Optimising gut health to maximise swine performance

During the last few years the impact of antibiotic use on animal production has been generally accepted, and it has been a global issue to reduce the use of antibiotics in animal production.

As this challenge is still in its implementation process, the impact of antibiotic reduction on productivity performance is showing us that the intestinal environment and specifically the intestinal microbiota is an undiscovered organ.

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It has been found in around 800 species in the swine gut with a main presence of the Phylum Firmicutes, Bacteroidetes, Proteobacteria, Actinobacteria and Spirochetes in the swine intestinal tract.

The bacteriological balance of the intestinal lumen and intestinal mucosa is crucial in order to maximise the physiological functions and maximise animal performance.

Nutrient digestibility, the intestinal immune system, and microbial degradation products are in the spotlight of the latest research as the main alternatives to antibiotic use.

It is necessary to be aware of the intestinal structure and multiple interactions between the host and the commensal bacteria, but also between mutual interactions between the commensal bacteria, that may lead to beneficial, neutral, or dysbiosis situations.

Due to a huge surface area created by intestinal villi, crypts and the enterocyte microvilli, the mucosa layer is the most active ground for interactions between the host and intestinal microbiome at the same time the nutrients are absorbed.

Mucosal defence barrier

Many interesting host cells like Paneth cells located at the bottom of the crypts, are producers of antimicrobial peptides like α-defensins, lysozyme or Reg III γ as a physiological reaction when bacteria are detected.

Also, the mucus layer produced by goblet cells is critical for limiting the penetration capacity of gut bacteria. This layer is formed mainly by water and mucin, which is a matrix of glycoproteins, with a thickness of 150μm. Across this mucus layer there is a gradient of oxygen that has an. influence on bacteria penetration capacities.

One of the main functions is to prevent the invasion of the epithelium by pathogen bacteria.

Peyer's patches are round follicles containing specialised cells that recognise the antigens and present to the immune cells as the first contact in the immune response.

The highest concentration is located in the distal ileum, and their activity is critical for the correct performance of the immune system.

Lactic acid bacteria (LAB)

Lactic acid bacteria (LAB) is an important group of Gram-positive bacteria, mainly facultative anaerobes with the capacity to ferment sugars to lactic acid.

There are hundreds of species and the beneficial impact on mucosal barrier function, the reduction of pathogens and improvement in intestinal health is generally accepted.

Prebiotics

Prebiotics are extensively used in animal nutrition to stimulate bacterial fermentation and improve intestinal balance and bacterial metabolites in the gut.

FOS, MOS, and dietary fibres are used for their positive impact on intestinal health. One of the targets for prebiotic use is to increase the beneficial bacteria in the gut.

Probiotics

Many different probiotics are available with an important role for lactic acid bacteria, which are interesting to reduce the load of pathogenic bacteria at the same time that produce free lactate available for the host and the beneficial bacteria.

It is important for any probiotic strain to be resistant in stomach conditions and enzymes, capacity to colonise the intestine, and the antibiotic resistant capacity.

Organic acids

Organic acids are extensively used in animal nutrition due to their capacity to modify pH, improve nutrient digestion and prevent the growth of micro-organisms, and also their bactericide/bacteriostatic capacity against pathogenic bacteria.

Lactic acid, formic acid, propionic acid, butyric acid, citric acid, acetic acid and their salts are some of the most popular acids used in feed formulation.

Swine intestinal bacterial diversity

The distribution of intestinal bacteria is not homogeneous in all intestinal sections. The bacterial population shows significant differences between the lumen composition and the mucosa composition.

Some bacteria have been adapted to the mucosa environment with expression of mucin-degrading capacity which allows for penetration capacity.

Additionally, there are several factors related to pH and oxygen concentration that have been demonstrated to influence bacterial distribution:

- pH gradient with the lowest values in the stomach (pH around 2), increasing through the small intestine with neutral or slightly basic pH in the distal ileum and acidifying again at 5.5-7.0 in the caecum and colon.

- Regarding oxygen concentration, there is a longitudinal gradient from the stomach to the distal caecum with a higher concentration of oxygen at initial sections and progressively reducing in the small intestine. At the caecum and colon, the lumen conditions are mainly anaerobic.

- Additionally, to oxygen gradient it is very interesting to understand the oxygen concentrations that exist between the intestinal lumen and the mucosal epithelium. The mucosal epithelium is highly oxygenated from the bloodstream (so it allows some facultative anaerobic growth under these conditions) but at the same time under physiological conditions the adsorption metabolism of different nutrients consumes high quantities of oxygen by oxidation of butyrate in the TCA cycle, so the epithelia limit with mucus layer becomes a strong hypoxic area.

Bacteria in the stomach

The stomach and progressively the small intestine are the intestinal sections with a lower bacterial load in comparison with the distal sections, such as the caecum and colon.

Lactobacillus and acinetobacter genera are frequently found in the stomach of swine, but streptococcus, prevotella and veillonella are also easily detected.

Bacteria in the ileum

The most common phylum in the ileum is Firmicutes. Interestingly, Bacteroidetes phylum is not predominant in this section but is present as a seed community for the distal part of the intestine.

Bacteria in the caecum and colon

The distal gut is the area with the highest bacterial concentrations and also where microbial activity is necessary for optimum balance and absorption processes.

The Bacteroidetes phylum, and specifically the genus Prevotella, is

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the most dominant in the caecum. Also, common phylum in the distal gut are the Spirochaetes, of the families Ruminococcaceae and Lachnospiraceae.

Production of short chain fatty acids (SCFA)

The production of short chain fatty acids (SCFA) is probably the most important action of the intestinal bacteria.

The natural production occurs under anaerobic conditions mainly in the distal intestine with production in the small intestine due to the higher microbial concentration in the caecum and colon and the oxygen gradient.

The main SCFA produced in the intestine are acetate, propionate, lactate and butyrate and the intestinal epithelium rapidly absorbs them by transporter proteins (MCT) that transport the SCFA alone or in combination with cations like Na+ or H+. It is also described that SCFA can enter into the epithelium by passive diffusion.

The main target for acetate is to be oxidised in the tricarboxylic acid cycle as an energy source and also be used in the production of fats and lipids.

The main target of propionate is to be used for gluconeogenesis in the liver.

For butyrate, beside some residual oxidation in the liver (similar to acetate), the main function is a general regulation of intestinal homeostasis and energy source for intestinal cells.

There have been multiple functions of butyrate described as a key molecule for intestinal integrity. The main benefits are related with its use as an energy source for intestinal cells and specifically for enterocytes and colonocytes; many publications have shown the increase in villi growth, Improvement in digestibility and the positive impact in animal nutrition.

In addition to previous benefits, antimicrobial peptides concentration and mucus layer are improved with supplementation with butyrate; tight junction proteins increase their expression and so decrease the permeability of the intestinal epithelium.

Butyrate also has a direct effect on the immune system, limiting the pro-inflammatory cytokines like IFN-γ. The anti-inflammatory effects on macrophages from the lamina propria has been described and a down regulation of pro-inflammatory mediators in macrophages as IL-6 and IL-12.

The role of butyrate as a colonisation barrier

Increasing levels of butyrate or other SCFA have been shown to inhibit the growth of pathogenic bacteria. This mechanism, related to pH effect on bacterial integrity, has been accepted as an antibacterial effect.

A new approach for butyrate action against bacterial invasion of the epithelium has been developed regarding the availability of 'terminal electron acceptors' available for microbial respiration.

As in physiological conditions, the intestinal epithelium and mucus layers show an oxygen gradient from the host to the anaerobic lumen.

Under inflammatory situations, the immune response increases the concentration reactive oxygen species (ROS). These ROS and their metabolites can serve as terminal electron acceptors for many pathogenic bacteria like Salmonella enterica.

The role of butyrate in this situation is crucial as butyrate reduce the inflammatory signals and reduce the production of immune-derived ROS.

The presence of high butyrate levels in the mucus layer at colonocytes plays an important role as it is oxidised to produce the ATP required for water absorption from lumen to the host. This process consumes a high quantity of oxygen and creates a hypoxic environment hostile for facultative aerobic pathogenic bacteria.

The downregulation of invasion genes, for example the pathogenicity island hilA, that is necessary for salmonella invasion, has also been studied as one mechanism for decreasing salmonella colonisation with butyrate.

Conclusion

In the production challenges we have faced in recent years and with increasing restrictions in antibiotic use, it is important to consider the intestinal tract as an independent organ with multiple inter-connections between nutrients, the bacterial ecosystem, and microbial metabolites.

The role of new feed additives is gaining more importance in animal nutrition, mainly because of the direct impact of nutrition on the microbial populations in the intestine.

We should not lose focus on the importance of SCFA, and especially of butyrate as a key molecule with a direct impact on intestinal health, and their growth promoting effect to maximise animal production. ■