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A critical review of feeding probiotics to pigs
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Introduction
The role of microorganisms in maintaining animal health is not new. In 1907, Metchnikoff hypothesized that health in ethnic populations was in part a consequence of the composition of their intestinal flora, and claimed that the intake of yogurt reduce toxigenic bacteria in the gut by yogurt lactobacilli with subsequent increased longevity of the host (Metchnikoff, 1907). In epithelia, in particular, commensals are important factors, which regulate local but also systemic defence mechanisms. It has been shown that intestinal microflora are important for resistance to several pathogens such as Salmonella, Shigella, and Vibrio, and that substantially higher doses of these bacteria are needed to kill animals with complete gut microflora compared to germ-free animals (Bohnhoff et al., 1954; Freter, 1955; Freter, 1956; Collins and Carter, 1978). Knowledge of the role of microflora has since been expanded, recently leading to attempts at manipulating such microflora. Oral administration of live nonpathogenic microorganisms may help in modifying the fragile intestinal microbial balance to the benefit of an animal’s health.

What are the probiotics and which are their properties?
Probiotics are products—containing viable defined microorganisms in sufficient numbers—which alter the microflora (by implantation or colonization) in a compartment of the host (Havenaar and Huis In t’ Veld, 1992). Several microorganisms, principally lactic acid bacteria, are considered as probiotics such as Lactobacillus species, Bifidobacterium species, other lactic acid bacteria (Enterococcus faecalis, E. faecium, Lactococcus lactis, Leuconostoc mesenteroides, Pediococcus acidilactici, Sporolactobacillus inulinus, Streptococcus thermophilus) and few non-lactic acid bacteria (Bacillus cereus var. toyoi, B. licheniformis, Propionibacterium freudenreichii, Saccharomyces cerevisiae, S. boulardii) (Hozapfel et al., 2001).

There is still much controversy as to how probiotics work, but the proposed mechanisms include
- adhesion and colonization of the gut mucosa (competition for receptors),
- competition for nutrients,
- production of antimicrobial substances, and
- stimulation of mucosal and systemic host immunity (McNaught and MacFie, 2001).

What is known in non-porcine species?
In humans, probiotics were thought to exhibit several helpful effects such as inhibiting pathogens (particularly those causing enteritis and cystitis), optimizing digestion, immunostimulation, anti-tumor effects (decrease in unfavorable metabolites, for example, ammonium and procarcerogenic enzymes in the colon), and anti-cholesterol actions (Schrezenmeir and de Vrese, 2001). The role of probiotics in infantile diarrhea has been better documented compared to other effects. Clinical trials have, for instance, shown that the number of individuals shedding rotavirus in their stools, the duration of diarrhoea, and the period of hospitalization can be significantly reduced by administration of certain probiotics (McNaught and MacFie, 2001). However, other probiotic microorganisms did not demonstrate similar benefits in the treatment of rotaviral infection in children, a finding suggesting a strain-related protection (Majamaa et al., 1995).

In veterinary medicine, however, their role against enteric pathogens is the main concern. Calves fed milk replacers supplemented with antibiotics or probiotics exhibited similar diarrhea reduction and growth performance from birth to 5 weeks of age (Donovan et al., 2002). Lambs provided with various probiotic preparations shed significantly less Escherichia coli O157:H7 when they were challenged with this serotype (LeMa et al., 2001). Similar results were obtained in feedlot cattle (Brashears et al., 2003) and in experimental mice (Shu and Gill, 2001). The effect of ingested viable Lactobacillus casei on oral infection with the enteric pathogen Listeria monocytogenes was investigated in rats, and it was shown that supplementation of L. casei significantly reduced the numbers of L. monocytogenes in the gastrointestinal tract, spleen, and liver (de Waard et al., 2002).
What is the objective of feeding probiotics to pigs? What are the advantages versus antibiotics?

Although there is considerable scientific debate regarding the importance of microbial resistance owing to the routine use of antibiotics in livestock feeds, there is consensus that we have opportunities to reduce their use. The use of penicillin and tetracyclines in animal feeds is considered a threat by many scientists since these drugs are used to treat human disease. As a consequence, a pathogen may develop resistance and then cause a human health problem that cannot be treated with those drugs. Considering that bacteria can transfer resistance to other types of bacteria species via R-plasmids (bits of genetic material smaller than chromosomes that replicate autonomously in the cell cytoplasm), this threat is thought by many to be particularly acute (Aiello, 1998).

Another potential risk of agricultural use of antibiotics, is the presence of chemotherapeutic residues in food. In Europe, large supermarkets commonly ask suppliers to provide written assurance that all pork was produced without growth promoting feed additives. Almost all growth promoters have been banned in European Union. A similar trend is beginning in the U.S., and some producers who have become involved in both raising and marketing antibiotic-free products are receiving a premium price.

What did the trials show on the use of probiotics to pigs?

In pigs, studies suggest several possible mechanisms for probiotics. These include an increase in intestinal lactic acid concentration and suppression of *E. coli* counts (Kovacs-Zomboksky et al., 1994), inhibition of adhesion of enterotoxigenic *E. coli* K88 to porcine small intestinal mucus (Jin et al., 2000), and an increase in the number of ileal goblet cells and the thickness of colonic mucosa (Breves et al., 2001).

Such products may play a role in combating enteric diseases. Gnotobiotic pigs receiving a *Streptococcus faecium* strain, and subsequently challenged with various pathogenic strains of *Escherichia coli* have shown less diarrhea, earlier recovery, and reduced morbidity and mortality when the *Streptococcus faecium* strain was administered prior to challenge compared to non-treated challenged pigs (Underdahl, 1983). It has been shown that, *Bacillus cereus* administered both in sows’ feed and in creep feed can significantly reduce suckling piglet mortality from 24% to 2% in a farm with mastitis problems (Alexopoulos et al., 2001). This may be caused by increased fat content of dam’s milk, or/and to the beneficial environment for the piglets due to modification of dam’s fecal excreta. In this same experiment, the dam experienced reduced loss of bodyweight and a shortening of weaning to service interval. Better microfloral balance in the gut and improvement of the body condition of the sow—as is the case in young animals—may also be a possible explanation.

Probiotics may also be helpful in preventing post-weaning diarrhea in the nursery stage. Morbidity and mortality was significantly reduced, by 40% or more, depending on the bioregulating microorganism and dose, and fewer pigs tend to excrete F4 haemolytic *Escherichia coli* when receiving probiotics compared to non-treated animals (Kyriakis et al., 1999).

A growth-promoting effect of some probiotics (e.g., *Bacillus licheniformis*) may also be observed after weaning (Kyriakis et al., 1999; Kyriakis et al., 2003; Kritas, 2000). Average daily weight gain and feed conversion ratio were significantly improved in probiotic-treated compared to non-treated antibiotic-free weaned pigs (Kyriakis et al., 1999; Kyriakis et al., 2003; Kritas, 2000). Thus, in some cases probiotics may also be viewed as substituting for antibiotics.

In a recent trial performed in the United States (with the support of National Pork Board), the potential economic benefit of the use of probiotics in weaned pigs in a high health status farm was investigated (Kritas and Morrison, unpublished data). Groups of pigs receiving low doses of antibiotics throughout the entire nursery period were compared with groups receiving a mixture of *Bacillus licheniformis* and *B. subtilis* (but no antibiotics or growth promoters). A total of 4,381 pigs allocated in 9 probiotic-groups and a total of 4,054 pigs allocated in 8 antibiotic groups participated in the trial. Average age entering the nursery was 19.4 days. The average initial and end bodyweight of pigs was 6.0kg and 25.6kg for antibiotic-group, and 6.0kg and 25.1kg for probiotic-group, respectively (*P*>.05). The average time in the nurseries was the same for both groups (43.5 days). The average daily gain, average daily feed intake, and feed conversion ratio were 0.436kg, 0.636kg and 1.39 for antibiotic-group, and 0.423lbs, 0.605kg, and 1.50 for probiotic-group, respectively (*P*>.05). Feed cost per pig was US$7.84 and US$8.07, and feed cost per kg of bodyweight was US$0.407 and US$0.427 for antibiotic and probiotic-group, respectively (*P*>.05). Mortality rate was 1.81% for antibiotic-group and 1.55% in probiotic group (*P*=.244). These results were encouraging and showed that pigs receiving probiotics can perform similarly to pigs receiving antibiotics in high health status nurseries. The implication is that the producer may be able to maintain the performance of nursery pigs, while reserving antibiotics administered through the feed for therapy or prevention of more serious health conditions.
Are the results consistent?

No they are not. While probiotics have been used for many years, systematic knowledge is rather shallow. Protocols for testing probiotics have varied substantially and do not allow for direct comparison. Each probiotic preparation is different, based on a single or a mixture of microorganisms, and not all microorganisms (and/or their metabolites) behave similarly against a certain pathogenic strain. Thus it is expected, for instance, that the effect of *Bacillus licheniformis*, *Streptococcus faecium*, or *Lactobacillus casei* against the same strain of *E. coli* will not be the same. Also, testing of probiotics has often been performed in non-target species and the target animal may carry different receptors involved in pathogenesis. Finally, the health status of a farm and factors that determine it (e.g., pig flow), may account for significant variability in results. All these effects create an impression of inconsistency of results, and therefore some researchers remain skeptical about their reported benefits.

However, inconsistency of results is a characteristic of every new development. Our opinion is that probiotics are not a panacea and should be used after critical thinking. They can be introduced in cases similar to that described as successful in literature. If novel applications are sought, limited number of pigs should be used and the product should be tested. Failure does not necessarily mean that probiotics do not work. Their effect is dependent on several factors as previously mentioned. Trial-and-error thinking should be practiced at least in the first years of investigating their effect. Their potential to substitute for antibiotics in simple illnesses and to produce “ecological” pork may also guide practitioners’ decisions.

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