Effect of different doses of silicon dioxide on the concentration of organic acids in the broilers liver

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Abstract. The article presents the results of a study of the amino acid and fatty acid composition of the liver of Arbor Acres broilers, which were fed with ultrafine particles of silicon dioxide at a dose of 100, 200, 300 and 400 mg per kilogram of mixed feed. It was found that the use of UFP SiO₂ in the cultivation of broilers contributes to an increase in the liver of poultry I-IV experimental groups of arginine content by 0.45-0.70%, histidine by 0.75-1.60%. The content of leucine, isoleucine, valine, threonine, and phenylalanine increased in the liver of broilers of the III-IV experimental groups by 0.11-0.96%, 0.1-0.6%, 0.10-0.13%, 0.13-0.47%, 0.23-0.53% compared to the control group. The content of linoleic acid in the liver samples of broilers of the I-IV experimental groups increased by 1.80-36.4%, the content of linolenic acid in the liver of experimental chickens of the III-IV experimental groups increased by 0.1-0.2%, and oleic acid – by 0.6-3.3%, respectively. A sharp increase in the content of AST and ALT in the blood of broiler chickens of the experimental groups was not observed, although there is a dose-dependent increase in the activity of these enzymes, which indicates an increase in liver function against the background of the action of ultrafine silicon dioxide.

1. Introduction

The liver is an organ that occupies a unique place in the metabolism. Each liver cell contains several thousand enzymes that catalyze the reactions of numerous metabolic pathways. The liver plays an important role in the metabolism, detoxification, and elimination of xenobiotics, including drugs and chemicals, thereby making the liver susceptible to their toxic effects [1].

The liver is the central organ that controls lipid homeostasis through complex but precisely regulated biochemical, signaling, and cellular pathways. Hepatocytes are the main cells of the liver parenchyma that control the biochemical and metabolic functions of the liver, including triglyceride metabolism. Additional cell types in the liver include cholangiocytes, Kupffer cells, stellate cells, and endothelial cells. Each of these cells performs specialized functions in the liver [2].

Recently, the beneficial effect of silicon on the development and health of farm animals and birds has been increasingly reported, which is associated with the widespread use of porous ultrafine silicon in various fields of biology, medicine and agriculture.

Porous silicon is not only biocompatible, but also biodegradable. This is due to its large surface area, which causes silicon to rapidly oxidize in an aqueous solution, making it easily soluble. The product of its decomposition, orthosilicic acid, is a compound that promotes a number of synergistic effects in relation to bone regeneration. It has been shown that particles made of porous silicon are...
stable during storage and then easily decompose in plasma, blood, and tissues.

The aim of our work was to study the effect of different doses of ultrafine silicon dioxide on the amino acid and fatty acid composition of the broilers liver.

2. Materials and methods of research

150 heads of healthy broilers of the ArborAcres cross were selected for the experiment in the vivarium of the Federal Research Centre of Biological Systems and Agrotechnologies of the Russian Academy of Sciences and groups of 30 heads each were formed according to the principle of analogues by random sampling, one of which was a control group. The conditions of detention corresponded to the recommendations of the Russian Research and Technological Institute of Poultry Farming [3]. Laboratory studies were conducted in the conditions of the Central Research Center of the Federal Research Center of Biological Systems and Agrotechnologies.

The experimental chickens were fed 2 times a day with dry, balanced compound feeds with nutritional parameters corresponding to the recommended norms of Russian Research and Technological Institute of Poultry Farming [4]. Broiler chickens of the control group were fed with the main compound feed, and poultry of the I-IV experimental groups were additionally injected with ultrafine silicon dioxide after dispersion in saline solution using UZDN-2T (35 kHz, 300 W, 10 µA, 45 min) at a dose of 100, 200, 300 and 400 mg per kilogram of feed. As the studied preparation, silicon dioxide was used in an ultrafine form, in which the mass fraction of silicon is not less than 99.8 %, and the hydrodynamic diameter is 388 ± 117 nm.

To substantiate the effect of the drug, blood and liver samples were taken according to the generally accepted method. The amino acid composition of the liver was determined by capillary electrophoresis using the "Kapel-105" system, and the fatty acid composition was determined by gas chromatography of the mass fraction of methyl esters of fatty acids using the "Crystal 2000M" gas chromatograph. Biochemical blood parameters were determined on an automatic biochemical analyzer CS-T240 using biochemical kits for veterinary medicine.

Statistical processing of the obtained data was carried out using the software package Statistica 10.0 and the software package "MS Excel 2016". The data are presented as: mean (M) ± standard error of mean (m). The results were considered reliable at P≤0.05.

3. Results and discussion

During the amino acid analysis of the broilers liver, it was found that in the liver samples of chickens of the I-IV experimental groups, there was a significant (p≤0.05, p≤0.01) increase in the arginine content by 0.62%, 0.45%, 0.70% and 0.67%, respectively. In the liver samples of chickens of the II-IV experimental groups, the histidine content increased by 0.75-1.60 %, respectively (figure 1).

![Figure 1. Content of non-essential amino acids in the broilers liver. Note: ** – p≤0.01; *** – p≤0.001 comparison with control group.](image-url)
The content of tyrosine in the liver samples of the III-IV broilers experimental groups increased by 0.16% and 0.50% (p≤0.001), proline by 0.13% and 0.23%, serine by 0.10% and 0.40% (p≤0.01), alanine by 0.07% and 0.9% (p≤0.01), glycine by 0.13% and 0.91% (p≤0.01), respectively, compared with similar indicators of the control group.

The concentration of tyrosine, histidine, proline, serine, alanine and glycine in the liver of broilers of the first experimental group decreased by 0.92% (p≤0.001), 0.60% (p≤0.01), 0.97% (p≤0.01), 1.0% (p≤0.01), 1.44% (p≤0.001) and 0.91% (p≤0.01), respectively, compared to the content of these same acids in the liver of control group chickens.

In the liver of chickens of the I-IV experimental groups, there was a decrease in the content of methionine by 0.74% (p≤0.05), 0.39%, 0.46 and 0.30%, respectively, compared with the indicators of the control group (Figure 2).

In the liver samples of the III-IV broilers experimental groups, a greater amount of such essential amino acids as leucine, isoleucine, valine, threonine, phenylalanine was deposited by 0.11% and 0.96% (p≤0.01), 0.10% and 0.60%, 0.10% and 0.13%, 0.13% and 0.47% (p≤0.001), 0.23% (p≤0.05) and 0.53% (p≤0.01), respectively, compared to similar acid concentrations in the liver of control group chickens. The lysine content in the liver of the experimental broiler chickens II-IV increased by 0.75%, 1.26% and 1.60%, respectively, compared to the control group samples.

Analysis of the fatty acid composition of the broilers liver showed that the content of linoleic acid in the liver samples of broiler chickens of the I-IV experimental groups increased by 1.8%, 5.3%, 36.4% and 32.7%, respectively. The content of linolenic acid in the liver of experimental chickens of the III-IV experimental groups increased by 0.1% and 0.2%, and oleic acid by 0.6% and 3.3%, respectively, compared with the control group (Table 1).

**Table 1.** Mass fraction of fatty acid from the total of fatty acids, % (M ± m).

| Name of the acid | Control | 1 experienced | 2 experienced | 3 experienced | 4 experienced |
|-----------------|---------|---------------|---------------|---------------|---------------|
| Palmitic acid   | 24.6±2.31 | 22.3±2.13     | 14.8±1.54     | 22.7±2.46     | 20.6±2.13     |
| Palmitoleic acid| 4.5±0.32 | 3.1±0.19      | 1.0±0.27      | 0.2±0.25      | 4.0±0.29      |
| Stearic acid    | 25.4±1.94 | 20.9±1.81     | 21.9±1.39     | 24.2±2.05     | 24.6±3.17     |
| Oleic acid      | 26.5±1.83 | 20.0±2.07     | 21.3±2.09     | 27.1±2.21     | 29.8±1.97     |
| Linoleic acid   | 18.7±1.31 | 20.5±1.97     | 24.0±2.16     | 55.1±1.86     | 51.4±1.76     |
| Linolenic acid  | 0.3±0.03  | 0.3±0.04      | 0.3±0.03      | 0.4±0.02      | 0.5±0.04      |

Palmitic acid is considered a toxic fatty acid for the liver [5]. The content of this fatty acid in the liver samples of broilers of the I-IV experimental groups decreased by 2.3%, 9.8%, 1.9% and 4.0%,
respectively, the content of palmitoleic acid by 1.4%, 3.5%, 4.3% and 0.5%, respectively, compared to the control sample.

Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) are liver enzymes that are considered important biomarkers of liver function. Their release into the bloodstream and an increase in their serum levels are indicators of liver problems, such as liver disease or damage to liver tissue as a result of exposure to chemicals.

| Indicator name | Control  | 1 experienced | 2 experienced | 3 experienced | 4 experienced |
|----------------|----------|---------------|---------------|---------------|---------------|
| AST            | 123.0±2.10 | 124.7±4.35 | 130.0±2.26 | 137.4±4.34 | 138.4±7.79 |
| ALT            | 5.17±2.31 | 7.37±0.47    | 7.03±0.35    | 7.50±0.57    | 7.53±0.78    |

As can be seen from table 2, a sharp increase in the content of AST and ALT in the blood of broilers of the experimental groups was not observed, although a dose-dependent increase in the activity of these enzymes was observed, which indicates an increase in liver function against the background of the action of ultrafine silicon dioxide.

4. Conclusion
Numerous studies have shown that the liver is one of the target organs of ultrafine silicon dioxide. The toxicity of UF SiO₂ depends on the particle size, with smaller particles causing more liver damage than larger ones. Other experiments suggest that large (150 nm) ultrafine particles of silicon dioxide do not cause functional and histological changes in vital organs.

Our studies did not reveal a toxic effect when using ultrafine particles of silicon dioxide in the feeding of broilers. An increase in the biological value of the liver as a by-product was noted due to an improvement in the amino acid and fatty acid composition of the liver, which was expressed in an increase in the content of essential amino acids, such as leucine, isoleucine, valine, phenylalanine [6] and omega-3 (linolenic) and omega-6 (linoleic) unsaturated fatty acids. These organic acids participate in redox processes, increase the elasticity and reduce the permeability of the vessel walls, form easily soluble compounds with cholesterol, accelerate its conversion in the liver into bile acids, and promote the elimination of cholesterol from the body [7-11].

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