For efficiency and health – think medium chain fatty acids (MCFAs)

There are big differences between different acids and in this article we would like to explain the different mode of action of different acids and some trial results with medium chain fatty acids (MCFAs).

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Organic carboxylic acids can be divided into several subgroups according to their molecular structure (Fig. 1).

Depending on its effect, they can be divided into three groups.

1. Acids that are included as regulators of feed hygiene, that limit the growth of fungi, yeasts or enterococci and that limit losses of associated nutrients. Examples of acids in this group are propionic and sorbic acid.

2. Acids that cause a decrease in pH in the stomach and improve the digestibility. This effect is of less importance in poultry, since birds are able to maintain a pH in the stomach which is low enough to ensure the protein digestion. Reducing the pH of the stomach will cause a bacteriostatic effect. Fumaric acid, formic acid and lactic are used in this regard.

3. Acids with a direct antibacterial effect. The reduction of pathogenic bacteria in the stomach will lead to a reduction in the incidence of diarrhoea and an effect stimulating health in general. This group is particularly important for the reduction of antibiotics. An example of acids which are antibacterial are the MCFAs.

Bactericidal effect

To eliminate pathogens in the stomach and to reduce infection pressure, there are very important properties of acids such as the following:

- pKa value: determines the ability of an acid to approach the bacteria.

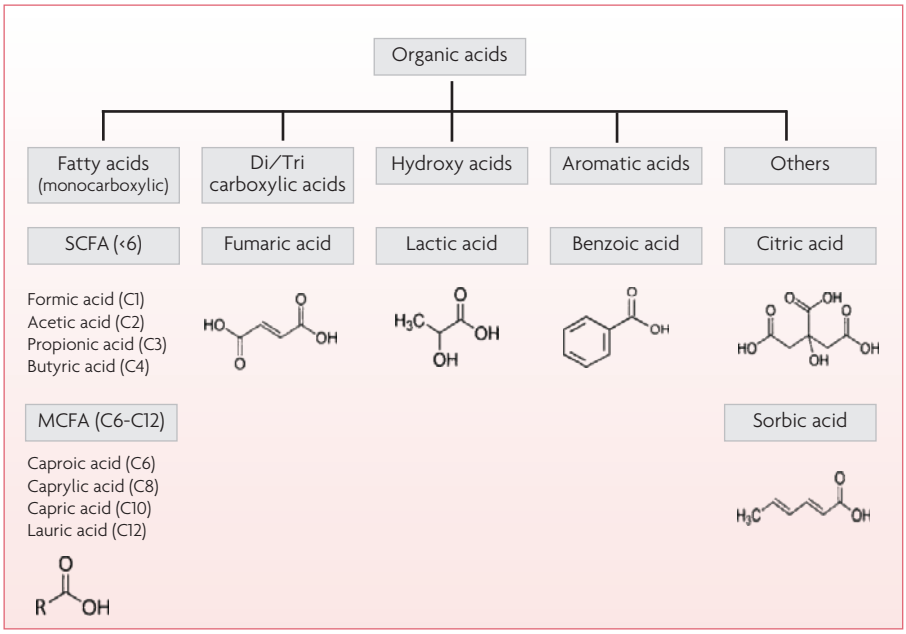

Fig. 1. Commercially used organic acids.

- HLB: determines the ability to destabilise the cell membrane of the bacteria.

The conditions of an efficient bactericide are a high pKa and an optimal HLB balance.

pKa value

The pKa value of an acid (Table 1) determines whether it is pH reducing or antibacterial. Each acid has a unique pKa value, which is the pH at which 50% of the acid appears in its undissociated (RCOOH) form and 50% in its dissociated form (H^+ + $RCOO^-$). So the molecules change depending on the pH of the medium.

Since the membrane of bacteria has a negative charge (due to the P which gives a negative charge in the phospholipid bilayer), we always need the undissociated form (RCOOH) of an acid before we can see an antibacterial effect.

This form is neutrally charged, and can be attracted by the cell membrane of bacteria. The dissociated form ($RCOO^-$) is negative, and so they can not approach the bacteria (negative and negative will never attract each other). If an acid has a pKa value of less than the environmental pH, the equilibrium moves to the dissociated form. Dissociation releases H^+ ions, resulting in acidification.

If the pKa value is bigger than the environmental pH, it will move the equilibrium to the undissociated form. An acid in the undissociated form is able to address the bacteria. This is the case with MCFAs.

The greater the difference between the pKa and the pH in the stomach, the more the equilibrium shifts towards the undissociated form and the greater the antibacterial effect. The MCFAs have the highest pKa value, so they will have a better antibacterial effect. In this sense, it is

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Table 1. pKa values of different acids.

Acid	pKa value	Acid	pKa value
Fumaric	3.02	MCFAs	4.90
Citric	3.13	Propionic	4.88
Formic	3.75	Butyric	4.82
Lactic	3.83	Acetic	4.76
Sorbic	4.76	Benzoic	4.20

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sometimes effective to use pH reducing and antibacterial acids together.

The reduction of pH will ensure a better action of the antibacterial acids by increasing the difference between pH and pKa. But in birds, the pH is already low enough, and pH reducing acids are often used for feed and water hygiene, but less as antibacterial action in the birds. For the antibacterial action, MCFAs are much more effective.

HLB value

Approaching bacteria is the first condition for being antibacterial. The second condition is an optimal HLB value.

- The membrane of the bacterial cell consists of phospholipids, which contain a hydrophilic head and a lipophilic tail.
- An organic acid also has a hydrophilic group carboxyl (COOH) and a hydrophobic tail (R).
- The amphiphilic character can be expressed in a value of HLB (hydrophilic – lipophilic balance).

To destabilise the bacterial cell membrane, the HLB value of acids should be similar to that of the bacterial cell membrane. The medium chain fatty acids have this optimal HLB and that is why they will destabilise the bacterial cell membrane in the most efficient way.

- Gram negative bacteria are more susceptible to caproic acid (C6) and caprylic acid (C8).
- Gram positive bacteria are more susceptible to capric acid (C10) and lauric acid (C12).

It is known that the combination of the four MCFAs work synergistically and broad spectrum as antibacterial acids. Acetic acid, butyric and propionic do not have this optimal HLB balance (they are too hydrophilic), and that is why they will be less bactericidal as MCFAs.

Mechanism of different forms of MCFAs

The MCFAs show lower minimum inhibitory concentrations compared to other acids, and provide an initial barrier against pathogens, directly in the stomach where the pH is low. Compared with medium chain triglycerides (MCT), which only release free MCFAs in the intestinal tract after the action of lipases, the action of free added MCFAs is much faster.

In addition, the MCFAs that are liberated from MCT will be less efficient since they are released in an environment where the pH is higher than 5.

That means that the MCFAs will switch to the dissociated form and will not be attracted by the bacterial cell membrane. That is why adding free MCFAs to the feed will be much more effective to have a direct action in the stomach. In addition, MCFAs have a powerful effect on persistence of pathogens at the intestinal level.

By reducing virulence of pathogenic bacteria such as salmonella or clostridium, its intestinal and systemic colonisation is reduced.

The MCFAs can also prolong the life of neutrophils, so they act much faster and stronger against pathogens that enter through other pathways, such as the lungs.

	Negative control	Positive control (AGP programme)	MCFAs
Lesion score (day 21)	2.00[a]	1.23[b]	1.27[b]
Body weight (g/bird) (day 42)	1962[b]	2128[a]	2109[a]
FCR (mortality adjusted) (day 42)	2.07a	1.97[b]	1.98[b]
Mortality (%) (day 42)	9.01[a]	3.79[b]	2.62[b]
EPEF (day 42)	197.9[b]	245.7[a]	245.6[a]

Table 2. Challenge trial against Clostridium perfringens.

Trial results

In a recent trial, MCFAs were shown to be the perfect alternative to AGPs. In a Clostridium perfringens challenge trial, 900 Cobb 500 birds (10 repetitions over three treatments, 30 birds per cage) were challenged with Clostridium perfringens.

The European production efficiency factor (EPEF: the number that concludes every important performance parameter) of the birds who received MCFAs was exactly the same as the EPEF of the birds who received the AGP programme.

Both groups performed significantly better than the negative control group. Also the lesion scores at day 21 were significantly better for the group which received MCFAs compared to the negative control group (Table 2).

It is clear that the trial model was successful: the performance of the birds is low and the mortality of the negative control group is around 9%.

That means there was a clear induction of the clostridium in the birds. From this trial, we can conclude that MCFAs are a good alternative to AGPs currently used in the market.

Conclusion

It is clear that the broad spectrum activity and the mode of action of MCFAs make them an ideal solution for reducing the use of antibiotics. ■

More information about the trial is available from the author on request