The effect of silicon-containing substances on the digestibility of feed and energy exchange in the body of poultry

A S Mustafina and S G Rakhmatullin
Federal Research Centre of Biological Systems and Agrotechnologies RAS, Orenburg, Russia
E-mail: vshivkovaas@mail.ru

Abstract. The article discusses results of studying effects of various doses of ultrafine particles of silicon dioxide (SiO$_2$) on the body of broiler chickens, the dynamics of their live weight, digestibility of nutrients in their diet and the transformation of energy and protein of the feed into the body of an experimental bird. It is established that the use of ultrafine silicon in feeding broilers will increase live weight of the experimental poultry by 3.3–3.5 %, reduce feed intake by 0.7–2.1 %, increase the digestibility of dry matter of growth compound feed by 0.8–1.2 %, raw fat – by 0.2–1.0 %, crude protein – by 0.2–0.5 %, and also increase the net growth energy in MJ per head by 3.5–3.9 %, as a percentage of gross energy – by 8.7–14.3 %, while reducing feed energy loss by 4.0 % and 2.4 %. Therefore, our data reflect the productive effect of highly dispersed silicon oxide on poultry.

1. Introduction
Poultry farming, as a fast-growing industry that significantly expands human nutrition sources, is very important for the agricultural sector. Industrial poultry uses highly productive poultry crosses, genetically determined productivity potential, which can be implemented with balanced feeding and hygiene poultry requirements. In industrial conditions, with the flow of all technological processes, the growth of broiler chickens is accompanied by the adverse effects of various environmental factors. These factors reflect in a decrease of resistance, safety and productivity levels [1, 2]. The provision of high-quality, complete, safe, cheaper feeds and compliance with veterinary and sanitary requirements largely determines the development level and the economy of poultry farming [3].

The productive qualities of poultry largely depend on feeding, namely the content of biologically active substances in a diet, including minerals, which are structural material in the formation of tissues and organs. Minerals participate in metabolism and other biochemical reactions that ensure normal functioning of a bird’s body and its high productivity.

The main role of feed is to provide nutrients that can be digested and used to maintain productive functions. To maximize productivity, pig and poultry diets should contain the right balance of essential nutrients needed to meet nutritional needs at various stages of production [4]. Currently, there is a research conducted on the methods of injection and the influence of various forms of mineral substances on productive and physico-chemical indicators of the product [5]. One of the promising directions for increasing the activity of minerals is their conversion to nanosized materials in order to increase the physicochemical activity and bioavailability for animals and birds [6–9]. At the same time, it is necessary to pay attention to safety problems of using ultrafine particles while assessing their toxicity [10–13].
The goal of the research is to study the effect of ultrafine particles SiO$_2$ (hydrodynamic radius 388 nm) in different doses on broiler chickens, their live weight dynamics, digestibility ratios of feed nutrients, balance and transformation of energy and feed protein in the body of the experimental bird.

2. Materials and research methods

The study was conducted on broilers of cross-country "Arbor Aykres". For the experiment, we selected 150 heads of 10-day-old broiler chickens. The groups were formed according to the principle of analogue pairs of 30 heads in each group.

An experimental bird lived in battery cages with free access to water and feed during a study conducted at the Federal State Budget Scientific Institution of the Federal Scientific Center of the BST RAS. The content, planting density, temperature and light conditions, air humidity, feeding and watering comply with the recommendations of the Serossky Scientific Research and Technological Institute of Poultry [14]. We tried to minimize animal suffering during the study.

The experiment lasted 32 days, including the preparatory and accounting periods, during which broilers received full feed. Experienced poultry was fed twice a day. Starting feed was wheat and soybean feed (1: 1.1), growth – wheat and corn mixed feed (1: 1.8). During the experiment, the chickens of the control group received the main compound feed, and the experimental birds received extra ultrafine particles SiO$_2$ to their main diet: for 1st experimental group at a dosage of 100, 2d experimental group – 200, 3d experimental group – 300, 4th experimental group – 400 mg/kg feed, respectively.

During the experiments, growth and development of chickens was assessed by weekly individual weighing, and the feed intake was recorded daily in each group. The CUC Testing Center on the basis of the FSBI Federal Research Center BST RAS studied the chemical composition of litter, feed and body tissues of broilers according to standard methods.

Based on the results obtained, we calculated energy in the body of the experimental bird. We determined values of gross and exchange energy for characteristics of energy exchange with an external environment. The amount of clean energy in the increased live weight of chickens was established by the method of comparative slaughter, thereby cutting birds into separate tissues and organs. The study considered the mass of tissues and organs during slaughter, their chemical composition, which made it possible to calculate the energy content in the body of animals, as well as the amount of net growth energy. We determined the effectiveness of feed transformation into body tissue of the experimental bird, as well as indicators of meat productivity by generally accepted methods.

Statistical processing of the results was carried out using the software package Statistica 10.0 and the data analysis package Excel 2016 software Microsoft Office. Data are presented as: average (M) ± standard error of the average (m). Reliable considered the results at P≤0.05.

3. Research results and discussion

At the beginning of the experiment, the live weight of broiler chickens averaged 232.33 ± 4.80 g. Starting from the first week of the reference period, analogues of the experimental groups consistently outstripped their peers from the control group. Live weight of chickens in the experimental groups after a weekly supply of finely dispersed silicon was higher than the control values by 2.6, 3.4, 5.8 and 5.2 %, respectively (Figure 1).

The maximum difference in live weight – 6.7 and 5.8 % was observed on the 14th day after the start of the accounting period in 3d and 4th experimental groups, respectively. After that, there is a decrease in live weight and by 42 days it was 1.6, 2.0, 3.5 and 3.3 % for 1st, 2d, 3d and 4th experimental groups, respectively. Thus, the effective growth-promoting effect of ultrafine particles of silicon oxide is observed up to 28 days of age, when the most intense metabolic processes in the bird's body occur.

Feeding of ultrafine silica contributed to a 1.0 % decrease in feed intake for the entire period of the experiment in the 1st experimental group, 2.1 % in the 3rd experimental group, and 0.7 % in the 4th
experimemntal group, and an increase of 1.9 % in the 2nd experimental group compared to the control
group.

![Figure 1](image.png)

**Figure 1.** Change in the difference of live weight of broiler chickens in the control and experimental
groups

Efficiency of using feed contributes significantly to the economic sustainability of broiler chickens
grown for meat, where feed is the most variable cost. Feed efficiency can be measured using feed
conversion and digestibility ratios. The obtained differences in the live weight of broiler chickens can
also be explained by the digestibility of the feed nutrients (table 1).

| Group         | Dry matter | Crude fat | Crude protein | Dry matter | Crude fat | Crude protein |
|---------------|------------|-----------|---------------|------------|-----------|---------------|
| Control       | 60.7±1.97  | 76.0±1.20 | 80.4±0.98     | 82.2±0.25  | 83.8±0.23 | 87.2±0.18     |
| 1 experimental| 58.0±1.20  | 73.7±0.75 | 75.6±0.70     | 80.2±0.80  | 83.6±0.62 | 85.2±0.59     |
| 2 experimental| 60.6±0.98  | 77.3±0.53 | 77.1±0.53     | 82.0±0.95  | 84.0±0.74 | 86.7±0.70     |
| 3 experimental| 61.1±0.90  | 77.5±0.56 | 77.6±0.56     | 82.9±0.52  | 84.5±0.48 | 87.4±0.39     |
| 4 experimental| 63.3±1.98  | 79.6±1.10 | 79.4±1.11     | 83.1±0.18  | 84.7±0.16 | 87.7±0.13     |

Note: *P≤0.05; **P≤0.01 in comparison with the control group.

Digestibility of dry matter of the starting feed for chickens in the control group was 60.7 %. In
chickens of the 1st and 2nd experimental groups, the value of this coefficient decreased by 0.3–4.6 %,
and in chickens of the 3rd and 4th experimental groups, on the contrary, increased by 0.7–4.2 %.
A similar picture is observed with the digestibility rate of dry matter of growth feed: for chickens of
the 1st and 2nd experimental groups, there is a decrease of 0.2–2.4 %, for chickens of the 3rd and 4th
experimental groups, an increase of 0.8–1.2 %.

The digestibility coefficient of raw fat of starting feed in chickens of the 2nd, 3rd and 4th
experimental groups increased by 1.8–4.8 %, and in chickens of the 1st experimental group a decrease
of this indicator by 3.0 % was noted. At the same time, for a given digestibility coefficient of growth
compound feed, a slight increase of 0.2–1.0 % was noted compared with the same value for chickens
in the control group.
The digestibility of raw protein starter feed decreased in all experimental groups by 1.2–6.0 % compared with the same value in the control group. There was also a slight increase of 0.2–0.5 % for the digestibility coefficient of crude protein of growth compound feed in chickens of the 3rd and 4th experimental groups.

One of the most important characteristics of the metabolic processes occurring in the animal’s body is efficiency of the use of exchange energy. According to the research results, it was found that the highest intake of gross energy of the feed was observed in the 2nd experimental group, because in this group, a greater amount of feed per head was consumed, and the lowest gross energy input was noted in the 3rd experimental group, where the feed intake is less than in the control group (table 2).

### Table 2. Balance and transformation of feed energy into the body of experimental broilers during the accounting period.

| Group       | Gross feed energy, MJ/head | Metabolic energy, MJ/head | Net gain energy, MJ/head |
|-------------|----------------------------|---------------------------|--------------------------|
| Control     | 67.0                       | 48.1                      | 5.06                     |
| 1 experimental | 66.4                       | 46.3                      | 5.15                     |
| 2 experimental | 68.3                       | 49.1                      | 5.18                     |
| 3 experimental | 65.6                       | 46.9                      | 5.25                     |
| 4 experimental | 66.5                       | 48.4                      | 5.23                     |

Analyzing laboratory data on the chemical composition of broiler carcasses, we calculated that the net growth energy for chickens of the 1st experimental group was 1.8 % higher than the corresponding values of the control group, the 2nd experimental group – 2.4 %, the 3rd experimental group – 3.9 %, the 4th experimental group – 3.5 %.

Figure 2 shows data on the energy loss of feed released by the body of the studied bird with litter and heat production, namely, the total energy loss in the broilers of the experimental groups is lower than the control values by 1.1, 1.2, 4.0 and 2.4 %, respectively, and net energy growth in 1st and 2d experimental groups is higher than the control values by 4.0 %, in 3d and 4th experimental groups – by 14.3 and 8.7 %, respectively.

![Figure 2. Loss of energy and net growth energy of the experimental bird](image-url)
processes such as biosynthesis of proteins, bones and lipids, and for biochemical processes related to maintenance, for active transport of ions, and for mechanical work [15]. Extracting energy and nutrients from food requires an interaction between the biochemical functions of the organism.

![Figure 3. Protein and Energy Conversion Rates](image)

The highest protein conversion rate of 32.3 % was observed in the 3rd experimental group, then in the 4th experimental (30.5 %), in the 2nd experimental (29.5 %), in the 1st experimental – 29.5 % and lastly in the control – 29.0 %. A similar pattern can be seen when calculating the energy conversion coefficient, namely in the control group it was 28.4 %, in 1st experimental group it was 7.2 % more, in 2d experimental group – 4.5 %, in 3d experimental group – 15.6 % and in 4th experimental group – 7.8 %.

The use of highly dispersed forms of silicon in the composition of feed for broiler chickens made it possible to more efficiently use the exchange feed energy, thereby increasing the transformation of feed protein into food protein, and the exchange feed energy into the energy of the edible parts of the chicken carcass.

The experimental results obtained on the productive effect of the finely dispersed form of silicon are confirmed by experimental data of other authors describing the effect of various ultra-dimensional trace elements metals, including traditional sources of trace elements [5–9]. Moreover, the effect of the drug cannot be explained only by the high bioavailability of trace elements from nanoscale sources or the biological role of silicon as a trace element [16].

4. Conclusion
The use of ultrafine silicon preparation in the amount of 300–400 mg/kg of feed for broiler chickens makes it possible to increase live weight of the experimental bird by 3.3–3.5 %, reduce feed intake by 0.7–2.1 %, increase the digestibility of dry matter of growth compound feed by 0.8–1.2 % , crude fat – by 0.2–1.0 %, crude protein – by 0.2–0.5 %, increase the net growth energy in MJ per head by 3.5–3.9 %, and as a percentage of gross energy – by 8.7–14.3 %, while reducing losses feed energy at 4.0 and 2.4 %.

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