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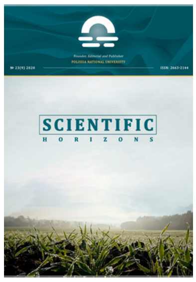

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The current state and prospects for the use of organic acids and their compositions in poultry feed: A literature review

Dmytro Masiuk
Doctor of Veterinary Sciences, Professor
Dnipro State Agrarian and Economic University
49000, 25 Serhii Yefremov Str., Dnipro, Ukraine
https://orcid.org/0000-0002-2800-2580

Victor Nedzvetsky*
Doctor of Biology Sciences, Professor
Dnipro State Agrarian and Economic University
49000, 25 Serhii Yefremov Str., Dnipro, Ukraine
https://orcid.org/0000-0001-7352-441X

Yaroslav Maksymchuk
PhD Student
Dnipro State Agrarian and Economic University
49000, 25 Serhii Yefremov Str., Dnipro, Ukraine
https://orcid.org/0009-0001-2617-1452

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Abstract. The use of antibiotics in poultry farming is critically limited, which leads to the search for and research of alternative compounds to replace antibiotics. Organic acids are considered one such alternative, but the antimicrobial and metabolic effects of fatty acid blends are still controversial and understudied. All this necessitates a systematic analysis of the current data on effective antibiotic replacement strategies. The purpose of this study was to analyse and summarise current ideas on the use of organic acid mixtures as an alternative strategy for sustainable poultry production. An analysis of current literature showed that one of the most promising alternatives to the use of antibiotics in poultry farming is mixtures of organic acids and their derivatives, which have antibacterial effects, lower pH, are involved in energy metabolism, and all this together contributes to intestinal function. Organic acids have a positive effect on physiological functions, namely, digestion and the immune system, are the main source of energy for colonocytes, and reduce the pathogenic bacterial load on the digestive tract. Mixtures of organic acids were shown to be more effective than their individual use, specifically, mixtures of short- and medium-chain fatty acids were shown to be highly effective in supporting the intestinal barrier, microbiome, and immunity, with the former acting better as growth promoters and the latter having higher antibacterial

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*Corresponding author

properties. The efficiency of organic acids alone or in mixtures depends on many factors, depending on the type of molecule, form, and dose. The expediency of further studies of the effects of organic acids was substantiated, which will be useful for the development of antibiotic-free strategies using the synergistic effects of their mixtures and multidirectional cytoprotective effect. The findings of this study will be useful for scientists and veterinarians to learn about the prospects of using organic acid compositions as antibiotic alternatives, specifically for the development of technological approaches to minimise their use

Keywords: blends of short-chain and medium-chain fatty acids; poultry farming; antibiotics; intestinal function maintenance

INTRODUCTION

Poultry farming is the most widespread form of livestock production in the world, due to its relatively low cost and short production cycle. At the current stage of poultry development, the best possible conditions have been created to fulfil the genetic potential of animals. According to N. Haulisah *et al.* (2021), one of the key methods of increasing broiler productivity since the 1950s has been the use of antibiotics as growth promoters (GPs). However, the use of these substances has brought the issue of antibiotic resistance to a new level that threatens humanity. The most widely used antibiotics, as GPs, have been used to improve feed conversion and health status of poultry (Salah *et al.*, 2019). The abandonment of antibiotics has initiated an increase in the number of studies on effective alternative methods of monitoring and correcting animal health, welfare and productivity, including in poultry farming.

A wide range of products have been proposed to replace antibiotics in feed, among which organic acids (OAs) show promising results (Mantzios *et al.*, 2023). The pool of carboxylic acids that are most common in living organisms is represented by free fatty acids and those that are part of the lipids of living organisms. According to D. Venegas *et al.* (2019), according to the chain length, fatty acids are divided into short-chain fatty acids (SCFAs) – containing up to 6 carbon atoms, medium-chain fatty acids (MCFAs) – containing 6-12 carbon atoms, and long-chain fatty acids (LCFAs) – containing 13-21 carbon atoms. There is also elongated chain fatty acids (VLCFAs), which have over 22 carbon atoms. All SCFAs have varying degrees of water solubility, which distinguishes them from LCFAs, which are insoluble. In the poultry industry, SCFAs are used more frequently and somewhat less frequently than MCFAs as an alternative to antibacterial preparations and growth stimulants. G. Galli *et al.* (2021) note that the effectiveness of SCFAs and MCFAs is influenced by a considerable number of factors, among which the key ones are the chemical structure, form of additive, its amount and method of supplementation, buffer capacity of feed, and its nutritional value.

Organic acids are widely used as additives in drinking water or as feed additives (acidifiers). They are often used in the salt forms (sodium, potassium, or calcium and/or partially esterified). According to M. Aljumaah *et al.* (2020), the advantage of using salts is their odourlessness, solid form (the purest organic salts are volatile), lower corrosivity, and better solubility. The efficiency of an organic acid depends on its molecular weight, pKa value and form (undissociated or dissociated), which together determine the difference in antimicrobial activity and bioavailability. Several OAs have a specific bioavailability. The bioavailability of OAs can be improved by choosing the correct form of additive that promotes OA adsorption by cells. F. Mannelli *et al.* (2019), N. Qi *et al.* (2023) pointed out that the use of fatty acid salts is the simplest solution, as these salts are solid, which facilitates the technology of feed production and improves their organoleptic properties. Microencapsulation is considered a promising way to deliver organic acids to the digestive tract. Therewith, the composition of the coating that envelops the OA ensures a more efficient release of these substances in the right place in the digestive tract.

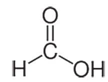
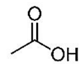
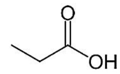
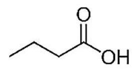
The purpose of this study was to summarise the current comprehension and prospects for the use of short- and medium-chain organic acids in poultry farming as safe substitutes for antimicrobial agents and/or growth promoters based on the analysis of available literature.

APPLICATION OF SCFAS IN POULTRY FARMING

OAs are organic compounds with acidic properties, the most common of which are carboxylic acids, whose acidity is related to their carboxylic group – COOH. These acids are weak, partially dissociated and have a pKa (pH at which the acid is half dissociated) of 3 to 5. SCFAs used in poultry production include oil, vinegar, propionic, dairy, formic, apple, wine, fumaric, and sorbic (Ricke *et al.*, 2020). SCFAs (acetate, propionate, and butyrate) are produced by bacterial fermentation in the intestine and have certain effects on metabolism and the immune system. Apart from being important cross-nutrition products, microbial metabolites also have a positive effect on the mucous membrane of the digestive tract. SCFAs play an important role in the metabolic and immune homeostasis of the digestive tract, as well as in the integrity of the intestinal barrier, which opens great opportunities for therapeutic development (Venegas *et al.*, 2019).

The intestinal microbiota releases SCFAs (mainly acetate, propionate, and butyrate) in the colon during fermentation, from where they are absorbed by the colon epithelium through passive and active transport. The pathways of formation of various SCFAs and the corresponding microbial producers were identified. The products of microbial fermentation of SCFAs are the main source of energy for colonocytes (Deleu *et al.*, 2021). At the same time, all commensal gut taxa ferment pyruvate to produce butyrate, while pathogenic bacteria, such as Fusobacterium, use different pathways, such as glutamate (4-aminobutyrate) and lysine, which are associated with the release of harmful by-products, such as ammonia. The key factors that limit the production of SCFAs in the digestive tract include pH, growth factors, and gas levels. Carbohydrates, which lead to high production of SCFAs, lower the pH in the colon, which affects the microbial composition and production of SCFAs. The availability of growth factors such as iron is crucial for the production of SCFAs. Significantly lower concentrations of butyrate and propionate were found in the faeces of iron-deficient rats. Iron deficiency induces an increase in the number of Lactobacilli and Enterobacteriaceae species and, conversely, a decrease in *Roseburia* and *Eubacterium rectale* species, which are the main producers of butyrate. Oxygen and Hydrogen levels affect the fermentation process and the production of SCFAs (Louis & Flint, 2017). Overall, only 4 SCFAs are currently widely used in poultry production (Table 1).

***Table 1**. Short-chain fatty acids used in poultry production*

Name		Formula		Mass (g/mol)	Diagram
Common	Systematic	Molecular	Structural		
Formic acid	Methanoic acid	CH_2O_2	H–C(=O)–O–H	46.0	
Acetic acid	Ethanoic acid	$C_2H_4O_2$	CH_3COOH	60.1	
Propionic acid	Propanoic acid	$C_3H_6O_2$	CH_3CH_2COOH	74.1	
Butyric acid	Butanoic acid	$C_4H_8O_2$	$CH_3(CH_2)_2COOH$	88.1	

***Source:** compiled by the authors of this study based on the literature data*

Acetic, butyric, and propionic acids are the most abundant SCFAs in the colon, where they have a positive effect on energy status by providing a carbon source for the intestinal microbiota through the activation of glyoxylate pathway enzymes. In commercial poultry production, SCFAs are mainly associated with antimicrobial activity and increased productivity (Scicutella *et al.*, 2021). The antimicrobial effect of propionic and butyric acids is conditioned by the acid dissociation constant (pKa = 3 – 5). Once in the intestine, they lower the pH, which inhibits potentially pathogenic bacteria, and increase the level of calcium, phosphorus, and magnesium in the blood serum due to improved absorption (Us *et al.*, 2017).

Lactic acid is used in poultry production both in pure form and in the form of butyrates, coated/encapsulated (lipid-coated) butyrate salts (Nguyen *et al.*, 2020) and butyrate glycerols (butyrine). Each product formulation has its own advantages and limitations in terms of bioavailability, cost, biosafety, stability, processing temperature/pressure, and digestive release. The use of an encapsulated form of lactic acid in laying hens showed better results than butyrate.

Butyric acid is one of the main acids that are successfully used in industrial poultry farming. This acid modulates the state of symbiotic microbiota and improves immunological homeostasis in the intestine. Butyrates (calcium or sodium salts) are easily converted to butyric acid in the digestive tract and are considered safe. Compared to other MCFAs, butyrate has a slight antibacterial effect, but is not expensive. The use of butyrate reduces the concentration of total circulating triglycerides and cholesterol in broilers (Khatibjoo *et al.*, 2018). Sodium butyrate is the most common form of butyric acid. There is a number of studies showing that the addition of butyric acid, in various doses, from 0.2 g/kg to 0.6 g/kg, to broiler chickens' diets improves performance, digestibility, and nutrient absorption, and reduces the incidence of disease. The mechanism of butyrate effect is that when sodium butyrate enters the stomach, it releases the Na ion (Gao *et al.*, 2022). Due to the low pH, butyrate is rapidly converted to the undissociated form of butyric acid (Elnesr *et al.*, 2020).

Butyric acid is formed by microbial fermentation in the colon and is the main source of energy for colonocytes, affects their proliferation, differentiation, gene expression, and protein synthesis, and improves its absorption. Butyric acid reduces bacterial colonisation of the intestinal wall by lowering the pH, which reduces the tendency to diarrhoea. The addition of butyric acid or butyric acid glycerides to turkey diets was shown to have a beneficial effect on feed conversion, intestinal morphology, and bird health by reducing pathogen concentrations in faeces (Makowski *et al.*, 2022). The use of feed additives based on butyric acid inhibits the spread of Salmonella infection and contamination of bedding with pathogens.

The addition of 0.5% acetic, lactic, or formic acid to drinking water limits the growth of *S. Typhimurium* in chickens (El-Saadony *et al.*, 2022). However, sublethal concentrations of undissociated acetic acid may not always stimulate the acid resistance of *Salmonella enterica sub.* enterica serovar *Enteritidis Phage* (Gavriil *et al.*, 2020). A relatively new area is the use of dietary fermented fibres to produce bioactive fatty acids in the intestines of animals (Ali *et al.*, 2022). The addition of 1% wheat bran with a particle size of 280 μm to the feed leads to its rapid fermentation in the digestive tract with the formation of butyric acid. These feed additives improve the performance of broiler chickens. Glycerol monolaurate is successfully used in poultry feeding, which not only improves meat quality, but also has antibacterial properties at a dose of 300 mg/kg against *Escherichia coli* and *Eimeria spp*. (Fortuoso *et al.*, 2019). The expressed antimicrobial effect of LCFAs formed as a result of fermentation of cranberry processing waste was shown. The beneficial effect of high doses of α-linolenic acid (21.0%) and linoleic acid (39.7%) obtained from fermentation products was aimed at preventing encephalomalacia, improving the immune response against infectious bursal disease virus (IBDV) and Newcastle disease (Islam *et al.*, 2020).

EFFECT OF SCFA ON METABOLISM AND IMMUNE DEFENCE

SCFAs are transported through the basolateral mucosa of the colon to the portal bloodstream, probably with the participation of SCFA-specific receptors. SCFA receptors, which are activated by acetate and propionate, were found on intestinal endocrine L cells. The GPR 109A receptor, which is expressed by colon epithelial cells, is activated by butyrate and provides IL10 production and an anti-inflammatory response. The OLFR 78 receptor is expressed in renal blood vessels and is involved in blood pressure regulation (Kotlo *et al.*, 2020). Despite a considerable amount of information on the effect of SCFAs on metabolism and energy homeostasis, the mechanisms of transport and biological activity of SCFAs are still understudied.

Along with the studied protective effects, there is an evidence of the damaging effect of butyrate on the intestinal barrier in the inflammation presence (Vancamelbeke *et al.*, 2019). Comparable results were obtained regarding the protection of colon stem cells from microbial metabolites. Some studies have shown conflicting data on the positive effect of butyrate on the intestinal barrier. For instance, butyrate promotes the growth of SCFA-producing bacteria in patients with digestive disorders (Facchin *et al.*, 2020). Oral administration of butyrate to mice aggravated colitis, while its intraperitoneal administration improved the animal health. On the other hand, inhibition of butyrate-producing microorganisms caused an exacerbation of colitis in mice. Acetate supplementation in mice plays a crucial role in the intestinal response to tissue damage and repair in colitis (Laffin *et al.*, 2019). Undoubtedly, further study is needed on both microbiome-derived and dietary-supplemented SCFAs pool to applicate SCFAs in digestive tract diseases. Despite the aforementioned data, the use of SCFAs for therapeutic purposes, their optimal therapeutic doses and indications for the use of SCFA-producing bacteria or SCFAs are still unresolved.

In vitro studies have provided evidence of the beneficial effects of butyrate on the intestinal barrier. Butyrate contributes to the Butyrate contributes to the intestinal barrier integrity by activating genes whose products maintain transepithelial electrical resistance (TEER). Butyrate has been shown to stimulate the energy metabolism of intestinal epithelial cells, modulate the production of hypoxia inducible factor 1 (HIF-1) and transcription factors, which together support the intestinal barrier function. Particularly important are the results of SCFAs' impact on the intestinal barrier and the immune system. SCFAs can modulate the adaptive immune system by stimulating macrophages and dendritic cells. SCFAs can initiate the transformation of naïve T cells into regulatory T cells (Oliveira *et al.*, 2018). Apart from polarising regulatory T cells, SCFAs also affect the polarisation and activation of Th1, Th2, and Th17 cells by inhibiting histone deacetylase (HDAC). Acetate, propionate, and butyrate also promote Th1 and Th17 differentiation in vitro. HDAC inhibition by butyrate and propionate promotes IFN-γ expression, which enhances antiviral immunity (Luu *et al.*, 2018).

The effect of SCFAs on certain types of immune cells (neutrophils, monocytes, and macrophages) is also achieved through a decrease in histone deacetylase (HDAC) levels (Ratajczak *et al.*, 2019). The effects of SCFA on cytokine transcription are conditioned by the activation of the nuclear factor kappa B cell (NF-κB). Thus, SCFAs are involved in the regulation of cellular response genes expression to damage, including infectious agents. Stimulation of cytokine production is a universal mechanism that ensures an adequate cellular response. In this response, it is critical to ensure a balance between pro- and anti-inflammatory factors. The ability of SCFAs to regulate anti-inflammatory cytokines and pro-inflammatory cytokines including IL-1β, IL-6, IL-8, and IFN-γ was found in broilers and piglets (Wu *et al.*, 2018). Furthermore, SCFAs affect neutrophil chemotaxis induced by inflammatory mediators. SCFAs can affect the differentiation and function of dendritic cells, specifically, in vitro studies showed butyrate inhibiting their maturation during incubation with various inflammatory inducers.

In addition to their regulatory effects, SCFAs are a complete source of energy for enterocytes. The content of SCFAs in the chicken caecum varies according to the content of the dominant microbiota (Cuccato *et al.*, 2021). Microbiota modification with antibiotics in mice showed a strong association between SCFAs content and the number of Bacteroides in the caecum. Elevated concentrations of SCFAs are considered beneficial for gut health by lowering pH and inhibiting pathogens. However, too high SCFAs content can inhibit beneficial taxa together with pathogens. This undesirable effect of organic acids supplementation to the diet reduces feed intake and inhibits weight gain in broiler chickens.

SCFAs inhibit cholesterol synthesis by inhibiting the activity of the enzymes 3-hydroxy-3-methylglutaryl-CoA synthase (HMGCS) and 3-hydroxy-3-methylglutaryl-CoA reductase (HMGCR). Thus, SCFAs are involved in the indirect regulation of energy metabolism by modulating cholesterol-dependent hormone synthesis and lipid metabolism. Another way in which SCFAs are involved in metabolic regulation is by reducing plasma glucose levels through the activation of the fatty acid receptors Ffar2 and Ffar3. The lack of butyrate-producing bacteria in the microbiome induced a decrease in FFAR2/3 receptor signalling, suppressed mucin formation, and increased intestinal permeability (Mishra *et al.*, 2024). Considering all the above-mentioned data, the use of SCFAs in poultry production requires a detailed comprehension of the protective mechanisms in the intestinal system cells as well as the possible risks of inhibiting intestinal function.

USE OF MEDIUM-CHAIN FATTY ACIDS

Medium-chain fatty acids (MCFAs) are considered a promising alternative to antibiotics due to their beneficial effects on digestion. MCFAs exhibit antibacterial activity, activate absorption, inhibit lipase production by bacteria and have a lower ability to dissociate (Dierick *et al.*, 2002). The mechanisms of action of MCFA are still unclear. MCFAs can act as non-ionic surfactants, incorporating into the bacterial double layer of lipids to form pores, leading to a critical increase in permeability and cell destruction. MCFAs are rapidly absorbed in the small intestine, transported to the liver as free fatty acids, and enter the mitochondria independently of fatty acyl-CoA carnitine transferases (Roopashree *et al.*, 2021). The administration of MCFAs reduces lipogenesis, lipid uptake, fatty acid biosynthesis, and increases their oxidation.

It is assumed that the antibacterial efficacy of MCFAs is comparable to that of SCFAs, but their mechanism of impact is different in respect to that of SCFAs. MCFAs have a pKa value of about 4.9 and their efficiency decreases with molecular weight magnification. An important feature of MCFAs is their ability to easily penetrate dense peptidoglycan (Gram+ bacteria) and/or phospholipid (Gram- bacteria) membranes in undissociated form (Hermans *et al.*, 2010). The MCFAs adsorbed by the cells dissociate in the protoplasm, lowering the pH, which initiates critical damage to microbial cells. This property of MCFAs makes them promising substitutes for antibiotics, especially against gram-positive cocci and *Escherichia coli*. Campylobacter spp. infections cause an estimated 250,000 cases of gastroenteritis in the EU and a cost of over EUR 2.4 billion annually (The European Union One Health 2018; Zoonoses Report, 2019). Despite the widespread occurrence of *Campylobacter* in warm-blooded animals, the main source of infection is birds, specifically broiler chickens (Peh *et al.*, 2020). Addition of MCFAs to the feed for 3 days reduces Campylobacter colonisation in 27-day-old broilers experimentally infected with *C. jejuni* at 15 days of age. Feed additives with MCFA significantly reduce *Campylobacter* carriage in broiler chickens.

MCFAs, namely caproic, caprylic, and capric acids, are digested and absorbed faster than long-chain fatty acids, improve digestion, absorption, and lipid transport. Furthermore, MCFAs prevent the adsorption of bacteria to the intestinal wall and reduce invasion by inhibiting the production of bacterial lipases. The beneficial effect of MCFAs (C6-C12) alone and their mixture with SCFAs (C2-C6) was shown in respect to performance, carcass characteristics, haematological and biochemical parameters of broiler chickens' serum. Monoglycerides synthesised using MCFAs are also considered as a promising alternative. Recently, the results of their beneficial effects on performance, intestinal histomorphology, amino acid digestibility, and blood chemistry of broiler chickens have been presented. A metagenomic analysis of organic acid use has shown a stimulating effect on the diversity of beneficial microorganisms, nutrient digestion, and muscle growth (Dauksiene *et al.*, 2021).

APPLICATION OF ORGANIC ACID MIXTURES IN POULTRY FARMING

Numerous studies on feed additives applying have shown that mixtures of organic acids (two or more) have significantly better efficacy than any one acid alone (Szabó *et al.*, 2023). Specifically, SCFAs enhances the antimicrobial effect of MCFAs, which supports the gut microbiota of piglets and feed conversion in laying hens. The polymodal effects of a mixture of fumaric, citric, malic acids with capric and caprylic acids on productivity, Lactobacillus content, IgG concentration and inhibition of E. coli growth were shown. The mixture of phosphoric acid (0.2 g/kg) and lactic acid (0.3 g/kg) increases the pH of the pectoralis major and thigh muscle within 24 hours. The use of a mixture of microencapsulated organic acids with MCFAs has a positive effect on egg production, egg strength, calcium concentration, and the content of *Lactobacillus* and *E. coli* in the faeces of laying hens.

There is a fairly considerable number of results showing the beneficial effect of organic acid mixtures on the intestinal function and health of productive poultry. Specifically, the use of mixtures of butyric, fumaric, and lactic acids in different proportions had a positive effect on poultry body weight gain, feed conversion rate, and increase in the height of villi in the small intestine. A positive effect of sodium butyrate supplementation with MCFAs salts on the intestinal health of broiler chickens has been shown (Sadurní *et al.*, 2022). The addition of SCFAs and MCFAs to the broiler diet reduces serum cholesterol levels, abdominal fat, and thigh fat percentage and improves meat quality. Combined use of MCFA and organic acids increases duodenal villi height and crypt depth in broiler chickens. In addition to blends of single organic acids, blends of essential oils with organic acids have recently been proposed. Testing of such mixtures has shown their effectiveness against pathogen contamination of poultry feed (Satterlee *et al.*, 2023). However, the scheme of feed additives use is of fundamental significance. For instance, the use of a mixture of organic acids and essential oils throughout the production cycle (35 days) with the addition of MCFAs for 5 days immediately before slaughter negatively affected broiler performance (Greene *et al.*, 2022). The authors suggest that this result may be due to changes in the microbiota of the small intestine caused by prolonged exposure to acid. Recent results of a study in Ukraine on the effects of the original SCFAs blend have shown the vital role of adhesion proteins and extracellular matrix in the barrier function of the small intestine (Masiuk *et al.*, 2023). Therewith, mixtures of SCFAs with MCFAs have been shown to be effective in treating poultry infected with Clostridium perfringens, Eimeria spp., and Salmonella typhimurium. At the same time, mixtures of formic acid, propionic acid, and sodium formate, varying in ratio, showed no differences in effectiveness against Salmonella.

CONCLUSIONS

According to the current regulatory framework, specifically EU regulations, the use of antibiotics in poultry farming is critically limited. Currently, OAs are successfully used as a prophylactic alternative to antibiotics. Research has shown that OAs are a cost-effective means of ensuring productivity, antimicrobial protection, and maintaining poultry health. Recent studies have shown that certain OAs improve digestion, immune response, and suppress pathogenic microflora. On the other hand, mixtures of OAs may have more powerful protective and stimulating effects depending on the composition and relative content of each component.

SCFAs have a wide range of effects on metabolism and immune defence in poultry, but despite the available data respectively their effects on metabolism and energy homeostasis, the mechanisms of transport and biological activity is still understudied. Butyrate has been shown to have a positive effect on the intestinal barrier and stimulates the metabolism of enterocytes. SCFAs can modulate the adaptive immune system by stimulating macrophages and dendritic cells. SCFAs are involved in the regulation of gene expression in the cellular response to damage, including infectious agents. Therewith, there is an evidence of the damaging effect of butyrate on the intestinal barrier during inflammation. Considering the above data, the use of SCFAs in poultry production requires a detailed understanding of the protective mechanisms of action on the cells of the intestinal system, as well as the possible risks of inhibiting intestinal function. The total use of SCFAs requires further studies of their effect on the efficiency of the intestinal barrier function and the expression of molecular markers of epithelial cell intercellular adhesion. Along with determining the expression, a significant criterion for assessing the beneficial effect of SCFAs is the production of pro- and anti-inflammatory cytokines by cells of the intestinal system, fatty acid receptors, energy metabolism, and proliferation of intestinal epithelial cells.

Recently, MCFAs have been increasingly considered as an alternative to antibiotics due to their high antibacterial activity, stimulation of absorption, inhibition of lipase production by bacteria and lower dissociation ability compared to other surfactants. However, the mechanisms of MCFAs' action are still unclear. A significant feature of MCFAs is their ability to easily penetrate microbial membranes in undissociated form, which is effective against Gram-positive cocci. The study of the antimicrobial effects of MCFAs mixtures is a crucial component of creating a modern antibiotic-free strategy.

Mixtures of OAs are more effective than their individual use. Mixtures of SCFAs with MCFAs have the most significant beneficial effect since SCFAs act better as growth stimulants and MCFAs have higher antibacterial properties. At the same time, the optimal content of individual OAs in the mixture, doses, and exposure times stays a compromise issue. The use of specific molecular markers to evaluate the effectiveness of OA mixtures will allow the development of criteria for the formation of antimicrobial feed additives with unique properties and a focus that meets the challenges in poultry production. Further research into the mechanisms of action of the OAs will allow the development of their mixtures with optimised properties in terms of antimicrobial protection, intestinal functions, and metabolic stimulation. In addition, OA mixtures can be useful for the prevention of chronic diseases, such as bacterial chondronecrosis and osteomyelitis in broiler chickens.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of financial interest or personal relationship regarding this document.

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Сучасний стан та перспективи застосування органічних кислот та їх композицій в кормах для птиці: Огляд літератури

Дмитро Масюк
Доктор ветеринарних наук, професор
Дніпровський державний аграрно-економічний університет
49000, вул. Сергія Єфремова, 25, м. Дніпро, Україна
https://orcid.org/0000-0002-2800-2580
Віктор Недзвецький
Доктор біологічних наук, професор
Дніпровський державний аграрно-економічний університет
49000, вул. Сергія Єфремова, 25, м. Дніпро, Україна
https://orcid.org/0000-0001-7352-441X
Ярослав Максимчук
Аспірант
Дніпровський державний аграрно-економічний університет
49000, вул. Сергія Єфремова, 25, м. Дніпро, Україна
https://orcid.org/0009-0001-2617-1452

Анотація. Застосування антибіотиків в птахівництві є критично обмеженим, що обумовлює пошук і дослідження альтернативних сполук для заміни антибіотиків. Органічні кислоти розглядаються як одна з таких альтернатив, однак антимікробні та метаболічні ефекти сумішей жирних кислот залишаються суперечливими та не повністю зрозумілими. Все це разом обумовлює актуальність системного аналізу сучасних даних стосовно ефективних стратегій заміни антибіотиків. Метою роботи було провести аналіз та узагальнення сучасних уявлень щодо застосування сумішей органічних кислот в якості альтернативної стратегії забезпечення сталого птахівництва. Аналіз сучасних літературних джерел показав, що однією з перспективних альтернатив використанню антибіотиків у птахівництві є суміші органічних кислот та їх похідні, які мають антибактеріальну дію, знижують pH, включаються в енергетичний метаболізм і все це разом сприяє інтестинальній функції. Органічні кислоти позитивно впливають на фізіологічні функції, зокрема, травлення та імунну систему, є основним джерелом енергії колоноцитів та знижують патогенне бактеріальне навантаження на травний тракт. Показано, що суміші органічних кислот виявляють вищу ефективність, ніж їх окреме застосування, зокрема, показана висока ефективність застосування сумішей коротко- та середньоланцюгових жирних кислот для підтримки інтестинального бар'єру, мікробіому та імунітету, при цьому перші краще діють як стимулятори росту, а другі мають вищі антибактеріальні властивості. Ефективність застосування як органічних кислот окремо, так і їх сумішей залежить від багатьох факторів, залежно від типу молекули, форми та дози задавання. Обґрунтовано доцільність проведення подальших досліджень ефектів органічних кислот, що буде корисним для розробки антибіотик-фрі стратегії використовуючи синергічні ефекти їх сумішей та багато спрямовану цитопротекторну дію. Робота стане в нагоді науковцям та ветеринарним лікарям для ознайомлення з перспективами застосування композиції органічних кислот як замінників антибіотиків, зокрема для формування технологічних прийомів з мінімізацією їх використання

Ключові слова: суміші короктоланцюгових та середньоланцюгових жирних кислот; птахівництво; антибіотики; підтримка інтестинальної функції
