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FEED ADDITIVES FROM MARINE HYDROBIONTS FOR BROILER CHICKENS

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The monograph presents new theoretically and experimentally substantiated results of comprehensive research on the use and effect on the body of broiler chickens of feed additives made from marine hydrobionts — Mediterranean mussels and red algae.

The publication should be useful for specialists in poultry feeding, veterinary medicine, and biology, students, and postgraduates of higher educational institutions.

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CONTENTS

LIST OF ABBREVIATIONS

ALP — alkaline phosphatase
ALT — alanine aminotransferase
AST — aspartate aminotransferase
BABS — bactericidal activity of blood serum
BGCP — bacteria of the coliform group
CFU — colony-forming units
DSTU — state standard of Ukraine (**D**erzhavnyi **St**andart **U**krainy)
LABS — lysozyme activity of blood serum
MA — mineral additive
MPC — maximum permissible concentration
PMA — protein-mineral additive
QMAFAnM — Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms

INTRODUCTION

The condition of the musculoskeletal system is one of the important indicators of the welfare, health, and productivity of broiler chickens (Kierończyk *et al.*, 2017; van der Eijk *et al.*, 2022; Wang *et al.*, 2023). Lameness or leg weakness is a major cause of poor poultry welfare and serious economic losses in meat poultry production worldwide. Foot-related disorders often have a multifactorial etiology, making diagnosis and appropriate treatment difficult (Liu *et al.*, 2021; Szafraniec *et al.*, 2022). The decisive factor determining the strength of bones is the content of inorganic substances, and primarily Calcium and Phosphorus (Saunders-Blades *et al.*, 2009; Zhang *et al.*, 2019). The bone tissue of broilers of modern crosses is less mineralized and more porous compared to their genetic predecessors, which is associated both with a higher growth rate and higher requirements for the composition of the diet (Świątkiewicz *et al.*, 2012).

In connection with the fact that the natural mineral deposits of Phosphorus are being depleted, the problem of finding non-traditional raw materials is of particular importance. Its source can be marine hydrobionts, which are used mainly for food, medical, and cosmetic purposes (Cordell *et al.*, 2012; Morris *et al.*, 2019; Ventura and da Silva, 2019).

The marine biosphere is a rich source of health-promoting substances such as bioactive peptides, polysaccharides, polyunsaturated lipids, carotenoids, polyphenolic compounds, minerals, saponins, and phytosterols. These substances show many potentially useful biological functions, including antioxidant, antimicrobial, antitumor, antidiabetic, antifibrotic, and neuroprotective effects (Hosseini *et al.*, 2022; Šimat *et al.*, 2022; Ahmed *et al.*, 2023). Research by scientists of the Odesa State Agrarian University has proven that marine hydrobionts such as mussels and red algae can be used as a source of protein, mineral, and biologically active substances (Harnazhenko *et al.*, 2007; Kovbasenko *et al.*, 2009) under organic standards of animal husbandry. They have a high nutritional value and are rich in macro- and microelements, including Iodine, protein, nitrogen-free extractives, and vitamins (Toyes-Vargas *et al.*, 2018; Ajala *et al.*, 2023).

Pastes made of finely ground particles of mussels and algae are the best form of feed supplements from hydrobionts. Using marine hydrobionts in animal feed can also help reduce pollution of the Black Sea coast caused by waste from their primary processing, which can be a source of infectious diseases for humans and animals (McLaughlan *et al.*, 2014; Ritzenhofen *et al.*, 2021).

Given the urgency of finding new non-traditional sources of nutrients and biologically active substances, our efforts were aimed at researching the effectiveness of using mineral and protein-mineral feed additives (MA and PMA) developed by us for broiler chickens.

Chapter 1

MARINE HYDROBIONTS AND SEAWATER: BIOLOGICAL FEATURES, CHEMICAL COMPOSITION AND USE

Seas and oceans are the most valuable sources of food on Earth. The importance of marine organisms as a natural source of new substances that can contribute to the food sector and general human health is increasing (Ngo and Kim, 2013; Šimat *et al.*, 2020). Consumer demand for healthy food products is growing. The marine biosphere is a rich source of health-promoting substances such as bioactive peptides, polysaccharides, polyunsaturated lipids, carotenoids, polyphenolic compounds, minerals, saponins, and phytosterols. These substances show many potentially useful biological functions, including antioxidant, antimicrobial, antitumor, antidiabetic, antifibrotic, and neuroprotective; they improve sleep, lower blood lipids, and heal wounds (Kim et Li, 2011; Hosseini *et al.*, 2022).

Hydrobionts of the sea are all living organisms adapted to stay in the water environment. The Black Sea is rich in hydrobionts and promising for their cultivation. The presence of a long coastline, a large area of water, and a warm climate contribute to their reproduction and growth and allow you to extract them throughout the year without any special expenses. Among them, fish, mollusks, and algae, which have been used for food by people living near the sea since ancient times, have the greatest importance for meeting human nutritional needs (Kovbasenko *et al.*, 2009).

Marine hydrobionts are not only valuable raw materials for the production of complete and delicate food products for humans but also non-traditional raw materials for the production of fodder and feed additives for farm animals. A significant contribution to solving the problem of the use of marine hydrobionts in feeding agricultural animals was made by research carried out by scientists of the Odesa Agrarian University under the leadership of Professor V. M. Kovbasenko. It was established that marine hydrobionts, as well as waste from their primary processing, are valuable raw materials for the production of non-traditional feeds rich in complete protein, minerals, and biologically active substances necessary for the growth and development of farm animals (Kovbasenko *et al.*, 1987, 1994, 2002, 2004, 2006, 2008, 2009, 2018; Harnazhenko, 2005–2007).

The northwestern part of the Black Sea is called the "kingdom of mussels". According to expedition research, mussel stocks range from 26.1 to 99.1 million cwt and average 77.2 million cwt, with an annual stock of 0.5 million cwt (Kholodov *et al.*, 2010). There are more than 70 species of mollusks in the Black Sea, among which two are of industrial importance: the edible mussel (*Mytilus edulis*) and the Mediterranean mussel (*Mytilus galloprovincialis*) (Lahunov and Koval, 1986). The advantage of mussels over other types of mollusks is their high productivity, which does not require feed and does not require special equipment for harvesting.

According to the current technical conditions, no more than 60% of caught mussels are used for food purposes, and the remaining 40% is the waste of primary processing, which consists of selecting larger specimens, as well as cleaning them from sand and other foreign particles. Thus, mussels, which make up the bulk of their primary processing waste, differ only in smaller size (Kovbasenko *et al.*, 1987).

One of the most promising sources of fodder and feed additives for animals can be seaweed, which is the main component of the hydrobionts of the sea. They are a valuable raw material for industry and, especially, for agar production. Seaweeds are the most "yielding" plants of the sea. Their reserves in the world's oceans amount to hundreds of millions of tons (Vodopianov and Babyi, 1981).

Some sea urchins pose a risk as invasive species, pose significant threats to local ecosystems, and additionally represent a significant socio-economic burden due to the large amount of biomass accumulated as waste. Therefore, developing measures for their utilization is relevant (Agabo-García *et al.*, 2023; Barcellos *et al.*, 2023).

There is another important point in solving the problem of using marine hydrobionts, namely, mussels and algae, in feeding. By using the waste of the primary processing of mussels, namely, the flaps of large mussels and the bodies of small ones, as well as the waste of algae processing in animal feed, a very important topical ecological and economic problem of their disposal is solved. Such waste from the activities of processing enterprises in the form of landfills pollutes the coastline and represents a potential source of the emergence and spread of infectious diseases in humans and animals (McLaughlan *et al.*, 2014; Morris *et al.*, 2019). It is proposed to use the flaps of mussels and shells in the production of effective bioadsorbents for the absorption of dangerous substances, including antibiotics, pyrethroids, and heavy metal salts (Alidoust *et al.*, 2015; Ma *et al.*, 2023; Míguez-González *et al.*, 2023). Blue mussel meal is an effective substitute for fishmeal in feeding Atlantic salmon (Azad *et al.*, 2023). Process water from the mussel cooking chain contains a significant amount of protein and fatty acids that can be used in animal feed (Forghani *et al.*, 2023).

The body of the Mediterranean mussel is elongated, consisting of a trunk and a leg, covered with a wedge-shaped shell, which is narrowed in front and widened at the back, and the top is shifted to its front end. The shell is represented by two symmetrical flaps, which are connected by a flexible ligament and an adductor muscle. While contracting, the latter tightly closes the edges of the flaps, protecting the body of the mollusk from external influences. The outer surface of the shell is calcareous and has a dark color, and the inner one is covered with a dense mother-of-pearl layer. The mussel's body is covered with a mantle that falls freely from the sides in two large folds. In the back of the body, the mantle grows, creating two tubes – food and air (Kholodov *et al.*, 2010).

The size of mussel populations is characterized by significant fluctuations, their number depends on many factors, first of all, on the sanitary condition of seawater.

That is why, for an objective assessment of such populations, it is necessary to conduct annual expeditionary studies of its quality indicators. Mussel harvesting begins in mid-September and ends at the end of May. In the summer, mussel fishing is stopped due to their reproduction.

Mussels are a valuable protein, mineral, and vitamin food product. The nutritional value of mussels is due to their unique chemical composition. Mussel meat has a high content of complete protein, which is chemically similar to fish, as well as fats, carbohydrates, vitamins, minerals, and biologically active substances. The chemical composition of mussel meat is subject to slight fluctuations depending on the season, environmental conditions, and physiological state. The highest content of organic substances contained in it is observed in autumn and summer, with trace elements in spring (Kovbasenko *et al.*, 2004).

Mussel meat contains 19 amino acids, including all essential amino acids. Regardless of the place of extraction, the content of essential amino acids is constant and amounts to 38.7%. In terms of the amount of such essential amino acids as lysine, tryptophan, histidine, phenylalanine, leucine, and arginine, mussel meat exceeds beef and a whole chicken egg (Toyes-Vargas *et al.*, 2018). Sea mussels are a potential source of protein in poultry feed due to their high content of methionine and cysteine (Jönsson *et al.*, 2010). The protein content of mussel meat is mainly influenced by its size (Vodopianov and Babyi, 1981). Marine mollusks have been found to contain compounds, including polysaccharides, with a wide range of biological activities, including antioxidant, immunomodulatory, and antitumor effects (Ahmed *et al.*, 2023).

In addition to protein, mussel meat is rich in minerals, which determines their high biological value as a source of macro- and microelements. Their total amount in terms of dry matter is from 11 to 16%. The meat of mussels contains Sodium, Potassium, Calcium, Magnesium, Ferrum, Copper, and Cobalt in a much larger amount than the meat of farm animals. Mussel meat is rich in B and D vitamins, as well as ascorbic acid and carotenoids (Kovbasenko *et al.*, 1987).

Flaps are rich primarily in Calcium and Phosphorus and contain about 40 trace elements that are well absorbed by the bird's body and are essential for their growth and development. The content of mineral substances in mussel flaps is more than 10 times higher than that of most traditional feeds and is unchanged (Berge and Austreng, 1989; Jonsson *et al.*, 2009).

Non-industrial (non-standard, smaller than 4.0 cm), as well as mussels, which do not meet veterinary and sanitary requirements in terms of freshness, and empty flaps, can be raw materials for feed production (Kovbasenko *et al.*, 2006). Bacterial insemination of mussels is a qualitative and quantitative reflection of the seawater in which they are found. Industrial mussels mainly grow and reproduce in the coastal waters of the sea, in the shallows, that is, in those areas that are most polluted by human waste (Kosianchuk and Fodchenko, 2015).

Given that mussels are a powerful biological filter through which 5-6 liters of seawater containing microorganisms, and physical and chemical pathogens pass every hour, they can represent a potential source of human and animal diseases (Antoshyna, 1990). Accumulation of pollutants often occurs in the digestive gland, which plays an important role in their absorption, elimination, and detoxification. In addition, it is known that the concentration of chemical pollutants in bivalves varies according to the season (Guéguen *et al.*, 2011; Mehouel *et al.*, 2022; Gomez-Delgado *et al.*, 2023). Water temperature, size, and the type of contaminant affect the degree of contamination of mussels (Novakov *et al.*, 2021; Giannico *et al.*, 2022). Given the ability of mussels to absorb and assimilate organic matter, as well as Vibrio spp. contained in seawater, they are used as a means of restoring coastal waters to a good ecological state (Ritzenhofen *et al.*, 2021). Moreover, nutrient removal costs make farmed mussel farming a cost-effective measure compared to the most expensive land-based measures (Petersen *et al.*, 2014).

It should be taken into account that water contaminated with metals (Zinc, Plumbum, Copper) hurts bivalve mollusks, disrupting the mineralization of the valves and thereby reducing their strength (Stewart *et al.*, 2021).

Insemination of mussels by microflora is highest in summer. If, in the summer, contamination of mussels with opportunistic microflora, incl. E. coli is 1×10^3 CFU per 100 cm^3 of mollusk content and is isolated from 50-80% of samples, then in winter its content decreases to 1×10^2 CFU per 100 cm^3 and such microflora is isolated from only 30-60% of samples (Avdeeva and Tretiakova, 1986). Mussels are most often contaminated with aerobic gram-positive non-spore forms of bacteria *Achromobacter, Flavobacterium, Micrococcus*, spore microflora of the genera *Pseudomonas, Aeromonas*, vibrios, clostridia, etc., which can be a source of food toxic infections and toxicoses (Antoshyna, 1990).

It is necessary to take into account not only the bacterial state of mussels after their extraction but also the secondary insemination that occurs after they are caught. Compliance with veterinary, sanitary, and technological requirements for transportation, storage, and primary processing of mussels contributes to reducing the content of microflora in them. Keeping mussels after catching them in running water helps to reduce the content of microflora not only on their surface but also in their tissues (Vodopianov and Babyi, 1981). Bacterial insemination of mussels is reduced if they are treated with chemical preservatives (ascorbic acid, sodium bisulfite, sorbic acid, sulfuric anhydride solution, etc.) that are approved for use (Tarasenko *et al.*, 2018).

In the process of storing mussels, complex biochemical processes take place in them, which lead to their deterioration. This must be taken into account when using mussel waste as a feed material (Lahunov and Koval, 1986).

Human uses seaweed for various purposes: consumption, as raw material for the production of animal feed, and as fertilizer to increase soil fertility, as well as for the production of biologically active and medicinal substances (de Jesus Raposo *et al.*, 2015; Geetha and Tuvikene, 2021). Extraction and processing of algae takes place in the countries of the East Asian continent, in European countries, as well as in the USA and Canada (Rupert *et al.*, 2022).

The Black Sea is extremely promising for the cultivation and extraction of algae. But in Ukraine, their livestock is only used for the production of agar and partly for the production of potassium salt, fertilizers, and iodine. In the Black Sea, out of 30 types of edible algae, no more than 0.05% of their quantity is used for economic needs. The chemical composition of algae indicates the possibility of using algae as a valuable feed additive for animals (Kovbasenko *et al.*, 2006).

Depending on the species, algae contain 4.4-11.4% of protein, 0.6-3.5% of fat, 3.2-27.6% of fiber, 33.4-65.9% of nitrogen-free extractives, and 11.3-38.5% of mineral substances. Their nutritional content can be compared to high-quality hay or even grain. In addition, algae are rich in iodine, the content of which varies from 200 to 8600 mg/kg of dry matter, which is hundreds of times higher than its content in forage crops (Gómez-Ordóñez *et al.*, 2012; Iji *et al.*, 2017).

Phyllophora nervosa and *Phyllophora Brodiaei* are the most widespread among different types of algae. It was established that *Phyllophora nervosa* contains a significant amount of minerals: Calcium – 4.32%, Phosphorus – 0.21%, Sulfur – 3.91%, Ferrum, Copper, Manganese, Cobalt – 1050-2696 mg per 1 kg of dry matter (Vodopianov and Babyi, 1981).

Red algae, which is a source of nutrients and biologically active substances, has a significant potential for use. Red algae are a rich source of polysaccharides, lipids, proteins, physiologically active substances, and secondary metabolites, such as polyphenols, which have a positive effect on the state of non-specific immunity in both animals and humans (Pujol *et al.*, 2002; Bansemir *et al.*, 2004; Lins *et al.*, 2009; Souza *et al.*, 2012; de Jesus Raposo *et al.*, 2015). Carrageenan, a polysaccharide obtained from red algae, has enormous economic potential in many industries, including pharmaceutical, food, cosmetic, printing, and textile (Jiao *et al.*, 2011; Ajala *et al.*, 2023). Such substances are characterized by multifunctionality, therapeutic potential, and immunomodulatory abilities, which makes them promising bioactive products and biomaterials with a wide range of biomedical applications (de Jesus Raposo *et al.*, 2015, Muhamad *et al.*, 2019). Seaweed carrageenans have antiviral, antitumor, anti-inflammatory, and immunomodulatory effects on the body (Campo *et al.*, 2009; Liu *et al.*, 2013; Yang *et al.*, 2023). Other red algae compounds, such as brominated furanone derivatives, have antimicrobial properties (Janssens *et al.*, 2008; Kulshreshtha *et al.*, 2016). Components of cultivated red seaweeds improve the immune response and have antihepatotoxic, anticoagulant effects (Liu *et al.*, 2013; Geetha and Tuvikene, 2021).

Phyllophora nervosa is a valuable industrial raw material from which agaroid is produced. After its production, waste with the technical name "iodka" remains, which looks like beet pulp, consisting of particles up to 3-5 mm in size (Kovbasenko *et al.*, 2008).

Therefore, marine hydrobionts such as mussels and red algae contain a sufficiently large amount of nutrients and biologically active substances that can be used in feeding farm animals. Sea mussels, which are mined in the Black Sea for food purposes, can be a health hazard not only for humans but also for animals as part of feed additives. That is why marine hydrobionts must be disposed of in compliance with the requirements for sanitary quality indicators under the current requirements.

In addition to hydrobionts, an important biological resource of the sea is seawater – the environment in which marine organisms reproduce and live.

It can be used in feed rations of animals as a non-traditional raw material that promotes growth and improves the quality of their products (Hryhoreva and Korchak, 1982). Sea water is a complex solution of mineral substances that determine its salinity. In the winter season, the salinity of the seawater increases slightly due to a decrease in the inflow of annual water. Of the biotic elements, seawater contains Nitrogen, Phosphorus, Silicon, Hydrogen, Oxygen, Ferrum, Manganese, and others, which determine the biological productivity of the seas (Melnyk, 2005). The content and concentration of biogenic chemical elements in seawater give it the properties of high-quality raw materials for feed production. However, it must be taken into account that seawater can contain a significant amount of pathogenic and conditionally pathogenic microflora (Hryhoreva and Korchak, 1982).

Bacteriological studies of seawater and bottom sediments in places of its sewage pollution revealed a significant number of aerobic gram-negative rods, bacteria of the genus *Pseudomonas, Aerobacter, Flavobacterium, Bacillus, Vibrio,* etc. The specific microflora of seawater is represented by nitrogenous bacteria – nitrogen fixers, denitro fixers; heterotrophic (saprophytes), of which cocci form up to 6%, non-sporing bacilli – about 84%, sporulating – up to 7% and mycobacteria – up to 4% (Melnyk, 2005). The high bacterial contamination of seawater is explained by the ability of most microorganisms to multiply in it. The duration of survival of dysentery bacteria in seawater is 10-15 days, typhoid bacilli – 20 days, the causative agent of tuberculosis – up to 19 months, and proteus – up to 12 months, depending on the water temperature (Kosianchuk and Fodchenko, 2015). Microorganisms multiply most intensively in seawater in the summer season. Among them, 80% are bacteria distributed in soil and freshwater, and only 12-14% are specific microflora inherent in the sea (Melnyk, 2005).

Taking into account the species composition of the microflora, the sanitary assessment of seawater, following the current requirements, is carried out in two main directions: determination of the total number of heterotrophic microorganisms and the coli titer.

At the same time, according to the data of other researchers, some enteropathogenic bacteria die in seawater after only a few hours. Their death occurs in the process of natural self-cleaning, which is carried out in a relatively short time. In 30 minutes to 1 hour. in seawater, up to 80% of microorganisms that arrived with wastewater can die (Hryhoreva and Korchak, 1982).

Numerical studies on the sanitary quality of marine hydrobionts were mainly aimed at establishing the degree of bacterial insemination. Research on the impact of other pathogens – biological, physical, and chemical, that can enter the body of hydrobionts has not been carried out enough, which is explained by the fact that until 2004, official documents of Ukraine did not provide for research on the content of toxic elements in mollusks and other marine hydrobionts, found in seawater (Kosianchuk and Fodchenko, 2015).

Therefore, seawater is a habitat for marine hydrobionts, rich in biotic chemical elements that can be used for the production of fodder for agricultural animals, as well as opportunistic and pathogenic microflora, which can be dangerous.

CONCLUSIONS

1. Free feeding of a mineral supplement in the form of coarsely crushed mussel flaps did not cause any significant change in the body weight of broiler chickens. Changes in morphometric indicators of macroscopic and microscopic structures of digestive organs were observed with its use, which indicate the development of protective and adaptive reactions to mechanical irritation of the wall of the oesophagus and stomach, and a high calcium content in the chyme of the small intestine. The condition of the esophagus and stomach of broiler chickens indicates the need to use a feed supplement made of mussels in the form of flour, which would not have a traumatic effect on the mucous membrane of the digestive organs.

2. Protein-mineral (PMA) additive, unlike mineral additive (MA), contains protein and fat – 5.6±0.05 and 1.8±0.07%, respectively. PMA has an advantage over MA in the content of Phosphorus by 556.9% and is inferior in the content of Calcium by 66.5% and dry matter by 43.1%.

3. It has been proven that feed additives made from marine hydrobionts are hygienically safe for use by broiler chickens: their microbial contamination by QMAFAnM was five times less than the maximum permissible level; they did not contain *Escherichia coli, Salmonella, Staphylococcus, Proteus*. MA and PMA did not show a toxic effect on white mice and cultures of the infusoria *Colpoda steinii*.

4. The use of PMA, prepared from a mixture of flaps and bodies of mussels and red algae, in broiler chickens contributed to an increase in body weight by 2.7% ($p \leq 0.05$) when it replaced part of the diet, and by 4.5% ($p \leq 0.001$) when the diet was enriched, while no such effect was detected when feeding MA containing only the flaps of mussels.

5. Enrichment of the main feeding ration of chickens with MA and PMA (groups D-2 and D-4) in the amount of 7% by weight led to an increase of functional activity of the duodenum, as evidenced by an increase in the surface area of the villi by 35.0 ($p \leq 0.01$) and 42.2% ($p \leq 0.01$) and an increase in the ratio of the height of the villi to the depth of the crypts by 9.0 and 31.9 ($p \leq 0.01$) %, respectively.

6. With the use of PMA in the diet of broiler chickens (groups D-3 and D-4), an increase in the hemoglobin content in the blood was noted by 7.6 ($p \leq 0.05$) and 8.0% ($p \leq 0.05$), as well as the number of erythrocytes by 5.8 and 9.8% and leukocytes by 6.1 and 6.3%, which contributed to the activation of the intensity of protein metabolism by increasing the content of total protein, albumins, globulins, as well as alanine and aminotransferase in the blood serum, which indicates an improved state of non-specific immunity.

7. According to a comparative assessment of the influence of microclimate parameters on the state of productivity and non-specific immunity of broiler chickens, a reliable increase in body weight by 4.7%, hemoglobin content by 7.6%, BABS by 34.5%, LABS by 35.9% was established with the use of PMA in terms of its normative indicators.

8. The introduction of feed additives (PMA and MA) into the diet of chickens contributed to the improvement of mineral metabolism in the body, as evidenced by reliable changes in blood serum indicators – an increase in the content of inorganic phosphorus in broilers D-1, D-2, D-3 and D-4 groups by 34.4; 26.2; 38.5 and 23.0%, a decrease in the calcium-phosphorus ratio by 23.0; 13.0; 24.0 and 20.0% and a decrease in the content of alkaline phosphatase by 53.5; 28.2; 44.6 and 57.8%, respectively.

9. Broiler chickens responded to the use of feed additives in the diet by strengthening bone tissue, as evidenced by the increased content of inorganic calcium and total phosphorus in the tibia, as well as its strength in chickens of the D-1 group by 19.9, respectively; 34.1 ($p \leq 0.01$) and 10.9%, D-2 group – by 23.6 ($p \leq 0.05$); 43.0 ($p \leq 0.001$) and 48.9 ($p \leq 0.001$) %, D-3 group – by 16.8; 43.6 ($p \leq 0.001$) and 10.8%, D-4 group – by 34.2 ($p \leq 0.05$); 70.9 ($p \leq 0.01$) and 52.2 ($p \leq 0.05$) %.

10. Feeding PMA to broiler chickens of D-3 and D-4 groups contributed to an increase in dry matter in minced meat by 2.6 ($p \leq 0.01$) and 1.8 ($p \leq 0.001$) %, and in its composition protein – by 1.4 and 3.9 ($p \leq 0.01$) %, tryptophan – by 0.05 and 0.18 ($p \leq 0.01$) %, and the protein qualitative indicator – by 29.7 ($p \leq 0.01$) and 36.4 ($p \leq 0.001$) %, while no such noticeable changes were found when using MA. The use of both feed additives led to a

significant decrease in the content of Strontium and Manganese in minced meat by 21.2-63.1% and 37.7-48.0%, respectively.

11. The economic efficiency of using MA in the rations of broiler chickens in terms of profitability when replacing more than 7% of the feed mass with it was 7.59 UAH, and PMA – under the condition of replacing and enriching the diet – 6.31 and 10.54 UAH per 1 UAH of expenses.

12. To reduce environmental pollution by waste from the primary processing of marine hydrobionts, enrich diets with minerals, increase the production and quality of meat of broiler chickens, and increase the strength of the bones of broiler chickens, it is suggested to use mineral and protein-mineral feed additives.

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