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The Role of Acidifers in Poultry Nutrition

Antibiotic growth promoters (AGP) are being used for the past five decades to improve the performance of poultry. Sub-therapeutic levels of antibiotics in poultry feed have increased feed efficiency and growth. They do not improve performance in germ free animals, indicating their action on microflora. A summary of the physiological, nutritional and metabolic effects of growth promoting antibiotics is shown in Table1.

Role of GIT Microflora

The gastrointestinal microflora of chicken plays a significant role in nutrition and growth. The competition offered by gut microflora for nutrients in poultry is often managed by in part through the use of low levels of antibiotics. This option is rapidly disappearing. As a result, there is a need to understand the role played by microflora in order to manage its effect on nutrition, growth, health and disease by suitable replacements for antibiotics.[2]

In chicken, the gut microflora plays a minor role in digestion of feed ingredients. However, the microbes play an important role in absorption of nutrients.

Factors affecting intestinal micro-environment

1. Substrate availability
2. pH
3. Redox potential
4. Toxins
5. Antibodies
6. Other bacteria

GIT microbes can be beneficial or harmful. The beneficial bacteria can inhibit the growth of pathogenic bacteria and prevent some specific intestinal diseases such as *Clostridium perfringens, E. coli, Salmonella sps etc.*

Any disruption in this balance may cause the proliferation of pathogenic or performance hindering microflora. The different microflora in the GIT of chicken is given in Figure 1.

The multiplication of harmful bacteria may start from the crop itself. Food stays in the crop for a longer time and the presence of moisture, temperature and time to multiply (depends on food retention time in crop), favors the multiplication of microflora. If acid-producing microbes reduce pH, multiplication of harmful bacteria is reduced.

Need for Alternatives to AGP?[3]

Antibiotic growth promoters have undoubtedly improved animal performance and health status. It is apparent that antibiotics function by modifying the intestinal microflora. The microbes can develop resistance to these antibiotics and when transferred to human beings, may pose a problem because of the resistance to these antibiotics. This has attracted global attention.

Many antibiotics in livestock and poultry production as growth promoters are banned in several countries and by 2005 all antibiotics may be banned. This ban on animal feed antibiotics throws spotlight on alternatives to antibiotics. There is also a demand for alternatives to antibiotics in an increasingly health conscious market.

The use of some feed additives reviewed (Table 2).

Table 1: Effects of growth-promoting antibiotics [1]

Physiological	Nutritional	Metabolic	Others
Increase	**Increase**	**Increase**	**Increase**
Nutrient absorption	Energy retention	Liver protein synthesis	Immunity
Feed intake	Nitrogen retention	Gut alkaline phosphatase	
	Nutrients retention		
	Plasma nutrients		
Decrease	**Decrease**	**Decrease**	**Decrease**
Feed transit time	Gut energy loss	Ammonia production	Secondary diseases
Gut wall diameter	Vitamin synthesis	Toxic amine production	by E. coli,
Gut wall length		Aromatic phenols	Cl. perfringes
Gut wall weight		Bile degradation products	
Fecal moisture		Fatty acid oxidation	
Mucosal cell turnover		Fecal fat excretion	
		Gut microbial urease	

What are Feed Acidifiers?

Feed Acidifiers are acids included in feeds in order to lower the pH of the feed, gut, and microbial cytoplasm thereby inhibiting the growth of pathogenic intestinal microflora. This inhibition reduces the microflora competing for the host nutrients and results in better growth and performance of the chicken. They also act as mold inhibitors. They are added upto 0.25% of the diet.

Most acids are efficacious and their effect remains as long as the acid is not volatilized.

Organic acids have been used extensively for more than 25 years in swine production and more recently in poultry.

The antimicrobial effect of organic acid ions in controlling bacterial populations in the upper intestinal tract leads to beneficial effects. Inorganic acids such as HCl and H_3PO_4 though pH reducing are ineffective.

Chemistry of Organic Acids[2]

Organic acids are organic carboxylic acids, including fatty acids and amino acids, of the general structure R-COOH. The short chain acids (C1-C7) are associated with antimicrobial activity. They are either

▪ Simple monocarboxylic acids such as formic, acetic, propionic and butyric acids or

▪ Carboxylic acids with hydroxyl group such as lactic, malic, tartaric and citric acids or

▪ Short chain carboxylic acids containing double bonds like fumaric and sorbic acids.

Organic acids are weak acids and are only partly dissociated. Most organic acids with antimicrobial activity have a pKa-the pH at which the acid is half dissociated-between 3 and 5.

Functionalities of Organic Acids

1. To help maintain an optimum pH in the stomach, allowing correct activation and function of proteolytic enzymes.
2. Total protein digestion in the stomach
3. To stimulate feed consumption.
4. To inhibit the growth of pathogenic bacteria.
5. Improves protein and energy digestibilities by reducing microbial competition with host nutrients and endogenous nitrogen losses.
6. Lowers the incidence of sub clinical infections and secretions of immune mediators.
7. Reduces the production of ammonia and other growth depressing microbial metabolites.
8. Increased pancreatic secretion and trophic effects on gastrointestinal mucosa.

Factors Influencing the Efficacy

- pKa-value
- Chemical form (acid, salt, coated or not),
- Molecular weight
- MIC-value of the acid
- Kind of micro-organism
- Animal species,
- Site and location in the GIT
- Buffering capacity of the feed

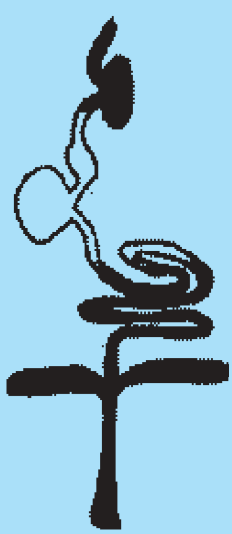
Mode of Action[7]

The antibacterial action of organic acids depends on whether the bacteria are pH sensitive or not. Only Certain types of bacteria are sensitive to pH (ex.: *E. coli, Salmonella* sp., *L. monocytogenes, C. perfringens*) while other types of bacteria are not sensitive (*Bifidobacterium sps., Lactobacillus sps*).

A. For pH sensitive bacteria:

The mode of action in pH sensitive

Figure 1: pH, resident time of feed and microbial population in gastrointestinal tract of chicken

Microflora 3 weeks	Parts	Gastro-intestinaltract	pH	Resident time Minutes	Microflora Adult
Streptococci[1] Coliform[1] Lactobacilli[1]	Crop		4.5 - 5.3	45	Streptococci[2] Coliform[3] Lactobacilli[3]
Streptococci[1] Coliform[1] Lactobacilli[1]	Proventriculus Gizzard		2.0 – 4.5	70	Streptococci[2] Coliform[3] Lactobacilli[3]
Streptococci[1] Coliform[1] Lactobacilli[1]	Ileum		5.6 – 7.9	160 - 200	Streptococci[1] Coliform[1] Lactobacilli[1]
Streptococci[1] Coliform[1] Lactobacilli[3]	Caeca		5.8 – 6.8	120	Bacteroidesi[1] Bifidobacteria[1] Peptostreptococci[1] Clostridia[1] Propionic bacteria[1] Eubacteria[1]
Streptococci[1] Coliform[1] Lactobacilli[3]	Colon Rectum		6.3 – 7.7	30-50	Mixture: Ileal and caecal bacteria[3]

[1] Dominant; [2]Predominant; [3]Significant: See Huyghebaert,

Table 2: Function of Feed Additives

Additives	Function
Organic acids	Exert antimicrobial action through pH depression
Enzymes	Improves ileal digestibility thereby indirectly overloading the microflora
Probiotics	Improves health and growth by altering intestinal microbial balance
Prebiotics	Selectively stimulate the growth or metabolic activity of a limited number of intestinal microflora.
Herbs and etheric oils	Antimicrobial agents by stimulating the endogenous digestive enzymes
Immunostimulants	Improving the immune system of the bird and enhance the resistance to disease

bacteria is shown in Figure 3. Organic acids in undissociated (non-ionized, more lipophilic) state penetrate the semipermeable membrane of bacteria cell wall and enter cytoplasm.

At the internal pH of bacteria (~7.0), the undissociated organic acids dissociate, releasing H+ and anions (A-). The internal pH of bacteria decreases. The pH sensitive bacteria are unable to tolerate a large spread between the internal and the external pH. A specific H+ -ATPase pump acts to bring the pH inside the bacteria to a normal level. This phenomenon consumes energy and eventually can stop the growth of the bacteria or even kill it.

The lowering of pH also suppresses the enzymes (e.g. decarboxylases and catalyses), inhibit glycolysis, prevent active transport and interfere with signal transduction. The anionic (A-) part of the acid trapped inside the bacteria (it can diffuse freely through the cell wall only in its non-dissociated form), becomes toxic involving anionic imbalance leading to internal osmotic problems for the bacteria.

Thus, the **antibacterial effect of organic acids** is by

- Modification of bacteria's internal pH,
- Inhibition of bacteria's fundamental metabolic functions,
- Accumulation of toxic anions in bacteria and
- Disruption of bacteria's cellular membrane.

B. For non-pH sensitive bacteria:

The non-pH sensitive bacteria tolerate a larger differential between internal and external pH. At a low internal pH, organic acids re-appear in a non-dissociated form and exits the bacteria. Equilibrium is created and the bacteria do not suffer (Figure 3 (B)).

Classification of Acidifiers

A. Organic
- I. Free form
- II. Salt form (Coated and Uncoated)

B. Inorganic

eg. Phosphoric Acid

Uses of Salt forms of Organic acids

- Are solids
- Less volatile
- Less corrosive
- More water soluble
- Odourless
- Easy to Handle

Site of Action

Organic acids exert their antimicrobial action both in the feed and in the GI-tract of the animal.

The antibacterial effect of dietary organic acids in chickens is believed to occur in the upper part of the digestive tract (crop and gizzard). Following the addition of a combination of formic and propionic acid, high concentrations of these acids could only be recovered from crop and gizzard.

Feed Acidification Strategies

Form of Organic acids incorporated

- Free acid form (powder or liquid) or,
- As salts form,
  - a) Free form or
  - b) Protected / Coated salts.

Inclusion Levels of Organic acids[8]

- At 0.5 kg / Ton of feed to control molds and
- At 2.5 to 3.0 kg / Ton of feed to reduce pH and help in control of Salmonella.

Impact of Organic Acids on Broiler Performance

Organic acids are beneficial in practical studies. The efficacy of poultry digestion depends on microorganisms, which live naturally in the digestive tract. Inclusion of formic and propionic acids reduced pH in crop and gizzard but not in intestinal tract. Organic acids in crop reduce *salmonella* populations. Organic acids reduce production of toxic components by bacteria and a change in the morphology of the intestinal wall and reduce colonization of pathogens on the intestinal wall, thus preventing damage to the epithelial cells.

Various studies revealed that body weight gain, feed intake, feed conversion rate, carcass weight, abdominal fat weight, abdominal fat percentage, intestinal weight were affected significantly ($P<0.05$) by giving organic acid mixtures. Organic acids enhance growth performance and carcass quality of broiler chicks. The effect of organic acids on poultry performance is depicted in Table 9.

Selection/ Screening of organic acids[10]

Comparative studies of six organic acids showed that the inhibiting effect of the acids was more pronounced in stomach contents than in content from the

Table 3: The characteristics of different organic acids[1]

Acid	Formula	MM (g/mol)	Density (g/ml)	State	pKa	Solubility in water	Corro sivity	MEn MJ/kg	Taste
Formic	HCOOH	46.03	1.220	Liquid	3.75	"	+++	11.34	—
Acetic	CH3COOH	60.05	1.049	Liquid	4.76	"	++	12.19	-0
Propionic	CH3CH2COOH	74.08	0.993	Liquid	4.88	"	++	17.78	-0
Butyric	CH3CH2CH2COOH	88.12	0.958	Liquid	4.82	"	+	22.43	+
Lactic	CH3CH(OH)COOH	90.08	1.206	Liquid	3.83	V	+	14.53	++
Sorbic	CH3CH :CHCH :CHCOOH	112.14	1.204	Solid	4.76	S	+		0
Fumaric	COOHCH :CHCOOH	116.07	1.635	Solid	3.02 4.38	S	+		0
Malic	COOHCH2CH(OH)COOH	134.09	1.601	Liquid	3.40 5.10	"	0	9.79	
Tartaric	COOHCH(OH)CH(OH)COOH	150.09	1.760	Liquid	2.93 4.23	V	+		
Citric	COOHCH2C(OH)(COOH)CH2COOH	192.14	1.665	Solid	3.13 4.76 6.40	V	0	10.29	++
Phosphoric	H_3PO_4				2.0, 7.0 12.0	"	++++		

MM, molecular mass in grams.
Solubility in water : " = soluble in all proportions; V = very soluble; S = slightly soluble
Corrosive : 0 = no corrosive; + to ++++ = slightly to highly corrosive
Taste : - = negative; 0 = neutral; + to ++ + favourable

small intestine, probably due to the lower pH in the stomach content. The bactericidal effect of the organic acids is :
benzoic acid > fumaric acid > lactic acid > butyric acid > formic acid > propionic acid

Benzoic acid is superior to other acids in exhibiting bactericidal effect on coliform as well as lactic acid bacteria in both stomach and small intestinal content. It is evident that combination of acids is preferred to individual acid in obtaining the desired antimicrobial effect. The *in vitro* systems offers a reliable method to investigate alteration in the microbiota in response to different conditions and provides a useful approach to the screening of organic acids to be subsequently tested *in vivo*.

Poultry diets usually have high alkalinity characteristics: (very rich in protein and mineral substances). Vegetal protein and calcium carbonate meals in feeds have a strong buffer function (Table 6).

The use of diets characterized by such a high buffer capacity can compromise the intestine capability to keep an acidity level that can support growth and in some cases, maintain beneficial intestinal microflora.

Many harmful bacterial species have a pH optimal for their growth around 7, whereas useful bacterial species such as lactobacillus and enterococcus have their best growth at pH around 6.

Poultry intestinal tract acidification allows modulation of the intestinal bacterial flora in a positive and natural way and, at the same time, it works against the multiplication of that bacterial flora that besides being harmful and dangerous for the animal health can represent a problem of legal nature connected to the foodstuffs health.

The buffering capacity of poultry feeds particularly of protein and mineral sources is high (Table 8). Buffering capacity or B-value in a feed is often expressed as meq of 1.0 M HCl required to acidify 1 kg of material (feed or feed ingredient) to pH 3 -5. Usually, the amount of 0.1 M HCl required to reduce the pH to 5 of 10 g feed in 90 ml distilled water is represented as buffering capacity [9].

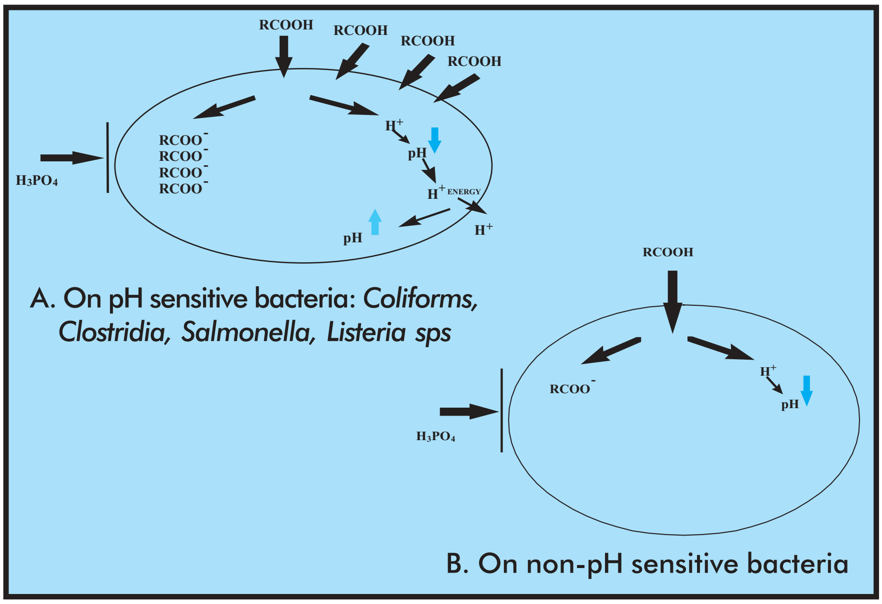
Note

1. pH of feed in water slurry and B-value are not related.
2. pH of feed ingredients are

Table 4: Antibacterial spectrum of organic acids: [3]

Acid	Effective	Less Effective	Not Effective
Formic acid	Yeasts& Bacteria - (E.coli&Salmonella)	LA-bacteria& Moulds	-
Acetic acid	Many species of bacteria	Yeasts & Moulds	-
Propionic acid	Moulds	Bacteria	Yeasts
Butyric acid	Bacteria (E.coli&Salmonella)	-	-
Lactic acid	Bacteria	-	Yeasts & Moulds
Citric acid	-	Bacteria	-
Malic acid	Some bacteria & Yeasts	-	-
Sorbic acid	Yeasts, Moulds & some Bacteria	-	-

Figure 3: Mode of action of organic acids



variable but B-values are much more variable.
3. Cereal has low B-values.
4. Protein sources have high B-values.
5. Mineral sources such as DCP has high B-value.
6. Limestone has a very high B-value.
7. B-values can be additive if same end point is used: say pH 5.0
8. B-values of different batches of a feed ingredient may vary.
9. It is not easy to calculate B-value of a final feed from B-value of ingredients.

In stomach (in proventriculus) in birds, gastric juice is secreted. This lowers pH in between 2.0 & 4.0. A low gastric pH is important to activate pepsin from pepsinogen, which digests protein. Fermentation of undigested protein by microbes leads to formation of toxic biogenic amines. Low gastric pH controls bacterial population. In the acid environment, pathogenic bacteria such as E.coli and Klebsiella sps as well as bacteroids diminish. Beneficial bacteria, such as Bifido and Lactobacilli sps are more tolerant towards low pH values[9].

In young animals, capacity to secrete gastric juice is limited. High B-value may pose problems. Pathogenic bacteria multiply in the digestive tract. The recommended B-value for poultry is about1-10 for 1-10 days age and 10-20 for 10-30 days age.

It may not be possible to reduce B-value of feed sufficient low. High protein and mineral supplements are necessary for broilers and layers. Organic acids are of value in controlling the pathogenic bacteria.

New Developments

Organic acids can be mixed with fatty acids, mono- and diglycerides to form microgranules. Organic acid is released slowly from these microgranules. Medium chain fatty acids (chain length: 6 to12 C) with a lower absorption rate by the host may improve the efficacy of the short chain fatty acids. Acids produced by fermentation with microbes (*Pediococcus acidilactici)* may be less expensive and equally effective.[4]

Limitations

- Palatability may be decreased, leading to feed refusal[5]
- Organic acids are corrosive to metallic poultry equipment
- Bacteria are known to develop acid resistance when exposed to acidic environments for over long term.[6]
- Presence of other antimicrobial compounds can reduce its efficiency
- Cleanliness of the production environment
- Buffering capacity of dietary ingredients

Conclusion

Prevention of infections, good nutritional balance and better performance is of paramount importance in poultry production. The use of alternatives to

Table 5 : Poultry Performance profile of organic acids[2]

Acid	Concentration (%)	Effects
Fumaric acid	0.50-1.00	Improvement in weight gain of broilers. Improved feed efficiency in both broilers and layers.
Buffered propionic acid	0.15-0.20	Increase in dressing percentage in female broilers and reduction in abdominal fat for males.
Malic acid	0.50-2.00	Increase in weight gain
Sorbic acid	1.12	Improves feed efficiency
Tartaric acid	0.33	Increase in weight gain
Lactic acid	2.00	Feed to gain ratio significantly improved. Body weight gain.
Formic acid	0.50-1.00	Reduction of caecal pH and bactericidal effect on *Salmonella*
Benzoic acid	0.20	Positive influence on growth
Butyric acid	0.15	Maintain the beneficial micro flora. Increase the proliferation and maturation of intestinal cells

Table 6: Acid-binding Capacity of feed ingredients at pH 3

Raw material	meq/kg (min./max.)
Wheat	180 / 240
Corn	135 / 172
Bran	502
Sunflower extrn meal	888
Soy e.m. 42	980 / 1,240
Soy e.m. 48	1,025/1,035
Fish meal	1,480/2,100
Calcium carbonate	19,680/20,000
Dicalcium Phosphate	7,860/10,150
Fumaric Acid	-6,400
Orthophosphoric Acid 60%	-5,500

Table 7: pH optimum for bacteria growth

Micro-organism	OptimalpH
Escherichia coli	6.0 / 8.0
Lactobacillus spp.	5.4 / 6.4
Salmonella spp. (most of)	6.8 / 7.2
Campylobacter jejuni	6.8 / 7.2

Table 8: pH and B-value of some common feed ingredients

Feed Ingredient	pH	B-value
Tapioca	5.2	1.3
Rice	6.5	2.8
Barley	5.8	3.0
Maize	6.1	3.5
Wheat	6.7	3.7
Sorghum	5.9	5.0
Triticale	6.8	7.0
Wheat middlings	6.7	11.4
Peas	6.5	11.0
Alfalfa meal	5.9	18.5
Potato protein	5.4	3.0
Rapeseed meal	5.3	6.8
Linseed	5.8	7.9
Soybean hulls	6.1	8.5
Soybeans	6.3	18.0
Sunflower seed hulls	6.1	16.4
Animal meal	6.2	25.4
Meat meal	6.0	26.0
Soybean oil meal 53%	6.6	28.8
Whey powder	6.4	31.0
Meat and bone meal	8.3	32.0
Milk powder	6.5	37.0
Dicalcium phosphate	7.3	248.0
Limestone	9.7	1750.0

antibiotic growth promoter in specific the use of organic acids in poultry feed is receiving greater attention.

It is hoped that nutritional control will lead to microbiological control, allowing for more consistent performance response in the absence of antibiotics.

In the absence of antibiotic growth promoters, nutrition and feeding strategies must supplement, not be a substitute for good management. The use of acidifiers in poultry diets appears promising. Combination of different acids seems to lead the way to greater efficacy.

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