Research Article

An Update on the Promising Role of Organic Acids in Broiler and Layer Production

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Abstract | Organic acids (OA) are natural compounds with weak acidic properties. Their use as feed preservatives and performance enhancers in livestock and poultry have been widely studied. In poultry feed, OA have been used mainly to combat the activity of *Salmonella* and *Escherichia*. They also enhance the uptake of digested proteins and important minerals. The advantages of using OA as feed additives greatly outweigh their disadvantages like decreased palatability. Organic acids can increase egg productivity and enhance the egg quality in layers. In broiler, use of OA is associated with improved weight of birds and feed conversion ratio. Dietary OA showed 1.85-8.48% increase in the FCR of chicken. Lactic acid fed 0.3 g/kg diet reduced *Escherichia coli* and *Salmonella* significantly in the cecum of broilers. Butyric acid fed 500 g/t feed significantly increased eggshell thickness, eggshell weight, and calcium concentrations in bones and reduced ammonia concentrations in the caecum. Egg production was increased upto 9.84% by the supplementation of OA. Organic acids also have promising effect on gut health evidenced by positive effect on all the intestinal parameters. Moreover, they known to improve meat production in broilers by increasing the nutrients absorption from gut. This review article discussed all the key aspects of OA, which are being used in poultry ranging from their characteristics, uses in broiler, and layers. The reviewed literature showed that there should be the development of targeted strategies for using OA as feed additives and ultimately improving the combination of multiple probiotic barriers and OA compounds. OA commonly used as an acidifier in chicken feed are consider attractive ways to improve digestion. The use of OA may be a good choice to improve the wellbeing of poultry birds. There's a belief that more research is required to determine the direct effect of OA in multiple stages of poultry health and diseases of infectious nature to determine the appropriate amount of supplementation of OA.

Keywords | Organic acids, Gut health, Natural compounds, Poultry health, Layer production.

Received | February 04, 2022; **Accepted** | March 25, 2022; **Published** | June 15, 2022
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Citation | Abbas G, Arshad M, Saeed M, Imran S, Kamboh AA, Al-Taey DK, Aslam MA, Imran MS, Ashraf M, Asif M, Tanveer AJ, Qureshi RAM, Arshad M, Niazi HAK, Tariq M, Abbas S (2022). An update on the promising role of organic acids in broiler and layer production. J. Anim. Health Prod. 10(3): 273-286.
DOI | http://dx.doi.org/10.17582/journal.jahp/2022/10.3.273.286
ISSN | 2308-2801

INTRODUCTION

Chicken are our "bread and butter" and Poultry industry is a most active sector which has become employment source for the growing human population (estimated to be 6.8 thousands million) throughout the world (Abbas et al., 2020; Abbas et al., 2021). Commercial poultry production throughout the world is facing the challenges of diseases like mycoplasmosis, coccidiosis, salmonellosis etc., which produce economical losses due to poor weight gain or even huge mortality. In the past, antibiotic were excessively used in poultry o overcome these problems, in order to improve growth performance and to protect the poultry from the antagonistic effects of non-pathogenic and pathogenic enteric microorganisms. But in modern poultry production use of antibiotics is intensively controversial due to the expansion of anti-bacterial resistance and potential consequence on the human health, environment and food safety issues. Since, January 2006, European Union has strictly expelled the usage of antibiotic in poultry production. Therefore, prebiotics, probiotics, phytochemicals and organic acid are being taken into account as an alternative and substitutes of antibiotics (Abbas et al., 2022; Abbas et al., 2018; Lagua and Ampode, 2021; Refaie et al., 2022; Saeed et al., 2020).

Use of organic acids (OA) as an alternative of antibiotics is of great interest in poultry production (Panda et al., 2009). The OA are carbon-based compounds possessing weak acidic characteristics. Carboxyl group of the carboxylic acids make it the most commonly found OA on this planet. The strongest among organic acids are sulfonic acids that possess sulfide group. Alcohols can also be considered as OA due to their hydroxyl group, but they are very weak (Jones et al., 1998). The acidity of an OA is measured by the comparative steadiness of its conjugate base. The thiol, enol, and the phenol group can also impart weak acidic properties to their parent compounds. Some examples which are commonly found in the organic acid are citric acid, tartaric acid, oxalic acid, formic acid, acetic acid, malic acid and propionic acid (Deng et al., 2016). Organic acids are ubiquitous in nature and also found in microbes, plants and animals. The main feature is their carboxylic group which is covalently linked to either of amides, esters or peptides (Doores et al., 2005). They were first discovered in 1817 by dry distillation of malic acid resulting in *tras* form of fumaric acid and *cris* form of maleic acid. In 1937, Kreb described the involvement of these acids in the tricarboxylic acid (TCA) cycle (Goldberg et al., 2006). Soon, their production on large scale began predominantly with microbial origin. Currently, a number of organic acids are being produced on industrial scale comprising mainly of bacterial and fungal origin (Mattey et al., 1992). Most of them are mono-carboxylic acids but now the focus is also shifting on di- and tri-carboxylic acids. Citric acid and lactic acid are the most widely studied and produced organic acids (Yao et al., 2004).The gastric pH was observed to have a drop in value however caecal pH does not exhibit a similar fall in value by OA supplementation. The OA concentration depletes as it reaches the caeca hence the effect is not as pronounced as in the crop. However, the drop in the gastric pH has a beneficial effect in the overall digestion process as the reduced gastric pH enhances the activity of pepsin (Adil et al., 2010). The peptides that were a product of the proteolysis stimulate the eventual release of some hormones like gastrin and cholecystokinin which aid the degradation as well as the absorption of protein. The OA also promoted the production of pancreatic juices (chymotrypsinogen A, B and procarboxy peptidase enzyme) resulting in better degradation of protein (Adil et al., 2010; Afsharmaneshet al., 2005). Major aspect of the use of dietary OA supplements for broilers is its effects on the small intestine architecture such as villus height, villus width and crypts depth (Loddi et al., 2004; Pelicano et al., 2005). The OA seem to have a significant effect on the height of villus as well as the crypt depth. The use of OA also lessens the muscularis thickness. These positive effects are attributed to the depleted inflammation levels at mucosal surfaces because of the modulatory effects of OA on the gut bacterial communities. In absence of inflammatory reactions, the intestinal tissues undergo positive changes like increase in villus height and crypt depth. Muscularis thinning is also beneficial in the absorption of nutrients. All those factors lead to a higher degree of nutrient digestibility and absorption (Savage et al., 1996; Bradley et al., 1994). Enhancing effects on the gastrointestinal tract (GIT) length are also observed with OA supplementation as it increases the length and weight of the GIT tract owing to gut cell proliferation (Denli et al., 2003). Potential mediators of GIT cell proliferation such as jejunal glucose transporter-2 (GLUT-2) expression, ilealpro-glucagon expression and plasma glucagon-like peptide 2 (GLP-2) concentrations were increased with the use of OA and SCFAs (short-chain fatty acids) were also considered to have a similar effect (Tappenden et al., 1998). Enhancement of these potential mediators of GIT cell proliferation and decrease in inflammatory reactions have a symbiotic effect on the improvement of intestinal tissues which aids the digestion, absorption and assimilation of nutrients (Salvi et al., 2021). Ascorbic acid was reported to have a significant hepatoprotective effect against drug induced deleterious effects (Omara et al., 2021).

Growth metrics such as feed conversion ratio and body weight gain indicate a spike with use of OA in the broiler feed. Improvement in the absorption and digestion of the nutrients results in increased weight gain which eventually leads to a better feed conversion ratio (Vogt et al., 1981).

However, an additional factor that helps improve the feed conversion ratio is the decreased feed intake. Feed intake falls slightly due to satiation effects produced by OA such as fumaric acid (Cave et al., 1978). As the utilization and assimilation of the already available nutrients improves, the need for additional nutrients falls and resultantly the feed intake also falls. The body weight gain however goes up as does the feed conversion ratio consequentially (Henry et al., 1987). Decreased microbial load in the gut leads to lessened competition for nutrients and eventually more nutrients get absorbed and utilized for the body to use in growth. There is no significant change in carcass properties have been observed by using dietary OA supplement in feed (Lückstädt et al., 2009). The use of OA as preservatives in grain and forage, and as nutrients in animal and poultry feed has been known for years. Their historic use in food preservation has been accepted by communities all over the world (Lückstädt et al., 2011). Their efficacy as performance enhancement, antimicrobial activity, feed preservatives, and nutrient digestibility has made them ideal candidates for use as an essential component of livestock and poultry feed. They reduce the microbial uptake, stabilize the gut micro-flora, and enhance the digestion and absorption from the intestines (Freitag et al., 2007). This review has summarized the importance OA in poultry industry with specific focus on broiler and layer birds. Various facts and figures about the correlation of bird performance with use of OA have been discussed to further highlight their potential to researchers to dig more focus on this research area.

Characteristics of organic acids

Generally, OA are considered as weak acids that are not completely dissolve in water, whereas strong mineral acids commonly do. Some OA like lactic acid and formic acid are soluble in water due to their lower molecular mass while benzoic acids in neutral form having higher molecular mass are insoluble. On the other hand, most of OA are easily miscible in the organic solvents such as*p*-TFoluene sulfonic acid which comparatively possess strong acidic properties and used in the organic chemistry often because it can efficiently dissociate in organic solvents (Baghernejad et al., 2011). In Table 1, the physiochemical properties of important organic acids is discussed.

Effects of Organic acid supplemented diet

The use of formic acid as feed preservative in poultry feed and as a supplement to enhance the production performance of poultry is well documented (Lückstädt et al., 2014; Abbas et al., 2013; Lückstädt et al., 2011; Garciá et al., 2007; Freitag et al., 2007; Hernández et al., 2006). Afterwards, the use of calcium formate in broiler diet has also reported to reduce level of *Salmonella* spp. in the poultry carcass and fecal samples (Açıkgöz et al., 2011; Hassan et al., 2010; Byrd et al., 2001). Buffered propionic acids were utilized to neutralize harmful gut micro-flora in the GIT of broiler chicken, as a resultant significant decrease in *Escherichia coli* as well as *Salmonella* spp. was observed in carcass (Ricke et al., 2020). Unadulterated formic acid's utilization in the diet of breeders diminishes the taint of hatchery and tray liners with *Salmonella enteritidis* (Humphery et al., 1988).

Fermentation with different natural acids to diets, for example, formic acid, propionic acid, fumaric acid, sorbic, and lactic acid have been accounted for diminishing the colonization of microbes (Hamed et al., 2013; Hassan et al., 2010) and synthesis of noxious metabolites, enhancing the absorbability of various proteins and elements like magnesium, calcium, zinc and phosphorus and also acting as substrate in the intermediary digestion (Dibner et al., 2002; Sohail et al., 2016). A few studies exhibited that supplementation of OA to the broiler diet improved the growth performance, diminished illnesses, and managerial issues. Hinton and Linton (1988) observed the effects of utilizing formic acid and propionic acid in combination on salmonellosis in broilers. They reported that 0.6% (6kg/t) of this natural acid mix showed good results in intestinal proliferation of *Salmonella* spp. when fed with both natural as well as artificially manufactured feed. Performance and hygiene improvements have been observed in the broiler with time by the use of OA (Hamed et al., 2013; Açıkgöz et al., 2011; Byrd et al., 2001). However, a noteworthy limitation is that OA are quickly processed in the foregut (Lückstädt et al., 2011), which lessen their effect on growth development. Mixing of OA with salts, for example, sodium diformate (C2H2Na2O4),ammonium formate, potassium diformate (C2H3KO4) or calcium propionate that reach the digestive tract seemed to have a huge effect (Paul et al., 2007; Mikkelsen et al., 2009; Lückstädt et al., 2011). The impact of the use of C2H3KO4 i.e., potassium diformate at dose rate of 0.3-1.2 percent until 35 days after hatching has been observed. Potassium diformate decreased the number of pathogenic microorganisms such as *Salmonella*, *Enterobacter* and *Campylobacter* in broiler and increased the number of useful microorganisms like *Lactobacillus* and *Bifidobacterium* (Mikkelsen et al., 2009; Lückstädt et al., 2011). The anti-microbial characters of OA were observed at low pH, in such conditions their dissociated carboxyl groups infiltrate the bacterial cells ultimately causing cell death. The OA which have a broader range of pKa (acid dissociation constants; the lower the value of pKa, the stronger the OA) have a wide spectrum of mechanism in the gut. Hence owing to their antimicrobial characteristics, OA are considered substitutes to synthetic promoters of growth (Dibner and Buttin 2002; Cherrington et al., 1991). OA regardless of the kind and quantity of acid used were observed to have a beneficial effect on the performance of broilers (Adil et al., 2010).

Table 1: Physiochemical Properties of Important Organic Acids

Acid	Molecular Formula	Molecular Mass	Physical Form	Solubility in Water
Acetic acid	CH_3COOH	60.1	Liquid	100%
Butyric acid	$CH_3CH_2CH_2COOH$	88.1	Liquid	100%
Citric acid	$COOHCH_2C(OH)(COOH)CH_2COOH$	192.1	Solid	High
Formic acid	HCOOH	46.0	Liquid	100%
Lactic acid	$CH_3CH(OH)COOH$	90.1	Liquid	High
Malic acid	$COOHCH_2CH(OH)COOH$	134.1	Liquid	100%
Propionic acid	CH_3CH_2COOH	74.08	Liquid	100%
Sorbic acid	$CH_3CH:CHCH:CHCOOH$	112.1	Liquid	Low
Tartaric acid	COOHCH(OH)CH(OH)COOH	150.1	Liquid	High

Table 2: Summarized effects of various studies that shown the importance of different organic acids.

Name of organic Acid	Dose	Specie	Effects (Increase: ↑, Decrease: ↓)	References
Butyric acid, Fumaric acid, Lactic acid	2% and 3%	Broiler	↓Coliform count, ↓Viable count in caeca, ↓ Crop pH, ↓Caecal pH, ↑FCR, ↑Body weight, ↓Feed intake	Banday et al., 2011
Butyric acid, Fumaric acid, Lactic acid	2% and 3%	Broiler	↑Serum Calcium (mg/dL), ↑Phosphorus (mg/dL), ↑Total protein (gm/dL)	Rehman et al., 2010, Banday et al., 2011
Butyric acid, Fumaric acid, Lactic acid	2% and 3%	Broiler	↑Villus height (µm), except for lactic acid (2%) that decreased villus height	Adil et al., 2010
Butyric acid, Lactic acid,	2% 2% and 3%	Broiler	↑Crypt depth (µm) in duodenum	
Butyric acid, Fumaric acid,	3% 2% and 3%	Broiler	↓Crypt depth (µm) in duodenum	
Butyric acid, Fumaric acid, Lactic acid	2% and 3%	Broiler	↓Muscularis thickness (µm) in duodenum, jejunum and ileum, ↑Villus height (µm) in jejunum and ileum	
Butyric acid	2% and 3%	Broiler	↑Crypt depth (µm) in jejunum	
Fumaric acid, Lactic acid	2% and 3%	Broiler	↓Crypt depth (µm) in jejunum	
Butyric acid, Fumaric acid, Lactic acid	2% 3% 2%	Broiler	↑Crypt depth (µm) in ileum	
Butyric acid, Fumaric acid, Lactic acid	3% 2% 3%	Broiler	↓Crypt depth (µm) in ileum	
Butyric acid, Fumaric acid, Lactic acid	2% and 3%	Broiler	↑GIT length	Denli et al., 2003

Butyric acid, Fumaric acid	2% and 3% 3%	Broiler	↑Glucose (mg/dL)	Adil et al., 2010
Lactic acid Fumaric acid	2% and 3% 2%	Broiler	↓Glucose (mg/dL)	
Butyric acid, Fumaric acid, Lactic acid	2% and 3% (except for Fumaric acid 2%)	Broiler	↓Cholesterol (mg/dL)	
Butyric acid, Lactic acid	2%	Broiler	↓SGPT (μ/L)	SA et al., 2008; Adil et al., 2010
Butyric acid, Fumaric acid, Lactic acid	3% 2% and 3% 3%	Broiler	↑SGPT (μ/L)	
Butyric acid, Fumaric acid, Lactic acid	2% 3% 2%	Broiler	↑SGOT(μ/L)	
Butyric acid, Fumaric acid, Lactic acid	3% 2% 3%	Broiler	↓SGOT(μ/L)	
Butyric acid, Fumaric acid, Lactic acid	2% and 3%		↑Ready to cook yield (%), ↑Dressing percentage, ↑Intestine length (cm), ↑Intestine weight (g), ↑Liver weight (g) (except in Lactic acid 3%), ↑Heart weight (g) (except in 2% Butyric and Fumaric acid), ↑Gizzard weight (g) (except in Butyric acid on 2% and 3%), ↑Total giblets weight (g), ↑Head weight (g), ↑Feather weight (g) ↑Blood weight (g), ↑Drumstick weight (g), ↑Breast weight (g), ↑Shank weight (g) (except in 3% Lactic acid), ↑Neck weight (g), ↑Back weight (g), ↑Wings weight (g), ↑Thigh weight (g),	Thirumeigmanam et al.,2006; Adil et al., 2011a
Butyric acid and lactic Acid	0.2% and 0.05%	Broiler	↑Antibody titer against ND	Salazar et al., 2018
Butyric acid	0.1% to 0.4%	Broiler	↓Caecal *E. coli*, *Salmonella* spp. and *Clostridium* spp. count, ↑*Lactobacilli* spp. count, ↑Villus height in duodenum and jejunum (day 21), duodenum, jejunum and ileum on day 42, ↑ Crypt depth in duodenum, jejunum and ileum	Nataraja et al., 2020
Butyric acid	4 g /kg	Broiler	↑villus length and width, ↑ serum protein, albumin, creatinine, aspartate aminotransaminase (AST), phosphorus and calcium ↓Serum uric acid and cholesterol,	Raza et al., 2019

Butyric acid	500 g/t feed (encapsulated)	Layer	↑Eggshell thickness, eggshell weight, ↑calcium concentrations in bones, ↓ammonia concentrations in the caecum	Alicja et al., 2016
Fumaric acid	1.5%	Broiler	↑body weight gains and FCR, ↓pH of crop, proventriculus and gizzard	Banday et al., 2015
Fumaric acid	10-15g/Kg	Quail	↑growth performance, ↑Digestibility of crude protein and metabolizable energy	Fayiz et al.,2021
Fumaric acid	5g/kg	Broiler	↑Serum total protein, albumin, globulin, total cholesterol, high-density lipoprotein cholesterol	Ding et al.2020
Fumaric acid	10g/Kg	Broiler	↑FBW, ADFI, ADG, antibody titres against SRBC, IgG, relative weights of spleen and bursa, activity of GPx in thymus and bursa, ↓ FCR and TC of thymus and bursa	He at al., 2020
Fumaric acid Thymol	0.9g/kg 0.6 g/kg	Broiler	↑FCR and increased ileal villi height-to-crypt depth ratio (VH:CD), cecal abundance of Bacteroidetes, Bacillaceae, and Rikenellaceae ↓Pseudomonadaceae	Abdelli et al., 2021
Lactic Acid	0.3 g/kg	Broiler	↓*Escherichia coli* and *Salmonella* in the cecum	Gao et al., 2021

FCR: feed conversion ratio; SGPT: Serum glutamic pyruvic transaminase; SGOT: aspartate aminotransferase; ND: Newcastle disease; FBW: Final body weight; ADFI: average daily feed intake; ADG: average daily gain; SRBC: Sheep red blood cells; IgG: Immunoglobulin G; GPx: Glutathione peroxidase

Serum analysis after the use of OA in broiler feed spotlight an increase in calcium, phosphorus and total protein levels owing to increased digestibility and absorption of these components in crop and intestine (Teirlynck et al., 2009). However, glucose levels as well as cholesterol levels did not go up significantly with organic acids supplementation. SGPT and SGOT values also did not indicate any considerable changes (Adil et al., 2010). Major aspect of the use of dietary OA supplements for broilers is its effects on the small intestine properties such as villus height, crypts depth and thickening of muscularis. OA increase the villus height, crypt depth and lessen the muscularis thickness (Loddi et al., 2004; Pelicano et al., 2005). All those factors lead to a higher degree of nutrient digestibility and absorption. Enhancing effects on the GIT length are also observed with OA supplementation as it increases the length and weight of the GIT tract owing to GIT cell proliferation (Denli et al., 2003).Table 2 summarizes different studies that have shown the importance of different organic acids.

Significance of organic acid in Layer production

Egg production

Layer egg production can be increased significantly by using OA as dietary supplement. Yesilbag et al. (2006) revealed a positive effect of OA supplementation on normal egg production (18 weeks of experimentation).Likewise, some other workers (Soltan et al., 2008; Rahman et al., 2012) suggested 1.5% OA supplementation to improve the egg production in commercial layers. The average percentage of hens' egg production increased significantly at an age of 70 weeks by about 5.77% to 9.84% when diet was supplemented by 0.078% of OA (formic acid, propionic acid, butyric acid, and lactic acid) compared to a basal diet. The feed conversion ratio (FCR) of the layers were greatly improved 1.85%, 8.48% and 7.74% in groups that supplemented with organic acid at 0.026%, 0.052% and 0.078% respectively.

Directed a baseline study in which an acidifier was added in poultry diet called phenylalanine (Wang et al., 2009). They determined that production of egg through the consumption of phenyl-rich acid diet was improved by 1.55%, 2.64%, and 2.69% by 0.5%, 1.0%, or by 1.5% OA respectively, in comparison with control group birds. Increase in the production of eggs was parallel with the increase in the amount of phenyl lactic acid. It is suggested that the increase in production is probably due to the anti-microbial activity of OA. Consumption of OA in poultry diet promotes the nutrient digestibility and thus can lead to increased feed efficiency and egg production.

Youssef et al. (2013) proclaimed that as compared to control diet OA supplemented layer diet exhibited an increase in feed intake (105 *vs.* 109 g/d/bird), egg production (88.50%*vs.* 97.30%), and feed conversion rate (1.98 *vs.*1.81). Likewise, (Grashorn et al., 2013) described that supplementation of OA (contained ammonium propionate

30%, formic acid 40%, lactic acid 26%, sorbic acid 0.5%, sodium benzoate 0.5%, and carrier3%) to layer diets significantly increased egg weight, production and FCR.

Park et al. (2009) studied the effect on layer bird's performance by the addition of 0.2% of OA in diet. The addition of OA produces good results in the production of eggs and FCR as well as reduces the production of soft shell and broken eggs. It was concluded that the addition of OA may improve the hens' production, quality of eggs, and reduce mortality. The OA is proposed to be associated with the increased utilization/ absorption of phosphorus and calcium and other minerals for shell formation (Dhawale et al., 2005; Boiling et al., 2000).

Presently, for growth improvement of birds in broiler and layer industry OA is preferred to be added in drinking water (Abbas et al., 2013; Chaveerach et al., 2004). Kadim et al. (2008) proclaimed that supplementation of acetic acid has been observed to improve average production of eggs during the hot season when given in drinking water. Abbas et al. (2013) proclaimed that improved feed conversion ratio and more egg production has been observed in layer those consumed drinking water withthe addition of formic acid during summer. The results revealed that hens consuming water with formic acid percentages, 0%, 0.05%, 0.10% or 0.15% exhibited improved egg production approximately 72%, 80%, 86% and 88% respectively.

Gut flora and environmental temperature variations are contributing factors to the performance of poultry by the use of OA (Mahdavi et al., 2005). Different vitamins and minerals concentrations in body tissue and serum of birds decreased due to high temperature (Abbas et al., 2021) leading towards reduction in egg production (Khattak et al., 2012). Supplementation of OA to the drinking water assists in the elimination of number of microorganisms in the water as well as from the proventriculus to direct gut microflora which promotes the digestion and absorption of feed in gut and enhances growth and development (Chaveerach et al., 2004). Supplementation of natural acids in water has been observed more viable than dietary addition since OA utilization is reduced depending upon the decrease in feed consumption during heat stress.

Egg quality

The incorporation of OA into the layer diet can significantly increase the egg weight and egg quality traits. Reported significant improvements in yolk index ($P < 0.05$) and albumen index ($P < 0.05$) in layer chickens treated with addition of lactic acid 1% concentration (Yalcin et al., 2000). The Haugh unit scale is used to define egg quality (storage quality) in relation to the height of the thick albumen in egg weight. Described that hens' diet containing 1% lactic acid, 0.05% of acetic acid and0.2% phenyl lactic acid caused improvements in the Haugh unit score (Yalcin et al., 2000). Found that eggshell weight, eggshell strength, albumen percentage, eggshell thickness and yolk pH were significantly improved when the drinking water of layers was supplemented with acetic acid (Kadim et al., 2008). Elaborated the improvement of egg thickness of layers fed diets supplemented by organic acids (Soltan et al., 2008). The eggshell strength of layers was reported to be improved by supplementation of 0.2% phenyl lactic acid (Wang et al., 2009). Similarly found that the eggshell thickness as well as eggs grade of layers consuming formic acid supplemented water were significantly higher (Abbas et al., 2013). The use of OA had positive effect on calcium absorption in layers that is why increasing the effectiveness of calcium (Abbas et al., 2013). Proclaimed that the weight and thickness of the egg shell of the layers raised at high temperatures could be significantly improved following the addition of OA. The development of egg quality can be the result of increased absorption of minerals and proteins contributing to improved quality that can lead to increased shell weight and thickness (Soltan et al., 2008).

Significance of organic acids in broilers' performance

In the world of poultry production, utilization of natural acids is acquiring a lot of consideration. The high degree of production and feed conversion ratio in the modern broiler industry could be accomplished by the utilization of OA. OA have properties relating to growth and development and can be utilized instead of anti-microbial agents (Fascina et al., 2012). Observed that butyrate with a concentration of 0.4% in the poultry diet gives the same advantages to bodyweight acquire as that of use of antibiotics (Panda et al., 2009). Furthermore, (Adil et al., 2010, 2011b) found that chicks whose diet was supplemented with OA showed a huge improvement in the performance when contrasted with chicks feed on the control diet. The most improved weight gain in broiler was observed when fed on the diet having 3% fumaric acid. The improved FCR could be due to better utilization of supplements bringing betterment in the body weight gain of chicks fed on OA in the diet. Adil et al. (2011a) also revealed that broilers fed on a diet supplemented with lactic acid, butyric acid and fumaricacid (2-3%) showed improved performance. The improvement in FCR was deemed to be because of decreased feed intake bringing better body weight gain as a result of better utilization of various feed nutrients.

The utilization of OA may be more valuable than the utilization of antimicrobials for the optimal growth of broilers in poultry production. Hassan et al., (2010) used two artificially manufactured combinations of OA (Biacid® and Galliacid®) and an antimicrobial (Eneramycin®) to compare their effect on broiler performance. The results showed a 16% improvement in weight gain in Galliacid® group than the control group; on the other hand chicks fed on the Bi-acid® and Eneramycin® showed 3% and 5.5% more weight gain respectively. Fascina et al. (2012) revealed that the utilization of OA combination (involving 30.0 percent lactic acid, 25.5 percent benzoic acid, 8 percent citrus extract,7 percent formic acid, and 6.5 percent acetic acid) in broilers improved performance when contrasted with the control diet at 42 days trial period along with better carcass attributes. The positive effect of dietary OA on performance may be because of a decrease in pH of stomach which has antimicrobial impact alongside improved diet absorbability (Ghazala et al., 2011).

Significance of organic acids on GIT of chicken

Healthy GIT is essential in achieving targeted growth and feed efficiency in poultry sector. OA supplemented diet significantly increased the height of villi, width of villus and the area of ileum, jejunum and duodenum of 14-days-old broiler chicks (Garcia et al., 2007). The study described that birds that feed on 0.5-1.0% formic acid-containing diet have the longest villi height of about 1273µm and 1250 µm in comparison with control of 1088 µm. Likewise, jejunum crypts were found deeper (266µm *vs* 186 µm, respectively; P< 0.05) in birds feeding on1% formic acid mixed diet than in birds feeding on antibiotic diet. Therefore, the study illuminated that formic acid supplemented diet can increase both crypt depth and villus height. It has been reported that SCFAs enhance the growth and multiplication of normal crypt cells, improving and maintaining the healthy tissues. Frankel et al. (1994) demonstrated some trophic related effects of SCFAs to increase height of villus, surface area and crypts depth in jejunum in rat colons when fed with butyric acid supplemented diet. Similarly, Leeson et al. (2005) proclaimed that butyrate regardless of the concentration (0.6%, 0.4% or 0.2%) in broilers feed could improve the crypt depth as well as the villus height in duodenum. Therefore, the addition of butyrate can be very helpful for intestinal growth of young birds. It is claimed that organic acid salts significantly raised villus height in the ileum, jejunum and duodenum part of intestine. Pelicano et al. (2005) proclaimed the elevated height of villus in ileum due to organic acid-based diets compared to diet without mannan oligosaccharide + OA salts. Intestinal histology results revealed that OA salts like Ca propionate and ammonium formate when supplemented with feed increase the villus height of various parts of intestine in comparison with control group by decreasing the intestinal proliferation of infectious and non-infectious bacteria possibly. Thus, improvement in the height of villus in intestine enhanced the role of gut epithelium to act as natural barrier against different types of pathogenic bacteria and toxins because pathogenic substances cause disruption in the natural micro flora and gut epithelial permeability, making it easier for invaders to alter the metabolic activities (digestion and absorption) resulting in chronic inflammation of mucosa.

OA commonly used as an acidifier in chicken feed are considered attractive ways to improve digestion. Samanta et al. (2010) described that OA compounds increased gastric proteolysis and lowered pH of chyme thus, resulted an improvement in the amino acids and proteins' digestion. Van Der et al. (2002) reported that the significant OA effect on intestinal digestion was linked to the slow digestion of nutrients in the intestine, improved absorption of essential nutrients and droppings that are less wet. Smulikowskaet al. (2009) described the nitrogen (N) retention capacity of some specific preparations of fat coated OA in broiler gut compared to non-supplemented diet. Increased N retention may be interlinked with a significant improvement in epithelial cells in the gastrointestinal tract. Unprotected OA in chicken feed are easily digested (Sugiharto et al., 2014), while fat-coated preparations prevented the breakdown of OA inside the stomach and aided to counteract their functionality and bioactivity by moving to distal intestines and better balancing of intestinal micro flora and histo-morphology in birds. The addition of an OA mixture (sodium bentonite and propionic acid) to the broiler feed has resulted in increased digestion and nutrient uptake (such as Ca and P) due to the proliferation of the desired micro flora (*Lactobacillus* spp.) of the digestive tract, this results in on increased retention of mineral elements and bones mineralization (Sugiharto et al., 2019). The graphical demonstration of promising benefits of different OA on poultry gut that have ultimate outcome of improve production and meat quality were shown in Figure 1.

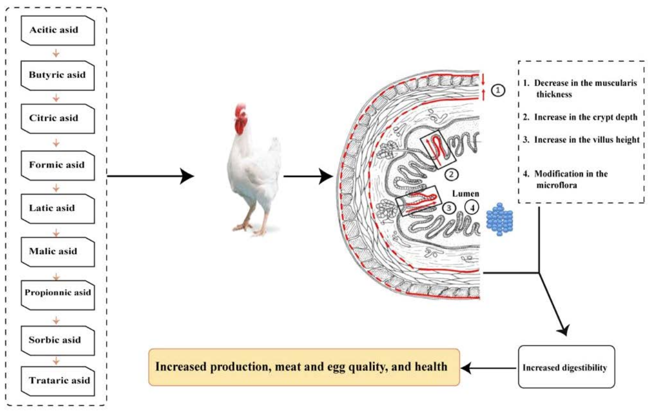

Figure 1: Showing the promising benefits of different organic acid in poultry

Significance of organic acids in meat production

Lactic and acetic acid solutions (1-3%) are the most frequently used supplements in poultry production. However, many others, like formic, propionic, citric, fumaric, and

L-ascorbic acid have been researched either individually or as a mixture for use in the chemical washing of the carcass. The exact mechanism of action is not completely comprehended on the microbial cell by organic acids, but it is hypothesized that the un-dissociated molecules of organic acid are responsible for the antimicrobial activity.

Conversely, Gill, (2009) inferred that, when taking the outcomes from three meat processing plants in the US, the clear impacts of the lactic acid spray could be ascribed to the washing impact of the treatment instead of any antimicrobial impact of the lactic acid. Greig et al. (2012) performed out a systemic overview and meta-investigation of the published research, observing the studies that reflected commercial conditions of processing. They proposed a more prominent decrease in the concentration and prevalence of conventional *E. coli* when acid is incorporated preceding dry chill, contrasted with dry chill alone, this improved efficacy is relatively small and should be evaluated against the expanded expense of chemicals and infrastructure. There is some proof that natural acids may improve the shelf life of atmospherically modified packaged food items, probably because they increase the period of the lag phase of the microorganisms (Podolak et al., 1996). Carpenter et al. (2011) reported that acid washing with acetic acid hindered the development of residual *E. coli* O157:H7 (a most hazardous strain of *E.coli*) for around 2 days, on an acid-treated meat plate. Nonetheless, detrimental sensory changes have been observed when meat was treated with lactic acid. Warm carcass surfaces treated with OA regularly showed some discoloration of tissue or fat surfaces. However, with boiling water pasteurization, this often vanishes or becomes less apparent after chilling (Carpenter et al., 2011).

Disadvantages of OA use in diets of poultry

There are some downsides of introducing OA in the poultry diets one of which is the refusal of feed due to change in palatability. Bacterial agents have been shown to develop resistance against the OA provided acidic environment when they had prolonged exposure. This leads to bacteria proliferating even when the birds fed with OA owing to the gradual resistance produced against the acidic environment. Anti-microbial compounds do not interact well with OA as the efficiency of the latter is reduced. Corrosive effects were observed on metallic poultry equipment that exposed to some organic acids (Goldberg et al., 2006; Hajati, 2018).

CONCLUSION

As the poultry industry is facing a growing need for antibiotic-free chickens, thus analyzing an effective alternative of antibiotics is the need of the hour, one that positively modulate microbiome in poultry gastrointestinal tract. It is also important that the approach chosen is easily incorporated into nutrition, animal care and housing for future use. The OA have acidifying functions that could be useful in poultry feed to avoid or fight pathogenic bacterial infections, so they can promote bird health and body function. However, a nutritionist should keep in mind various significant factors i.e., age of the birds, the microbiota of intestinal tract, gut environment or pH, etc. that can buffer different nutritional elements. Without a doubt, the discovery of microbiome sequences provides a chance to mimic the GIT poultry community in OA response. Literature proclaimed that OA (e.g., butyrate) supplementation, regardless of doses could improve the GIT architecture in growing chickens therefore; the addition of OA in the diet of young birds is recommended for intestinal growth. There's a more research is required to determine the direct effect of OA in multiple stages of poultry health to determine the appropriate amount of supplementation of organic acids. Moreover, research should be done to find the most effective ways to reduce harmful pathogens in the stomach that may antagonize the effects of OA for further improve the poultry performance, and gut histomorphology.

CONFLICT OF INTEREST

The authors have no conflict of interest.

NOVELTY STATEMENT

The objective of the present manuscript is to find out befits of using organic acids in broiler and layer production. Although some scientists worked on this topic there was a need to summarize all the researches in a table form. In the present study, the effect of organic acids in layer and broiler production is studied exclusively.

AUTHORS CONTRIBUTION

Ghulam Abbas, Muhammad Arshad, Maria Arshad, Muhammad Saeed and Muhammad Saeed Imran designed the project/study. All authors critically revised the manuscript for significant intellectual contents and approved the final version.

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