Development of organic acids and essential oils

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Organic acids have been used in swine diets for decades. The main target of using organic acids is to lower the acidity in the stomach of young piglets. More recently organic acids have been used in alternative feeding strategies without antibiotics.

Latest research shows that the effect of organic acids can even be boosted when combined with plant extracts. This combination has already shown promising results for swine and poultry.

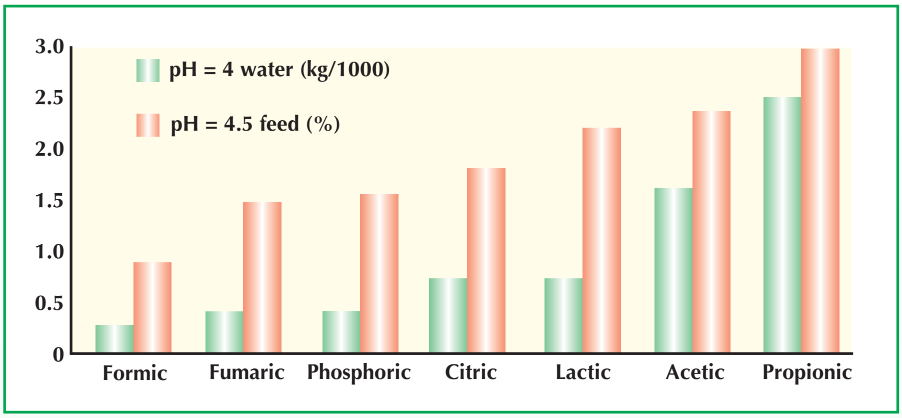

Fig. 1. The pH effect of different acids in feed and drinking water.

The pH lowering effect

It is obvious that the pH lowering effect of organic acids is still the major mode of action of acidifiers in diets for young swines. The production of hydrochloric acid in the stomach is insufficient for an optimal performance up to a body weight of 50kg.

	M	pKa
Formic acid	46	3.75
Acetic acid	60	4.76
Propionic acid	74	4.88
Lactic acid	90	3.86
Fumaric acid	110	4.54
		3.03
Citric acid	210	5.19
		4.77
		3.15
Phosphoric acid	98	12.32
		7.21
		2.12

Table 1. Molecular weight (M) and pKa value of different acids.

In the 1970s 1-2% of fumaric or citric acid were dosed in piglet feed. Those acids were easy to handle as they were presented in a dry form with a neutral smell. However, those acids are not the most efficient acids for pH reducing effects.

As shown in Fig. 1, it is clear that formic acid is the strongest acid for a pH lowering effect. This is due to its typically chemical characteristics – small molecules and low pKa value (see table 1: M=46, pKa 3.75). Even compared with the inorganic acid phosphoric acid, formic acid is much stronger in reducing the pH to the level of 4.0 (drinking water) or 4.5 in feed. The inorganic phosphoric acid does have three pKas for dissociation. However, to acidify drinking water to pH=4 the lowest pKa does not have any extra effect as this pKa value is not reached in the water.

The optimal inclusion level of organic acids depends on the buffering capacity of the ingredients. This is also illustrated by Fig. 1. The pH value drops down very quickly in drinking water which hardly contains any buffering elements.

Depending on the type of acid, 0.3-2.5kg per 1000 litre is needed to reduce the pH under 4.0. More acids are needed in feed to bring the pH below 4.5, 9.5-30kg/t. This difference with water is due to the buffering elements in feed.

So feed containing many buffering elements like minerals and protein sources needs more acidification to reach the optimum buffer capacity.

Another important reason to use organic acids in feed is the antimicrobial

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Table 2. Generations per four hours of E. coli (K88:K91:O149). Negative value means bactericidal effect.

Acid	Dosage (kg/ton feed)	pH level		
		5	6	7
Formic acid	0	6.8	7.0	8.4
	2.5	3.9	4.9	8.2
	5	0.1	0.8	7.8
	10	-0.6	0.2	7.0
Lactic acid	0	6.7	7.0	8.3
	2.5	4.0	5.4	8.4
	5	-0.8	3.8	8.4
	10	-3.0	0.4	8.3
Citric acid	0	6.8	6.8	8.0
	2.5	6.7	6.8	8.0
	5	6.5	6.5	8.0
	10	6.5	6.8	8.7
Fumaric acid	0	8.0	8.2	8.9
	2.5	8.0	8.2	8.6
	5	8.0	8.0	8.5
	10	ns	ns	ns
Phosphoric acid	0	6.4	6.5	8.3
	2.5	7.3	6.6	8.6
	5	7.5	6.7	8.7
	10	7.0	7.0	8.0

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effect. Much research has been done to demonstrate the antibacterial function of organic acids in particular. Organic acids are commonly used in the food industry to prevent spoilage by different micro-organisms.

In the feed industry propionic acid is known for preventing mould growth during storage of feed, raw materials and silages. Organic acids are also used for decontamination of raw materials which have been contaminated with salmonella.

It has also been proven that organic acids can control pathogenic bacteria in the gastrointestinal tract of pigs and poultry. This antibacterial effect is different for each acid per micro-organism. In cooperation with several laboratories, Franklin has set up an extensive database of these antibacterial effects.

For the in vitro research Franklin uses a test model for the intestinal tract. This means using a bacteria-flora selected from the intestinal tract of slaughtered animals tested at different pH levels.

To determine the differences between organic acids, the pH of the medium should not be below 4.5 as most bacteria no longer grow anymore at this low pH level. Therefore, the pH should be between 5-7 to show the difference between the acids.

Table 2 shows the results of the in vitro tests. Especially the short chain fatty acids like formic acid and lactic acid have a strong antibacterial effect.

At pH5, lactic acid is already bactericidal at 5kg/ton of feed. Citric acid, fumaric acid and the inorganic acid phosphoric acid do not show any antibacterial effect at the different pH levels. The difference in antibacterial activity between those acids can be explained by Fig. 1.

Small organic acids like formic and lactic acid are, in their undissociated forms (= low pH), able to pass through the cell membrane of bacteria. Once inside the cell, the acid dissociates and produces H+ ions which lower the pH in the bacteria cell. The bacteria have to use their energy trying to restore the normal pH balance.

The RCOO- anions produced by the dissociation of the acid can disrupt DNA and protein synthesis, putting the organism under stress so that it is unable to replicate or replicate rapidly. This anion effect is specific for each acid and micro-organism.

Organic acids with high molecular weight (M) like citric acid, fumaric acid and the inorganic acid phosphoric acid can not penetrate through the cell wall as they do not have a lipophyl character.

At higher pH levels (6-7) formic acid and lactic acid are already dissociated outside the bacteria cell and become negatively charged. This means that they are no longer able to penetrate into the bacteria. This effect can also be seen in Table 2, which shows that there is no antibacterial activity left at pH 7.

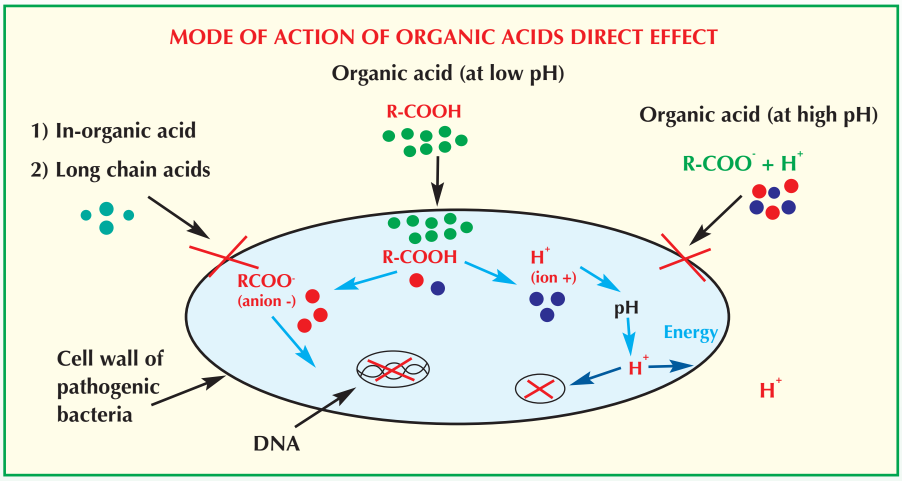

Fig. 2. Mode of action of the antibacterial effect of organic acids.

Enhancing the mode of action

The latest developments to enhance the mode of action of organic acids are to combine organic acids with so called plant extracts or essential oils.

Those substances have been used for thousands of years for different food applications, like the improvement of taste and flavour. Another important aspect is their antimicrobial effect to prevent food spoilage.

Using essential oils in feeds is a relatively new development. It is important to use the correct levels of essential oils to promote feed intake instead of feed refusal and still show their antibacterial aspect.

This aspect has been especially researched by Franklin Products International BV, resulting in a selection of

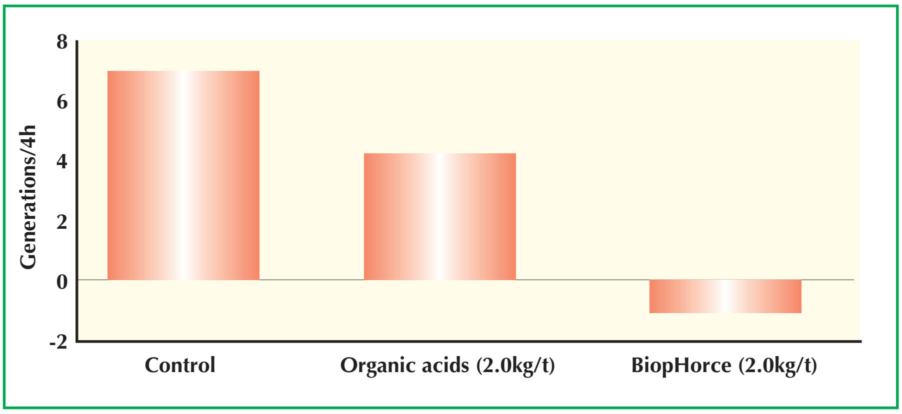

Fig. 3. Reduction of E. coli at pH 6.

essential oils which have a pronounced antibacterial activity and synergistic effects with organic acids.

The selected essential oils have the capability to destroy the cell membrane of pathogenic bacteria cells. This 'opens the door' for organic acids in their dissociated form (anions) at higher pH level to penetrate into the cell wall and have their detrimental effect on DNA.

The synergistic effect is that lactic and formic acid also have an antibacterial effect at higher pH level 6-7 and that only small levels of essential oils have to be used to be bactericidal as they interact with the acid anion.

Fig. 2 shows the extra effect of the combination of organic acids (lactic + formic acid) and essential oils at pH 6 even at a low dosage level of 2.0kg/ton.

The control is growing with seven generations, the acid group with 4.25 generations.

However, the BiopHorce combination is bactericidal -1 generation per four hours. Compared with Table 2 it is obvious that the essential oil boosts the effect of organic acids at higher pH levels.

The implication for animal nutrition is that this combination also has an antibacterial effect in the first part of the intestinal tract where the pH varies between 6-7.

This effect has also been proven in vivo during a challenge test. During this challenge test piglets were infected with E. coli under strict controlled circumstances.

By counting the numbers of E .coli in the faeces, the effect of an additive can be determined. Parameters like diarrhoea and other health parameters were also tested.

Using this infection model the effect of organic acids and essential oils were tested under high infection pressure as if under practical circumstances.

Fig. 3 shows the results of the comparison between the use of only organic acids and a combination of organic acids with essential oils.

By using organic acids and essential oils there is less growth of E. coli and a faster reduction after the infection period (see Fig. 4).

Also the other parameters were in favour of the combination of organic acids and essential oils – 5% extra growth and a lower diarrhoea score.

The combination has proven its extra antibacterial effects not only in vitro, but also in vivo.

At the moment BiopHorce is successfully used in antibiotic free programmes both for swine and poultry.

The product can be dosed direct into feed or via premix and can be used via drinking water of the animals. ■

More test results and references are available from the author on request.

Fig. 4. Effect of organic acids and essential oils at E. coli in faeces by piglets after an oral challenge with E. coli.