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MECHANISMS AND NUTRACEUTICAL METHODS FOR IMPROVING THE FEED CONVERSION RATIO OF POULTRY

Abstract

*The materials of the article consider the main problems of modern poultry farming. The regulation of the intestinal barrier function and the resistance of poultry to infections is proposed using the complex preparations Activil-3 and Butyvil 400. The mechanisms and nutraceutical methods for improving the feed conversion ratio for farm poultry are considered in detail. The main characteristics of nutraceuticals for livestock and poultry farming, their main functions and examples of preparations and active substances are given. The main physical properties of the complex preparations of the probiotic Activil-3 and the postbiotic Butyvil 400 are characterized and investigated. Activil-3 contains live bacteria: Clostridium butyricum (4b1830) - not less than 1*106 CFU/g, Bacillus licheniformis (4b1700i) - not less than 1*109 CFU/g, Bacillus subtilis (4b1700i) - not less than 1*109 CFU/g. A comparative assessment of sodium and calcium butyrates is carried out. The efficiency of assimilation of different forms of butyric acid is schematically presented. The main advantages of sodium butyrate, which allow its use in compound feeds, are established: very high biological activity and inability to dissolve in water at any pH value of the medium. The results of the dynamics of the mechanism of improving the intestinal barrier function when using sodium butyrate - Butyvil 400 in chicken diets for 14 days are presented. The optimal doses of the drugs when mixed with feed for broilers have been established: Activil-3 - 100-300g/t; Butyvil 400: from 0 to 14 days - 300-500g/t, 14-28 days - 200-300g/t, older than 28 days - 100-300g/t. With the complex use of the probiotic Activil-3 and the postbiotic Butyvil 400 in broiler diets, an increase in the live weight gain of poultry, a decrease in the feed conversion ratio by 3-10% to FCR, improved uniformity of the livestock, increased egg production and improved shell condition, and reduced treatment costs. The economic benefit was confirmed by lower costs for antibiotics and veterinary drugs, a higher yield of safe marketable products, and farm profitability.*

Keywords: poultry, premixes, probiotics, postbiotics, Activil-3, Butyvil 400, feed conversion.

Introduction

The modern poultry industry in the world and in Ukraine faces a number of serious problems that affect productivity, product safety, farm economics and food security. The main key challenges are:

1. Disease and biosecurity - the main threat to poultry farming, which is associated with high-risk avian influenza (HPAI) [1], which continues to be one of the most difficult problems in poultry farming worldwide. Frequent outbreaks seriously reduce the population and force farmers to massively cull poultry, which leads to economic losses, egg and chicken shortages, as well as humanitarian problems. Repeated outbreaks have shown that basic biosecurity measures alone are not enough - comprehensive vaccination programs and new control strategies are needed.

2. Rising feed costs and production costs. The cost of grains (corn, soy products) and feed ingredients accounts for up to 65–75% of the cost of poultry production, and due to market fluctuations [2] this creates significant financial pressure on farmers. In addition, high costs for energy, transport and equipment maintenance [3] also affect profitability.

3. Economic challenges in Ukraine. After the war, domestic consumption of chicken in Ukraine fell [4] due to a shrinking population, which leads to a decrease in the domestic market and reduced profits for producers. Ukrainian producers also face stiff competition in foreign markets [4], especially from other exporters.

4. Management problems and staff shortage. Insufficient technical knowledge and professional training of farmers leads to poor farm management [5], deterioration of poultry conditions and increased losses. The lack of qualified personnel (veterinarians, agronomists, technologists) [6] also undermines efficiency.

5. Market instability and logistical difficulties. Overproduction of day-old chicks, infrastructure shortages, uncertain logistics and price fluctuations create instability in the chicken and egg market [7], especially for small and medium-sized farmers. Due to price fluctuations, farmers either reduce production or oversupply [7] in an uncontrolled manner, which is detrimental to long-term sustainability.

6. Environmental and social issues. Poultry farming generates significant amounts of waste (litter, feed residues). Improper disposal of this waste can contaminate soil and water, which is detrimental to long-term sustainability [8], causing conflicts with local communities and environmentalists. In some countries, public attention to animal welfare, free-range farming and sustainable production methods [2] is affecting production strategies and profitability.

7. Product safety and quality. The use of antibiotics, food safety issues, bacterial and parasitic risks, and challenges in providing quality vaccines are ongoing problems [9-11] that require constant monitoring and modernization of practices.

Problem statement

The quality of products depends on the safety of animal husbandry and feed. The relevance of this issue,

taking into account the current realities of poultry farming, depends on high stocking density, stress factors [12-14], strategies for obtaining the highest technological indicators and the desire to obtain superprofits, restrictions on the use of antibiotics [13, 15, 16] and other drugs.

One of the safety solutions in poultry farming is the nutraceutical approach in the development of premix and compound feed formulations - this is a modern feeding strategy that combines the classic provision of nutrients with a targeted effect on health, immunity, productivity and quality of products (meat and eggs).

Nutraceuticals are biologically active substances of natural origin [17, 18] that are introduced into feed or water to:

• improve the health and resistance of poultry;
• increase the efficiency of nutrient absorption;
• stimulate growth and productivity without the use of antibiotics.

Nutraceuticals occupy an intermediate position between feed additives and veterinary drugs [17, 18], the main groups, action and active substances are given in Table 1.

The purpose of the work is to study the effect of complex preparations Activil-3 and Butyvil 400 on the intestinal barrier function and resistance of poultry to infections.

To achieve the goal, the following tasks were solved in the work:

- the properties of complex preparations Activil-3 and Butyvil 400 were investigated;
- a comparative assessment of sodium and calcium butyrates was conducted;
- the complex effect of preparations in the composition of compound feeds for poultry was assessed.

Materials and methods

The work used a systematic analysis of scientific publications devoted to the mechanisms of formation of the feed conversion ratio in poultry and the use of nutraceutical approaches to improve it. The information base of the study was the results of experimental and review works of domestic and foreign authors, published in scientific journals, monographs, materials of international conferences, as well as recommendations of specialized industry organizations. The analysis mainly included publications published within the last 10–15 years, with a priority on works containing experimentally substantiated data on the impact of nutraceutical components on the digestibility of nutrients, the morphofunctional state of the gastrointestinal tract, intestinal microbiota and metabolic processes in poultry. The criteria for selecting sources were scientific validity, clearly described research methodology, statistical processing of results and practical significance for feed production and poultry farming.

During the study, general scientific methods of analysis, synthesis, comparison and generalization of information were used. Comparative analysis of the results of different authors allowed us to assess the effectiveness of individual groups of nutraceutical additives (probiotics, prebiotics, postbiotics) in improving the feed

Table 1 - Definition of nutraceuticals for livestock and poultry

Group	Main action	Examples / active substances
1. Prebiotics	Stimulate the growth of beneficial intestinal microflora	Mannan-oligosaccharides (MOS), fructooligosaccharides (FOS), inulin, β-glucans
2. Probiotics	Populate the intestines with live beneficial bacteria, displace pathogens	Bacillus subtilis, Lactobacillus spp., Enterococcus faecium, Bifidobacterium spp.
3. Postbiotics	Probiotic metabolites (organic acids, short-chain fatty acids, bacteriocins)	Sodium butyrate, propionic, lactic acid, lysozyme, Lauryl-90
4. Organic acids	Lower intestinal pH, inhibit pathogens, improve digestion	Formic, fumaric, citric, propionic acid; acid combinations
5. Butyrates (salts of butyric acid)	Nutrition of enterocytes, regeneration of intestinal villi, anti-inflammatory effect	Butyvil®, Adimix®, Tributyrin, ButiPEARL®
6. Phytonutrients (phytonutrients)	Antimicrobial, antioxidant, immunostimulating effect	Essential oils of oregano, thyme, cinnamon, rosemary; allicin, curcumin
7. Humic and fulvic acids	Adsorb toxins, modulate microbiota, stimulate immunity	Humifeed® Sodium and potassium humates, Humifirst®, Humifeed®
8. Antioxidants of natural origin	Protect cells from oxidative stress, improve product quality	Tocopherols (vit. E), polyphenols, grape seed extract (Nor-Grape®), rosemary
9. Omega-3 fatty acids	Anti-inflammatory effect, improve yolk quality, cardiovascular health	DHA, EPA from fish oil or algae
10. Enzymes	Increase nutrient absorption, reduce antinutritional factors	Xylanase, β-glucanase, phytase, protease
11. Immunostimulants and metabolic modulators	Increase nonspecific immunity, stress resistance	β-glucans, nucleotides, echinacea, β-carotene, selenium-methionine
12. Mycotoxin adsorbents with bioactive properties	Bind toxins and have additional antioxidant effect	Humates, modified clays, zeolites with antioxidants

conversion ratio and reducing the loss of drinking substances.

The systematization of the obtained data was carried out taking into account the biological mechanisms of action of nutraceuticals, in particular their influence on the activity of digestive enzymes, the state of the intestinal microflora, the barrier function of the intestine and energy metabolism. The generalized results were used to form a comprehensive picture of modern nutraceutical strategies for increasing the efficiency of feed use in industrial poultry farming and to identify promising areas of further research.

Studies of the poultry intestine were evaluated using morphological and histological methods [19, 20], which allow assessing the structural and functional state of the intestinal mucosa (duodenum, jejunum, ileum, cecum). Samples were taken after humane slaughter of the poultry. Tissue fixation was performed in 10% neutral formalin, followed by embedding in paraffin or cryoembedding. After that, histological sections (4–6 μm) were prepared, which were stained with hematoxylin-eosin and PAS reaction. In the experimental tissue samples, the height and width of the villi, the depth of the crypts, the ratio of "villus/crypt", the thickness of the epithelium, the number of goblet cells, the presence of destructive changes in the mucosa were visually determined [19, 20].

Research results and discussion

The drug Activil-3 is a fourth-generation probiotic. It is a multicomponent biologically active feed mixture [21], which contains live bacteria, the main characteristics of which are presented in Table 2.

The symbiosis of the listed bacteria (Table 2) allows not only to improve the intestinal microflora, but also to significantly reduce the risk of bacterial diseases due to the natural displacement of opportunistic bacteria (Escherichia coli, Salmonella sp., Clostridium perfringens), stimulating the reproduction of lactic acid bacteria.

The main advantages of the drug Activil-3 include [21-23]:

- helps slow down the passage of food masses through the digestive tract, thereby creating conditions for more complete absorption of nutrients. In addition, excipients prolong digestion and contribute to improving the feed conversion ratio;

- it is possible to combine Activil-3 with coccidiostats and other drugs;

- used as an auxiliary agent for the prevention and treatment of gastrointestinal infections of bacterial and viral etiology, normalization of intestinal microflora in dysbacteriosis of various origins, growth stimulation, increased livestock safety and productivity, extension of the egg-laying period, reduction of the feed/egg ratio;

- reduces feed consumption per unit of production, relieves stress of various nature, helps to increase the body's natural resistance and the level of immunity during and after vaccinations;

- reduces the content of harmful gases (ammonia, hydrogen sulfide) in livestock premises. Improves the biological qualities of litter.

The drug Butyvil 400 is a protected drug of directed action [24]. Microencapsulated multicomponent mixture of sodium butyrate, thymol and cinnamic aldehyde in a specific capsule of hydrogenated vegetable fat.

Composition of active ingredients: Sodium butyrate 40%, Cinnamic aldehyde 4%, Thymol 1%.

Sodium butyrate is rapidly neutralized in the stomach, so the sodium butyrate used in the Butyvil 400 mixture is encapsulated in a fat matrix [24-30], which gradually releases butyrate under the influence of lipase and reduces the negative impact on the intestinal wall as butyrate moves throughout the digestive tract.

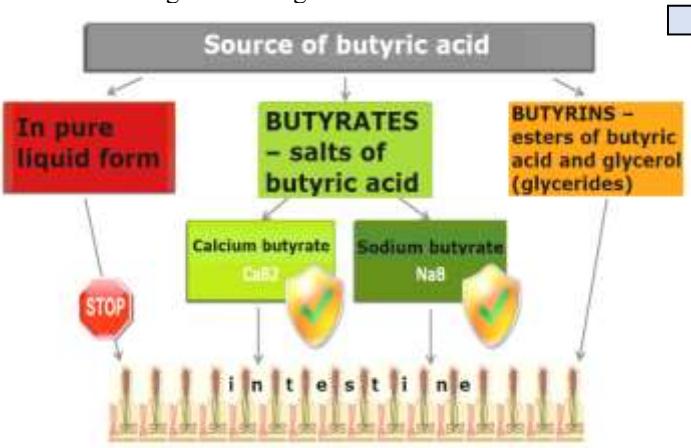

Fig. 1 – Absorption of different forms of butyric acid

Table 2 - Component composition and characteristics of Activil-3

Composition	Content, CFU/g	Characteristics
Clostridium butyricum (4b1830)	not less than $1*10^6$	Spore-forming bacterium that synthesizes a large amount of short-chain fatty acids, especially N-Butyric acid, which, in turn, has an antimicrobial effect on gram-negative bacteria, in particular Escherichia coli, Salmonella sp., Clostridium perfringens.
Bacillus licheniformis (4b1700i)	not less than $1*10^9$	Spore-forming bacterium that synthesizes vitamins in the digestive tract, in particular vitamin K, riboflavin, folic acid; helps maintain acid-base balance in the large intestine and absorb nutrients; stimulates the growth of probiotic microflora and inhibits the growth of pathogenic microorganisms, such as Shigella dysenteriae; restores intestinal microflora.
Bacillus subtilis (4b1700i)	not less than $1*10^9$	Spore-forming bacterium that inhibits gram-positive and gram-negative bacteria by competitive displacement, without causing resistance.

Let's consider the difference between sodium butyrate and calcium butyrate, and which is better to use in poultry feed production. Butyrate, used as a food (feed) additive, usually refers to salts of butyric acid - sodium butyrate and calcium butyrate. There are a number of important differences between the two salts of butyric acid, which determine the features of their use (Table 3): Sodium butyrate has higher biological activity (interacts with body cells at the point of contact of the active substance), and its solubility does not depend on the acidity of the medium. Calcium butyrate has a higher content of butyric acid anions compared to the sodium salt. At the same time, the reactivity and biological effect of the calcium salt are less pronounced, and the solubility is directly dependent on the pH of the medium.

The action of the feed additive is due to its composition [31, 32]. Sodium butyrate has resorptive, antiseptic and phagocytic effects. Sodium butyrate reduces the growth and penetration of pathogenic bacteria, reduces the expression of genes responsible for infection and fixation of E.Coli, Clostridium, Campilobacter and Salmonella. Sodium butyrate promotes the growth of animals and poultry and improves the efficiency of nutrient absorption. It is a source of energy for the intestinal mucosa and restores microvilli, increasing their absorption surface, thereby improving intracellular digestion and absorption of nutrients. Thymol, which is part of the feed mixture, is a natural essential oil with antioxidant properties. It inhibits the growth of mold fungi that produce mycotoxins dangerous to animals. Thymol has antispasmodic, immunostimulating, anthelmintic and antimicrobial effects. Thymol is effective against a wide range of gram-negative and gram-positive bacteria, as well as against yeast and mold fungi. Thymol is rapidly absorbed and metabolized in the digestive tract, affects the detoxification of the body by combining the hydroxyl group with sulfates and glucuronic acid.

Table 3 – Comparative characteristics of butyrates

Indicator	Sodium butyrate	Calcium butyrate
Chemical formula	$CH_3(CH_2)_2COONa$	$(CH_3(CH_2)_2COO)_2Ca$
Molecular mass	110	214
Concentration of butyric acid, %	79,1	81,3
Biological activity	✅ VERY HIGH	Average
Dissolution characteristics	✅ DOES NOT DEPEND on the pH of the medium	At pH greater than 6 practically insoluble

Table 4 – Dosage of drugs when mixed with feed [32]

Purpose	Activil-3, g/t	Butyvil 400, g/t
Broilers		
0-14 days	100-300	300-500
14-28 days		200-300
28+ days		100-300
Laying hens	100-300	100-200
Parent stock		100-300
Turkeys	300-500	200-500
Ducks	300-500	300-500
Purpose	• for microbiota balance • pathogen suppression • immune stimulation	• enterocyte nutrition; • intestinal villi development; • reduce inflammation

The essential oil also helps improve digestion and assimilation of feed in broilers and other poultry species by stimulating the production of pancreatic juice, bile and digestive enzymes. Cinnamic aldehyde is the main component of cinnamon essential oil (up to 90%), which determines its smell. Cinnamic aldehyde is also used as a fungicide, has low toxicity. Essential oils (thymol and cinnamic aldehyde) effectively inhibit salmonella, E. coli (E.Coli) and clostridia (Clostridium perfringens), penetrating the cell and destroying its genetic material.

Sodium butyrate in combination with essential oil form a synergism and mutually enhance the effect of suppressing various microbial infections.

Thanks to the combination of active ingredients, the feed mixture Butyvil 400 helps to reduce feed conversion, improves feed digestibility, reduces the number of pathogenic bacteria and increases the number of beneficial ones, supports poultry health, its resistance to stress, and is also an antioxidant.

Butyvil 400 is used to increase technical indicators (increase in live weight of animals and poultry, increase in egg laying, increase in egg mass, improve egg shell strength), normalize metabolism in the body and increase their digestibility, which has a positive effect on the development of intestinal microflora.

Based on zootechnical studies, the optimal rates of introduction of Activil-3 and Butyvil 400 into poultry diets were experimentally established, which are given in Table. 4.

When diluting drugs in water for broilers and laying hens, 50-100g of the drug is used per 1 ton of water.

The work studied the effect of the drugs Activil-3 and Butyvil 400 on the barrier function of the intestine of broilers on days 7 and 14. Two groups of birds were formed, control and experimental, each with 20 heads. Activil-3 and Butyvil 400 were introduced into the feed of the experimental group of broilers from the first day in an amount of 200 and 300 g/t, respectively. On days 7 and 14, the intestine was analyzed for morphological features. Photographs of individual sections of the intestine of the control and experimental groups of broilers (duodenum, ileum, cecum), at a magnification of 40 and 100 times, are presented in Fig. 2.

Analysis of the photographs shows that the drugs in the complex exhibit a synergistic effect, and the mechanisms for improving the intestinal barrier function include a physical barrier (villi, crypts), a chemical barrier (mucus, antimicrobial peptides), a microbiological barrier (probiotic ↔ pathogens), an immune barrier (IgA, macrophages).

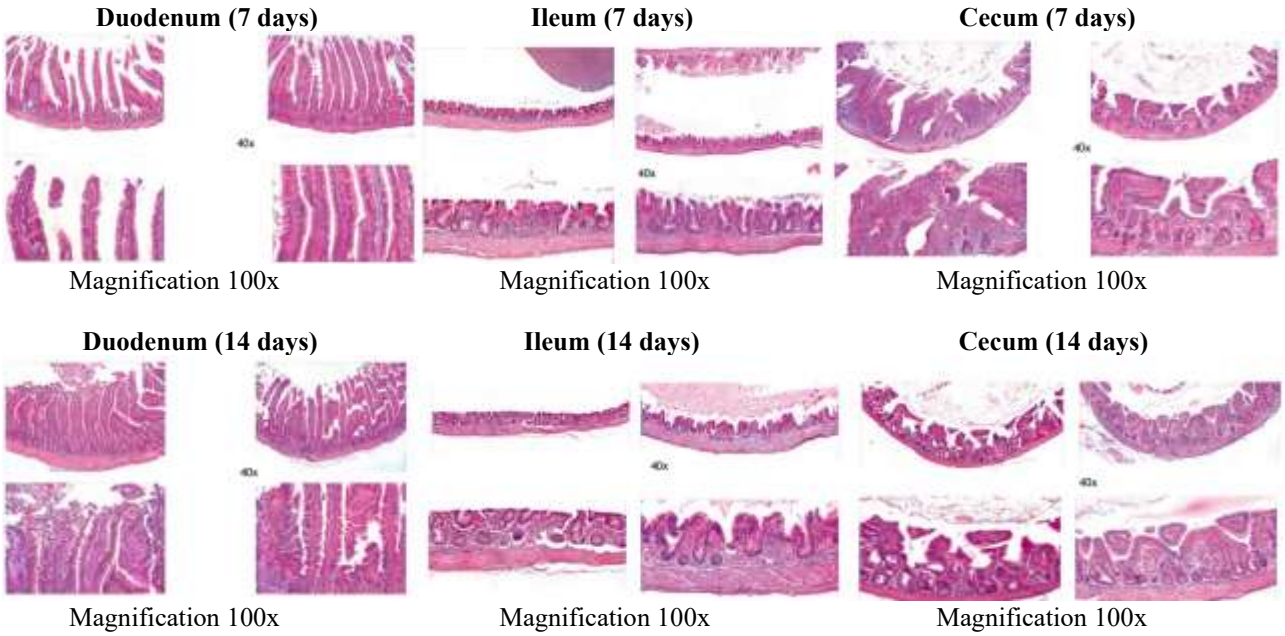

Fig. 2 - Effect of Activil-3 and Butyvil 400 on the condition of the broiler intestine

During the experiment, the efficiency of feed conversion was noted, which was observed in better nutrient digestion, reduced energy expenditure for inflammation, stable microbiota (less competition) and a 3–10% decrease in FCR (Feed Conversion Ratio).

The synergism of the drugs' action ensured stable poultry performance: reduced mortality and intestinal diseases, higher livestock survival, manifestation of an anti-stress effect before heat stress and vaccination, and provision of the "Intestinal Shield" effect against pathogens.

Compound feeds for broilers produced in production conditions with the introduction of the drugs Activil-3 and Butyvil 400 had practical results in poultry farms. When feeding the compound feed, an increase in the live weight gain of broilers was observed, a decrease in the "Feed Conversion" indicator, an increase in the uniformity of the livestock, and a decrease in the cost of treatment. When used in the diets of laying hens, an increase in egg production and an improvement in the quality of the egg shell were observed. The complex use of these drugs allows for economic benefits, since there is less spending on antibiotics and veterinary drugs, there is a greater yield of safe marketable products and the sustainability and profitability of the farm.

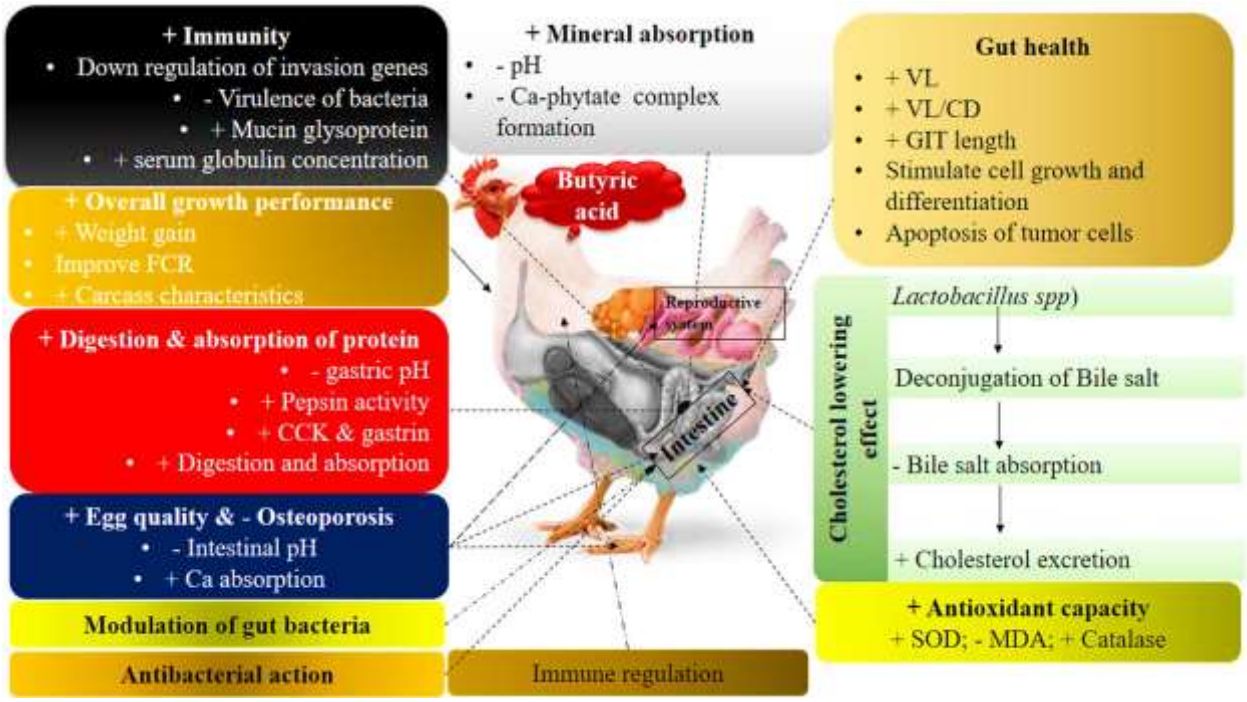

Fig. 3 – Schematic representation of the effect of butyric acid salts on the resistance of poultry [33]

Conclusions

The results obtained indicate that nutraceuticals in poultry farming are the key to antibiotic-free technologies. Their combined use, for example, the complex use of probiotics and sodium butyrate with a phytogenic component, gives a synergistic effect, improving intestinal health (villi morphology, microbiota), feed absorption, 3-10% conversion (FCR), the immune response of the bird's body, productivity and quality of meat or eggs.

The main production solution is the use of the complex nutraceutical solution Activil-3 + Butivil 400, which significantly strengthens the barrier functions of the intestine, optimizes feed conversion, increases the resistance of birds to infections and provides a step towards antibiotic-free modern poultry farming.

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МЕХАНІЗМИ ТА НУТРИЦЕВТИВНІ МЕТОДИ ПОКРАЩЕННЯ ПОКАЗНИКУ КОНВЕРСІЇ КОРМУ ПТИЦІ

Анотація

*У матеріалах статті розглянуто основні проблеми сучасного птахівництва. Запропоновано врегулювання бар'єрної функції кишечника та резистентності птиці до інфекцій за допомогою комплексних препаратів Активіл-3 та Бутивіл 400. Детально розглянуто механізми та нутрицевтивні методи покращення показнику конверсії корму для сільськогосподарської птиці. Наведено основні характеристики нутрицевтиків для тваринництва та птахівництва, їх основні функції та приклади препаратів та діючих речовин. Надана характеристика та досліджені основні фізичні властивості комплексних препаратів пробіотика Активіл-3 та постбіотика Бутивіл 400. Активіл-3 містить живі бактерії: Clostridium butyricum (4b1830) - не менше 1*106 КУО/г, Bacillus licheniformis (4b1700i) - не менше 1*109 КУО/г, Bacillus subtilis (4b1700i) - не менше 1*109 КУО/г. Проведена порівняльна оцінка бутиратів натрію та кальцію. Схематично представлено ефективність засвоєння різних форм масляної кислоти. Встановлені основні переваги Бутирату натрію, які дозволяють використовувати його у складі комбікормів: дуже висока біологічна активність та не здатність розчинятися у воді при любому значенні pH середовища. Наведено результати динаміки механізму покращення бар'єрної функції кишечника при використанні натрію бутират - Бутивіл 400 у раціонах курчат протягом 14 діб. Встановлені оптимальні дози препаратів при змішуванні з кормом для бройлерів: Активіл-3 - 100-300г/т; Бутивіл 400: від 0 до14 діб - 300-500г/т, 14-28 діб - 200-300г/т, дорослі 28 діб - 100-300г/т. При комплексному використанні пробіотика Активіл-3 та постбіотика Бутивіл 400 в раціонах бройлерів встановлено збільшення приросту живої маси птиці, зменшення показника конверсія корму на 3–10 % до FCR, покращення однорідності поголів'я, збільшення несучості і покращення стану шкаралупи, зниження витрат на лікування. Економічна вигода підтвердилась меншими витратами на антибіотики та ветеринарні препарати, більшим виходом безпечної товарної продукції та прибутковістю господарства.*

Ключові слова: сільськогосподарська птиця, премікси, пробіотики, постбіотики, Активіл-3, Бутивіл 400, конверсія корму.

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