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Nutritional effects of organic acids

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SUMMARY – The summary of numerous trials showed that acids can nearly compensate for the effects of antibiotic growth promoters. The mode of actions of organic acids and their salts is not totally understood. The paper includes some results of trials, which help to explain the responses like reduced pH and acid binding capacity in feed, increased digestibility of crude protein, energy, calcium and phosphorus and reduced amount of microbes in the duodenum.

Key words: Pig, nutrition, acid, salt, digestibility.

RESUME – *"Effets nutritionnels des acides organiques". Une récapitulation de plusieurs essais a montré que les acides peuvent presque compenser les effets des promoteurs de croissance antibiotiques. Le mode d'action des acides organiques ainsi que leurs sels, n'est pas totalement compris. Cet article présente quelques résultats d'expériences qui aident à expliquer des réponses telles qu'une diminution du pH et de la capacité de liaison des acides chez les aliments composés, une digestibilité accrue de la protéine brute, l'énergie, le calcium et le phosphore, et des quantités réduites de microbes dans le duodénum.*

Mots-clés : *Porcins, nutrition, acide, sel, digestibilité.*

Introduction

As the use of organic acids are becoming better accepted by feed manufacturers, animal producers and public, there is a developing interest in substituting them for antibiotic growth promoters.

Freitag *et al.* (1998) summarized numerous trials, where antibiotics and acids were tested. The addition of Carbadox showed (average of 9 trials) an improvement in weight gain and feed intake of 18.2 and 11.7%, respectively. Feed conversion ratio (FCR) was reduced by 7% (Table 1).

Table 1. Comparison of Carbadox and formic acid in piglets†

Parameter	Carbadox	Formic acid
Weight gain, mean (min./max.)	+18.2 (–1.6/+37.1)	+14.7 (+3.1/+22.1)
Feed intake, mean (min./max.)	+11.7 (+2.3/+26.4)	+6.9 (–1.8/+14.2)
Feed/gain, mean (min./max.)	–7.1 (+7.2/–20.7)	–5.8 (–1.6/–14.5)

†% of control, 9 trials for each product Freitag *et al.* (1998).

In a comparable number of trials with formic acid weight gain and feed intake were increased by 14.7 and 6.9%, respectively and FCR reduced by 5.8%. No negative effect on feed intake was observed, when formic acid was dosed up to 1.25% in the feed. From this overview it can be concluded, that formic acid can nearly compensate for the effects of an antibiotic growth promoter.

What are possible explanations for the effects of acids and their salts? According to Roth and

Kirchgessner (1995) it is possible to differentiate between effects in the feed and digestive tract.

Effects in the feed

Even under good conditions, all compound feeds have a certain content of molds, bacteria and yeasts, which may be multiplied under unfavourable storage conditions. Preservatives reduce the incidence of germs in the feed and thus the quantity of germs consumed by the animals. The hygienic quality of the feed is significantly improved.

The addition of organic acid lowers the pH value of the feed and also provides acid-binding capacity. Particularly for piglets, a favourable effect of the use of acids is noticed. At the time of weaning neither the enzymatic digestion nor the hydrochloric acid production in the stomach of the piglets are sufficiently developed. Additionally, during the starter period a feed is used with a high acid binding capacity due to its high content of crude protein and macroelements. In addition to this specific composition of the diet, a general stress situation for piglets comes up due to the separation from the sows.

During the period of weaning all these factors could lead to a higher risk of problems in digestibility and diarrhoea.

Effects in the digestive tract

The influence of organic acids in the digestive tract can be split into two parts, the acidification and the action of the anion of the organic acids. The addition of organic acids induces a more rapid reduction of the pH value in the stomach, which results in a shorter time to reach the optimal pH of 4 to 3 (Fig. 1).

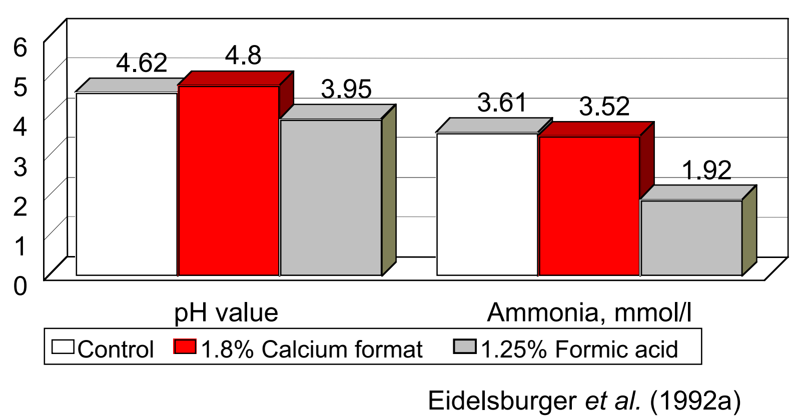


Fig. 1. Nutritive effects of formic acid and calcium formate at identical amounts of formate anions in piglet feed.

This range of pH is needed for an optimal activation of pepsinogen and pepsin. The response leads to an improvement of the digestibility of protein, which has been proven several times (Fig. 2).

The addition of formic acid reduces the formation of ammonia in the stomach of the piglets (Fig. 1), which may be caused by a reduction of the deamination of amino acids. As a result, more amino acids are available for the absorption and the retention of protein. The energy for the metabolism of ammonia to urea in the liver and the renal release of urea is available for growth. The accelerated reduction of the pH in the stomach also has an inhibiting effect on microorganism with a low acid tolerance in the stomach.

Does the addition of acids and their corresponding salts lead to the same response? Kirchgessner and Roth (1987) have studied these questions in a trial with piglets. They compared formic acid

(1.2%) with sodium formate (1.8%) using identical amounts of acid anions in the feed (Fig. 3).

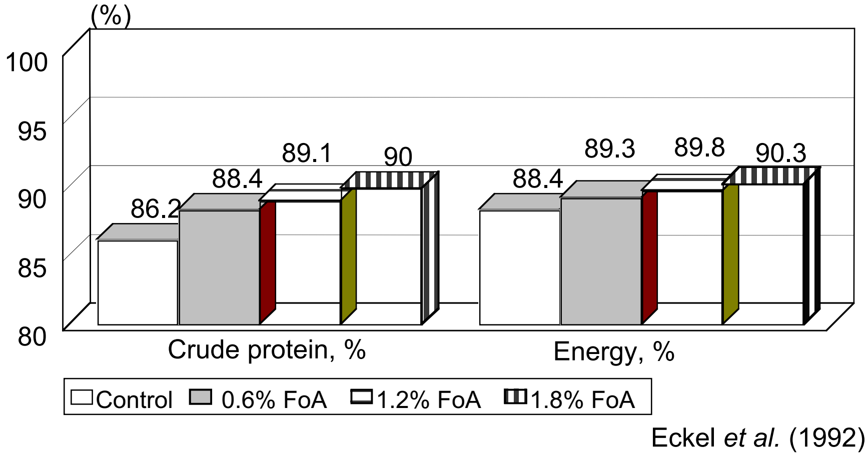


Fig. 2. Influence of formic acid (FoA) on apparent digestibilities of protein and energy in weaner piglets (5-12 kg LW).

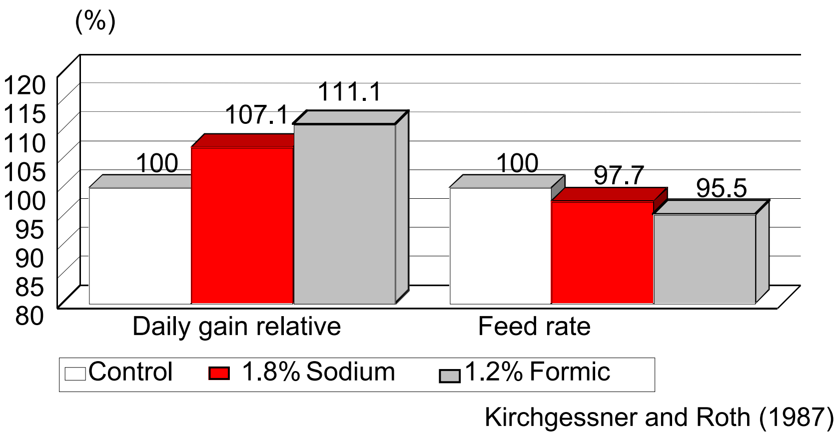


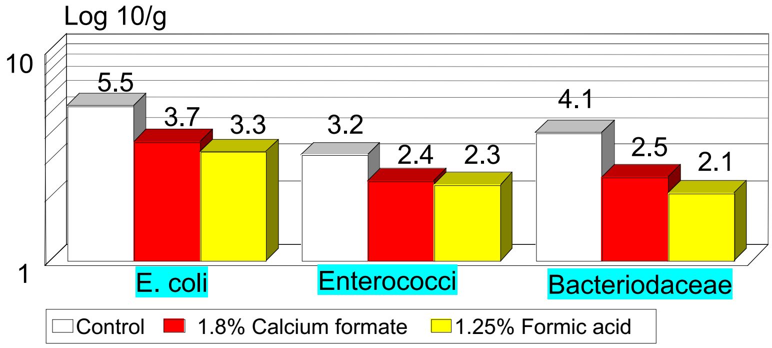
Fig. 3. Nutritive effects of formic acid and sodium formate at identical amounts of formates in piglet starter.

The addition of the salt increased gain by 7% and reduced feed conversion ratio by around 2%. The corresponding values for the acid were 11 and 4.5%. From this experiment it can be concluded that the effects can partly be related to the anion, but the stronger effect can be related to the addition of formic acid, possibly caused by the additional acidification. However, the effect on the microflora in the duodenum of the piglets appears to be attributed mainly to the additions of the anions (Fig. 4).

In this trial, Kirchgessner *et al.* (1992) obtained almost the same reduction of *E. coli*, Enterococci and Bacteriodaceae when calcium formate or formic acid (in a formate-equivalent dosage) were used. These results indicate that the anion of the organic acid contributed decisively to the nutritive effects of organic acids. This conclusion is supported by results of Eidelsburger *et al.* (1992b), who compared the influence of HCl and fumaric acid on the performance of piglets (Fig. 5). While fumaric acid showed a significant response on performance (gain: +4%, FCR: –5%), the addition of HCl didn't influence the performance of the piglets.

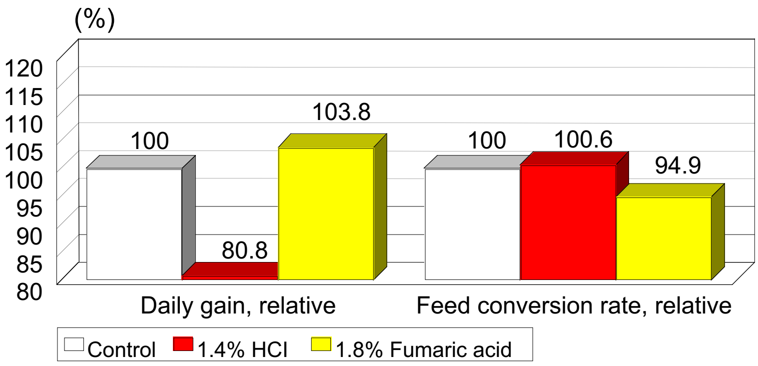
The supplementation of pig-feed with organic acids improved the digestibility of macroelements, too. Kemme (1998) investigated the influence of a combination formic and propionic acids (75:25). An addition of 0.6% of this mixture caused an improvement of digestibility of crude protein, calcium and phosphorus (Fig. 6).

Microbial counts in duodenum of pigets (3 h postprandial)



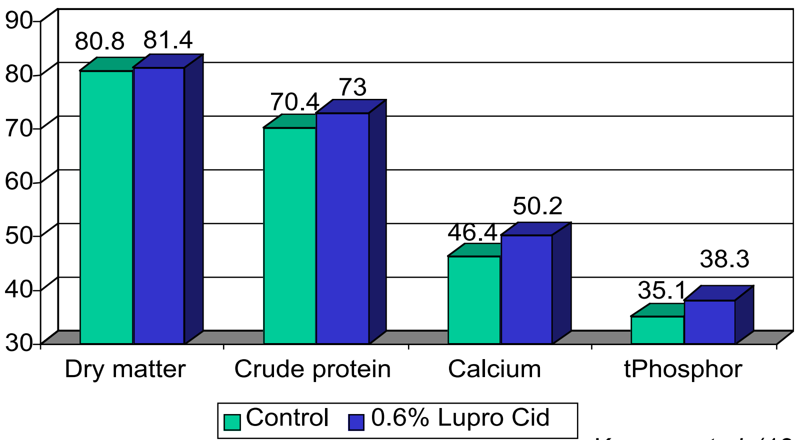
Kirchgessner *et al.* (1992)

Fig. 4. Nutritive effects of formic acid and calcium formate at identical amounts of formates in piglet starter.



Eidelsburger *et al.* (1992b)

Fig. 5. Nutritive effects of organic acid (fumaric acid) and inorganic acid (HCl) at identical reduction of pH value in piglet rearing feed (13-23 kg LW).

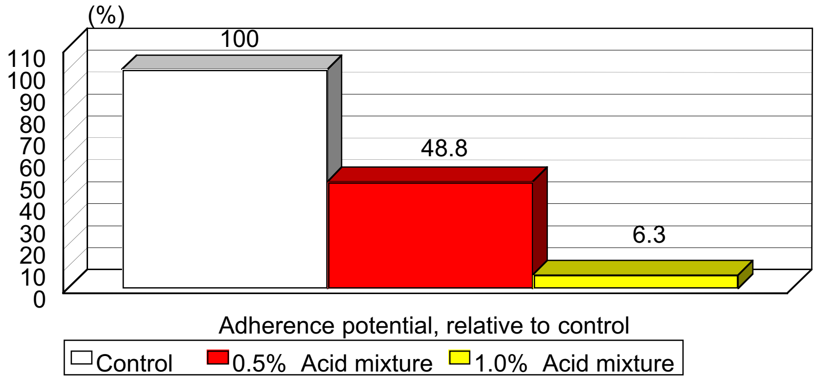


Kemme *et al.* (1998)

Fig. 6. Influence of Lupro-Cid (FA:PA 75:25) on apparent digestibilites in

grower pigs (45 kg LW).

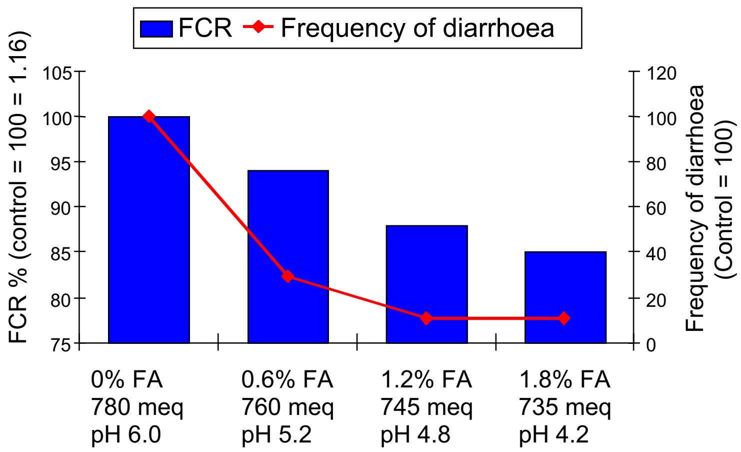
Further possible actions of organic acids and their salts in the small intestine can be concluded from *in vitro* studies conducted by Gedek (1993). In these experiments increasing additions of an acid mixture, containing 50% propionic acid and 50% formic acid, were added to a grower feed. The adherence potencial of *E. coli* with fimbria to the gut wall was investigated. The ability of the *E. coli* to adhere to the gut wall decreased dramatically with increasing dosage of the acid mixture (Fig. 7).



Gedek (1993)

Fig. 7. Influence of additions of an acid mixture (50% formic + 50% propionic acid) to pig feed on the adherence potential of *E. coli* with fimbriae to the gut wall.

In this context it is very important that the risk potential of *E. coli* to cause diarrhoea is closely related to their adherence to the gut wall. After binding to the gut wall these microorganisms produce and liberate their enterotoxins and this is the main reason for the diarrhoea. Based on the pH value conditions in the small intestine it can be concluded, that this effect of organic acids should be related to the bactericidal and bateriostatic properties of the anions of the organic acids. These conclusions are supported by the results of Eckel *et al.* (1992) (Fig. 8). In this trial the addition of formic acid (0 to 1.8%) led to a reduction of the pH (6.0 to 4.2), buffer capacity (780 to 735 mg), feed conversion ratio (1.16 to 0.99) and frequency of diarrhoea (110 to 40%).



Eckel *et al.* (1992)

Fig. 8. Influence of formic acid on pH and buffer capacity of a prestarter and on the FCR and the frequency of

diarrhoea (5-12 kg LW).

One step further to the addition of organic acids might be the combination of acids with phytase and amino acids. The use of microbial phytase is a tool to reduce the addition of inorganic Ca- and P-sources, which generally leads to a reduced buffer capacity of the feed. The reduction of the crude protein content of the diet and the addition of amino acids could round off this feeding concept especially for piglets.

Conclusion

The mode of actions of the addition of organic acids and their salts is not totally understood in order to explain the response in performance and health, which are published in literature.

But some facts help to declare the responses:

(i) Reduced.
- pH in feed and in stomach.
- Acid binding capacity.

(ii) Reduced ammonia concentration in the stomach.

(iii) Increased digestibility of
- Crude protein.
- Energy.
- Calcium.
- Phosphorus.

(iv) Reduced amounts of microorganisms in the duodenum.

(v) Reduced adherence potential of *E. coli* to the gut wall.

Generally, the efficacy of organic acids are higher than their salts and inorganic acids.

A new approach could be the combination of organic acids, phytase and amino acids, which may be a tool to combine maximum performance with sustainable, environmental friendly pig nutrition.

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