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Enhancing intestinal function of monogastrics

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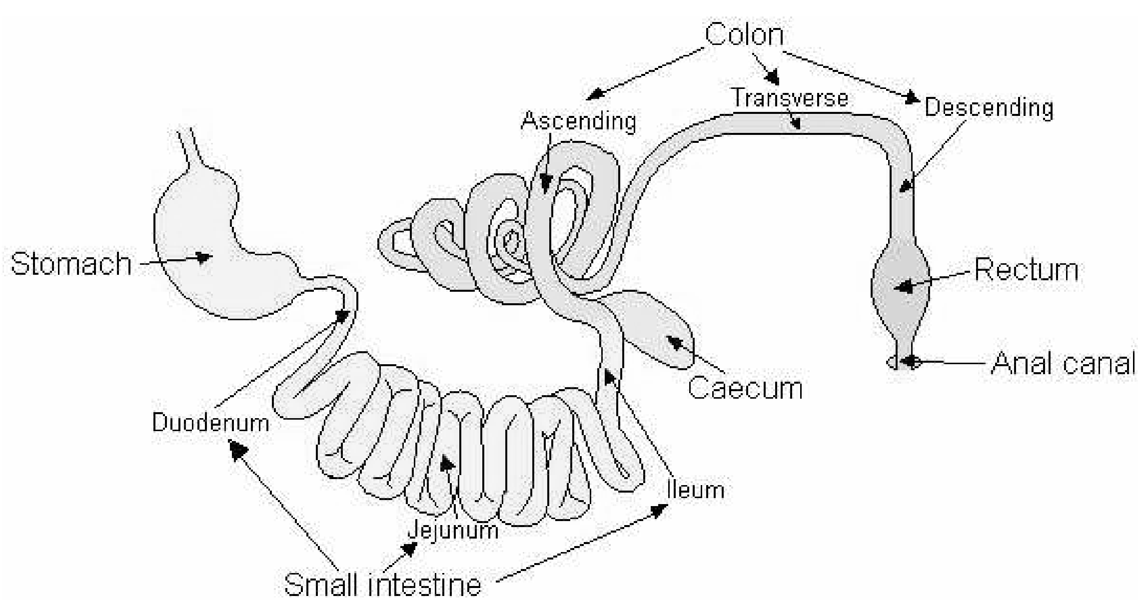
Introduction

The alimentary tract of monogastrics is an essential organ, which maintains the nutrient status of the gut, as well as provides nutrients to maintain the nutritional status and homeostatis of the whole organism. In most monogastric animals, the gastrointestinal tract is composed of the stomach, small intestine (duodenum, jejunum and ileum), and large intestine (caecum, colon and rectum) as shown in **Figure 1**.

The gastrointestinal tract is the first organ to respond to composition of the diet, therefore, enhancing intestinal function will require an understanding of gastrointestinal tract system. Generally, the function of the gastrointestinal tract is to take care of the food and its breakdown into simpler molecules that are absorbed across the enterocytes lining the villi or lymph to satisfy the nutritional needs of the animal. Simultaneously, the gastrointestinal tract is responsible for the protection of the body against penetration of toxic substances and pathogens, which are present in the feed (Iatropoulos, 1986). The luminal surface of the whole gastrointestinal tract is covered with mucosa consisting of epithelial cells and mucus. Mucus is a complex glycoprotein (mucin) secreted by epithelial cells, and protects the epithelium. Mucus lubricates the food and can immobilize bacteria, and also contains immunoglobulins (IgA) that are involved in the defense against pathogens (Junqueira, 1989).

Food chewed and mixed with secretions of the salivary glands in the mouth is directed through the oesophagus to the stomach where the food is mixed with gastric secretions (hydrocholic acid and pepsin). The food is released at a controlled rate (Bastianelli, 1998) into the small intestine, where the contents is mixed with the secretion of mucosal cells and pancreatic juice and bile. The digestion of food completed and the products are absorbed along the small intestine. The anatomic adaptation is due to the extension of the surface by folds and villi formed by the mucus membrane. Any undigested feed is transported to the colon where the absorption of water and electrolytes occurs. The undigested feed also acts as substrate for the microflora to increase the microbial mass. Thus the two primary functions of the gastrointestinal tract is to act as the critical interface between the digested feed and the blood circulation and to house the intestinal microflora, which is important for maintenance of gut health, but can also be a problem when pathogenic microflora gain the upper hand over the beneficial microflora.

Figure 1: Gastrointestinal tract of most monogastric animals.



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The performance of the gastrointestinal system can be improved by modifying:

- gastric pH
- level and type of enzyme production
- secretions of the gastrointestinal tract
- products of fermentation and overall microbial balance

The numerous factors that enhance the gastrointestinal function of monogastrics include antibiotics, enzymes, probiotics, prebiotics, and botanicals. This paper will discuss the benefits of these factors on intestinal function.

Enzymes

Along the gastrointestinal tract, pigs have a variety of enzymes to aid in digestion of feed. Young pigs produce inadequate amounts of certain enzymes and adult pigs lack the proper enzymes to digest some plant materials containing complex carbohydrates, such as cellulose, xylans and β-glucans (Partridge, 1993). Therefore, the addition of enzymes to feed may be useful strategy to increase its digestibility. Dietary enzymes may supplement the pigs own digestive enzyme activity or enhance the pigs ability to utilize the nutrients in complex feedstuffs which normally pass unchanged through the gastrointestinal tract. Amylase, protease and lipase additions have shown to improve post-weaning growth and minimize digestive disturbances (Liu and Baidoo, 1996). The use of β-glucanase and xylanase are beneficial with high fiber grains such as hulless barley, (Yin et. al 2001), wheat, barley and their by-products Cheeson, 1987). The enzyme phytase can decrease the anti-nutritional effects of phytate which binds 50 – 75% of the phosphorus in vegetable matter (Baidoo et. al. 2003). The use of feed enzymes has become strongly established in the feed industry especially when considering alternative feeding systems for mongastrics.

Antibiotics

Antibiotics have been used in animal production since the 1950s. The primary effects of the antibiotic growth promoters are increased growth, improved feed efficiency and lower incidence of certain diseases. The beneficial effect of antibiotics is the influence on gastrointestinal microflora. The is achieved by controlling clinical and sub-clinical diseases, stabilizing gut microflora, reducing the abduction of important nutrients from the small intestine by incorporation into the bacterial mass and reducing bacterial degradation of nutrients such as vitamins and amino acids. The development of antibiotic resistance microflora has increased the search for alternatives for antibiotics. These alternatives to antibiotics are likely to be effective if they function to control and stabilize the gastrointestinal tract microflora.

Botanicals in animal feed

Essential oils from various botanical parts of herb and spice plants are extracted by steam distillation or cold press systems. Essential oils are very complex mixtures of compounds and their chemical composition and concentrations can vary due to many factors, including genotype, growing and harvesting conditions, methods of extraction and sample preparation. For instance, thyme oil contains carvacrol and thymol and these can vary from 3% to 60% of the total oil content (Lawrence and Reynolds, 1984). Variability in any animal response is clearly related to the dose of the active component included in the nutritional package. Essential oils are composed of several classes of compound including, terpenes, phenols, alcohols, ketones, aldehydes, esters, ethers and oxides. Various essential oils have been reported to improve animal performance by their stimulating action on gut secretions (Harada and Yano, 1975; Platel and Srinivasan, 1996). The use of cayenne pepper containing capsaicin and piperine, and also cinnamon bark containing cinnamaldehyde has been demonstrated to stimulate salivation (amylase production) and pancreatic enzyme secretions (protease production). The increases in enzyme production can result in improvements in digestibility and availability of nutrients from feedstuffs. Reducing the amount of undigested material passing into the large intestine limits the amount of substrate available for proliferation of pathogenic bacteria.

Many essential oils have antibacterial activity (Dorman and Deans, 2000). The main active components are terpenes and phenols. The principal mode of action is thought to be due to damage to the cell wall lipo-protein structure allowing for leakage of cytoplasmic contents. It is critical to have standardized active components and not crude plant extracts to obtain consistent antibacterial function. HPLC and GC traces should therefore be obtained with each consignment of oil to ensure the presence of adequate amounts of the essential oil

The dietary amount of oil to be used as a nutritional supplement will depend on the bacterial organism being targeted and the type of oil being used. Minimum Inhibitory Concentrations needs to be known for the different oils and for the different specific bacteria. This allows maximum and consistent effect in the animal and minimizes the cost of the nutritional supplement. The ideal oil or mixture is one that has less antibacterial activity against the beneficial bacteria and is very potent against the potential pathogen. The absorption, metabolism and excretion of various essential oils has been studied and due to quick absorption and rapid metabolism, the breakdown products are either eliminated by the kidneys in the form of glucuronides or exhaled as CO_2 (Kohlert et al., 2000). Rapid clearance and short half lives indicate minimal risk of tissue accumulation. However a withdrawal period of a few days prior to slaughter would be prudent.

At weaning the piglet needs to adjust from passive immunity received from the sow and develop active immunity based on exposure to microorganisms in its environment. The stress of moving and mixing pigs, together with dietary changes, often triggers an increase susceptibility to a pathogenic disease challenge. The quest for alternatives to sub-therapeutic doses of antibiotics in swine feed has recently included the testing of a number of herbs or herbal mixtures. Many of these "natural remedies" are known to have natural antimicrobial activity effects (which may protect pigs against pathogens). They may also increase the palatability of diets and thereby increase feed intake.

The following botanicals have been suggested for inclusion in swine feeds based on their pharmacological characteristics.

Oregano (Origanum vulgare ssp.)

It has been suggested that oregano stimulates organic and micro-biotical digestion (De et al., 1999). Oregano supports digestion and regulation of gastrointestinal metabolism, exerts antibacterial properties and hinders overgrowth of pathological flora in the digestive tract of pigs (Kyriakis et al., 1996; Sivropoulou et al., 1996). A study stated that 1000 ppm-dose oregano feed supplementation during the postweaning period significantly improves weight gain and health of the pigs (Gertenbach and Bilkei, 2001). According to published data, oregano etheric oils exert insecticidal (Konstantinov et al., 2003), antioxidant (Economou, et al, 1991), antioxidant, antibacterial (Didry et al., 1994; Omoregbe et al., 1996; Valsaraj et al., 1997; Ali-Shtayeh et al., 1998), antifungal (Thompson, 1989), and anti-inflammatory effects (Azuma et al., 1986). The oregano oil is a phenolic compound comprising of more than 30 different ingredients. The major components, which have also shown the strongest antimicrobial activity, are carvacrol (81-84%) and thymol (1.6-2.8%) they work together, showing a synergistic effect, although the ratio of carvacrol to thymol within the oil seems to play a major role in its antimicrobial activity. Other components (e.g. polyunsaturated fatty acids) of oregano etheric oils do not negatively influence the antibacterial effect of oregano (Juven et al., 1994). The postparturient immune system of the sow might be positively influenced by oregano, diminishing delayed immune response and increasing leukocyte activity of the sows early postpartal uterus (Bilkei, 1995). Such an effect might improve uterine involution and protect the sow from possible urogenital infections post partum (Bilkei, 1995). The increased performance of oregano-fed sows might have been the cumulative result of anti-inflammatory, antibacterial and antioxidant effects of oregano etheric oils. Additionally, an appetite enhancing effect might have resulted in higher voluntary feed intake in the oregano treated sows (Mauch and Bilkei, 2004). Oregano as a feed additive of natural origin may be more consumer and environment friendly, and cost effective than antibiotics. Nevertheless, there is currently no evidence that oregano would be as effective and safe as antibiotics, particularly if it exerts antimicrobial effects.

Echinacea (purple coneflower)

Echinacea species are perennial herbs capable of growth throughout the temperate regions. There are nine species, but *E. augustifolia*, *E. purpurea* and *E.pallida* are most commonly considered for medicinal purposes (Taylor, 1968). The whole plant, including aerial portions and t aproots, has been utilized. Additionally, pressed juice from the aerial portion of *E. purpurea* and aqueous and alcohol extracts of the roots have viral inhibition characteristics in cell culture (Wacker and Hilbig, 1978). The German government has approved oral use of Echinacea for respiratory and urinary tract infections and topically for improving wound healing. Liquid preparations have been shown to have immune-stimulating activity and enhance several white blood cell types as well as phagocytes (cells that can destroy bacteria and protozoa (Goldberg, 1999).

Goldenseal (*Hydrastis canadensis*)

Goldenseal, native to eastern North America, is a perennial herb. The most pharmacologically active isoquinolone alkaloid, berberine, is concentrated in the rhizome and roots. Berberine has been demonstrated to possess antimicrobial, immunostimulatory, anticonvulsant, sedative, hypotensive, choleretic and carminative activity. This antimicrobial activity has been demonstrated against a wide range of bacteria, protozoa and fungi (Duke, 1985). Berberine and berberine-containing plants are generally considered non-toxic. The LD50 for berberine in rats was reported as greater than 1000 milligrams per kilogram body weight (Hladon, 1975).

Peppermint (*Mentha piperita*)

Peppermint grows under a wide range of conditions. The most popular varieties are black peppermint (*Mentha piperita* var. *vulgaris*) and white peppermint (*Mentha piperita* var. *officinalics*). The major medicinal components of peppermint are the volatile oils found predominantly in the aerial portions of the plant. The principal components of these oils are terpenoids, menthol, methone and menthyl acetate. Other components that may have pharmaceutical properties include polyplenols, flavonoids and betaine. Menthol possesses carminative, antispasmodic and cholerectic properties. Peppermint and other members of the mint family have demonstrated significant antiviral capability including treatment of the common cold (Kerman and Kucera., 1967). Peppermint also inhibits antimicrobial activity against *Streptococcus pyogenes*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Candida albicans* (Sanyal and Varma, 1969). The LD50 of menthol in rats is 3,280 mg/kg and a fatal dose for humans was reported as 1 g/kg. Hypersensitivity reactions (skin rashes) have also been reported (Bridges et al., 1995).

Probiotics

The swine intestine is inhibited by a large diversity of bacteria which can perform different functions through bacteria-bacteria interactions and host-bacterial interactions for the host. Thus, the intestinal microflora has been considered as a postnatally acquired organ (Schiffrin and Blum, 2002). The balance and stability in the microflora composition is very important for the homeostasis of the host and an intestinal disease condition is often characterized by a disturbed microflora community in the gut. The term 'probiotics' has been defined 'a live microbial feed supplement which beneficially affects the host animal by improving its microbial balance' (Fuller, 1989).

The normal microflora prevents colonisation of the gut by pathogens through "barrier effect" which can be achieved through the following mechanisms: (i) the competition against pathogens for mucosal specific niches; (ii) the competition against pathogens for nutrients; (iii) the production of bactericidal or bacteriostatic products; (iiii) the production of some digestive and protective enzymes and certain vitamins; (iv) modulation of cellular mechanisms related to host defenses and tissue homeostasis (Holzapfel et al., 1998; Blum et al., 1999). Even in the normal microflora of a host in healthy state, some minor groups of pathogenic and opportunistic organisms including bacteroides, clostridia and *Escherichia coli* are present in low numbers. The presence of these organisms in the gut does not necessarily mean that the disease will develop since their pathogenic effects are kept in check by the normal equilibrium of gut microbial metabolism (Holzapfel et al., 1998; Ziemer and Gibson, 1998). The disease can occur when homeostasis of the normal flora is disturbed by the invasive bacteria or other factors which allow overgrowth of the pathogens (Ziemer and Gibson, 1998).

Antibiotics have been routinely supplemented at prophylactic level in swine diet to improve health status and promote growth performance. Possible ban on the use of antibiotics in the future in animal agriculture promotes the investigation on antibiotic alternatives including probiotics. Probiotics offer dietary means to support the balance of intestinal flora. They have been claimed to be able to counteract local immunological dysfunctions, to stabilize the gut mucosal barrier function, to prevent infectious succession of pathogenic microorganisms or to influence intestinal metabolism (Holzapfel et al., 1998). Collins and Gibson (1999) summarized that an effective probiotic should 1) exert a beneficial effect on the host, 2) be nonpathogenic and nontoxic, 3) contain a large number of viable cells, 4) be capable of surviving and metabolizing in the gut, 5) remain viable during storage and use, 6) have good sensory properties, and 7) be isolated from the same species as its intended host. Strains of lactic acid bacteria such as *Lactobacillus* and *Bifidobacterium*, strains of *Bacillus* and *Streptococcus*, and yeast have been used as probiotics in swine (**Table 1**).

In general, inconsistent results have been reported with the probiotics studies in swine, which may be explained by the following several reasons (Stavric and Kornegay, 1995):

- the health and nutritional status of the animal
- the presence of any kind of environmental stress
- genetic and strain differences of the animals
- the age and type of animal
- probiotic viability and stability
- the species specificity of problem (probiotic to host)
- dose level and frequency of feeding or administering
- drug and other interactions
- lack of systematic investigation by researchers

In addition, the effect of probiotics was slower and milder than antibiotics. Probiotics may promote growth under situations in which certain pathogens are present or in poor sanitary conditions. Although the presence of normal gut bacteria contributes to many beneficial effects as stated before, it can also result in negative effects including a thicker gut wall, heavier intestinal weight, reduced absorptive capacity, and a more rapid mucosal cell replacement rate, probably due to the host responses to bacterial antigens or metabolic byproducts (Anderson et al., 1999). The gut microbiota may be competitive with the host in the small intestine though cooperative in the large intestine. The indigenous microbiota in the small intestine can depress pig's growth performance by (1) competing with the pig for nutrients, and (2) producing microbial metabolites that increase gut mucosa turnover and consequently reduce growth efficiency (Anderson et al., 1999). Therefore, a net beneficial effect can be only observed when the positive effects of probiotics supplementation outbalance the negative effects due to the inhibition of normal gut microflora.

Prebiotics

The composition of the swine microflora is influenced by many factors including the age, nutritional requirements,

Table 1: Studies investigating the use of probiotics in swine

Probiotics used	Animal	Effects	Reference
Bifidobacterium pseudolongum *Lactobacillus acidophilus*	Sucking and weaning pigs	promoting the growth and reducing the mortality and rate of diarrhea. improved ADG was more evident during suckling period than during weaning period.	(Abe et al., 1995)
Lactobacillus acidophilus	piglets	Improved BW gain and feed conversion. Increased number of leukocytes in blood.	(Pollmann et al., 1980a)
Streptococcus faecalis	piglets	promoted colonization by beneficial bacteria and decreased the occurrence of detrimental bacteria, such as *Salmonella,* in the intestine	(Ozawa et al., 1983)
Lactobacillus acidophilus *Streptococcus faecium*	piglets	Improved BW gain Effect of *L. acidophilus* on piglets was different from that of *S. faecium*	(Pollmann et al., 1980b)
Active dry yeast (*Saccharomyces cerevisiae*)	Sow and piglets	greater content of gamma globulin in sow milk improved postweaning rate and feed efficiency	(Jurgens et al., 1997)
Active dry yeast (*Saccharomyces cerevisiae*)	Weanling pigs	Decreased number of total bacteria and lactobacilli (Exp. 2), increased yeast cells in feces (Exp. 1) Improved ADG when diets contained growth-promoting antimicrobials (Exp. 2)	(van Heugten et al., 2003)
Yeast culture (*Saccharomyces cerevisiae)*	Weanling pigs	no effect on ADG and ADFI, variable effects on G:F no effect on apparent nutrient digestibilities	(Kornegay et al., 1995)
Yeast culture (*Saccharomyces cerevisiae)*	Weanling pigs	Only improved ADFI	(Mathew et al., 1998)
Bacillus subtilis, *Bacillus licheniformis*, and *Bacillus pumilus*.	Finishing pigs	No effect on growth performance and nutrient digestibilities	(Kornegay and Risley, 1996)
Bacillus subtilis	Sow Weanling pigs Growing pigs	No effect on performance	(Danielson, 1988)

immunologic status, intestinal pH, digesta transit time, interactions between flora components, and presence and availability of fermentable material in the gut. Of these, it is probably the amount and type of growth substrate that has the most influential role. Using prebiotics in swine diet is another way of beneficially modulating gut microflora in addition to probiotics. A prebiotic is "a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and(or) the activity of one or a limited number of bacteria in the colon and thus improves host health." (Gibson and Roberfroid, 1995). Most searches for prebiotics are directed toward

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the growth of lactic acid–producing microorganisms due to their purported health-promoting properties (Collins and Gibson, 1999). Example prebiotics include fructooligosaccharides (FOS, such as oligofructose and neosugar), inulin, galactooligosaccharides (GOS), Lactulose, and Lactitol.

Prebiotics such as inulin and FOS differed from other fermentable carbohydrates (e.g., resistant starch and other dietary fibers) in that the colonic fermentation of inulin or FOS is accompanied by a significant change in the composition of the colonic microbiota due to selective proliferation of bifidobacteria (Gibson and Wang, 1994) and a concomitant inhibition of the growth of other bacteria such as enterobacteria (Mitsuoka et al., 1987), *clostridia* (Kullen et al., 1998; Estrada et al., 2001) and *salmonella* (Oyarzabal and Conner, 1996). The toxic compounds formed during the fermentation of feed in the gut, including ammonia and amines (liver toxins), phenols and cresols (cancer promoters), and indole and skatole (carcinogens), are often classified into growth-depressing metabolites (Anderson et al., 1999). Since 40 to 55% of colonic solids are bacterial mass, the amount of toxic metabolites formed by gut fermentation cannot be ignored. Bacteria known to participate in the formation of these metabolites are *Escherichia coli*, *clostridia*, *Bacteroides spp*., *Streptococcus fecalis*, and *Proteus* (Tomomatsu, 1994). Bacterial enzymes such as azoreductase and beta-glucuronidase, the synthesis of which depends on bacteria and gastrointestinal ecology, synthesize these metabolites. Clostridia show the highest, whereas bacteroides, eubacteria and peptostreptococci show less, and bifidobacteria show almost no activity of these enzymes (Saito et al., 1992). In addition to promoting fecal putrefaction, these harmful bacteria often are disease causing. In swine, the enterotoxic diarrhea can be caused by *Escherichia coli*, *Clostridium perfringens*, *Salmonella enterica*, and *Brachyspira spp.* (Moxley and Duhamel, 1999).

The intestinal microflora at weaning includes large numbers of bifidobacteria that are adapted to the utilization of oligosaccharides present in the maternal milk (Chesson, 1994). The inclusion of oligosaccharides in the weaner diet minimises the changes in the intestine and helps to maintain the bifidobacteria microflora at the particularly stressful period of weaning (Chesson, 1994). Bifidobacteria are anaerobic, rod-shaped, gram-positive bacteria that are normally present in the intestinal flora of humans and animals (Scardovi, 1986).

Several authors reported increased growth and improved feed conversion ratio together with an improved intestinal health as a consequence of FOS or trans-galacto-oligosaccharides (TOS) inclusion in young pigs' diets (Hidaka et al., 1985; Fukuyasu and Oshida, 1986; Hidaka et al., 1986; Katta et al., 1993; Oli et al., 1998). Estrada et al. (2001) found that 18 d old piglets fed 0.5% FOS combined with two administration of oral dose of *B. longum* grew faster ($P < 0.001$), had reduced fecal total anaerobes and clostridia and increased bifidobacteria than negative control group only in the first week of the study. Other authors reported no or slightly negative effects of FOS on young pigs' growth performance and intestinal bacterial populations (Farnworth et al., 1992; Kornegay et al., 1992; Houdijk et al., 1998). Several factors may be responsible for explaining the inconsistent results. First, the efficacy of feed additives such as antibiotics, organic acids, prebiotics and probiotics vary substantially under different management conditions. At optimal growth performance, little or no response to these feed additives can be expected. However, when growth performance is reduced due to intestinal microbial imbalance, the response to these additives may increase (Cole, 1991). Second, the inconsistent reports may be due to the length of the studies, the different products used (e.g., the different chain length of the fructan) as well as group specific situations.

Early-weaned pigs have low feed intake at weaning. Thus, administering inulin through drinking water may be more efficient way to ensure adequate inulin intake for early-weaned piglets compared with dietary intake. A study conducted at the University of Minnesota (He et al., 2002) showed that supplementation of inulin in water ($3\ g \bullet d^{-1}$) tended to improve early weaned piglets' growth performance. The subsequent study with wean to finish pigs showed that continuous supplementation of inulin in water can improve pig performance during the late growth stage (> 50 kg BW, see **Figure 2**) (He, 2004). However, the improved growth rate by inulin was not associated with an increased plasma concentration of insulin-like growth factor-I (data not shown). In that study, the dietary treatments were: (1) corn soybean meal control diet, CON; (2) CON supplemented with inulin (Encore Technologies, Minnetonka, MN) in water, INU; (3) dried unmolassed ground sugar beet pulp with inclusion rate of 5%, 7%, 9%, 12% and 12% for 5.7-10, 10-20, 20-50, 50-90, and 90-115 kg BW, respectively, SBP; (4) CON supplemented with 0.5% antibiotics (supplied 100 mg aureomycin, 100 mg sulfamethazine, and 50 mg penicillin per kg diet; ASP 250, Alpharma) for 5.7-10, 10-20, and 20-50 kg BW, 0.0% for 50-90, and 90-115 kg BW, AB.

The results of the studies implied that beneficial type of microflora may develop and exert growth promoting effect through continuous and long time prebiotic (inulin) supplementation. It is critical to understand the microbiological mechanism of action for prebiotics. However, with traditional plating method, the change in microflora composition due to prebiotics was hardly detectable (**Table 2**). On the contrary, not only the reduced total number of bacteria but also the microflora composition change due to antibiotics intervention was detected. Another in-

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Figure 2: Effect of inulin supplemented in water, sugar beet pulp, and anbiotics supplementation on the growth performance of wean to finish pigs.

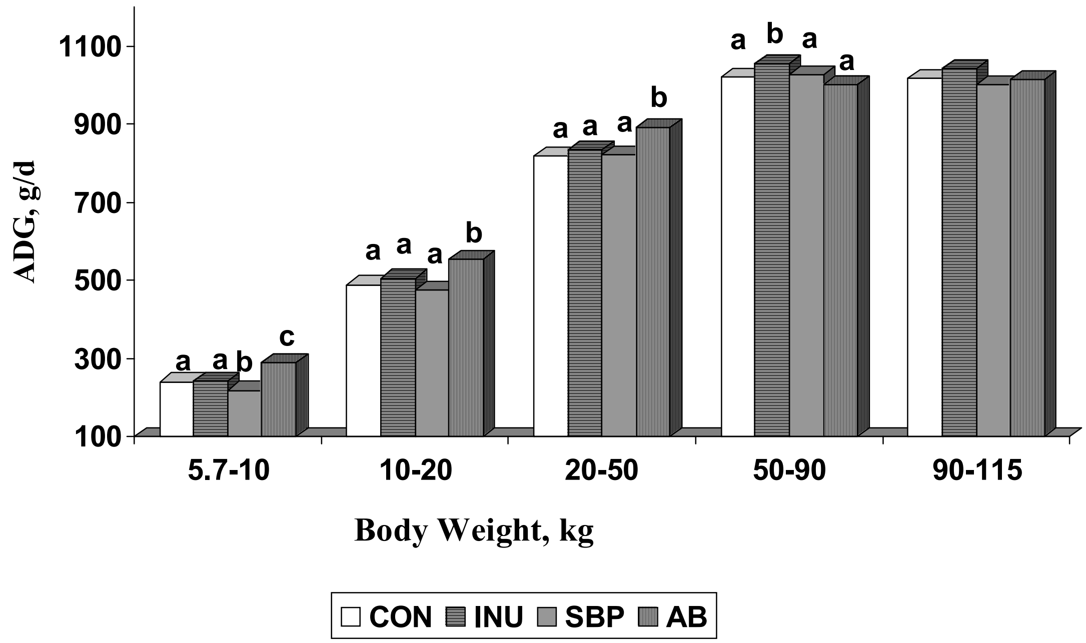

Table 2: Prevalence of microorganisms ($\log_{10}$ cfu/ g fresh weight contents) in feces of pigs fed different diets[A]

Criteria	Diet			
	CON	*INU*	*SBP*	*AB*
20-50 kg BW				
Total aerobes	10.30^{b}	10.40^{b}	10.06^{b}	9.35^{c}
Coliforms	5.23	5.35	5.02	5.90
Lactobacilli	9.53	9.54	9.34	9.34
Total anaerobes	10.31^{b}	10.50^{b}	10.21^{b}	9.49^{c}
Bifidobacteria	9.96^{b}	9.71^{b}	9.64^{b}	8.73^{c}
50-90 kg BW				
Total aerobes	7.67^{b}	8.40^{c}	7.82^{b}	8.53^{c}
Coliforms	3.11	3.34	3.03	3.26
Lactobacilli	6.82^{b}	6.97^{bc}	7.73^{d}	7.45^{cd}
Total anaerobes	7.52^{c}	7.91^{bc}	7.61^{c}	8.37^{b}
Bifidobacteria	7.07	7.05	7.15	7.15

[A] CON = control diet; INU = inulin supplemented in water diet; SBP = dried sugar beet pulp supplemented diet; AB = antibiotics supplemented diet. SEM = standard error of the mean. Means with different superscripts within rows are different ($P < 0.05$).

teresting finding of this study was that withdraw of antibiotics from the feed in growing-finishing stage resulted in increased number of bacterial counts as well as changed microflora composition in the feces. Using other technique such as direct gas chromatography of fecal samples, the microfloral change due to prebiotics (inulin), though probably milder than the change due to antibiotics, can be clearly detected (He, 2004).

Limited information is available for the effect of inulin or FOS on nutrient utilization in pigs. It seems that inulin hardly affects nutrient utilization, especially protein. In weanling pigs and growing pigs, diets supplemented with 0.75 or 1.5% FOS did not affect either ileal or fecal digestibility of dry matter, organic matter, or crude protein (Houdijk et al., 1999). Similar results were obtained with finishing pigs. When 6% inulin was added to barley-wheat-soybean meal diet in 90 kg pigs for 7 d, consumption of inulin did not affect ileal protein digestion, or the viscosity in the ileal effluent. In addition, no significant difference in fecal nitrogen digestibility and excretion was found but colonic ammonia concentrations were lower in pigs when inulin was given. Besides, plasma urea concentration and nitrogen retention were not affected by inulin intake although there was a tendency that the increase in fecal nitrogen output was compensated by a proportional decrease in urinary nitrogen excretion when inulin was consumed. (Vanhoof and De Schrijver, 1996b).

In finishing pigs, when 6% inulin was added to the diet, ileal and fecal absorption, as well as retention of Ca and P tended to decrease (Vanhoof and De Schrijver, 1996a), although the lower ileal absorption of Ca, and P in pigs receiving inulin may not be related to the ileal viscosities or the binding capacities of inulin (Levrat et al., 1991). Thus the effectiveness of inulin in swine diets on mineral utilization remains to be proved.

Another possibility in microflora management procedures is the use of synbiotics, in which probiotics and prebiotics are used in combination. Because its specific substrate is supplied, the survival and proliferation of the probiotic organism could be selectively promoted. However, there are only limited studies with synbiotics and more research is warranted in order to justify their use in practice. Estrada et al. (2001) found that 18 d old piglets fed 0.5% FOS combined with two administration of oral dose of 10^{10} *B. longum* grew faster, had reduced fecal total anaerobes and clostridia and increased bifidobacteria than negative control group only in the first week of the study.

Summary

The gastrointestinal tract is capable of responding and adapting to variations in dietary composition. Antibiotics have improved animal performance by controlling the gastrointestinal tract for over half a century. There are improvements in understanding the physiology of digestive system of monogastrics and the role of gut microflora in health and disease. The quest for alternatives to feed antibiotics has lead to the testing of enzymes, botanicals, probiotics and prebiotics as feed additives that could enhance intestinal function in monogastrics.

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