Eubiotics and their role in pig nutrition and health

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Despite being beset with a host of diseases, global pig production continues to grow, especially in Asia. However, with the spiralling feed raw material prices, farmers are constantly finding ways to maximise the genetic potential of pigs and one of these measures is to maintain a healthy gut.

While in the past, farmers relied heavily on AGPs in modulating the intestinal ecosystem, the banning of AGPs in Europe has intensified the search for alternatives to antibiotics.

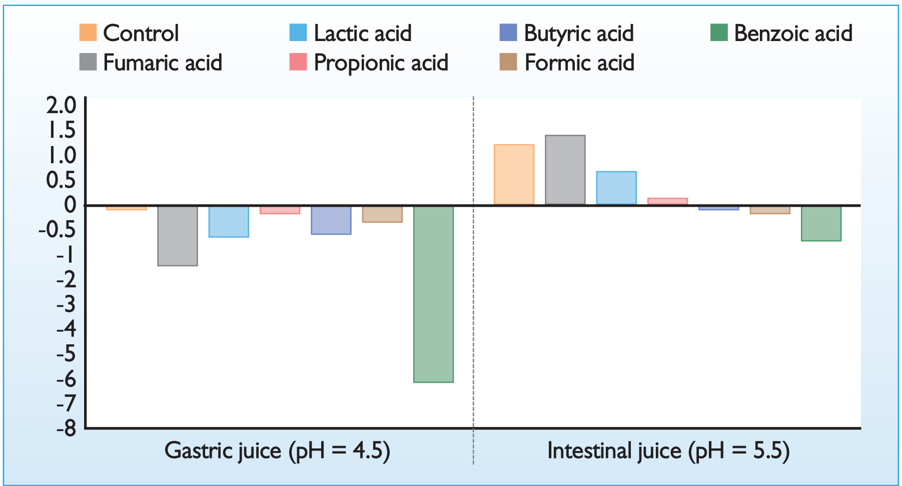

Fig. 1. Specific bacterial growth or death rate in response to various organic acids in swine stomach content at pH 4.5 and small intestinal content at pH 5.5.

Antimicrobial resistance

The key issue which precipitated the ban was the growing problem of antimicrobial resistance in human medicine.

While it is generally accepted that the greater majority of the resistance originates from medical use to treat human disease, concerns were expressed that the use of antimicrobials in animals may be a contributory factor to human resistance.

In 2008, reports indicated that Korea's Ministry for Food, Agriculture, Forestry, and Fisheries was tightening restrictions on the use of antibiotics in animal feed. USDA reported that Korea would phase down the number of allowable drugs over the period of 2008-2011 as a way to reduce their overall use in compound feed that are premixed during production.

Eventually in July 2011, South Korea followed the lead of the EU in banning the use of AGPs. As consumer pressure on food safety mounts and the threat of antibiotic resistance grows, it is just a matter of time before other countries in Asia will legislate against AGP use.

Consumer preference

For the affluent consumers in the West, particularly in Europe, animal welfare, quality, safety and sustainability are important considerations.

Retailers on the other hand are keeping close tabs on these developments and for them traceability and certifications are a must to stay in business.

In the USA, the evolution is less marked than in Europe although organic production is increasing as consumers in large US cities are demanding more natural products. The high profile food scandals and diseases have driven the public to look for safety which they trust the FDA/USDA to ensure. Two major companies have started marketing 'antibiotic-free meat'.

All these consumer demands come with a price tag; hence both in the USA and Europe the retail price is still a key decision parameter especially during crisis times

Table 1. Definition of eubiotics and associated product subgroups.

Eubiotics definition	Products to maintain health and performance by modulating the gut flora			
Concepts	Direct acting gut flora modulators	Probiotics	Prebiotics	Immune modulators
	Compounds directly modulating the microflora via growth inhibition (organic acids, phytogenics)	Living micro-organisms improving the intestinal microbial balance (lactic acid prod. bacteria, yeast, sporulated bacillus)	Oligosaccharides serving as substrate for probiotics and/or regulating epithelial gut cell adhesion (FOS, MOS; mannan, inulin)	Compounds stimulating the animal's immune system (nucleotides, immunoglobulins, glucans)

Natural alternatives

The aforementioned developments in the industry have been the main drivers in the advent of eubiotics in the swine industry.

Eubiotics are defined as non-antibiotic products maintaining the desired balance of the good bacteria and pathogens or 'eubiosis' in the digestive tract. The eubiotics definition covers the four subgroups of direct acting gut flora modulators, probiotics, prebiotics and immune modulators as described in Table 1.

Several eubiotics have been introduced in the market with differing modes of action

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Micro-organism	pH value	Minimum inhibitory concentration (ppm)
Pseudomonas spp.	6.0	200-480
Micrococcus spp.	5.5-5.6	50-100
Streptococcus spp.	5.2-5.6	200-400
Lactobacillus spp.	4.3-6.0	300-1800
Escherichia coli	5.2-5.6	50-120
Bacillus cereus	6.3	500

Table 2. Antibacterial activity of benzoic acid in vitro (adapted from Lueck, 1980).

32-100kg	Control	Benzoic acid (%)		
		0.5	1.0	1.0/0.5
Replicate (pens)[1]	61	61	62	60
Number of pigs	546	546	555	537
Feed intake (FUgp/pig/day)	2.63	2.68	2.67	2.69
Daily gain (g)	963	1006***	1005***	1011***
FCR (FUgp/kg gain) [2]	2.74	2.67**	2.66***	2.66***
Lean meat (%)	60.5	60.0**	59.9***	59.9***
Production value, index	100	110**	110**	110**

[1]9 pigs/pen; [2]1.07 FUgp/kg feed; (*=p<0.05; **=p<0.01; ***=p<0.001)

Table 3. Effect of benzoic acid in finishers

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yet having the same goal: achieving the desired ratio between the good bacteria and pathogens. Probiotics are micro-organisms that have a positive effect on the host by improving the balance of pathogenic to beneficial bacteria in the gut.

Although their use has grown over the years, there is still a lot to be learned about the gut microflora and how their growth and multiplication can be modulated to positively influence the microbial balance.

Prebiotics are non-digestible oligosaccharides serving as substrate for probiotics and/or competing with pathogens regulating gut cell adhesion.

Direct acting gut flora modulators are defined as compounds directly modulating the microflora via growth inhibition. Examples of these are essential oil compounds and organic acids.

Organic acids are now routinely used in weaning piglets during the transition from suckling milk to consuming solid feed to aid in acidifying the feed to prevent bacterial growth and improve digestion of feed ingredients. Benzoic acid and its salts have been used for many years as preservative agents by the food industry. Numerous researches have demonstrated the key properties of this organic acid.

Antibacterial effects

Dissociation of benzoic acid is strongly pH dependent and in its un-dissociated form it exhibits various antibacterial and antifungal activities. Rahn and Conn (1944) reported that the antimicrobial effect of benzoic acid was nearly 100 times as efficient in strongly acid solutions as in neutral ones.

Its spectrum of activity includes mainly Enterobacteria, Bacillus spp. and Micrococci, as well as various fungi and yeasts. Its inhibitory action on yeasts and fungi is the background for a long term use of benzoic acid as the food preservative. In vitro antibacterial activity of benzoic acid is shown in Table 2.

Knarreborg et al. (2002) compared the antimicrobial effects of six different organic acids (formic, propionic, butyric, lactic, benzoic and fumaric acid) in swine stomach content (pH 4.5) and in small intestinal content (pH 5.5), using a specially developed in vitro methodology. The results of this experiment showed that benzoic acid demonstrated the strongest antibacterial property.

After ingestion with the swine diet, benzoic acid obviously exerts strong antibacterial effects on the gut microflora, which can already be observed in the stomach. Due to lower pH values in the stomach, the proportion of the un-dissociated form remains high in this part of the gastro-intestinal tract, allowing strong antibacterial activity. A study in piglets reported by Maribo et al. (2000) revealed a marked reduction in the density and activity of the gastro-intestinal microbiota.

Effects on performance

In 12 studies, the dietary addition of 0.5% benzoic acid resulted in an average improvement of 10.6% and 5.7% in weight gain and feed conversion, respectively when compared with a negative control. On the other hand, when matched up against different acids (single or blend of acids) and antibacterial agents, it registered an average improvement of 5.7% and 2.1% in weight gain and feed conversion respectively.

In a recent study, conducted by Holm (2011) at the Pig Research Center of the Danish Agriculture and Food Council, supplementation of 0.5% benzoic acid had the same effect as 1% benzoic acid as shown in Table 3. The other group of eubiotics which has been extensively evaluated is essential oils. These tend to be the oils extracted from plants which vary depending on plant species, soil type, climatic conditions, harvesting conditions and storage.

Essential oil compounds, on the other hand, refer to the specific active compounds from essential oils. Whereas a mixture of essential oils may vary in the active ingredients due to the natural variation in the plants from which they were derived, a mixture of essential oil compounds will be consistent, reproducible and measurable.

Effects of essential oils

- Stimulation of digestive enzymes:

The mechanism of hot spices activating sensory nerve fibres is through an ion channel. Platel and Srinivasan (2000) reported that the dietary consumption of the active principle of certain spices like capsaicin, piperin and curcumin, stimulated pancreatic enzyme production in rats

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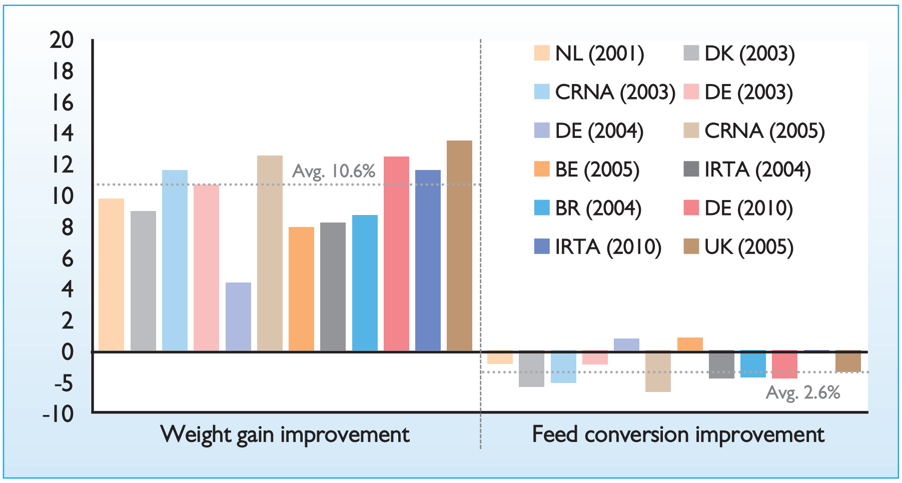
Fig. 2. Efficacy of benzoic acid in piglet diets compared to negative control (Wiemann 2011, DSM internal data, unpublished).



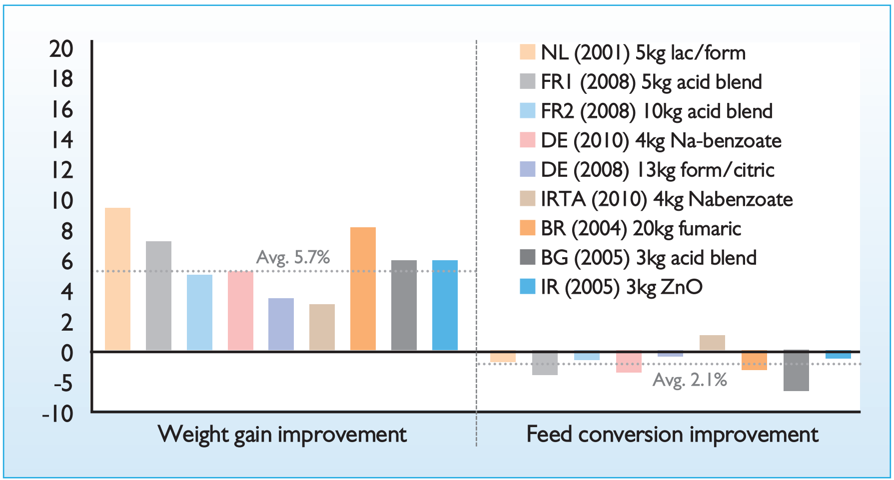


Fig. 3. Efficacy of benzoic acid compared to competitive solutions (Wiemann 2011, DSM internal data, unpublished).

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without affecting feed intake. The stimulation, by hot spices, of endogenous enzymes is a well known effect with the basic mechanisms recently elucidated.

● Antimicrobial effect:

The antimicrobial properties of essential oils are well known and a huge amount of literature is available and the basic mechanisms for some of them were reported. Kamel and McKay (2003) reported that two different commercial blends of essential oils and essential oil compounds could alleviate the growth depression induced by a challenge with Clostridium perfringens in broiler chickens.

● Effect in pigs:

Series of trials conducted in universities around the world, which have been confirmed by extensive trials in the field, have led to the development of specific blends of essential oil compounds with profound effects on pig farming. The basis of all these blends is to take advantage of the different properties of the active components targeting the specific needs of the specific species and the challenges each faces under commercial farming. Essential oil compounds are, to a greater and lesser extent, volatile which gives them certain aromatic properties. They act via the stimulation of the olfactory nerves and taste buds. The pig is especially sensitive to smell during the search for, and ingestion of, feed. A Belgian research institute demonstrated the feed intake response to a blend of essential oil compounds with aromatic property (CRINA) as shown in Table 4. Essential oil compounds like piperin are known to stimulate the production of digestive enzymes. Fig. 5 shows the results of a study conducted at the University of Gottingen, where production of pancreatic amylase in piglets and growing pigs was significantly increased in the group supplemented with a blend of essential oil compounds.

Table 4. The effect of essential oil compounds on feed intake.

	Control	CRINA
No. of animals	40	40
Initial weight (kg)	8.1	8.1
Final weight (kg)	25.7	26.9
Feed intake (g/d)		
Day 1-14	437	457
Day 14-42	744	788
Day 1-42	642	678

Many essential oil compounds have antimicrobial activities, For instance, thymol and eugenol develop their action against bacteria by interacting with the cell membrane. This interaction causes conformational changes in the membrane structure, leading to the leakage of ions across the cell membrane.

Bacteria can usually counterbalance these effects, but bacterial growth is slowed down. A study conducted at Bunge Industries, Australia demonstrated that a specific blend of essential oil compounds reduced the excretion of haemolytic E. coli (Fig. 3). Eubiotics can either be used as single products or a combination of two or more eubiotics. Zhang et al. (2012) evaluated a combination of benzoic acid and either essential oil compounds or probiotic. Results indicated that the combination of benzoic acid + essential oil compounds could improve the growth performance, increase the faecal Lactobacillus population, decrease E. coli counts, as well as reduce faecal noxious gas emission in weanling pigs.

Conclusion

The tightening restrictions on the use of AGPs, the mounting consumer pressure on food safety and the changing consumer preference are the key drivers to the search for viable alternatives to in-feed antibiotics. Several well researched eubiotics have shown promising results in university and field trials and have eventually been successfully used in commercial conditions.

Organic acids like benzoic acid, essential oil compounds, probiotics and nucleotides can be used either as single products or one can combine two or more eubiotics to achieve a higher response. While there has been a number of research studies on the effect of eubiotics, more need to be conducted to fully understand how they act and how farmers can get the most out of their use to maintain gut health and reduce the need for antibiotic treatment. ■

References are available from the author on request

Fig. 4. The effect of essential oil compounds on the production of digestive enzyme.

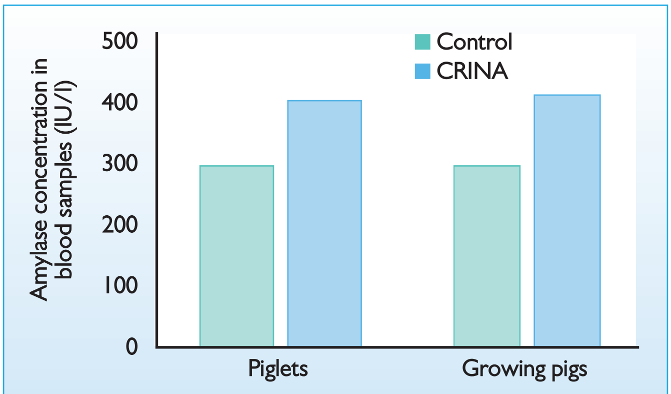

Fig. 5. In vivo effect in piglets of a specific blend of essential oil compounds on haemolytic E. coli excretion.