Investigating Organic Acids as Potential Replacements for Antibiotics in Broiler Production

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Abstract

The extensive use of antibiotics in poultry production has significantly contributed to improved growth performance and disease control. However, this practice has raised serious public health concerns due to the emergence of antibiotic-resistant bacteria, prompting a global call for alternative strategies. This chapter explores the potential of organic acids as effective substitutes for antibiotic growth promoters (AGPs) in broiler production. It provides a comprehensive overview of the role of antibiotics in poultry, the associated risks of antimicrobial resistance, and the resistance patterns observed in key poultry pathogens including *Escherichia coli*, *Clostridium perfringens*, *Salmonella* spp., *Mycoplasma* spp., and *Pasteurella multocida*. Emphasis is placed on the antimicrobial and growth-promoting potential of organic acids, which offer a promising, resistance-free approach to maintaining gut health and production efficiency in poultry. The chapter also highlights challenges in organic poultry production and discusses the prospects and limitations of using organic acids as part of a sustainable poultry health management strategy.

Keywords: Probiotics, Prebiotics, Antimicrobial resistance, Feed additives, Poultry industry

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Introduction

Chicken are the most abundant domesticated animal population, with a worldwide occurrence. Humans keep these domesticated birds such as chicken, ducks, turkeys etc. for obtaining eggs and meat to fulfill their nutritional needs. These domesticated birds are referred as "poultry". Chickens are the most important poultry species accounting over 90% of the poultry population of the world (Khan et al., 2022). The Poultry industry being an important sector of Agriculture of Pakistan plays a vital role in economy of Pakistan. It is a source of livelihood of millions of people. According to the latest survey, there are about 20,000 poultry farms, which are producing 2250 million kg meat and 18,000 million table eggs per annum (Saleem et al., 2025). Since 1960s Commercial poultry has been playing a pivotal role in providing meat and daily proteins to the population in Pakistan. The evolution of poultry industry in Pakistan did not take place smoothly; instead it has faced several problems such as disease outbreaks and retail price instability (Hussain et al., 2015).

Poultry producing farmers now begin to use antimicrobials as treatment and growth promoters in order to deal with these crises. Antibiotic use in poultry production has been common practice for decades on the purpose of promoting growth, improving feed efficiency and preventing or treating bacterial infections (Abreu et al., 2023). Increasing global poultry meat/egg production is the result of role played by antibiotics in poultry health coupled with consistent publication of production performance (Alagawany et al., 2021). In terms of their uses, it was found that antibiotics were initially fed at subtherapeutic dosages in feed to promote growth and improve flocks' overall performance which has since greatly reduced mortality rate and increased productivity (Abreu et al., 2023). Besides threatening animal health, this resistance is also a serious threat to public health, since resistant pathogens can cross over to humans through the food chain, direct contact or environment pathways (Kumar et al., 2020).

Therefore, regulatory bodies and consumers have progressively pressured the poultry industry to reduce or cease antibiotics use, particularly those antibiotics important for human medicine (de Mesquita Souza Saraiva et al., 2022). In response to these concerns, the poultry industry has investigated alternative preventive and growth promoting strategies. The other possible alternatives of probiotics, prebiotics, phytogenic and organic acids etc. (Khan et al., 2022). Among all organic acids in particular, the antibacterial property and the beneficial effect on intestinal health without leading to antibiotic resistance of organic acids have become increasingly popular (Du et al., 2024). With a growing need for antibiotic-free poultry products, knowing the parts and success of alternatives like organic acids is important to the sustainable future of poultry production (Haque et al., 2020). The beneficial bacteria known as probiotics can be used to protect the gut from harmful infections in chickens and keep them healthy (Yousaf et al., 2022). But when a serious enough infection needs to be treated with antibiotics there is no longer anything organic about the birds (Abd El-Hack et al., 2022).

To date, more strong research data is still lacking on natural methods for the microbiological safety improvement of organic poultry (Chowdhury et al., 2023). Even some studies have found that the levels of contamination may be the same for organic as for conventional poultry products (Abd El-Hack et al., 2022). Mandatory outdoor access, use of slow growing breeds and smaller slaughter facilities can raise risks of contamination (Yadav et al., 2022a), as well as exposing birds to environmental pathogens, are other challenges for organic poultry production. The potential development of new organic alternatives to AGPs, under which they function and their possible influence in the poultry industry are discussed in this review (Abd El-Hack et al., 2022).

1. Resistance of Antibiotics

A pressing problem for the poultry industry and public health is the development of antibiotic resistance by poultry pathogens (de Mesquita Souza Saraiva et al., 2022). After many years of using antibiotics for growth promotion, disease prevention and treatment, the spectrum of antibiotic sensitive bacteria has decreased and many bacteria pathogens have developed mechanisms to live and multiply in the presence of the antibiotic (Muteeb et al., 2023). It also makes the treatment less effective, increases mortality and in food chain may also help spread resistant bacteria to humans (Kumar et al., 2020).

A. Antibiotic Resistance in Different Diseases

Colibacillosis (*Escherichia coli*)

Colibacillosis is a widespread bacterial infection characterizing all ages of poultry, is credited to *E. coli*. Common reported antibiotics has been frequently reported include fluoroquinolones, aminoglycosides, tetracyclines and sulfonamides. Increasingly, MDR *E. coli* strains are isolated from poultry farms complicating disease management.

Necrotic Enteritis (*Clostridium perfringens*)

Necrotic enteritis, caused by *C. perfringens*, is often controlled with antibiotics like penicillin, bacitracin, and lincomycin. However, resistant strains have been documented, particularly against bacitracin, making alternative strategies necessary to manage the disease effectively (Kulkarni et al., 2022).

Salmonellosis (*Salmonella* spp.)

Salmonella infections are an important problem in poultry health, as well as food safety. It is also known to be resistant to commonly used antibiotics, including ampicillin, tetracycline and chloramphenicol, around the world. Multi drug resistant Salmonella strains, including resistance to critical antibiotics (fluoroquinolones and cephalosporins) presents a major challenge to both veterinary and human medicine. (Bisola Bello et al., 2024).

Mycoplasmosis (*Mycoplasma gallisepticum* and *Mycoplasma synoviae*)

Antibiotics such as tylosin, tiamulin and enrofloxacin are used to control or control Mycoplasma infections in the poultry. But resistance to macrolides, fluoroquinolones and tetracyclines is increasingly reported, complicating control of the disease and its cost (Bottinelli et al., 2022).

Fowl Cholera (*Pasteurella multocida*)

Fowl cholera, caused by *P. multocida*, historically responds well to sulfonamides and tetracyclines. Nevertheless, resistant strains are now reported, particularly to tetracycline and erythromycin, leading to treatment failures and higher flock losses (Geda, 2024).

B. Need of Alternatives in Poultry

The growing concerns over antibiotic resistance have highlighted the urgent need for effective alternatives in poultry production (Figure 1). For many years, antibiotics have been used not only to treat infections but also as growth promoters to enhance production efficiency. However, the emergence of antibiotic-resistant bacteria poses a significant threat to animals and human health. This has led to stricter regulations on antibiotic use in many countries and increased consumer demand for antibiotic-free poultry products (Haque et al., 2020).

As the low up to decrease antibiotic usage in the poultry business, there is an urgent requirement for option strategies to maintain poultry health, accomplish ideal development and accomplish generation execution (Abd El-Hack et al., 2022). Probioecics, prebiosics, organic acids, essential oils and phytogenic compounds are possible alternatives (Shehata et al., 2020). These alternatives strengthen the birds' immune system and improve gut health and that of protecting against pathogenic microorganisms (Abd El Hack et al., 2022). It is necessary to develop and prepare effective antibiotic alternatives, not only for tackling public health issues but also to sustainably and profitably run the poultry industry (Haque et al., 2020). The transition to antibiotic-free production systems can be made only if reliable and natural substitutes can be found which can support animal welfare without reducing productivity (Iannetti et al., 2021).

2. Organic Acids: Classification and Available Sources

Naturally occurring compounds having specific carboxyl (-COOH) groups are termed Organic Acids and classified according to their chemical properties (Chukwudi et al, 2026). Organic acids have recently attracted attention in poultry production as effective alternatives to antibiotics since they improve gut health, enhance nutrient digestion and inhibit the growth of pathogenic microorganisms. However, their antimicrobial activity, as well as their positive influence on gut environment confers them as effective tools for promotion of poultry health and performance in antibiotic free production systems (Haque et al., 2020).

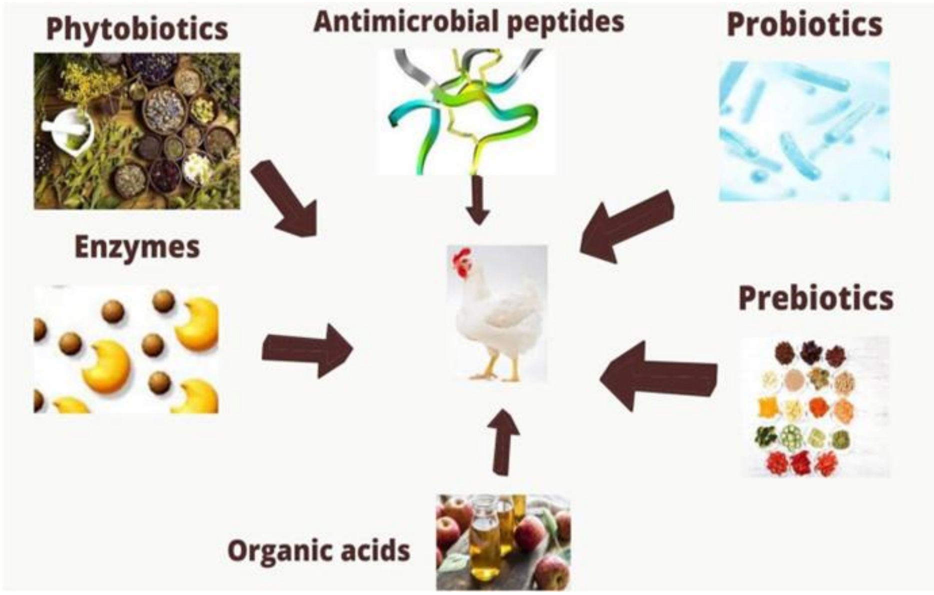

Fig. 1: Alternatives of antibiotics in poultry (Khan et al., 2022)

A. Classification of Organic Acids

Broadly, organic acids may be classified with respect to the chemical structure and functional properties of these acids:

Simple Organic Acids

One of these are short chain fatty acids such as formic acid, acetic acid, propionic acid and butyric acid (Markowiak Kopec and Slizewska 2022). Their strong antimicrobial effects are able to lower their gut pH (Ribeiro et al., 2022).

Hydroxy Organic Acids

Among them are lactic acid, malic acid and citric acid. Besides for their antimicrobial properties these acids also participate in different metabolic processes and in the absorption of nutrients and energy production (Du et al., 2024).

Aromatic Organic Acids

Benzoic acids and others like them contain an aromatic ring structure. These are highly effective against Gram-negative bacteria and have something of a role in feed formulation as preservatives and for gut health (Bensid et al., 2022).

Dicarboxylic Acids

These include fumaric acid and succinic acid, two carboxyls, for instance which have much stronger acidifying properties and also some additional antimicrobial effects compared to monocarboxylic acids (Coban, 2020).

B. Available Sources of Organic Acids

However, organic acids can be found in different form from natural and synthetic sources:

Fermentation Products: Bacteria such as Lactobacillus species, produce many organic acids such as lactic acid and acetic acid, by the fermentation of carbohydrates (Bangar et al., 2022).

Plant Extracts: There are some plants that normally have organic acids, for instance, in citrus fruits, citrus acid and in apples and other fruits, malic acid (Jia et al., 2023).

Synthetic Production: In view of the rising demand, several organic acids are currently industrially produced to maintain consistency in quality for applications in animal nutrition (Du et al., 2024).

Microbial Synthesis: Certain microbes can be genetically engineered or cultivated to produce large quantities of organic acids under controlled fermentation conditions (Coban, 2020).

In poultry production, organic acids are commonly added to feed or water either individually or in combination (blends) to maximize their beneficial effects. Encapsulation technologies are also employed to protect organic acids from early degradation and to ensure their targeted release in the intestinal tract (Abdelli et al., 2020).

C. Organic Acids in Poultry

Short-Chain Fatty Acids (SCFAs)

Short-chain fatty acids are organic acids with fewer than 6 carbon atoms. These are naturally produced in the gut through the fermentation of dietary fibers by gut microbiota. In poultry, SCFAs play a critical role in maintaining gut health and improving immune function (Ali et al., 2022). Examples include Acetic acid, Propionic acid, Butyric acid. Acetic acid lowers gut pH, enhancing mineral absorption and inhibiting harmful bacteria. Propionic acid reduces the growth of pathogenic bacteria and improves nutrient utilization. Butyric acid enhances gut health, strengthens the gut lining, and stimulates beneficial bacteria.

Medium-Chain Fatty Acids (MCFAs)

Medium-chain fatty acids are organic acids with 6 to 12 carbon atoms. These acids are more effective than long-chain fatty acids in terms of antimicrobial action, as they are more readily absorbed and metabolized by animals (Çenesiz & Çiftci, 2020). Examples include Caprylic acid (C8), Capric acid (C10), Lauric acid (C12). Caprylic acid exhibits strong antimicrobial effects against Gram-positive bacteria, helping to prevent gut infections. Capric acid enhance the immune response and exhibits antibacterial and antiviral properties. Lauric acid known for its potent antiviral and antibacterial activities, helping to control disease-causing organisms in the poultry gut. MCFAs have antimicrobial properties and are used to promote gut health by reducing harmful microbial populations, thus enhancing bird performance (Çenesiz & Çiftci, 2020).

Carboxylic Acids

Carboxylic acids are a broader class of organic acids that contain a carboxyl group (-COOH). This group is responsible for their acidic properties. Carboxylic acids can be short-chain or long-chain acids, and many are used in poultry feed to improve performance and health (Abd El-Ghany, 2024). Examples include Acetic acid, Lactic acid, Citric acid, Fumaric acid. Acetic acid promotes the growth of beneficial gut bacteria while inhibiting harmful microbes. Lactic acid improves digestion by acidifying the gut environment, promoting the absorption of nutrients. Citric acid increases the absorption of calcium and phosphorus, improving bone strength and production performance. Fumaric acid enhances gut health by improving digestive enzyme activity and nutrient absorption.

3. Origins of Acids

Poultry production uses acids (natural and synthetic). Individual properties of these different origins include differences in cost, availability and efficiency when carrying out the specific acid in poultry health and performance (Abd El-Hack et al., 2022).

Natural Origins

Plant, animal or microbial (microbe) derived natural acids are generally less harmful to the environment and more sustainable. Extracted from natural sources or produced by biological processes, they have some advantages such as enhanced bioavailability and reduced toxicity usually comparable or even superior to those of natural acids (Saini et al., 2022).

Plant-Derived Acids

Many organic acids are found naturally in fruits, vegetables, and herbs. These include citric acid from citrus fruits, malic acid from apples, and benzoic acid from certain berries (Suriyaprom et al., 2022). These plant derived acids are readily accepted by animals as part of their diet, have fewer regulatory restrictions compared to synthetic acids, provide additional nutritional benefits beyond acidification, such as antioxidants and vitamins.

Microbial Fermentation

The *Lactobacillus* and *Bifidobacterium* are both microorganisms that are used to ferment, creating popular acids such as lactic acid and butyric acid. In fact, these acids are generally better at enhancing gut health and immunity. (Ayivi et al., 2020). Benefits include the fermentation by-products are often more bioavailable and the process mimics natural digestion processes in the poultry gut, supporting a healthy microbiome.

Animal-Derived Acids

Specific organic acids such as butyric acid can also be produced naturally by the fermentation of fiber in an animal's gastrointestinal tract (Tugnoli et al., 2020). These acids contribute directly to the gut environment, enhancing digestive efficiency.

Synthetic Origins

The industrial way of manufacturing of synthetic acids often involves petrochemical or agricultural sources. Typically, these acids are more cost-effective on large production scales and are more consistent and stable than their natural counterparts (Ghai et al., 2024).

Industrial Production

Chemical processes that use raw materials like hydrocarbons, alcohols, or natural gas are used to produce synthetic acids (such as formic acid, propionic acid and fumaric acid) (Ghai et al., 2024). Large-scale production makes synthetic acids more affordable and widely available. Synthetic acids are produced in a controlled environment, ensuring high purity and uniform quality in every batch. The properties of synthetic acids can be tailored to specific needs in poultry nutrition, such as targeted release or increased stability.

Blends of Synthetic and Natural Acids

In many cases, synthetic acids are mixed with natural acids to optimize their benefits in poultry feed. This combination allows for the balance of cost-effectiveness and the enhanced biological activity of natural acids (Zheng et al., 2025). These provide a balanced approach, combining the best of both worlds for improved poultry health and productivity.

Table 1: Key Differences between Natural and Synthetic Acids

Aspect	Natural Acids	Synthetic Acids
Source	Derived from plants, animals, or fermentation processes	Manufactured through chemical or industrial processes
Cost	Can be more expensive and less consistent	Generally more affordable and consistent in quality
Purity & Stability	Can vary in purity and stability	High purity and stability, especially in large-scale production
Bioavailability	Often better absorbed due to natural origins	Effective but may need to be modified for bioavailability
Regulations	Often subject to fewer regulations	May face stricter regulations, especially regarding their use in food and animal products

4. Mechanism of Action of Organic Acids in Broilers

Organic acids are popular in poultry nutrition for their action to maintain gut health, improve nutrient digestion and enhance immune function. The diverse ways organic acids cause positive effects in broilers involve many biological processes that contribute to improved growth, fend off disease and, in general, promote health (Du et al., 2024).

i. Lowering Gut pH

In the gut of broilers, the chief means by which organic acids function is by lowering the pH of the gut (Figure 2). Since these acids dissociate in the acidic environment, they release hydrogen (H+) ions and therefore lower the pH of the gut content (Chukwudi et al., 2025). A lower pH creates an inhospitable environment for harmful microorganisms like *Salmonella, Escherichia coli*, *Clostridium perfringens*, and *Campylobacter* (Hakeem & Lu, 2021). These pathogens are less able to thrive or reproduce in an acidic environment, reducing the incidence of infections and gut-related diseases in broilers (Fancher *et al*., 2020). On the other hand, beneficial bacteria like *Lactobacillus* and *Bifidobacterium* thrive in slightly acidic conditions (He et al., 2023). By lowering the pH, organic acids can help promote the growth of these beneficial gut microbes, which further enhances intestinal health and immune responses.

ii. Enhancing Nutrient Absorption

However, organic acids, especially weak acids such as citric acid, lactic acid, formic acid, etc., are found to improve absorption of major nutrients, mainly minerals, including calcium, phosphorus and magnesium (Alhamad et al., 2020). By lowering the pH in the digestive tract, organic acids help to solubilize minerals, making them more readily available for absorption in the intestines (Pearlin et al., 2020). This is particularly important for bone development and overall growth in broilers. The acid environment created by organic acids also aids in the activation of digestive enzymes, such as pepsin, which break down proteins more effectively. This leads to better utilization of the protein in the diet, improving growth performance and feed efficiency (Pearlin et al., 2020).

iii. Modulation of Gut Microbiota

Modulation of gut microbiota composition by organic acids is significant. The former selectively inhibits the growth of pathogenic bacteria, while at the same time encouraging beneficial bacteria to proliferate (Dai et al., 2021). Formic acid and butyric acid have a direct antimicrobial effect on a broad range of pathogens. Undesirable for any of the reasons enumerated by such as, interfering with bacterial cell wall integrity, inhibiting metabolic pathways, lowering the internal pH of bacterial cells and leading to inactivation or death (Martinez et al., 2020). Certain beneficial gut microbes use some organic acids, especially butyric acid, as a source of energy. This encourages the fortune of favorable microbial such as Lactobacillus species, which will further support gut health by occupying niche space and competing with pathogens for nutrients (Du et al., 2024).

iv. Immune System Modulation

Organic acids are known to influence the immune system of broilers, helping to enhance disease resistance and overall health (Du et al., 2024). The development and maintenance of the intestinal mucosal barrier depends on organic acids, especially on the short-chain fatty acid, butyric acid. Prevention of pathogen entry in the bloodstream is achieved through blocking pathogen access into the bloodstream, directly by promoting the secretion of mucus and indirectly via strengthening tight junctions between intestinal cells. Advances have been made in the controlled administration of organic acids to stimulate the secretion of immunoglobulins (IgA), which are key mucosal immunity components neutralizing pathogens in the gut. Second is this contributes to a stronger immune defense against infections (Ebeid & Al-Homidan, 2022).

v. Reduction of Oxidative Stress

Rich sources of antioxidants such as citric acid, can reduce broiler oxidative stress when used as organic acids (Ebeid & Al-Homidan, 2022). Antioxidant property of some of the organic acids scavenge free radicals and lower down the oxidative damage in the tissues. It supports better overall health, increases immune function and supports growth (Du et al., 2024). In addition, organic acids may decrease inflammatory responses in the gut, otherwise associated with poor growth and disease susceptibility. The anti-inflammatory action in this regard is supportive to better health and welfare among broilers (Ebeid & Al-Homidan, 2022).

vi. Improved Feed Conversion and Growth Performance

The organic acids however, protect optimal digestion, absorption and gut health hence improving feed conversion ratios (FCR) and general growth performance (Chukwudi et al., 2025). Broilers need better nutrient utilization and healthier gut conditions for improved production outcomes which these acids contribute to creating.

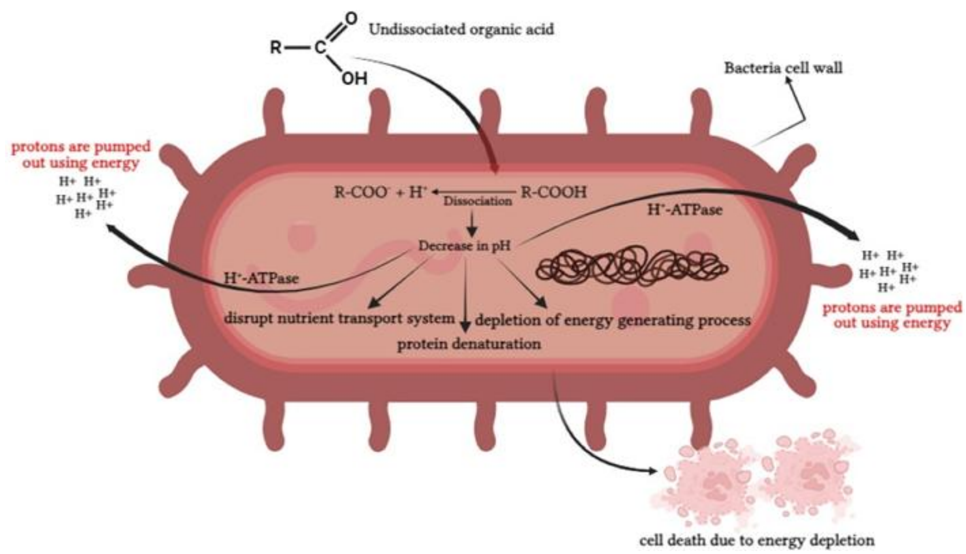

Fig. 2: Mechanism of Action of Organic Acids in Broilers (Chukwudi et al., 2025)

5. Antimicrobial Effects

Organic acids inhibit pathogen growth by creating an acidic environment, damages the bacterial cell structure and causes cell death, offers protection against fungal and viral pathogens, prevents bacterial growth by interfering with critical metabolic enzymes, inhibits bacterial replication, promotes beneficial bacteria while inhibiting pathogenic growth and prevents pathogenic bacteria from forming biofilms, increasing their susceptibility to antimicrobial agents. Organic acids are a valuable tool in poultry production for controlling pathogenic microorganisms, improving gut health, and reducing the need for antibiotics, thereby supporting a more sustainable and healthier poultry industry.

6. Organic Acids as growth Promoters

A study was conducted on broilers (age of 14 to 35 days) to observe the effect of organic acids on growth performance, intestinal microflora and carcass properties. And it was concluded that organic acid mixtures are more suitable and efficient growth promoters than antimicrobials. It was found that organic acids improve performance of broilers and also decrease intestinal *E.Coli* and Salmonella species thus they are better substitutes to antibiotics (Hassan et al., 2010). As organic acids act by lowering pH of digesta and increasing pancreatic secretions. This acidic environment controls the microbial load of intestines, ultimately leading to increased body weight gain and feed efficiency by eliminating organisms that compete for nutrition with broilers. Organic acids are also seen to improve the protein digestibility and minerals absorption, influencing morphology of mucosa (Vinus et al., 2017).

Table 2: Effect of different organic acids on production performance and protein digestibility

Sr #.	Organic Acids	Inclusion Rates	Results	Reference
1	Citric Acid	20 & 40 mg/kg diet	Increased dry matter and protein retention	(Esmaeilipour et al., 2011).
2	Fumaric Acid	3% of the diet	Highest weight gains	(Adil et al., 2011).
3	Ammonium Formate	3mg/kg diet	Increased live weight gain and FCR at day 21 in broilers	(Paul et al., 2007).
4	Butyric Acid	0.4% of the diet	Superior FCR	(Panda et al., 2009).
5	Formic Acid and Acetic Acid	0.5% and 0.75% respectively	Improved both ME and protein digestibility	(Ghazala et al., 2011).
6	Citric Acid and Acetic Acid	0.5 % of the diet	Showed significant improvement in body weight gain and FCR	(Islam et al., 2008).
7	Acidifier mixture (Formic, Phosphoric, Lactic, Tartaric, Citric and Maleic acids)	0.15% of the diet	Increased body weight gain	(Hashemi et al., 2014).

8. Challenges and Limitations of Using Organic Acids in Poultry

Cost and Economic Viability

Organic acids can be expensive, especially those derived from specialized sources, which may limit their use in large-scale poultry operations where cost-effectiveness is a primary concern (Bist et al., 2024).

Stability and Storage Issues

A few organic acids such as volatile acids like butyric acid, degrade under heat and humidity and need to be stored properly to preserve effectiveness (Smedemark et al., 2020).

Dosage and Efficacy Variability

Excessive use of organic acids causes gut irritation or bacterial imbalance in the gut and the ideal dosage of organic acids varies from poultry systems and breeds (Ebeid & Al-Homidan, 2022).

Acid Sensitivity in Birds

Organic acids can irritate the gastrointestinal tract at high concentration in younger birds or sensitive birds which can reduce feed intake and growth (Ebeid & Al-Homidan, 2022).

Limited Long-Term Data

Further research on long term effect of organic acids on poultry health and productivity and their interaction with other feed additives will be needed (Chukwudi et al., 2025).

Impact on Gut Microbiota

Using organic acids is effective with pathogens, but using high doses can destroy beneficial bacteria in your gut causing an imbalance in your microbiome (Ebeid & Al-Homidan, 2022).

Limited Spectrum of Activity

However, organic acids are not effective against all pathogens, for instance viral infection or some Gram positive bacteria and may require in combination with other treatment (Burns et al., 2021).

Environmental Concerns

Organic acids contribute to environmental pollution of local ecosystems especially water and soil through improper disposal or overuse (Michael, 2021).

Conclusion

Organic acids help poultry producers maintain improved gut health, reduce infections and increase efficiency without antibiotics. Since they support a healthy stomach environment, protect against harmful bacteria by lowering pH, interfere with bacterial membranes, increase nutrient intake and encourage the growth of helpful gut microbiota. Organic acids improved immune function and lower oxidative stress. Yet, organic acids do come with some difficulties in poultry farming. Examples of these issues are related to cost, whether the medicines stay stable during storage, finding the correct dose and the chance of upsetting the stomach. Although organic acids have value against some diseases, their effectiveness is narrow and their effects on the health of chickens over time are still unclear. Additionally, using antibiotics incorrectly can upset the bacteria in the gut and improper disposal and overuse affect nature in some ways. Good results with organic acids require to be cautious. Applying them as they should make poultry production much greener and give up on antibiotics. More research into how long they take to work and how to use them wisely is needed to get the most out of their advantages and limit their problems.

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