WP

NUTRITION

The value of organic acids in drinking water

Acidification of feed and water is used as a management strategy to compensate for the loss of growth promoters. Organic acids – either alone or in combination with inorganic acids - can be employed effectively in drinking water applications.

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The use of organic acids in animal agriculture has increased significantly over the past decade. Today they are commonly used for managing food safety concerns, improving feed and water sanitation, gastric pH reduction in young animals, control of enteric diseases and subsequent improvement in animal performance. As sub-therapeutic antimicrobials come under increased scrutiny (in 2006 there will be a complete ban of these antibiotics), organic acids are gaining acceptance as a key component in an overall strategy to manage animal production.

Acidification improves performance

Numerous research studies have shown that the bacterial load of feed and water can be reduced via acidification. Today this practice is receiving much attention in livestock feeding. Both inorganic (mineral) and organic acids have demonstrated value in improving the relative hygiene of both feed and water. In drinking water applications, this improved hygiene is in part due to the pH reduction brought about by inclusion of soluble acids and the resulting suppression of the proliferation of many pathogenic bacteria. Overall effectiveness of acidification as an antimicrobial intervention is dependent on the combination of acids used and micro-environmental conditions, specifically pH.

Organic acids are becoming routinely employed to reduce the environmental load of bacteria present in water and feed as well as improving the antibacterial action of organic acids in the upper GI tract. The result is a lowered presence of pathogenic microbacteria entering the lower gastrointestinal tract. This reduction translates into fewer pathogenic bacteria, and a reduction of toxic microbial metabolites (e.g. the polyamines; putrescine and cadaverine) and ammonia in digesta. The impact is less immune stimulation and reduced competition for the nutrients in the gut, which can lead to improved digestibility and greater nutrient retention. Organic acids, but not mineral acids, can increase the release of secretin, a hormone which assists in the initiation of the release of both pancreatic enzymes and bile. This greater presence of digestive enzymes can produce improved digestibility and promote the proliferation of gut tissues. The ultimate benefit is better overall performance as measured by weight gain, feed conversion and monetary return.

Inorganic acids

Common inorganic acids used include hydrochloric, sulfuric and phosphoric, with the latter being most frequently employed. Inorganic acids serve to effectively reduce pH of the upper GI tract. Though inorganic acids are generally less expensive than organic acids, they are typically more corrosive and present handling challenges in the working environment.

Inorganic acids are routinely used in the diets of weanling pigs, as these young animals have not yet developed the ability to produce sufficient gastric acids and low pH to optimise the action of proteolytic enzymes. It is important to understand that inorganic acids are not by themselves effective antimicrobials. Their primary function is to reduce digestive tract pH. The low pH environment fostered by inorganic application provides an environment more suitable to proliferation of non-pathogenic, acidophilic bacteria, such as *Lactobacillus*. Simultaneously, they enhance the activity of organic acids present in the digestive tract by supporting a lowered digestive tract pH. The net result is a higher concentration of the more desirable bacteria and a suppression of pathogenic bacteria and moulds.

Table 1 - Structure, molecule weight and dissociation constant of selected organic acids

Acid	Formula	MW	pKa
Formic	$HCOOH$	46.02	3.75
Acetic	CH_3COOH	60.05	4.76
Propionic	CH_3CH_2COOH	74.08	4.88
Butyric	$CH_3CH_2CH_2COOH$	88.10	4.82
Lactic	$CH_3CH(OH)COOH$	90.08	3.83
Sorbic	$CH_3CH{:}CHCH{:}CHCOOH$	112.12	4.76
Fumaric	$COOHCH{:}CHCOOH$	116.07	3.02
Malic	$COOHCH_2CH(OH)COOH$	134.09	3.40
Tartaric	$COOHCH(OH)CH(OH)COOH$	150.09	2.93
HMTBa	$CH_3SCH_2CH_2CH(OH)COOH$	150.12	3.53
Citric	$COOHCH_2C(OH)(COOH)CH_2COOH$	192.12	3.13

For each acid, a constant of dissociation (pKa)is defined as the PH at which 50% is dissociated and 50% is non dissociated

Acids in Blue are Liquid at Room Temperature Acids in Green are Solid at Room Temperature

Organic acids

Organic acids are characterised by the presence of one or more carboxyl groups (COOH). *Table 1* lists a variety of commonly used organic acids. Those in blue (e.g. formic, butyric, HMTBa) are liquid at ambient temperature and those in green (e.g. citric, sorbic, tartaric) are solid at ambient temperature. HMTBa (methionine hydroxy analogue) is the active component of Novus' Alimet® feed supplement.

Figure 1 - Organic acid antibacterial effect

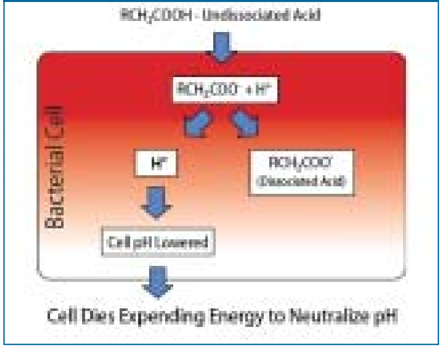


Figure 2 - Organic acids are more effective antimicrobials than inorganic acids at reduced pH

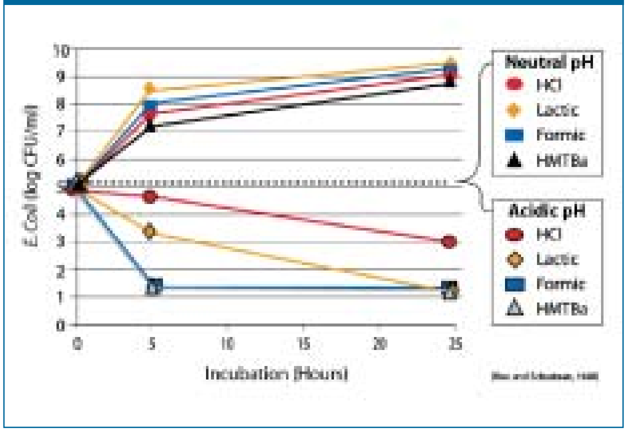
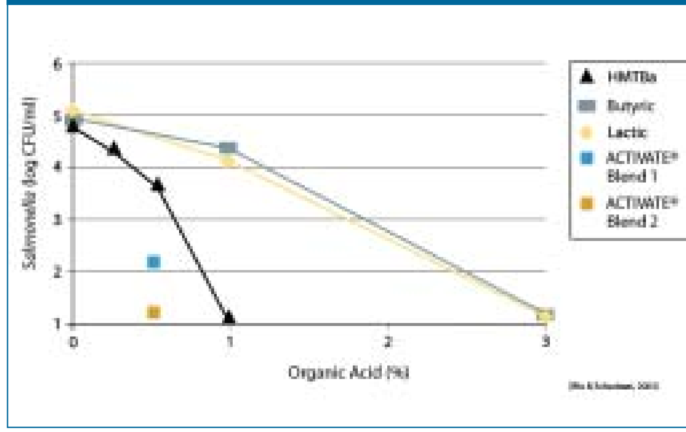


Figure 3 - Organic blends show increased efficacy over individual acids



Efficacy highly pH dependent

The organic acids generally used in livestock feed and water applications are typically highly effective antimicrobials. This is due to an organic acid's ability to pass through bacterial cell walls when the carboxylic acid portion of the acid is protonated (COOH), *Figure 1*.

To optimise the bactericidal activity of organic acids, the pH must be reduced to, or below, the dissociation constant or pKa of the acid. The pKa is the pH at which 50% of the carboxyl groups are protonated (COOH vs COO^-). The non-dissociated (COOH) form of the organic acid exists in the acidic environment of the gut and is able to move across the cell wall by passive diffusion. Once within the cytoplasm of the cell, which is typically at or about neutral pH (7.0), the acid dissociates, and a hydrogen ion (H^+) is released. This affects a decrease in the intracellular pH; the cell then diverts metabolic energy to replace the hydrogen ion. Repeating the process numerous times ultimately results in the demise of the bacteria. This effect is specific to certain organic acids and is pH, or more accurately pKa, dependent. Organic acids that are highly effective antibacterials at low pH may have little value in a highly buffered system approaching neutral pH 7.0. The molecular weight and the composition of the anion portion of the acid can impact the acid's ability to diffuse through the cell wall.

Figure 2 illustrates the antimicrobial activity of a number of acids at neutral and acidic pH. All are more effective at reducing *E. coli* counts in an acid pH environment, with HMTBa and formic being the most effective. However, note that at neutral pH the *E. coli* continue to proliferate regardless of specific acid present.

Blends are effective antimicrobials

Much research has been dedicated to the evaluation of acids in combination to generate an antimicrobial effect which is more beneficial than that of the single acids. Acid blends have been effectively used to reduce pH, shifting the microenvironment closer to the pKa of individual organic acids to optimise their antimicrobial activity. In addition, effort has been devoted to combinations and specific ratios of the organic acids to create environments less conducive to bacterial growth. *Figure 3* shows examples of some of these efforts.

These data demonstrate the efficacy against *Salmonella* of three different organic acids in a low pH stomach model with feed. Each acid shows a dose response to the reduction of *Salmonella* in this model. Activate Nutritional Acid Blends are a proprietary family of organic acid blends which contain Alimet® (HMTBa). The Activate blends tested at a total acid concentration of 0.5% are made of the three different organic acids with the blends differing in the ratios of the acids. Each of the Activate blends is more effective than the individual acids at that concentration demonstrating a more than additive (synergistic) effect of the HMTBa-containing acid blends.

Effective water dispersible acid blends

Organic acids have application in both feed and in drinking water systems. For water dispersible acid blends to be an accepted component of on farm poultry production, they must meet certain criteria:

- The acids employed cannot be noxious or aggressive toward equipment, livestock or personnel,
- Total 'acid content' of the blend must be sufficient to offset the buffering (CO_3^{-2}) capacity of the farm water supply and economically achieve water pH less than 3.5,
- Formulations should be designed to provide for maximum acid synergy. This is effected by selecting the best acid blend and assuring inclusion at a concentration to assure pathogen kill,
- Regardless of vendor, the blended acid product must provide consistent, measurable, bottom-line value.

Optimal dosing dependent on water pH

Application of organic acids in drinking water systems is not complex, with low cost technology available to help determine application rates needed to establish a pH at or below the pKa of the employed acids for maximum effectiveness. Flocks can easily be managed and treated on an as-needed basis. Because there is considerable variation in the buffering capacity of drinking water it is important to adjust the addition rate accordingly. Measuring the carbonate content of water is a common and quick way to measure buffering capacity. Testing kits from any manufacturer are widely available at such places as pet supply centres which sell them for aquariums. F*igure 4* shows the test being performed, changing from clear to blue and then to yellow when the test is complete. The number of drops added determines the carbonate hardness (KH). The addition rate of acid needed to achieve the desired pH can then easily be determined from this hardness value. It is also highly recommended that the pH be measured at the final waterer in the drinking water system as a final check of the acid addition level.

Figure 4 - A simple pond or aquarium water test kit determines the carbonate hardness (KH) of drinking water

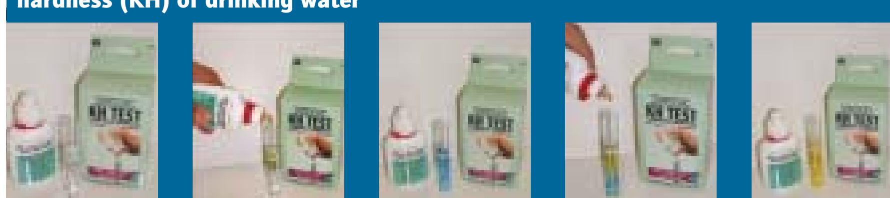
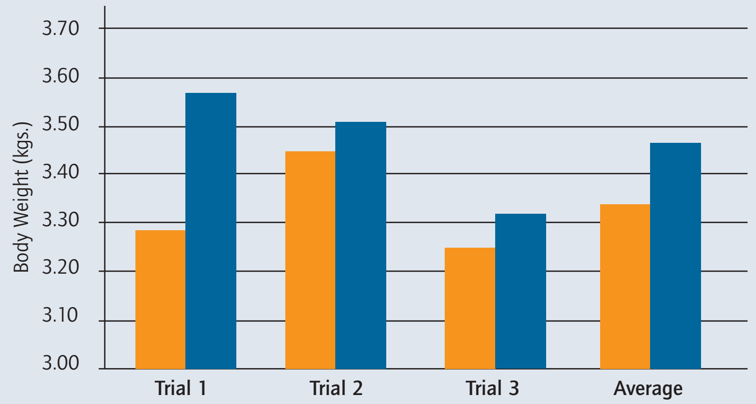


Figure 5 - Activate WD improved broiler weights at top USA integrators



	Trial 1	Trial 2	Trial 3	Average
Control (kgs.)	3.270	3.447	3.243	3.320
ACTIVATE WD (kgs.)	3.565	3.501	3.311	3.460
WD Concentration %	-04%	-08%	-04%	
Days Use Pre-Harvest	10	14	10	
Payback	>50	>4	>10	

Performance improvements

Organic acids via the drinking water serve as an aid in improving water hygiene, as enteric acidifiers and ultimately affect improved flock performance as a result of reducing pathogen load (*Figure 5*). In this example birds were provided Activate® WD in three separate field trials with a single integrator. Due to varied water hardness, the product was added at either 0.04% or 0.08% to maintain a drinking water pH of <3.5. Regardless of application rate or duration, 10 or 14 days pre-slaughter, performance improvements were observed.

These gains translated into net return for that application of from 4 to 50 fold.

Organic acids are also being used to improve hygiene for improved food safety reasons. Efficacy against *Salmonella, E. coli,* and C*ampylobacter* has been widely demonstrated. Reduction in pathogens has also been shown to have a positive impact on enteric diseases such as necrotic enteritis. In some cases it is possible to identify farms that are consistently pathogen positive. Once these farms are identified, whether pre-slaughter or from past bacteriological monitoring at the processing plant, the flock can then be targeted and treated prior to processing. The organic acid therapy can be administered:

- at placement, to suppress colonisation of pathogens and promote beneficial microflora
- during challenge periods throughout the growout to minimise pathogen blooms
- immediately prior to processing to reduce pathogen load(e.g. *Salmonella*)

All are done as part of an orchestrated comprehensive program of pathogen reduction and performance enhancement. ■

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