Journal of Applied and Natural Science 9 (4): 2152 - 2157 (2017)

JANS

Advances in role of organic acids in poultry nutrition: A review

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Received: May 8, 2016; Revised received: July 4, 2017; Accepted: October 3, 2017

Abstract: Anti microbial drug resistance concerns scientists all around the world epically one used as livestock feed additives. Feed grade antibiotics are given in non therapeutic doses which lead to survival of pathogenic microbes which in turn develop drug resistance, thus necessitating researchers to search for alternative ways to feed grade antibiotics besides doing least compromise on growth parameters. Organic acids are used in poultry to lower the pH of intestinal tract which favours good microbes which in turn suppress pathogenic microbes thus evicting the use of antibiotics. They are used in poultry diets and drinking water to elicit a positive growth response, improving nutrient digestibility, performance and immunity in poultry. Literature shows that organic acids have more or less pronounced antimicrobial activity, depending on both the concentration of the acid and the bacterial species that is exposed to the acid. The variability in response of organic acids and its possible mechanisms are discussed. Scope of this paper is to provide a view of the use of organic acids in the prevention of enteric disease in poultry, the effect on the gastrointestinal tract (GIT), immunity and performance of broiler or laying hens. In the current review beneficial aspects of organic acids along with different dose combinations are discussed to promote its optimum utilization in poultry nutrition and production.

Keywords: Broiler, Growth, Hen, Organic acids, Performance

INTRODUCTION

In commercial poultry industry it is said that profit comes for happy gut, meaning healthy intestinal villus lead to better absorption of nutrients. Even if quality feed is given but the intestinal villus are damaged due to toxins from pathogenic microbes, the required low feed conversion ratio (FCR) cannot be achieved which is a must for profitability. Antibiotic feed additives have used to stabilize intestinal microbes, gut thinning due to less cell proliferation which increases nutrient absorption. They have long been supplemented to poultry feed to stabilize the intestinal microbial flora, improve the general performances and prevent intestinal pathology (Khan *et al.,* 2016). European Commission (EC) has however phased out and banned the marketing and use of antibiotics as growth promoters in feed (Luckstadt, 2014). To overcome the limitations of low performance due to removal of antibiotics from feed scientists are compelled to find alternative solutions like organic acids, prebiotics, probiotics, herbs and enzymes in poultry production (Bagal *et al.,* 2016). Organic acids are used in commercial feeds for antimicrobial activity and feed preservation (Wang *et al.,* 2009). There are two types of dietary acids for poultry which are classified as inorganic and organic acids. However, organic acids have been more often used for poultry diets. Organic acids are defined as carboxylic acids including fatty acids having a chemical structure of R-COOH.. In organic acids only short chain fatty acids such as formic (C1), acetic (C2), propionic (C3), and butyric acid (C4), and other carboxylic acids such as lactic, malic, tartaric, fumaric, and citric acid have been most commonly used in the poultry industry because their physiochemical properties (Dibner and Buttin, 2005). With dietary acidification the count of good bugs (lactobacilli, bifidobacter) increases and reduction in bad bugs (E. Coli) which competes with host for available nutrients including reduction in toxins (Partanen and Mroz, 1999). The growth inhibition of potential pathogenic bacteria and zoonotic bacteria like *E. coli* and *Salmonella spp.*, in the feed and in the gastrointestinal tract lead to better growth performance of animals. In poultry production, organic acids have been either added to drinking water to keep the watering system free from microorganisms or used to minimize the effect of feed borne microbes like *Salmonella spp.* (Broek *et al.,* 2003). Organic acids increase gastric proteolysis, amino acid digestibility and form complexes with Ca, P, Mg, Zn etc resulting in an improved mineral digestibility (Li *et al.,* 1998; Giesting and Easter, 1985). The present study will be highly useful for researchers, scientists, veterinary professionals, poultry and pharmaceutical industry to enrich their knowledge in promoting organic acid usage in poultry industry helping to draw a line for anti-

ISSN : 0974-9411 (Print), 2231-5209 (Online)

biotics as feed additive.

Antimicrobial activity of organic acids: As pathogenic microbes or bacteria multiply in GIT tract they damage the villus and also make the intestinal membrane thick due to cell proliferation which makes the penetration of nutrients difficult resulting is reduced growth performance. Organic acids penetrate the cell wall of these pathogenic microbes which disrupts the normal cell functioning causing death of microbe. The proposed sequential bactericidal mechanism can be described in several steps (Mani Lopez *et al.,* 2012). The protonated form of organic acids penetrates across bacterial cell wall which then dissociates into its conjugated base form with reduction in cellular pH. Low pH creates a stressful environment which leads to cellular dysfunction and reduced bacterial multiplication. Broiler chickens fed diets containing organic acid blends have less pathogenic bacterial loads such as coliforms and Clostridia while on the contrary they have higher beneficial bacteria such as Lactobacilli in the ileum compared with those fed diets containing antibiotic growth promoters (Khan 2016).

Organic acids due to their property of lowering the pH of the gastrointestinal tract may also prevent bacterial transfer from the diet or environment (Kil et al., 2011). Various studies regarding the effects of dietary organic acids on microbial populations in the GIT have reported significant effect of supplementation of organic acids which is summed up in table 1.

However, the average reductions in the numbers of coliform bacteria or E. coli count were greater than those of lactic acid-producing bacteria or Lactobacilli counts in the ileum or the cecum. The reason for higher Lactobacilli count may be due to less susceptibility to pH changes while coliforms are more sensitive to pH reductions than Lactobacilli in the GIT (Kim *et al.,* 2009). Thus early development of acidic pH will be very helpful to set lactobacilli in the GIT thus helping to give a good early start in chicks which is very vital and essential in commercial poultry industry.

Effect of organic acid on gastrointestinal tract (GIT): In poultry industry it is a well established fact

Table 1. Effect of organic acids on gastrointestinal microbial population in broilers chickens.

Organic acid	Inclusion g/kg	Changes in microbial count, $\log_{10}$ CFU				References
		Ileum		Cecum		
		LAC	COLI	LAC	COLI	
Citric acid	30	-	-	-0.2	-0.2	Biggs and Parson, 2008
Citric acid	30	0.2	-0.5*	-	-	Aydin *et al.,* 2010
Fumaric acid	5	0.2	-1.7	-0.4	-0.5	Pirgozliev *et al.,* 2008
	10	-0.2	-1.1	-0.3	-1.4	
	15	-0.8	-0.6	-0.5	-0.6	
Sorbic acid	5	-0.6	0.2	-0.5	-0.6	Pirgozliev *et al.,* 2008
	10	-1.2	-1.1	-0.4	-1.8	
	15	-0.7	-1.2	-0.8	-1.6	
Blend	3	-	-	-0.1	-0.2*	Kim *et al.,* 2009
	5	-	-	-0.1	-0.1*	
Mean		-0.44	-0.86	-0.37	-0.82	
SE*		0.20	0.23	0.07*	0.22	

An astric mark (*) represents significant difference ($p<0.05$), LAC- lactobacillus, COLI- total coliform bacteria, Blend- lactic acid (40%) + Fumaric acid (20%) + citric acid (30%) + formic acid (10%)

Table 2. Effect of dietary organic acids on dry matter (DM) and protein retention in broiler chickens.

Organic acid	Inclusion, g/kg	Changes in retention %		Reference
		DM	Protein	
Citric acid	15	-0.3	-1.4	Ao *et al.,* 2009
	20	1.3	2.1	
Citric acid	20	0.9	-0.1	Esmaeilipour *et al.,* 2011
	40	4.4	2.9	
Citric acid	25	7.2	27.9	Nezhad *et al.,* 2011
	50	-2.2	8.1	
Formic acid	5	1.4	-1.6	Hernandez *et al.,* 2006
	10	-1.4	-1.7	
Formic acid	2	0.2	1.6	Panda *et al.,* 2009[b]
	4	-0.7	1.3	
	6	-1.7	5.9	
	8	-0.2	5.7	
	10	0.0	5.7	
Formic acid	5	2.7	2.2	Pirgozliev *et al.,* 2008
	10	6.4	5.5	
	15	0.8	-1.5	

Table 3. Overall effect of dietary organic acids on the growth performance of broilers of chicken, a survey of 31 publications by Kim *et al.,* 2015.

Organic acid	No. Exp	Inclusion g/kg	BWG% change		Feed intake		Gain: feed, %change	
			Mean	+/-	Mean	+/-	Mean	+/-
Citric acid	8	5-50	4.7	8/6	-1.3	6/7	6	11/3
Fumaric acid	3	1.2-4.5	1.3	5/1	1.9	4/1	0.2	5/5
Formic acid	5	1-10	2.8	5/2	0.4	1/3	5.3	11/0
Formic acid salt	2	3-25	2.6	1/10	-0.5	0/1	-11.5	¼
Butyric acid	5	1-25	1.9	0/1	-0.5	4/6	2.5	9/1
Propionic acid	1	2	11.2	2/10	5.1	1/0	6.1	1/0
Propionate salt	1	3	0.5	1/1	-6	0/1	6.5	1/0
Blend	6	1-6	0.3	0/1	-1.7	3/3	3.2	5/2

that key to farm success goes through gastrointestinal tract of poultry. Without a healthy gut it is not possible to achieve target growth rates and feed efficiency. Many researchers have documented positive effects of organic acid supplementation in terms of the villus height, width and area of small intestine. Several trials in broilers have concluded that diets containing organic acids have significantly increased the villus height and area in duodenum, jejunum and ileum of chicks (Rodríguez Lecompte *et al.,* 2012). Pelicano *et al.* (2005) reported higher villus height in the ileum with the diet based on organic acid salts compared with diet fed without mannan oligosaccharide (MOS) plus organic acids. Frankel *et al.* (1994) demonstrated that butyric acid supplementation had increased the villus height, crypt depth and surface area in the colon and jejunum of rats. Several other reports indicate that broilers fed diets containing formic acid had the longest villi (1273 μm) compared with control i.e 1088 μm. While as Garcia *et al.,* 2007 reported that crypts of jejunum were deeper in birds fed the organic acids than birds fed the antibiotic diets (266 vs. 186 μm) in the same experiment. (Further it was concluded that formic acid supplementation increased both the villus height and crypt depth. Short-chain fatty acids (SCFA) have been demonstrated to stimulate the proliferation of normal crypt cells, enhancing healthy tissue turnover and maintenance

Leeson *et al.* (2005) and Panda *et al.* (2009) reported that butyrate, irrespective of concentrations (0.2%, 0.4% or 0.6%) in the broiler's diet had improved the villus length and crypt depth in the duodenum. Thus, butyrate supplementation could be highly helpful to young birds for intestinal development. Adil *et al.,* 2010 in another study concluded that the highest duodenal, jejuna and ileal villus heights were recorded in the birds fed diets supplemented with 3% butyric acid, 3% fumaric acid and 2% fumaric acid, respectively. The increase of villus height of different segments of the small intestine may be attributed to the role of the intestinal epithelium as a natural barrier against pathogenic bacteria and toxic substances that are present in the intestinal lumen. These pathogen substances which cause disturbances in the normal micro-flora or in the intestinal epithelium may alter the permeability of this natural barrier, thus facilitating the invasion of pathogens resulting in modification of the metabolism i.e. ability to digest and absorb nutrients which leads to chronic inflammatory processes in intestinal mucosa (Khan, 2013). Thus consequently, there is decrease in the villus height, increase in the cell turnover and decrease in the digestive and absorptive capacities

Teirlynck *et al.* (2009) reported that the thickening of mucous layer on the intestinal mucosa contributes to the reduced digestive efficiency and nutrient absorption. So organic acid salts reduced the growth of many pathogenic intestinal bacteria. Consequently, organic salts reduced intestinal colonization and infectious process, thereby, decreased inflammatory process at the intestinal mucosa, this improved villus height and function of secretion, digestion and absorption of nutrients (Pelicano *et al.,* 2005; Iji and Tivey, 1998).

Effect of organic acid on nutrient digestibility: To achieve more returns in terms of lower feed conversion ratios one of the most logical approach seems to increase the nutrient digestibility. However organic acids which are normally used as an acidifier in poultry feeds are emerging as an attractive options for improving nutrient digestibility. The key of interest in organic acids lies in the fact that there is no residue in meat or environment besides not leading to any microbial resistance like in case of antibiotics. In a study by Ao *et al.,* 2009 concluded that 2% citric acid in the broiler diet increased the retention of DM, CP and neutral detergent fibre. Similarly, Ghazala *et al.* (2011) reported that dietary 0.5% of either fumaric or formic acid and 0.75% of acetic or 2% citric acid improved crude protein (CP), ether extract (EE), crude fibre (CF) and nitrogen-free extract (NFE) of broiler diets. Moreover, Hernandez *et al.* (2006) and Garcia *et al.* (2007) reported that supplementation of formic acid (0.5%) in broiler finisher diet improved apparent ileal digestibility (AID) of dry matter (DM) (67.8%) and CP (72.5%) as compared with control (56.4% DM and 60.7% CP). According to Jongbloed *et al.* (2000) reduced pH in the upper part of the GIT may increase nutrient digestibility in diets. Due to reduced pH in the stomach, pepsinogen and other zymogens get activated by adjusting gastric acidity closer to that required for optimal activity resulting in increased enzyme activity, improved digestion of proteins and possibly other nutrients as well. More over, in a study by Mayer, 1994 acidic digesta may decrease gastric emptying providing more time for nutrient digestion in the GIT. Several researchers have demonstrated that dietary supplementation of organic acids has improved the retention of protein and other nutrients. Further, data analyzed from six different experiments (Table 2) indicated that broiler chickens fed diets containing various inclusion levels of dietary organic acids generally had greater retention of dry matter (DM) and protein than those fed control diets.

There was average improvement in DM retention and protein content to be 1.0% and 1.7% respectively . Expirements for ileal digestibility and true ileal digestibility of amino acids need to be conducted to further establish the effect of dietary organic acids.

Effect of organic acid on broiler performance: Lower feed conversion ratio (FCR) and higher levels of production are the need of the modern broiler industry which to a certain extent could be achieved by the use of specific feed additives. In vast options of feed additives organic acids have emerged as to have growth promoting properties and can be used as alternatives to antibiotics (Fascina *et al.,* 2012). The pig industry has received much more attention as compared to poultry which might be due to inconsistent reported effects. Dietary supplementation of organic acids increased the body weight and feed conversion ratio (FCR) in broiler chicken. According to Brzoska *et al.* (2013) organic acid (0.3–0.9%) have a growth enhancing and mortality-reducing effect in broiler chickens, with no significant influence on carcass yield. Panda *et al.* (2009) found 0.4% butyrate in the broiler diet was similar to antibiotics in maintaining body weight gain with no added advantage was seen by enhancing the concentration of butyrate from 0.4% to 0.6% in the diet. However there are reports by Leeson *et al.* (2005) and Antongiovanni *et al.* (2007) suggesting a lower level (0.2%) of butyrate to maintain the performance of broiler chickens.

Fascina *et al.* (2012) reported that the use of an organic acids mixture in broiler diets improved its performance and better carcass characteristics. Hashemi *et al.* (2014) added an acidifier mixture (formic, phosphoric, lactic, tartaric, citric and malic acids) in the broiler diet at the rate of 0.15% and reported increased body weight gain in organic acid supplemented group. Such a positive impact of dietary acidifiers on growth performance might be due to a reduction of pH values in the feed and digestive tract, killing the pathogenic organisms which are sensitive to low pH or selectively increasing the acid loving lactobacillus and a direct antimicrobial effect (Ghazala *et al.,* 2011).

A survey was conducted by Kim *et al.* (2015) of 31 recent publications and compared the effects of diets on body weight gain, feed intake, and feed efficiency (gain to feed ratio) with those of control diets (Table 3).

Effect of organic acids on immunity: In commercial poultry it is a set belief that prevention is better than cure as treating of large flocks of broiler birds is nether practically possible nor commercially feasible. Thus strong managemental practices and prevention of diseases is the key to profit. Keeping this in mind one of the most logical approach seems to enhance the natural immunity or disease fighting capacity of poultry. Several studies on organic acids have demonstrated stimulatory effect on natural immunity in poultry. Lohakare *et al.* (2005) in his study measured titers of infectious bursal disease (IBD) postvaccination showed significantly higher IBD titres in Vitamin C (0.2%) supplemental group. The possibility of this increased titer in Vitamin C group might be due to speeding up of differentiation of lymphoid organs by increasing the activity of the hexose monophosphate pathway thus increasing the circulating antibody. There was significant increase in CD4 and TCR-II cells in the 0.1% Vitamin C group as compared with control and these cells participate in the immune response to the exogenous antigen, stimulating the synthesis of Interleukin-2, which activates CD8, natural killer (NK) cells and B cells. In a study by Ghazala *et al.* (2011) birds fed an organic acid supplemented diet had heavier immune organs (bursa of Fabricius and the thymus) and higher level of globulin in their serum as well. Houshmand *et al.* (2012) found that dietary addition of organic acids resulted in significant increases in antibody titres against Newcastle disease in broilers.

Factors affecting inconsistent results: The responses of broiler chickens to dietary organic acids have shown considerable inconsistency. There are reports from a positive effect on performance to total negative effect on performance, whereas other studies were unable to find beneficial effects on growth performance. Results with supplementation with organic acids are also variable among the previous experiments using different inclusion levels and sources of organic acids and several possible factors responsible for these variations can be identified which will be discussed below.

Currently there is a huge variety of ingredients and by products used in poultry industry to reduce the cost and increase performance. This variation in dietary ingredients and their chemical properties such as buffering capacity could be one of the main factors for variation in response of organic acids (Partanen, 2001). While as the source and amount of dietary protein and minerals also affect the buffering capacity of diets, which influence the degree of acidification that develops with the inclusion of organic acids (Mroz *et al.,* 2005). Microbial load in the environment can be another possible factor causing variation in results. Dietary organic acids may affect the microbial population in the GIT and its antimicrobial effects would be more pronounced when birds are exposed to less sanitary conditions (Kil *et al.,* 2011). Thus differences in sanitary conditions among experiments may be other possible reason for the inconsistent results.

Conclusion

The results from the literature show that organic acid supplementation, irrespective of type and level of acid used, had a beneficial effect on the performance of broiler chicken. The beneficial effects can be summed up as significantly increased the villus width, height and area of the duodenum, jejunum and ileum of broilers thus boosting the performance of broilers. Organic acids also improved nutrient digestibility by reducing microbial competition with the host for nutrients and endogenous nitrogen losses. They lower the incidence of subclinical infections by secretion of immune mediators, reducing production of ammonia and other growth-depressing microbial metabolites. They have proved to be a promising alternative to growth promoting antibiotics as their supplementation does not lead to antibiotic resistance besides protecting environment as well by less fecal nitrogen losses.

REFERENCES

Antongiovanni, M., Buccioni, A., Petacchi, F., Leeson, S., Minieri, S., Martini, A. and Cecchi, R. (2007). Butyric acid glycerides in the diet of broiler chickens: effects on gut histology and carcass composition. *Ital J Animal Sci*., 6:19–25

Ao, T., Cantor, A.H., Pescatore, A.J., Ford, M.J., Pierce, J.L. and Dawson, K.A. (2009). Effect of enzyme supplementation and acidification of diets on nutrient digestibility and growth performance of broiler chicks. *Poultry Sci.,* 88:111–117

Adil. R, Imtiyaz, Q.M and Khan, T.M. (2010). Effect of feeding organic acids on intestinal health of broilers. *Poultry Sci.,* 31:54-58

Aydin, A., Pekel, A.Y., Issa, G., Demirel, G. and Patterson, P.H. (2010). Effects of dietary copper, citric acid, and microbial phytase on digesta pH and ileal and carcass microbiota of broiler chickens fed a low available phosphorus diet. *J Appl Poultry Res.,* 19:422-431

Bagal, V.L., Khatta, V.K., Tewatial, B.S., Sangwan, S.K. and Raut, S.S. (2016). Relative efficacy of organic acids and antibiotics as growth promoters in broiler chicken. *Veterinary World, 9*: 377-382

Biggs, P. and Parsons, C.M. (2008). The effects of several organic acids on growth performance, nutrient digestibilities, and cecal microbial populations in young chicks. *Poult Sci*., (12): 2581-2589

Broek, G. V. D., Bergh, M. V. D., Ebbinge, B., Selko, B. V. and Tilburg. (2003). Clean drinking water during production by use of organic acids. *World Poultry,* 19:34-37

Brzoska, F., Sliwinski, B. and Michalik-Rutkowska, O. (2013). Effect of dietary acidifier on growth, mortality, post-slaughter parameters and meat composition of broiler chickens. *Ann Animal Sci.,* 13:85–96

Dibner, J.J. and Richards, J.D. (2005). Antibiotic growth promoters in agriculture: history and mode of action. *Poultry Sci.*, 84:634–643

Esmaeilipour, O., Shivazad, M., Moravej, H., Aminzadeh, S., Rezaian, M. and van Krimpen, M.M. (2011). Effects of xylanase and citric acid on the performance, nutrient retention, and characteristics of gastrointestinal tract of broilers fed low-phosphorus wheat-based diets. *Poult Sci.,* 90:1975-1982

Fascina, V.B., Sartori, J.R., Gonzales, E., Barros De Carvalho, F., Pereira De Souza, I.M.G., Polycarpo, G.V., Stradiotti, A.C. and Pelícia, V.C. (2012). Phytogenic additives and organic acids in broiler chicken diets. *Revista Brasileira de Zootecnia,* 41:2189–2197

Frankel, W.L., Zhang, W., Singh, A., Klurfeld, D.M., Don, S., Sakata, T. and Rombeau, J.L. (1994). Mediation of the trophic effects of short chain fatty acids on the rat jejunum and colon. *Gastroenterology.* 106:385–390

Garcia, V., Catala-Gregori, P., HernáNdez, F., Megias, M.D. and Madrid, J. (2007). Effect of formic acid and plant extracts on growth, nutrient digestibility, intestine mucosa morphology, and meat yield of broilers. *J Appl Poultry Res.,* 16:555–562

Ghazala, A.A., Atta, A.M., Elkloub, K., Mustafa, M.E.L. and Shata, R.F.H. (2011). Effect of dietary supplementation of organic acids on performance, nutrients digestibility and health of broiler chicks. *Int J Poultry Sci.,* 10 (3):176–184

Giesting, D.W. and Easter, R.A. (1985). Response of starter pigs to supplementation of cornsoybean meal diets with organic acids. *J. Anim. Sci.,* 60:1288-1294

Hashemi, S.R., Zulkifli, I., Davoodi, H., Bejo, M.H. and Loh, T.C. (2014). Intestinal histomorphology changes and serum biochemistry responses of broiler chickens fed herbal plant (Euphorbiahirta) and mix of acidifier. *Iran J Appl Animal Sci.*, 4:95–103

Hernandez, F., García, V., Madrid, J., Orengo, J., Catalá, P. and Megías, M.D. (2006).Effect of formic acid on performance, digestibility, intestinal histomorphology, and plasma metabolite levels of broiler chickens. *Br Poult Sci.,* 47:50-56

Houshmand, M., Azhar, K., Zulkifli, I., Bejo, M.H. and Kamyab, A. (2012). Effects of nonantibiotic feed additives on performance, immunity and intestinal morphology of broilers fed different levels of protein. *South Afr J Animal Sci.,*42:22–32

Iji, P.A. and Tivey, D.R. (1998). Natural and synthetic oligosaccharide in broiler chicken diet. *World's Poultry Sci J.,* 54:129–143

Jongbloed, A.W., Mroz, Z., Van der Weij-Jongbloed, R. and Kemme, P.A. (2000). The effects of microbial phytase, organic acids and their interaction in diets for growing pigs. *Livest Prod Sci.,* 67:113-122

Khan, S.H. and Iqbal, J. (2016). Recent advances in the role of organic acids in poultry nutrition. *Journal of applied animal research.* 44: (1)359–369

Khan, S.H. (2013). Probiotic microorganisms-identification, metabolic and physiological impact on poultry. *World's Poultry Sci J.,* 69:601–612

Kim, J.W., Kim, J.H and Kil, D.Y. (2015). Dietary organic acids for broiler chickens: a review. *Colombian journal of animal science and veterinary medicine,* 28:(2)10-18

Kim, D.W., Kim, J.H., Kim, S.K., Kang, G.H., Kang, H.K., Lee, S.J. and Kim, S.H. (2009). A study on the efficacy of dietary supplementation of organic acid mixture in broiler chicks. *Kor J Anim Sci Technol.,* 51: 207-216

Kil, D.Y., Kwon, W.B. and Kim, B.G. (2011). Dietary acidifiers in weanling pig diets: a review. *Rev Colomb Cienc Pecu*., 24:231-247

Luckstadt, C. (2014). Effects of dietary potassium diformate on growth and gastrointestinal health in weaned piglets in Vietnam. *Conference on International Research on Food Security, Natural Resource Management and Rural Development organized by the Czech University of Life Sciences Prague,* 17–19

Leeson, S., Namkung, H., Antongiovanni, M. and Lee, E.H. (2005). Effect of butyric acid on the performance and carcass yield of broiler chickens. *Poult Sci.,* 84:1418-1422

Lohakare, J.D., Ryu, M.H., Hahn, T.W., Lee, J.K. and Chae, B.J. (2005). Effects of supplemental ascorbic acid on the performance and immunity of commercial broilers. *J Appl Poultry Res.,* 14:10–19

Li, D. F.,. Che, X.R .,. Wang, Y. Q., Hong, C. and Thacker, P.A. (1998). The effect of microbial phytase, vitamin D3, and citric acid on growth performance and phosphorus, nitrogen, and calcium digestibility in growing swine. *Anim. Feed Sci. Tech.*, 73:173-186

ManiLopez, E., García, H.S. and López-Malo, A. (2012). Organic acids as antimicrobials to control *Salmonella* in meat and poultry products. *Food Res Int*., 45:713-721

Mroz, Z. (2005). Organic acids as potential alternatives to antibiotic growth promoters for pigs. *Adv Pork Prod.,* 16:169-182

Mayer, E.A. (1994). The physiology of gastric storage and emptying. In: physiology of the gastrointestinal Tract. *3rd ed. New York: Lippincott Raven Press,.* p.929-76

Nezhad, Y.E., Gale-Kandi, J.G., Farahvash, T. and Yeganeh, A.R. (2011). Effect of combination of citric acid and microbial phytase on digestibility of calcium, phosphorous and mineralization parameters of tibia bone in broilers. *Afr J Biotechnol*., 10:15089-15093

Pirgozliev. V., Murphy, T.C., Owens, B., George, J. and McCann, M.E.E. (2008). Fumaric and sorbic acid as additives in broiler feed. *Res Vet Sci*., 84:387-394

Pelicano, E.R.L., Souza, P.A., Souza, H.B.A., Figueiredo, D.F., Boiago, M.M., Carvalho, S.R. and Bordon, V.F. (2005). Intestinal mucosa development in broiler chicken fed natural growth promoters. *Braz J Poultry Sci.,* 7:221–229

Panda, A.K., Rao, S.V.R., Raju, M.V.L.N., Sunder, G.S. (2009). Effect of butyric acid on performance, gastrointestinal tract health and carcass characteristics in broiler chickens. *Asian-Australas J Anim Sci*., 22:1026-1031

[b]Panda, A.K., Raju, M.V.L.N., Rama Rao, S.V., Shyam Sunder, G. and Reddy, M.R. (2009). Effect of graded levels of formic acid on gut microflora count, serum biochemical parameters, performance, and carcass yield of broiler chickens. *Indian J Anim Sci.,* 79:1165-1168

Partanen, K. (2001). Organic acids-their efficacy and modes of action in pigs. In: Piva K.E, Knudsen B, Lindberg J.E, editors. Gut environment of pigs. Nottingham U.K: *Nottingham University Press*.p.201-17

Rodríguez -Lecompte, J.C., Yitbarek, A., Brady, J., Sharif, S., Cavanagh, M.D., Crow, G., Guenter, W., House, J.D. and Camelo-Jaimes, G. (2012). The effect of microbial-nutrient interaction on the immune system of young chicks after early probiotic and organic acid administration. *J Animal Sci*., 90:2246–2254

Teirlynck, E., Bjerrum, L., Eeckhaut, V., Huygebaert, G., Pasmans, F., Haesebrouck, F., Dewulf, J., Ducatelle, R. and Van Immerseel, F. (2009). The cereal type in feed influences gut wall morphology and intestinal immune cell infiltration in broiler chickens. *Br J Nutr.,* 102:1453 –1461

Wang, J.P., Yoo, J.S., Lee, J.H., Zhou, T.X., Jang, H.D., Kim, H.J. and Kim, I.H. (2009). Effects of phenyllactic acid on production performance, egg quality parameters, and blood characteristics in laying hens. *J Appl Poultry Res.,* 18:203–209