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Review

Application of Humic Substances in Agricultural Industry

Olga Bezuglova * and Aleksandr Klimenko

Federal State Budget Scientific Institution "Federal Rostov Agricultural Research Centre", Rassvet Village, Aksay Region, Rostovskaja Oblast, 346735 Rostov-on-Don, Russia; dzni@mail.ru
* Correspondence: lola314@mail.ru

Abstract: Increasing agricultural productivity and, in particular, the productivity of livestock is one of the primary tasks in the present stage of development of society. This involves rational feeding and the use of biologically active substances, including humic preparations that activate the digestive and metabolic processes in the animal, promoting the transformation of feed nutrients in assimilable form, raising daily milk production and weight gain, and can play an important role in solving this urgent problem. The applications of humic substances in animal husbandry are diverse, but their use as feed additives is not developed sufficiently, and in the EU countries it is not sanctioned. Researchers in different countries have shown that humic substances in animals operate on the cellular and subcellular level, as they do in plants. Low molecular weight fractions HS enter the cell and are involved in metabolic processes, contributing to the optimization of inorganic ion passage through the intestinal wall, thereby promoting the absorption of minerals necessary for normal functioning of the organism. That is how the stimulating influence of humic substances on separate systems and on the organism as a whole is manifested. Humic substances formed from various natural materials are currently being tested in various branches of animal husbandry (cattle, pig breeding, poultry farming, fish farming, fur farming), and all the information received presents convincing evidence of the high efficiency of the humates. Such materials as peat and brown coal, vegetable waste, and vermicompost can act as a source of humic substances. However, in each case, more research is needed, specifying the dosage and schedule of their use.

Keywords: humic preparations; growth factors; agricultural plants; microorganisms; animals

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1. Introduction

Humic acids (HA) are the main organic components of soil and solid fossil fuels, brown coal, peat, and sapropel. In soils rich in humus, their content reaches 5–7%, whereas in some types of brown coal (leonardite), it can exceed 80%. They are formed during plant and animal residue decomposition under the action of microorganisms and abiotic environmental factors and serve as the main constituent of soil humus. Orlov [1] gave them the following definition, "Humic substances are more or less dark colored and composed of nitrogen-containing high-molecular organic compounds of acidic nature," emerging in soil as a result of biochemical processes. Humic substances (HS), primarily humic acids and fulvic acids, attract the deliberate attention of scientists for many reasons. The acidic nature of these compounds is explained by the presence of carboxyl groups, which allows them to be considered polycarboxylic acids [1–4]. However, their nonstoichiometric composition, irregular morphology, heterogeneity of structural elements, and polydispersity make it impossible to use the traditional method of numerical description of the structure of organic compounds, which is to characterize the number of atoms in a molecule, and the number and types of bonds between them. That is precisely why Perminova [5] suggested that with regard to humic substances, the concept of a molecule becomes void; we can only talk about a molecular ensemble with each parameter of it being described by a distribution. In fact, HS are self-assemblies of natural polyelectrolytes widely occurring throughout the environment [6]. Such an interpretation is in line with the hypothesis given by Piccolo, who suggested a supramolecular structure for humic substances [7]. Piccolo [8] considers HS as supramolecular associations of self-organizing heterogeneous and relatively small molecules resulting from plant litter decomposition. This understanding of the structure of humic substances, according to Piccolo, better explains their significant role in ensuring and maintaining soil's physical and chemical properties and their reactivity toward pesticides and other environmental pollutants. Later, by separating HS into fractions and with subsequent chromatography, Nebbioso and Piccolo [9] showed that hydrophobic compounds are mainly distributed in the largest fraction, while hydrophilic components are eluted in the smallest fraction. Further study of the structure of humic compounds showed [10] that they actually represent a humus matrix of a complex multilevel organization. A possible variant of the supramolecular organization of humic acids is represented by a spatial structure consisting of two to four layers of condensed aromatic systems, supplemented by a network of chain fragments of different regularity and length [11].

Today, however, these purely scientific chemical terms are being increasingly applied in practical agriculture. This is explained by the fact that humic substances have high physiological activity, which is expressed in stimulating the growth and development of both plants and animals.

2. Effect of Humic Substances on Growth Processes in Plants

Humic substances are characterized by stimulating and adaptogenic effects on the cellular and subcellular levels. Numerous confirmations have been obtained in vitro and in the field that they affect the growth processes in plants. Notably, the studies were carried out with HS of various origins on different agricultural plants, in different natural zones, and on soils of different fertility capacities. In such experiments, a comparative assessment of the physiological activity of various preparations was carried out, the range of concentrations stimulating plant growth was determined, and the effect on plant productivity and yield quality was studied. Enhanced root formation accompanied by the development of the assimilation apparatus and increased growth of the aerial part was found in plants under the effect of humic substances [12–21]. In plants, phosphorus metabolism changes, which are expressed in a higher number of organophosphorus compounds participating in the reactions of energy transfer and transformation. Sugars accumulate with the intense use of absorbed phosphorus and increased synthesis of nucleic acids [21–28]. Protein metabolism is accelerated, which is accompanied by increased plant growth, decreased nitrate content in the finished product, and improved quality [22,29–32]. The amount of essential amino acids, such as valine, histidine, leucine, isoleucine, and phenylalanine, increases with a slight decrease in the content of lysine and tryptophan [33–35]. The intensity of the processes of respiration, photosynthesis, and water exchange grows, the concentration of chlorophyll and ascorbic acid raises; a clear correlation of the intensity of plant respiration and photosynthesis, the energy potential and activity of redox enzymes with the action of physiologically active substances is observed, especially in the initial phases of plant development [23,36–40]. A decrease in plant attack by root rot is registered [41]. Through the action of humic fertilizers on the plant organism, the yield of agricultural crops increases by an average of 30–90%, even under exposure to fertilizers [24,42–47].

3. Effect of Humic Preparations on Microorganisms

It has been found that humic preparations in soils adjust the regime of nutrient intake [48,49]. In particular, in carbonate chernozems, where plants sorely lack phosphorus fertilizers due to soils' low supply with mobile phosphorus, intensified mobilization processes for this element in plants are observed, which is associated with an increase in the number of microorganisms in the rhizosphere zone [26,47]. The mechanism of humic substances affecting growth, development, and productivity of plants is likely to be explained by their connection with rhizosphere microorganisms and their activation by root secretions of plants treated with humic preparations. The impact of humic substances on soil microorganisms is diverse and affects many aspects of their vital function (Table 1).

Most authors agree that the main effects are somehow related to the membrane, its state, and permeability. Nevertheless, it is still too early to state any final concept of the effect of HA on microorganisms.

Table 1. Stimulatory action of humic substances (HS) on soil microorganisms.

Causes of the Stimulatory Action of HS on Microorganisms	Effect	Reference Data
HAs stimulate the processes of respiration and nitrogen fixation in bacteria	Enhanced growth of the bacterial community, primarily azotobacter	[50–53]
Capacity of humic acid (HA) to chelate trace nutrients	Increased availability of trace nutrients	[54–56]
HA is a source of carbon and energy in the humus mineralization process	Release of bound elements of mineral nutrition	[55,57]
The effect of HA on the membranes of microorganisms (higher permeability)	Slower plasmolysis and deplasmolysis in the *Saccharomyces cerevisiae* yeast	[58,59]
	Improved conditions for the penetration of nutrients into the cell	[60]
HAs sorb substances inhibiting the growth of nitrifying bacteria and trigger their switch to heterotrophic growth	Stimulation of the growth of nitrifying bacteria	[61]
Sorption of HA on the cell walls of bacteria creates a protective layer contributing to withstanding higher concentrations of toxicants, the resistance of bacteria to toxicants improves	copper oxide nanoparticles	[62]
	heavy metal salts	[63]
	radionuclides	[64]
	phenolic compounds	[65]
	atrazine and quinoline	[66]
Penetration of HA into bacterial cells is enhanced under stress caused by salinity	Reduction of the negative effects of stress	[67]
HA, as well as malic and succinic acids, increase the content of sugars and organic acids in the rhizosphere of maize	Growing population of soil microbial communities	[68]

Scientists' keen interest in humic substances, and numerous developments in this area have led to the fact that, at present, the application of humic preparations and fertilizers in crop farming is expanding.

4. Application of Humic Preparations in Animal Husbandry

HS can also be successfully used in animal husbandry. Gorovaya and co-authors [69] provide many examples of the use of humic substances in this industry. Humic substances have anti-inflammatory, adsorptive, and antibacterial effects [69–71], which makes them possible to be successfully used in many branches of animal husbandry. Numerous experiments proving the positive effects of the use of humic substances have been carried out with such species of animals as laboratory rats [72–75], pigs [76–78], sheep [79,80], and cattle [81–83]. A particularly large number of studies have been carried out in poultry farming with broiler chickens and laying hens, quails, and other types of poultry [84–90] and in fish farming [91–94].

In the USSR, the Presidium of the Veterinary Pharmacological Council under the Main Directorate of Veterinary Medicine of the State Agro-Industrial Sector of the USSR back in 1987, based on the results of state production tests, made a decision to use concentrated sodium humate as a feed supplement in the diets of cattle and poultry [66]. In the EC, the use of HA and their sodium salt for the oral treatment of all animals on food production farms is currently permitted [95]. However, humic acid substances are not currently authorized as a feed additive under EU regulations, so they cannot be considered for use as such in organic farming [96,97]. The fact that HS are used to treat animals might make EU legislators cautious about authorizing their use as feed additives.

In the meantime, the European Union has permitted the use of organic acids, such as formic, propionic, lactic, citric, fumaric, and sorbic acids and their salts (e.g. calcium formate, calcium propionate) in poultry farming, as they are considered to be safe [98,99]. Therefore, the use of organic acids in growing broilers and laying hens increases their immunity and productivity through improved use of nutrients [100]. At the same time, humic acids are also carboxylic acids of natural origin, the effectiveness and safety of which has been proven in crop farming and animal husbandry, both in experimental studies and in production tests. Table 2 shows examples of the use of humic preparations in poultry farming. They indicate that, notwithstanding some variations in dosage, different age groups of the tested chickens, and the use of humates from various manufacturers, humic preparations, as a rule, improve the growth and condition of broiler chickens. In an experiment where added humate did not have a positive effect [101], the cause should be most likely sought in the dosage of humate. Such facts indicate the need to continue research focusing on experimental conditions. This refers not only to the applied dosage, which should be optimal, but also to the age of chickens.

Table 2. The effectiveness of the introduction of humates as a feed supplement in growing broiler chickens.

Tested Chickens	HA Dosage	HA Effect	Reference Data
Broiler chicks	2.5 kg of Farmagulator DRY^{TM} Humate /per ton of feed	Feeding Humate during the grower period had the most beneficial effect in terms of growth and feed conversion on broiler performance.	[88]
Broiler chicks (Ross-308) from 1 to 49 days of age	Humate, Farmavet International Inc., Turkey at a dose of 0.1–0.3% to basic diet	Humate supplementation had no effect on performance, slaughter, and carcass characteristics, a slightly improvement was observed in FCR for H<sub>1<sub> group fed with diet containing 0.1% humate. In addition, no dead chicks were observed in the humate groups, while there was 1.8% mortality in the control group.	[102]
Hybrid 9-weeks-old ISA BROWN chickens	0.5 g per chicken/day	After concurrent treatment with HA and MeHg, Hg concentrations were lower by 20.6%, 23.8%, 23.0%, and 18.6% in liver, kidneys, brain, and muscle tissues.	[103]
Broiler chicks from 1–28 days of age	5.0 or 10.0 g humate kg^{-1} into feed	Adding humate negatively affected the productive performance of broiler chicks in respect to feed conversion ratio and performance index.	[101]
Broiler chicks	Oxygumate at a dose of 0.1–0.3% to feed contaminated with aflotoxin	HA reduced the toxic effects of aflatoxin in growing broilers (liver damage and some hematological and biochemical changes in serum).	[104]
Broiler chicks Cobb 500, from 14 days of age	Sodium humate, 1.5% in the feed based on rape	Positively affected the dynamics of digestion and uptake, which contributed to the improvement of bone development and immunity in broilers.	[105]
Broiler chicks COBB 500, 1 day of age	8 g and 10 g per kg of feed	1% of humic substances had a positive effect on growth parameters ($p > 0.05$), breast and thigh meat yield, improved individual blood parameters, and increased calcium content in broiler bones ($p < 0.05$).	[106]
One-day-old chickens of hybrid ROSS until 42 days.	0.3–0.7% Humac Natur Mycosorb	Had a positive effect on the nutritional value of chicken meat, as it contributed to higher content of calcium and magnesium in the muscles of the breast and thigh.	[107]

5. The Mechanism of the Effect of Humic Substances on the Animal Body

Possible ways of exposure of animals to humic substances were explored in vitro and in the work environment. For example, Visser [108] studied the distribution of totally labeled humic acid (HA), which was injected intra-abdominally or with drinking water, in rats when studying the possibility of HS entering the tissues of animal bodies. Irrespective of the method of intake, the label was detected in almost all organs, metabolites, and excretions of animals, which indicates the entry of HAs into the tissues of the animal body and their metabolization. The same author, in experiments with isolated pieces of liver, found that in the presence of humic acid, the metabolism of carbon-labeled D-glucose, L-leucine, and uridine is accelerated. In model experiments with isolated pieces of the small intestine, he also demonstrated that HAs improve the passage of inorganic ions through the intestinal wall. All these facts allowed Visser to draw a conclusion about the possibility of HA passage through cell membranes and their metabolization in an animal body.

Stepchenko [109,110] proved that adding biologically active supplements of humic nature to the diets of animals stimulates metabolic processes and the digestibility of nutrients, promotes increased nitrogen deposition, and activates absorption of calcium and phosphorus, as well as some other mineral elements. A group of scientists from Belarus [111] established, based on studies of the morphobiochemical parameters of the blood of cows, that supplementing the diet of cows with the humic preparation Gumosil was accompanied by a 5.5% higher hemoglobin, 6.6% more erythrocytes, and a 5.2% higher alkaline reserve, which also allowed the authors to draw a conclusion about activation of metabolic processes in the bodies of cows. Total protein in the blood serum, which reflects supply with nutrients and macronutrients, increased in the blood of the cows fed with the humic preparation by 7.7%. At the same time, the content of albumin and gamma globulins increased by 8.3 and 14.2%, respectively, which contributed to improved protective reactions in the animals of the experimental group. As a result, the experiment [110] showed an increase in the average daily milk yield in the experimental group by 6.4%. Meanwhile, the gross milk yield per cow was 1433.4 kg, which is 103.5 kg higher than in the reference group. The fat yield from the milk of the cows in the experimental group increased by 7.8%. It was also established that the quality of products improved in terms of the content of solid matter, lactose, and protein.

Griban [112] showed that humic preparations stimulate formation, development, and maturation of blood cells (leukocytes, erythrocytes, platelets), the synthesis of blood proteins, and the use of glucose by body tissues; as a result, there is a credible increase in the level of daily milk production in cows and body weight gain in calves, piglets, and lambs. Similar results were obtained for the use of the humic preparation Guvital when feeding sows and raising post-weaning piglets [113], and for the preparation Rostok when feeding bulls and heifers [114]. El-Zaiat et al. [115] have shown an improvement in blood values in goats fed with HA. They found an increased level of total protein, globulin, and glucose, a decreased content of urea nitrogen, cholesterol, non-esterified free fatty acids, and ketone concentration in the blood. It turned out that humic acids have the ability to affect the intracellular processes of enzymatic decomposition of proteins in various brain structures; the introduction of hydrohumate into the diet of stressed rats increased the adaptive ability of the animals [116]. The authors suggested that the cause could be explained by the membrane trophic properties of the humic preparation.

American researchers [117] found that HS improves the growth performance of pigs and helps to reduce ammonia excretion from manure. Scientists from Korea [118] conducted research on supplementing pig feed with humic substances and concluded that the supplemented diet improves growth rates, the relative number of blood lymphocytes, and meat quality. The changes listed contribute to improved immunity of the animals under study.

Accordingly, humic substances, as biologically active compounds, penetrate into an animal's body and ensure optimization of metabolic processes, thus displaying their stimulating effect on individual systems and the entire body as a whole.

The most frequently mentioned humic preparations used in animal husbandry as a feed additive are sodium humate (known as Guminat), oxygumate, and hydrohumate.

Sodium humates are sodium salts of humic acids obtained through alkaline extraction from sedge and reed peat following the technological procedure developed by the Dnepropetrovsk Agricultural Institute [119]. The Cancer Research Center of the Russian Academy of Medical Sciences has found that Guminat has a pronounced stimulating effect, is not toxic, has no negative side effects on the animal body, and contains no carcinogenic substances. This drug was recommended as a feed supplement to increase the meat productivity of young cattle and pigs. Ten to twelve milligrams of Guminat per 1 kg of animal body weight for a month contributed to an increase in the average daily gain by over 15%. When the animals were slaughtered after the experiment, no pathologies were found in the muscles or parenchymal organs (liver, heart, lungs, kidneys, spleen) [69].

A positive effect of Guminat has also been established with regard to the reproductive function of cows in the postpartum period. Its daily feeding to cows at the 7–8th months of pregnancy reduces the level of pre- and postnatal complications, facilitates the delivery process, and helps increase the livability of offspring. In cows, erythropoiesis (the process of erythrocyte formation) and immunoglobulin synthesis increase, and the activity of leukocyte phagocytosis grows by 10%. In newborn calves, the content of immune proteins increases by 13%, erythrocytes–by 7%, and hemoglobin–by 12% [69].

Guminat as a microadditive in the diet of bulls improves the quality of their sperm: sperm motility increases by 8%, spermatozoid concentration by 11%, resistance by 23%, and the number of live sperm cells by 20%. In addition, its use increased the number of lymphocytes in the blood of servicing bulls: T-lymphocytes by 6.2% and B-lymphocytes by 5.3% [69].

In addition to sodium humate, liquid and powdery nitrohumic growth stimulants are used as feed supplements in animal husbandry, poultry farming, and fur farming. Feeding its liquid form to suckling pigs contributed to an 8.3% higher average daily weight gain compared to the reference group. Whereas the addition of dry ammonium nitrohuminate in the amount of 400 mg per 1 kg of body weight in the diet of 2–4-month-old animals increased the average daily weight gain by 33.8%. This can be explained by better digestibility of feed nutrients and a large deposition of protein in the body of animals [120]. In recent years, it has been reported about the use of ligno-humate in animal husbandry with an increase in the reproductive capacity of sows and the productivity of suckling pigs, with the latter being explained by an improvement in the chemical composition of sows' milk [121]. It is also important that the use of humic preparations improves the livability of young animals. At the same time, different preparations differ in the degree of a pronounced effect. In addition, their effectiveness depends on the species, age, and physiological condition of animals [116].

For the same purposes, biostimulant BST is used, which is a growth stimulator obtained from peat by oxidizing it with atmospheric air under pressure. It is added in an amount of 1 g per 100 kg of body weight. Meanwhile, the productivity of cattle increases by 15–25%, and in pigs by 21%, as compared to the reference group. As seen from the findings of long-term tests, the preparations are harmless and do not impair the taste of meat [120].

A technology to produce peat molasses (feed molasses hydrolyzed from peat) by treating peat with sulfuric acid has been developed in Latvia. It is a thick, viscous, opaque brown liquid, bitter with a sweet flavor and caramel smell. It contains about 25% HA and other physiologically active substances: amino acids, organic acids, biogenic amines, and hormones. The addition of molasses to the diet of young cattle in the amount of 5% increases the average daily weight gain by 15% [120].

At the Boksitogorsk Biochemical Plant, feeding peat sugar is produced by means of acid-free hydrolysis of peat containing HAs. Feeding peat sugar to cows contributes to 10–15% higher milk productivity, and the weight of young animals increases by 11–17%. Sugared peat formed in the course of thermochemical destruction of high-moor peat with a low degree of decomposition is a feed supplement, as it contains 16% of easily digestible carbohydrates. In addition, it also includes HS. When included in the diet, the supplement makes it possible to increase weight gain by 10% [120].

Farms in the Leningrad Region have mastered the production of nutritious feed from sphagnum peat. Carbohydrate peat feed is obtained by heating peat with steam in a standard steam cooker and processing it with quicklime and calcium carbonate. When peat is treated with urea or its mixture with alkali, carbohydrate protein peat feed, which also includes HS, is obtained. The use of this technique allows you to increase the digestibility of feed (carbohydrate protein peat feed against carbohydrate peat feed) by 40% [120].

In Kharkov, in the BIOMOS Specialized Research and Production Complex, synthetic biomoses–biologically active metal complex compounds like natural humic substances have been developed [122]. They are used for prevention and treatment of dyspepsia, a digestive disorder resulting from the insufficient release of enzymes, in calves. The effectiveness of dyspepsia treatment with biomos is 98–99% and of its prevention is 99–100%. The content of total protein in the blood serum also increases, and as a result, the weight gain increases by 20%. A similar effect of biomoses is seen in piglets.

The use of sodium humate in poultry farming is very effective. The egg production of laying hens and the biological properties of hatch able eggs are improved, and an immunostimulating effect manifested in increased activity of phagocytes and the response of B cells is also observed [88]. The introduction of sodium humate into the diet of chickens in the form of drinking solutions increases the livability of young animals up to 100% and daily weight gain–by 9–14%; weight gain in ducklings increases to 24–43%, while the values of hemoglobin, vitamin A, and nucleic acids also improve [123].

It was suggested that one of the causes for the positive effect of humates on poultry is increased absorption of nitrogen, phosphorus, and other nutrients under the influence of HS due to their chelating properties [123]. At the same time, a study where laying hens received 30–60 g of sodium humate per 1 ton of grain showed no significant differences in the quality of eggs with a statistically insignificant increase in egg weight compared to the reference group [124].

Potassium humate is a black powder with a high concentration of humic acid salt (up to 80 g/L). Applied in the diets of dry cowbanes (4 g/head per day), it contributed to a 22.4% increase in the body weight of newborn calves, and 23–28% higher intensity of growth and development of young calves of up to 2 months of age [125]. Rapid postpartum recovery of the reproductive system was also noted in cows, which significantly increased the conception rate. Average daily milk yield increased by 18–20% with a simultaneous reduction in the consumption of metabolic energy and crude protein of dry matter of feed by 13.5–14.5%, compared with the reference group of animals.

The same authors showed that the introduction of potassium humate at a dose of 75–100 mg per 1 kg of combined feed contributes to increased productivity of poultry in the experimental groups during the reference period (125 days) by 3.2–15.1%, the weight of eggs by 2.4–4.4%, in comparison with reference poultry.

The advantages of feeding poultry and fine-wool sheep with the addition of potassium and sodium humate have also been established [126,127].

Liquid potassium humate is recommended as a feed supplement to increase weight gain and reduce morbidity in fish. As a matter of curiosity, the introduction of the drug into the fertilization medium raises the percentage of egg fertilization from 34 to 64%. The identical effect is achieved when it is administered to female carp 36 h before the eggs are taken. In addition, more viable off springs were obtained [128].

Humic preparations are used as a feed supplement in fur farming as well. The use of a nitrohumine preparation on minks reduced the number of stillborn kits by 6%, also contributed to an increase in weight gain by 12–15% and an improvement in the quality of skins. The humic preparation Khristekol introduced into the diet of minks had a positive effect on the reproductive function of the animals–the number of littering females and kits in one female increased, the livability of young animals, and the quality of fur increased [120].

The addition of natural HS to the feed of dairy goats (at a dose of 3 g/kg of body weight) was also followed by higher productivity of animals. Increased milk yield did not entail a change in the composition of milk; at the same time, a decrease in the level of cholesterol was observed in the blood serum of goats [129].

It is important that feed supplements with humates help to reduce the negative impact of certain adverse environmental factors. For instance, when keeping cows in the conditions of increased radiation, feeding zeolite in combination with humate and a perlite-humic mineral mixture in the form of supplements to the diet corrected the physiological status of animals and heightened the indices of their immunobiological reactivity and milk productivity [130]. Humic acid is also effective for neutralizing neurotoxins in the case of sublethal chronic botulism in cattle [131]. The use of HA is also effective in neutralizing lead poisoning, which damages the thyroid gland in chickens [132], decreases the accumulation of lead and cadmium in fish, and increases their growth rate [133]. This effect of HS in living organisms is explained by their high chelating ability. They bind to toxins, including heavy metals, pesticides, radioactive particles, and environmental carcinogens, and remove toxins from the body–liver and digestive tract.

Some authors warn that the results of the application of humates are largely determined by their properties, which in turn depend on the source and method of obtaining; therefore, further research and verification of each product is essential to develop specific recommendations for their use [134].

6. Conclusions

Widespread use of humic preparations in animal husbandry is ecologically and economically feasible; however, their use as feed supplements has not been sufficiently developed. Studies by scientists from different countries have demonstrated that humic substances in the animal body work on the cellular and subcellular levels. Low molecular weight fractions of HS penetrate into the cell and are involved in metabolic processes, optimizing them and promoting the passage of inorganic ions through the intestinal wall. Thus, the stimulating effect of humic substances on individual systems and on a whole body is manifested. So far, humic preparations have been tested in various branches of animal husbandry (cattle breeding, pig breeding, poultry farming, fish farming, fur farming, etc.), and all the data obtained present convincing evidence of the high efficiency of humates. Moreover, such media as peat, brown coal, plant waste, and biological humus can act as a source for the production of humic preparations. However, in each specific case, more research is needed to specify the dosage and intake regimens.

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