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Use of Organic Acids as Potential Feed Additives in Poultry Production

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ABSTRACT

Historically organic acids (OA) have been used by humans as natural food preservatives and hygiene promoters with regard to the microbial growth and to enhance freshness and shelf-life of edible food items. This characteristic of microbial growth inhibition of OA also makes them suitable replacement to antibiotic growth promoters in poultry. OA are chemically weak acids, which prevent or completely seize the proliferation and colonization of pathogenic bacteria in the intestine of birds. Thus, reducing the competition for the nutrients as well as production of harmful microbial metabolites. This in turn improves bird’s performance and enhances the specific and non-specific immunity by improving the bird’s intestinal epithelial layer. OA also help improving absorptive capacity of the intestinal cells by improving the crypt-villus structures as well as by improving the digestive secretions, thus influencing a boost in the digestion of proteins, carbohydrates and especially the minerals. This results in enhanced growth rate and feed efficiency in poultry. This comprehensive review about dynamics of OA revealed that this potential feed additive will be used as performance modifier in commercial poultry production, functioning as gut microbial modifier, immune modulator and nutrients digestion enhancer. This review updates the last decade's developments about OA in poultry production.

Key words: Organic acid, Antimicrobial activity, Digestibility, Performance, Poultry

INTRODUCTION

Increased growth rate and improved feed efficiency (Miles et al., 2006) along with prevention of sub clinical diseases are the main reasons why dietary antibiotic growth promoters (AGP) have been practiced during the last 50 years in poultry production. However, their constant use at low dosage develops resistance in the bacteria (Collignon, 2003) and residues in the animal products.There was a fear of transferring these antibiotic-resistant bacteria to humans via food chain (Dibner and Buttin, 2002), therefore, European Union (EU) banned the use of AGP in animal nutrition in 2006 (European Union, 2003 and 2005). Ban on the use of AGP in poultry feed resulted in a poorer production performances and there was a change in the microbial ecology in gastrointestinal tract of birds. However, Danish industry evidence showed little effects of this ban on the productive performance. This situation therefore, compelled animal nutritionists and researchers to search for other non-therapeutic alternatives for poultry feed such as organic acids (OA) (Panda et al., 2009), plant extracts, (Taylor, 2001) enzymes, probiotics, prebiotics, herbs and essential oils (Islam, 2012). The use of OA and their salts in the poultry production were considered as safe therefore, they were allowed to be used as feed additive by the European Union (Adil et al., 2010). Moreover, most of the research during last decade shows that OA are excellent promoters of growth performance and gut health in commercial poultry production (Sohail and Javid, 2016). Therefore, it is important to understand and highlight their importance, impact and mode of action, to be able to maximize the benefits when included in poultry diets.

Organic acids

Any substance that contains the R-COOH group in its structure and has acidic properties is called an Organic Acid (OA) and hence include fatty acid and amino acid. Chemically they are weak acids and contrary to mineral acids they do not dissociate completely in water. The pKa is a logarithmic measure of the acid dissociation constant, the most important property that categorizes the strength and affects the activity of OA. The lower or more negative the number, the stronger and more dissociable the acid. It is important for OA’s antimicrobial properties that its pKa value should be in the range of 3-5 (Dibner and Buttin, 2002).Due to this partial dissociation, not allOA’s have

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the ability to influence gut microflora or have antimicrobial properties. OA are short chained acids (C1-C7), consisting of either a simple monocarboxylic acids i.e. formic, acetic, propionic and butyric acids or ones containing carboxylic group at the alpha carbon like tartaric, lactic, malic, and citric acids, which exhibit antimicrobial properties. Acids like fumaric and sorbic acid also have antifungal properties. The OAs and their salts do not exhibit their beneficial effects solely through their antimicrobial activity in feed and GIT of birds but also act as performance enhancers in many ways (Al-Kassi and Mohssen, 2009). These include an improvement in the growth rate through increase in the digestion and absorption of different nutrients, improvement in crypt-villus structure i.e., crypt depth and villus height and width and stimulation of the digestive secretion of different organs.

Antimicrobial activity of organic acids

Major objective of the dietary acidification in poultry is to reduce the pathogenic bacteria (Partanen and Mroz, 1999; Griggs and Jacob, 2005) or increase beneficial bacteria number, both in the feed and by influencing the gut or intestinal environment (Ewing, 2009), so as to support enteric health and growth performance. However, their magnitude of microbial activity in the gut depends on the physiological status of the organism as well as physicochemical characteristics of the environment (Ricke, 2003). Most common bacteria that affect the intestinal health of poultry are *Salmonella*, *Escherichia coli* (*E. coli*), *Clostridium*, etc. Though a very small effect but these bacteria compete with the host for the nutrients and produce different types of metabolites like ammonia and amines, possibly a result of amino acid deamination, hence leading to reduced growth of the poultry birds. So, by reducing the number of these bacteria, growth rate gets enhanced. OA can provide control over *E. coli*, *Campylobacte*r and *Salmonella*challenges in poultry (Chaveerachet al., 2002 and Heres et al., 2003). *Salmonella* infection in poultry mainly spreads through contaminated feed (Ao, 2005), therefore, an in-feed addition of OA will prevent the foodborne *Salmonella* species (Broek et al., 2003). Likewise, OA can be added in the water to keep it free from all type of microorganisms. Albuquerque et al. (1995) reported that out of 136 feed ingredient samples studied for the incidence of Salmonella,19.85% were contaminated with *Salmonella*. Acid-intolerant species such as *E. coli*, *Campylobacter* and *Salmonella* families are particularly affected by the actions of OA (Al-Kassi and Mohssen, 2009). Hinton et al. (2000) reported that low pH and higher number of lactobacilli lower the incidence of the *Salmonella* in crop of broiler chicks. Similarly in feed addition of formic acid reduces the foodborne infections of poultry (Humphrey and Lanning, 1988 and Rouse et al., 1988). The pH value in crop decreased ($P<0.05$) in the broiler chicken fed OA based diets (Adil et al., 2011). Dietary supplementation of formic and propionic acid laying hens also resulted in lowering of the pH of the crop and gizzard, this lowered pH has also been shown to kill the *Salmonella in-vitro* (Thompson and Hinton, 1997).As a consequence fowl typhoid can be prevented/controlled (Berchieri and Barrow, 1996). Izat et al. (1990) documented that dietary acidification with buffered propionic acid lessen the number of *E. coli* in the small intestine. A mixture of OA significantly lowers the total bacterial count especially gram negative bacteria in broilers (Gunal et al., 2006). The RCOO- anions produced from OA can hinder bacterial genetic regulation i.e., DNA and protein synthesis. Van Immerseel et al. (2006) reported that at low dose butyric acid can suppress genes responsible for the Salmonella invasion. In an *in-vitro* study Entani et al. (1998) reported that a media containing 0.1 percent acetic acid inhibited the growth of 17 strains of the bacteria including *Salmonella typhimurium* and eight strains of *E. coli*. Adil et al. (2011) reported addition of OA to the diets of broiler chicken significantly decreased ($P<0.05$) the caecal viablecoliform counts compared to the unsupplemented group. Butyric acid supplementation decreases the colonization of salmonella in the liver and spleen in broilers (Fernández-Rubio et al., 2009). Maribo et al. (2000a) found that benzoic acid supplementation in the feed of pigs resulted in significantly lower counts of lactic acid bacteria, *lactobacilli*, coliform and yeast throughout the entire GIT.

Mycotoxinsthat are the metabolites of fungi are the major threat to the poultry industry as these suppress the immune system; reduces the dietary energy contents as well as causing poor feed conversion and less growth rate etc. A variety of OA such as acetic acid, lactic acid, propionic acid, or blends of acids are used to help control mold contamination (Higgins and Brinkhaus, 1999 and Santin, 2010). For the *in-vitro* assay, paper discs soaked in a spore solution were placed on the surface of agar plates containing increasing concentrations of the respective OA. *In-vitro* efficacy of propionic, acetic, lactic, undecylenic, butyric, valeric, benzoic, and sorbic acid against the *Aspergillus spp*., *Geotrichum spp*., *Mucor spp*., *Fusarium spp*., *Penicillium spp*., and *Scopulariopsis spp*. indicated that mold inhibiting property of the valeric acid is highest, followed by propionic acid and butyric acid. These three acids completely inhibit the growth of above mentioned mold at the concentrations of not higher than 0.35%. All the other OA showed fewer mold inhibiting activity and the least activity was shown by the lactic acid. Fusarium was the most susceptible mold when comparing the efficacy of different OA on different molds (Higgins and Brinkhaus, 1999). Propionic acid and butyric acid with effective inclusion rates of 0.1% and 0.2% were equal in their efficacy to inhibit *Aspergillus spp*. and *Fusarium spp*., respectively. Maribo et al. (2000b) compared bactericidal activities of six different acids in the stomach and small intestine of pigs against coliforms. The order of bactericidal activities of different OA were as follows from higher to lower order: benzoic acid >fumaric acid > lactic acid > butyric acid > formic acid > propionic acid.

Antimicrobial activity of OA is highly affected by the surrounding pH as pH affects the dissociation of the OA (Cherrington, 1991). When pH is low, ionization of the OA will also be less. Undissociated forms of OA are lipophilic and can diffuse across cell membranes of bacteria and fungi (Partanen, 2001). Once internalized into the more alkaline pH of the cell cytoplasma they dissociate quickly into their constituent ions resulting in lowering of the pH (Young and Foegeding, 1993) and as a consequence disrupting the nutrient transport system and enzymatic reactions (Cherrington, 1991). Concentration of the hydrogen ions due to dissociation of the acids increases and bacteria try to pump out these protons (hydrogen ions) from the cell. This process requires energy, so the availability of energy for the proliferation lessens, resulting in bacteriostasis (Luckstadt and Mellor, 2011; Suiryanrayna and Ramana, 2015). This direct antimicrobial activity makes OA an excellent choice as feed and food preservatives as well as hygiene promoters.

Coccidiosis, an important manage mental disease of poultry, causing more than $3 billion worth of economic losses to the world poultry industry annually (Dalloul and Lillehoj, 2006) is caused by the Emeria; a genus of protzoal parasite. Abbas et al. (2011) studied the anticoccidal effects of acetic acid against the *Eimeriatenella* by using 1, 2 and 3 percent acetic acid; and 125 ppm amproliumin drinking water. Results showed that acetic acid lowered the oocyte score, lesion score and mortality percentage in broilers. These effects were more prominent at 3%level of acetic acid but there was no difference between 3% acetic acid and amprolium in preventing the coccidiosis. Further studies are necessary in this regard for understanding the anticoccidial effects of other OA. Microbial growth inhibitory properties of some OA are presented in table 1 and table 2.

Table 1. The inhibitory effect of some organic acids used in animal nutrition on microbial growth.

Organic acid	Properties[1]		Growth inhibitory[2]		
	Molecular formula	Acid dissociation constant (pKa)	Bacteria	Yeast	Mould
Formic acid	HCOOH	3.75	++++	+	+
Lactic acid	$CH_3CHOHCOOH$	3.86	+	-	-
Acetic acid	CH_3COOH	4.76	++	+++	+++
Propionic acid	$CH_3CH2COOH$	4.87	++	+++	+++
Citric acid	$C_3H_5O(COOH)$	3.10-5.40	n.a.	n.a.	n.a.
Sorbic acid	$C_6H_8O_2$	4.76	+++	++++	++++
Benzoic acid	C_6H_5COOH	4.20	+++	++++	++++

[1]Adapted from Pölönen and Wamberg (2007); [2]adapted from Lassén (2007)

Table 2. Effects of different organic acids on various types of bacteria.

Organic Acid	Bacteria	Sample tested	Effect	Reference
Butyric acid	*Salmonella enteritidis*	Caecal colonization	Decreased total count	Van Immerseel et al. (2004)
Formic acid	*Salmonella*	Cloacal swabs and content	Not detected	Hinton et al. (1985)
Formic, propionic and acetic acid	*Campylobacter*	Boiler Feed	Decrease total count	Chaveerach et al. (2002)
Buffered propionic acid	*Escherichia coli*	Boiler Feed	Decreased the count	Izat et al. (1990)
Butyric acid	*Escherichia coli*	Caecum, small intestine and crop	Decreased the count	Panda et al. (2009)
Organic acid mixture	*Coliform*	Ileum and caecum	Decreased the count	Pirgozliev et al. (2008)
Malic acid	*Escherichia coli*	Intestine	Decreased the count	Moharrery and Mahzonieh (2005)

Table 3. Effectof different organic acids on the gastrointestinal tract of monogastric animals**.**

Organic Acid	Route	Effect on Intestine	Reference
Butyric acid	Feed	Increased the villus height	Adil et al. (2010)
Formic acid	Feed	Increased the villus height and crypt depth	Garcia et al. (2007)
Citric acid	Feed	Lowered the pH of digesta and gastrointestinal tract	Radcliffe et al. (1998)
Fumaric acid	Feed	Increased the villus height	Adil et al. (2010)
Lactic acid	Feed	Increased the villus height	Adil et al. (2010)
Butyric acid	Feed	Lowered the pH of crop and small intestine	Panda et al. (2009)

Effect of organic acids on gastrointestinal tract

Being the major organ responsible for nutrient digestive and absorptive phase, gastrointestinal tract plays a vital role in the chicken growth (Amit-Romach et al., 2004). It is also the largest reservoir of commensal bacteria and other microbes in bird’s body. Therefore, epithelium of the intestine is the natural obstacle to the bacteria and toxic substances entering the body. Different pathogens, chemical toxins and stress conditions alter the permeability of this natural defense (Pelicano et al., 2005), by shortening of villus height and extension of intestinal crypt resulting in lower villi height to crypt depth ratio (Mista et al., 2010), aiding the invasion of pathogens and leading to inflammatory processes at the intestinal mucosa (Podolsky, 1993). This subsequently leads to increased cell turn over, decrease in villus height, and lowering of the digestive and absorptive processes (Visek, 1978). Dietary inclusion of organic acids are known to have strong antibacterial properties and beneficial effects on intestinal acidity and histomorphology, which are imperative to support enteric health and growth performance of poultry (Geyra et al., 2001 and Loddi et al., 2004). Evident from Adil et al. (2010) and Cengiz et al. (2012) study who reported that dietary inclusion of OA in broiler diets resulted in an increase in the villus height. Mista et al. (2010) reported that these histopathological changes in the small intestine can be averted through the use of short chain fatty acids; mainlyacetate, propionate and butyrate in mice. Similarly Fukunaga et al. (2003) while working on rats reported that short chain fatty acids can accelerate gut epithelial cell proliferation, thereby increasing intestinal tissue weight and resulting in changes in mucosal morphology. Effect of different OA on the gastrointestinal tract is presented in Table 3.

The proposed mode of action of OA is related to the reduction of intestinal pH (Waldroup et al., 1995), which might be followed by alterations in the intestinal ecosystem (Canibe et al., 2001).For example butyric acid supplementation of broilers diets @ 0.2, 0.4, and 0.6 percent, significantly decreased the pH of crop, proventriculus and gizzard as compared to control and furazolidone group, maximum reduction in the pH was recorded at 0.4 and 0.6% butyrate compared with 0.2% butyrate (Panda et al., 2009). Eventhough inclusion of 0.4% and 0.8% buffered propionic acid in broiler diets resulted in decreased total number of *coliforms* and *E. coli* in the small intestine of the bird however, it had no effect on intestinal pH (Izat et al., 1990). Likewise, acetic lactic and citric acid does not affect the pH of different intestinal segments (Abdel-Fattah et al., 2008).

OA salts such as ammonium formate and calcium propionate at the dose rate of 3 mg/kg diet can significantly improve intestinal villus height (Paul et al., 2007).Likewise, dietary organic acid in broilers at the age of 42 d resulted in a significant increase in villus width, height and area of the duodenum, jejunum and ileum region (Kum et al., 2010).

Short chain fatty acids are also believed to cause an increase in the plasma glucagon-like peptide 2 and ileal pro-glucagon mRNA, glucose trans-porter expression and protein expression, which are all signals that they can potentially mediate gut epithelial cell proliferation (Tappenden and McBurney, 1998).

Effect of organic acids on immunity

Dietary OA play an important contributory role in the immune status of the bird. Reduction of subclinical infections (Humphrey and Lanning, 1988) and stimulation of the growth of beneficial bacteria may contribute to increased nutrient digestibility and a reduction in nutrient demand by the gut-associated immune tissue and microorganisms (Dibner and Buttin, 2002).

The immune mechanisms in birds are fairly similar with the mammals and are directly influenced by genetic, physiological, nutritional, and environmental factors (Sharma, 2003). The immune system of bird is complex and is composed of several cells and soluble factors that must work together to produce a protective immune response. Major constituents of the avian immune system are the lymphoid organs. Thymus and Bursa of fabricius are of utmost importance because these are involved in the development and differentiation of the T- lymphocytes and B-lymphocytes respectively (Qureshiet al., 1998). Functional immune cells leave the primary lymphoid organs and populate secondary lymphoid organs. Secondary lymphoid organs include spleen, gut-associated lymphoid tissues, gland of Harder, bone marrow and bronchial-associated lymphoid tissues (Sharma, 2003).

Citric acid supplementation enhances the density of lymphocytes in the lymphoid organs, so enhances the non-specific immunity (Chowdhuryet al., 2009 and Haque et al., 2010). Birds having the greater density of lymphocytes have stronger immune status to combat antigens (Khan et al. 2008). Wang et al., (2009) found that the dietary supplementation of phenylacetic acid increase the lymphocyte percentage in a short duration in layers. Organic acid supplementation causes hyperthyroidism and peripheral conversion of thyroxin (T4) to triiodothyronine (T3) which means that these birds have better immune competence and bursa growth (Abdel-Fattah et al., 2008). However, erythrocyte, leukocyte, eosinophil, heterophil and lymphocyte are not influenced by OA (Khosravi et al., 2010). Citric acid supplementation increases the bioavailability of Zn from the soybean meal in poultry (Boling et al., 2000b), a metal known for its immune enhancing properties (Kidd et al., 1996).

Dietary supplementation with acetic and lactic acid increases the serum globulin and decreases the albumin to globulin ratio (Rahmani et al., 2005; Abdel-Fattah et al., 2008). Globulin is a source of antibody production, so its serum level is a good indicator of immune responses and consequently better disease resistance (Griminger and Scanes, 1986). Das et al., (2011) and Houshmand et al., (2012) reported an increased antibody titer against Newcastle disease in broilers by dietary supplementation of OA.

Effect of organic acid on the nutrient digestibility

Protein and energy are the major factors influencing the performance of birds. Depending upon the regional location, protein in poultry diet can be supplied by animal and/or vegetable sources. Amongst vegetable protein sources, soybean meal remains the priority of animal nutritionists. However, there is a downside to it since it contains major anti-nutritional factors for poultry e.g., galacto-oligosaacharides, lectins and trypsin inhibitors; the major anti-nutritional factors present in soybean meal (Huisman and Jansman, 1991). Digestion of the protein in chicks is badly affected by the undigested galacto-oligosaacharides (Gdala et al., 1997) due to absence of α-1,6-galactosidase(Gitzelmann and Auricchio, 1965). Ao (2005) studied *in-vitro* effect of citric acid on the release of reducing sugar and α-amino nitrogen from soybean meal having different levels of protease and α-galactosidase. Results indicated that citric acid increases activity of both the exogenous galactosidase enzymes, thus enhancing the liberation of α-amino nitrogen and reducing sugars. Li et al. (1998) in an experiment using citric acid addition to the phytase supplemented swine diets reported a non significant improvement in dry matter, nitrogen, phosphorus and calcium digestibility. While other researcher (Dibner and Buttin, 2002; Omogbenigun et al., 2003; Suiryanrayna and Ramana, 2015) reported that organic acid supplementation in simple stomach animal diets resulted in an improved protein digestibility and energy availability by reducing microbial competition with the host for nutrients, endogenous nitrogen losses and production of ammonia. As OA increased the digestion of the protein, this consequently reduces the emission of ammonia and sulfur containing gases from the poultry house.

It is thought that reduction in the pH of digestadue to organic acid supplementation may increases the pepsin activity (Afsharmanesh and Porreza, 2005), resulting in enhanced protein digestibility (Gauthier, 2002).Pepsin proteolysis the proteins, thus producing the peptides which act as a strong stimulant for the release of hormones including gastrin and cholecystokinin (Hersey, 1987).These hormones then acts on pancreatic cells signaling them to release digestive enzymes. OA also act by increasing pancreatic secretions resulting in enhanced production of pancreatic juice (Smantha et al., 2009).As a consequence higher concentrations of trypsinogen, chymotrypsinogen A, chymotrypsinogen B, procarboxypeptidase A and procarboxypeptidase B are produced, which then lead to increased protein digestion (Kirchgessner and Roth 1982; Afsharmanesh and Porreza, 2005). Hume et al. (1993) studied the metabolism of propionic acid and found that 75% of this acid is used as energy source. Likewise Runho et al. (1997) reported improved metabolisable energy contents of broiler diets due fumaric acid supplementation.This proposes a correlation between energy levels and OA.

Thyroid hormones (Tri-iodothyronine) play a major role in regulating the oxidative metabolism in poultry. Any marked change in thyroid function (hypothyroidism or hyperthyroidism) will result in altered metabolic rate (Whittow, 2000). Abdel-Fattah et al., (2008) studied the effects of dietary organic acidification in broiler chicks using variable doses i.e., 1.5 and 3%, of lactic, citric and acetic acid to evaluate the effects on thyroid hormones and reported a significantly elevated serum Triiodothyronine (T3) concentration of organic acid fed broilers however, T4 levels were not significantly affected.

Minerals are crucial for normal physiological, structural and catalytic functioning of the body, (Underwood and Suttle, 1999) and therefore, must be supplied through feed. Minerals represent about 3.5% of the total body composition, of which 46% is calcium (Ca), 29% is phosphorus (P) and 24% included potassium (K), Sulphur (S), sodium (Na), chlorine (Cl) and magnesium (Mg). Minerals, especially Ca and P help to build bones and make them strong and rigid. Trace levels of iodine (I), iron (Fe), manganese (Mn) and zinc (Zn) are also included in the dietary mineral supplements to the poultry. OA reportedly increase the digestion of minerals in poultry. Citric acid (40 to 60 g/kg of diet) is very efficacious in improving P utilization in chickens fed on maize soybean meal diets and reduced the available phosphorus requirement by approximately 1 g/kg diet (Boling et al., 2000b). Boling et al. (2000a) also reported that the dietary citric acid supplementation increases the bioavailability of Zn to the chicks. Citric acid supplementation also increases the retention of Ca, P and Zn, thereby increased their levels in plasma (Brenes et al., 2003). Likewise acetic acid, citric acid and lactic acid increased the serum Ca and P (Abdel-Fattah et al., 2008). Adil et al., (2010) used butyric acid, fumaric acid and lactic acid in broiler diets and reported a significant increase in the serum concentration of Ca and P. Dietary supplementation of

OA resulted in chelation of anions of OA with the minerals making them less reactive with vitamins and more bioavailable to the birds (Li et al., 1998). There are many factors which affect the bone development e.g. genotype, age of bird, dietary Ca and P level, dietary vitamin D_3, dietary fiber content and type of feed ingredients. Monogastric animals consume diets composed mostly of oilseed and cereal grains that contain high level of P present in the form of phytic acid or phytate. The P in this form is generally unavailable to poultry due to low phytase activity found in the digestive tract (Cromwell, 1992). Many studies showed that OA can increase phytate P utilisation by poultry (Boling-Frankenbach et al., 2001 and Brenes et al., 2003). Maximum activity of microbial phytasecould be reached at lower pH values, thus it could be achieved by adding OA in the diet. Benzoic acid supplementation increase the uptake of the Ca by 0.85 g per day, retention of P by 0.74 g day, retention of K by 0.77 g day and plasma levels of the P in growing pigs (Sauer et al., 2009).

Pirgozliev et al. (2008) reported that birds fed organic acid supplemented diets excreted less mucin (measured as sialic acid (SA)), an indicator of endogenous losses, than birds fed supplemented diets. Increased concentration of SA in digesta or excreta is often connected to gut health problems (Reutter et al., 1982), thus dietary organic acid supplementation improves the gut health of birds.

Bone ash is the direct indicator of mineral deposition and bone strength. Citric acid supplementation at the rate of 6% to the broiler diet resulted in an increased bone ash of up to 43% compared to the groups fed non-supplemented diets (Boling et al., 2000b). Shohl (1937) observed a 61% increase in femur ash when rats consumed Ca and P deficient diets supplemented with citric acid/sodium citrate. Perhaps citric acid, a strong chelator of Ca, removes Ca from or decreases Ca binding to the phytate molecule, thus making it less stable and more susceptible to endogenous phytase.

Effect of organic acids on performance and profitability of poultry

The effects of OA on performance are not consistent for the poultry. As stated before quoting Ricke (2003), the magnitude of the organic acid response varies due to several reasons. OA increase the average live weight, daily gain (BWG), daily feed consumption and improves the feed conversion ratio (FCR) (Al-Kassi and Mohssen, 2009). Fumaric acid significantly increases the BWG (Skinner et al., 1991) at the rate of 0.5% and 1.0% without affecting feed in take in broilers and layers. Likewise, Patten and Waldroup, (1988) recorded a higher BWG in broilers with no effect on feed utilization when fed fumaric acid supplemented diets. Adil et al. (2011) reported that dietary supplementation with the butyric acid, fumaric acid and lactic acid at the 2 and 3% level each; resulted in higher final live BWG, improved FCR in broilers. Vogt et al. (1982) studied malic, sorbic, and tartaric acids (0.5 to 2%) in broilers and reported increase in BWG, with optimal levels of 1.12 and 0.33% for sorbic and tartaric acids, respectively and improved FCR. Izat et al. (1990) reported that formic acid, calcium formate and buffered propionic acid did not affect the feed utilization. Panda et al. (2009) studied the effect of butyric acid supplementation in broiler ration at the dose level of 0.2, 0.4 and 0.6 percent and documented improved BWG, FCR and a decrease in the weight and percentage of abdominal fat. Butyric acid was as much effective as furazolidone. Similarly body weight and FCR significantly improved by using 2% lactic acid in broiler diet (Versteegh and Jongbloed, 1999). Buffered propionic acid significantly improved the dressing percentage in female broilers and reduced abdominal fat in males at 49 days of age (Izat et al., 1990). Likewise Patten and Waldroup, (1988) suggested an increase in broiler production profitability through increased BWG when dietary supplementation of OA was adopted.

Contrary to the above findings Brown and Southern (1985) found that chick performance is not affected by the supplementation of citric acid and ascorbic acid. Supplementation of propionic acid depresses the feed intake and growth performance but similar results are not reported by the use of lactic acid (Cave, 1984). Though lacking any suggested reason for these effects, Alcicek et al. (2004) reported that dietary supplementation of the organic acid does not affect the feed intake and FCR at 21 and 42 day of age in broilers. Citric acid addition in the broiler diets does not have any significant effect on egg production, egg mass, egg size, feed efficiency, specific gravity of egg and body weight of laying hens (Boling et al., 2000a).

Meat preservation

Consumer interests regarding natural and certified organic foods are increasing. These consumer preferences increased the demand for bio-preservation of the food. OA are one of the best food preservatives(Ewing, 2009). Contaminated poultry meat causes the food borne diseases in humans. More than 76 million citizens in USA became ill by ingesting food especially meat products contaminated with pathogenic bacteria (Mead et al., 1999) which resulted in 1600 deaths (Callaway et al., 2003). Short chain OA are commonly used food preservatives and there is an increasing trend of bio-preservation of food in European countries as these can be used safely without creating residual effects. Lactic or acetic acid reduced the potential of *Campylobacter* in carcass or meat (Cudjoe and Kapperud, 1991). Addition of formic and propionic acid in the broiler feed causes sub-lethal damage of *Salmonella* resulting in the incomplete colonization (Thompson and Hinton, 1997). Poultry meat is preserved in order to prevent contamination, as contaminated poultry meat cause many foodborne diseases in humans (caused by microorganisms such as *E. coli*, *Clostritdium perfringens*, *Clostridium botulinum*, *Campylobacter jejuni*etc.). Some fungi like *Aspergillusflavus* and *Aspergillus paraciticus* also produce different type of diseases by producing toxins (Prange et al., 2005). Out of these, *Salmonella* is a major foodborne pathogen associated with poultry meat because fecal material and dirt from feathers and the hide, as well as dirt of processing equipments can contaminate the carcasses during slaughtering and packaging operations. Due to high pH (5.5-6.5), water activity (0.98-0.99) and enriched nutrient profile, fresh poultry meat is highly perishable and provide favorable environment for growth of food contaminating microorganisms (Acuf, 2005). *Salmonella gallinarum* and *Salmonella enteritidis* are frequently found in poultry and poultry products but rarely cause illness in humans (Braden, 2006). *Salmonella typhimurium*is the most common serotype associated with laboratory confirmed illness cases (CDC, 2009). Therefore, in this scenario OA can be used as potential hygiene promoters, where they lower the pH and also act as a complexing agent for ions, thereby inhibiting microbial growth (Ewing, 2009).

Environmental and economic challenges of using organic acid in poultry

All in all the usage of OA on the basis of above mentioned properties not only makes them a good choice for poultry production but also ensures a lower biological, environmental and economic overhead compared with other available supplements. For example enhanced nutrient digestibility will have nutrient sparing effect which along with better production performance will also lower the losses, therefore reducing the risk of environmental pollutionfrom animal production (Lückstädt and Mellor, 2011). This is particularly true for a reduction in nitrogen and mineral related environmental issues from poultry facilities (Dibner and Buttin, 2002; Riemensperger, 2012). Therefore their usage in poultry production is economically justifiable.

Possible adverse effects of using organic acid

However, there were few concern raised by the scientists regarding the adverse effects of OA supplementation on organoleptic properties (the appearance and texture) of poultry meat (Dickens and Whittemore, 1994 and Dickens et al., 1994). There is also an environmental concern for the disposal of waste water from poultry units using OA supplementation along with a fear of the emergence of acid-resistant pathogens (Fabrizio et al., 2002). Gabert and Sauer (1995) noted a reduction in ileal digestibility of both CP and amino acid when diet was supplemented with fumaric acid in growing pigs.

CONCLUSION

OA inhibit the growth of pathogenic bacteria, especially zoonotic bacteria, e.g. *Campylobacter*, *E. coli* and *Salmonella*, in the feed and gastrointestinal tract of poultry which is of great importance with respect to poultry health. They also cause reduction in the microbial load on poultry meat products. OA improve the mucosa growth, villus height and width, crypt depth and decrease the intestinal pH. They also boost the immune system and the digestibility of protein, carbohydrate and minerals, thus enhancing the growth performance of poultry. Therefore, OA can be meritoriously used as a replacer of the antibiotic growth promoters in poultry.

Competing Interests

The authors declare that they have no competing interests.

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