.0143±0.0007*** | 0.0148±0.0002*** |
| Cr      | 0.045±0.0006 | 0.181±0.025 | 0.13±0.0260** | 0.133±0.0045*** | 0.443±0.001*** |
| Cu      | 1.38±0.42 | 0.775±0.045 | 0.620±0.0755 | 1.020±0.013 | 0.370±0.050 |
| Fe      | 21.49±4.4 | 121.12±16.900 | 80.50±6.310*** | 121.31±11.81*** | 56.60±2.670*** |
| I       | 0.295±0.047 | 0.389±0.0390** | 0.363±0.002 | 0.147±0.01* | 0.151±0.0019* |
| Mn      | 0.859±0.013 | 0.579±0.005*** | 0.809±0.001* | 0.879±0.011 | 0.420±0.0045*** |
| Ni      | 0.186±0.007 | 0.093±0.015 | 0.489±0.004*** | 0.174±0.0026 | 0.240±0.0023*** |
| Se      | 0.23±0.005 | 0.191±0.0140 | 0.167±0.001*** | 0.237±0.004 | 0.250±0.0007* |
| V       | 0.005±0.0001 | 0.0139±0.0001*** | 0.0155±0.0003 | 0.0092±0.0002*** | 0.011±0.00014*** |
| Zn      | 18.25±1.569 | 14.75±0.343 | 31.91±3.530** | 19.55±3.050 | 13.98±0.232* |

Figure 1. The difference in the dynamics of the increase in live weight of broiler chickens
Based on the microelement analysis of broiler chickens, we observed in birds of group I both a pronounced increase in a number of elements and their decrease (Table 1). Thus, in group I, an increase in the content of iodine and vanadium was noted, while the content of boron, cobalt and manganese decreased.

In the carcass of group II broilers, a decrease in some elements, such as B, Mn, Se, by an average of 56, 6 and 25% and the accumulation of Co, Cr, Fe, I, Ni, V, respectively, relative to the control group were found.

The addition of chromium nanoparticles in feed of experimental group III poultry had significant impact on the content of minerals in the body. Thus, in group III, we noted increase in content of cobalt, chromium, iron and vanadium in body of broiler chickens. At the same time, the content of boron and iodine in this group decreased.

The inclusion of chromium in NP feed with dosage of 400 µg/kg reduced the content of B, I, Mn, Si and Zn in the body by 3, 50, 52, 61 and 23% relative to the control group. At the same time, in group IV, the content of cobalt, chromium, iron, nickel, selenium and vanadium increased.

Analysis of the chemical composition of the body of birds shows that with increasing concentration of chromium NPs in the diet, the content of K, Mg and P in the tissues of birds of II group increased significantly (9, 50 and 89%), Na in III (1%) of the experimental groups (p≤0,05) (Table 2).

| Element | Control | I group | II group | III group | IV group |
|---------|---------|---------|---------|-----------|---------|
| Ca      | 2.71±0.109 | 5.91±0.984** | 6.36±0.579*** | 8.87±0.858*** | 2.06±0.249 |
| K       | 3.07±0.091 | 2.65±0.184*** | 3.33±0.448 | 3.06±0.141 | 1.67±0.025*** |
| Mg      | 0.31±0.028 | 0.25±0.003*** | 0.44±0.111 | 0.33±0.044 | 0.21±0.002* |
| Na      | 1.18±0.027 | 1.17±0.002*** | 1.16±0.035 | 1.21±0.039 | 0.63±0.009*** |
| P       | 3.91±0.879 | 2.09±0.081** | 7.31±0.011** | 3.58±0.001 | 3.04±0.11 |

Note. *,**, *** - Differences with control are significant at p≤0,05, p≤0,01, p≤0,001

It is very important to study the concentration of toxic substances in body of broiler chickens. The impact of toxic elements leads to pathological changes in the body of animals, causes a metabolic disorder, the structure of organs and neurohumoral systems. Of particular interest is the increase in the content of a large number of chemical elements regardless of which group they belong to.

The element-wise determination of the concentration of microelements in the body of birds revealed a significant difference that characterizes changes in the elemental status of the organism depending on the dose of chromium NPs of various concentrations. In group I, an increase in the contents of I, Ni, V, Ca, Cd, Hg, and Pb was observed. At the same time, the content of B, Co, Mn, Se, Si, Zn, K, Mg, Na, P, Sr in this group decreased.

In group II, an increase in the content of B, Co, Mn, Ni, Zn, Co, P, Pb, Sr. At the same time, the content of Cr, Fe, Se, Cd, Hg decreased in this group.

In group III, an increase in the content of Cr, Fe, Ca, Al, Cd was observed. At the same time, the content of B, Co, I, Pb decreased in this group.

In group IV, an increase in the content of B, Co, Cr, I, Ni, Se, V, Pb was observed. At the same time, the content of Fe, Mn, Si, Zn, K, Mg, Na, Cd, Hg, Sr decreased in this group.

Depending on the concentration of chromium nanoparticles in the diet, the most active phase is the range of 100–200 µg/kg, at which the active metabolism of the main chemical elements occurs.

Based on the knowledge that indicates the likelihood of interaction between chemical elements, as well as taking into account the antagonism and synergy between chemical elements already in the process of their absorption in the digestive tract, some relationships of chemical elements in the body of broilers are calculated (Table 3).

According to Table 3, it can be seen that the concentration of Fe increases with respect to Zn and Cu, Ca to P and Cr to V.
Table 3. Indicators of the ratio of pools of chemical elements in the body of broiler chickens

| Element | Control   | I group    | II group    | III group    | IV group    |
|---------|-----------|------------|-------------|--------------|-------------|
| Fe/Zn   | 1.17±0.08 | 8.18±0.004*| 2.47±0.003* | 6.23±0.003*  | 4.10±0.02*  |
| Ca/P    | 0.68±0.02 | 2.69±0.02* | 0.88±0.03*  | 2.51±0.05*   | 0.68±0.02*  |
| Fe/Cu   | 15.72±0.30| 158.68±19.35* | 126.81±16.78* | 119.1±15.21* | 147.9±10.04* |
| Cr/V    | 8.92±0.14 | 12.41±0.18* | 8.45±0.07*  | 13.63±0.11*  | 44.5±5.87*  |

4. Conclusion
The introduction of chromium nanoparticles into the diet of broiler chickens in dosages of 100–200 µg/kg stimulates the exchange of chemical elements expressed in an increase in Co, Cr, Ca, Zn and

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