Gut health in poultry production: a holistic approach.

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Challenges of modern broiler production

The impressive genetic improvement of broiler growth rate has enabled the poultry industry to meet with a worldwide increased demand for poultry meat. Compared to the broiler production in 1950-1960ths, the birds today grow twice as fast. This improvement in growth and the corresponding feed conversion ratios put enormous pressure on the digestive system of the birds. Therefore it is essential to create a healthy intestine from the very beginning and to maintain optimal gut functions throughout the whole growth period to avoid enteric diseases, like necrotic enteritis-NE and bacterial enteritis-BE or dysbacteriosis. Any factor that compromises the integrity of the intestinal mucosa and its bacterial community will lead to decreased nutrient absorption. Additionally, activation of immune system and repair processes will cost valuable nutrients and energy. Considering all of the above, financial success of the poultry business is directly depending on intestinal health.

Because of the risk of antimicrobial resistance connected with consumer concern for animal welfare and food safety, recent pressure on the usage of antimicrobials has caused intensive investigations to find alternative solutions to develop a healthy digestive system in animals without extensive use of antibiotics. Management changes and different alternatives for antibiotics such as probiotics, prebiotics, phytogenic products, organic acids and enzymes have been investigated to improve intestinal health and general animal performance.

A holistic approach to gut health is to look at the whole, not just focussing on enteric diseases, but working on all contributing factors and considering the complex interactions between different parts: feed, microbiota and host immunity.

Development of a balanced gut microbiota ecosystem and the complex host – microbiota interaction.

The intestine serves as the most important interface between expensive feed ingredients and the final result: broiler meat production. On the one hand, the intestinal mucosa has a huge surface area that acts as a selective barrier between the tissues of the bird and the luminal content. This barrier must provide adequate protection against invasion of pathogenic bacteria. On the other hand, the intestinal mucosa must assure most efficient absorption of nutrients from the feed, mainly in the first part of the gut, and additional fermentation takes place by bacteria in the caeca. To achieve optimal performance we need early enteric development for good immunity and nutrient absorption capacity; and a rich and diverse microbial ecosystem in balance with the host mucosal defence barrier. The life span of the broiler to reach slaughter weight has become shorter; early feeding will enhance development of intestines, muscles, skeleton and the immune system. Choosing the right feed composition and additives will optimise the intestinal microbial community and limit inflammatory response.

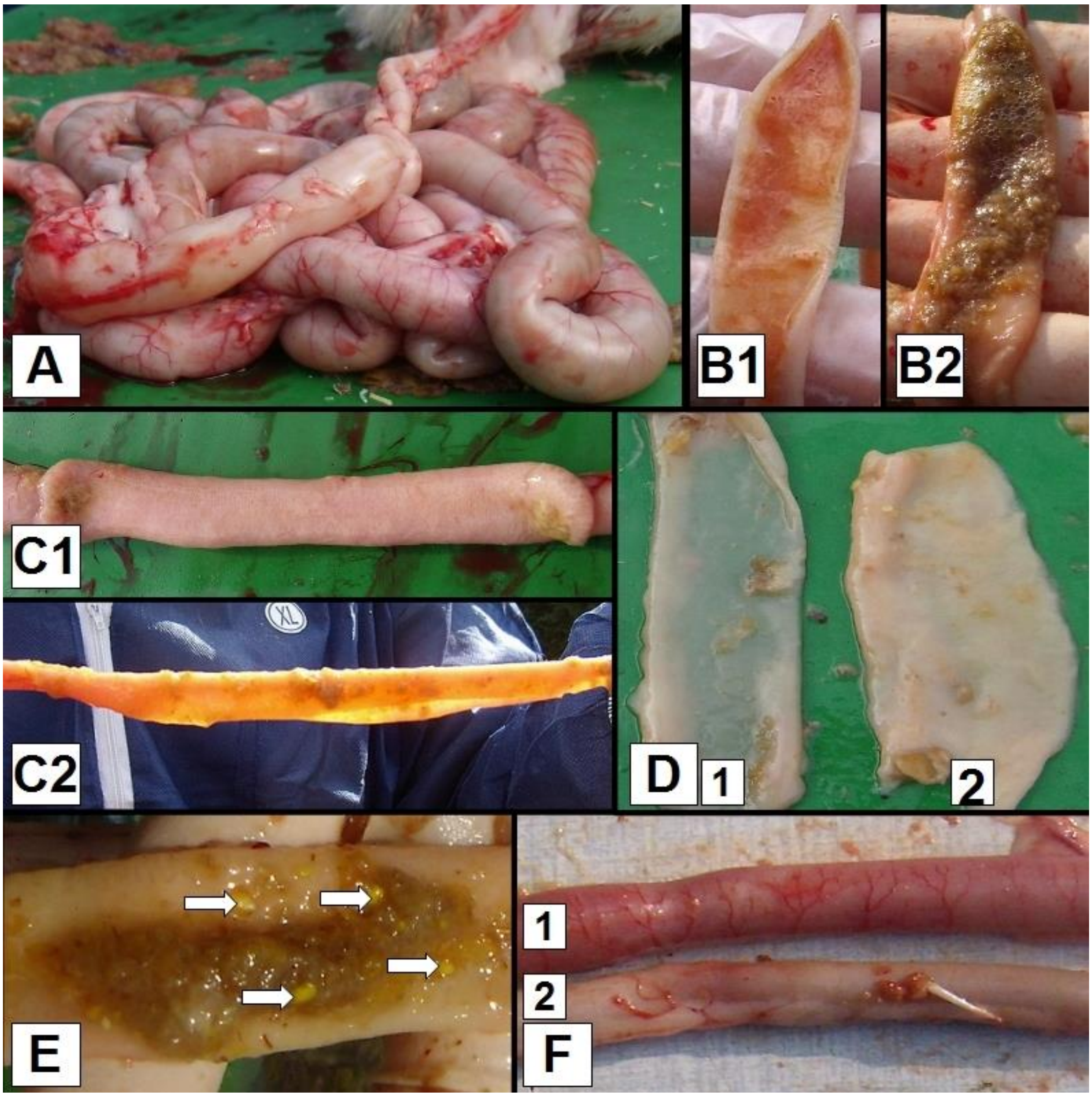

Figure 1 (After De Gussem, 2010). Macroscopic dysbacteriosis score system parameters. **A.** Overall gut ballooning; **B.** Content of the intestinal tract, **1.** Mucoid, orange intestinal content, **2.** Foamy intestinal content; **C.** Tonus of the intestinal tract, **1.** Good tonus, **2.** Lack of tonus; **D.** Macroscopically visible thickness of the intestinal tract, **1.** Macroscopically thin intestinal tract, **2.** Intestinal tract with normal thickness; **E.** Undigested particles in the colon (arrows); **F.** Inflammation of the gut, **1.** Inflammation, **2.** No inflammation.

Vicious circle of bacterial enteritis

Since the ban of antimicrobial growth promoters in Europe in 2006, digestive problems such as bacterial enteritis BE or dysbacteriosis and even necrotic enteritis, have increased. The etiology of BE is multifactorial, in modern broiler breeds, selected for maximal growth rate and high feed intake, abundance of non-absorbed nutrients in the gut lumen, in absence of growth promoters with antibacterial properties, causes a chain of events that exacerbates the proliferation of some clusters of bacteria that leads to an inflammatory reaction of the gut wall. This reaction of the gut wall on its turn instigates microscopic and macroscopic changes that, as in a vicious circle, will lead to poorer physiologic status of the intestine and to poor digestive and absorptive functions, resulting in even more nutrients in the intestinal lumen, and more substrate for bacterial growth .

The pathogenesis of BE can be described as a vicious cycle in 4 steps – Fig 1. In the **first step**, the shift of the healthy gut towards BE starts with oversupply of nutrients in the intestinal lumen. In a today's broiler, the very high feed intake has accelerated the general feed passage rate in the intestine. So, even minor violations of the digestion and absorption will lead to an increase of the number of nutrients, especially of undigested proteins and high-energy nutrient particles in the hind gut. Among gut damaging factors of infectious origin, coccidiosis is considered to be the most important, but also virus infections can destroy intestinal epithelia, shorten intestinal villi and lead to poor absorption of the intestine. The stressors of non-infectious origin are dietary changes, nutritional imbalance, soluble non-starch polysaccharides (NSP), enzymatic dysfunctions, mycotoxins and management issues. As a consequence of the oversupply of nutrients in the intestinal lumen, a shift in proliferation of some clusters of bacteria occurs in the small intestine in **step 2** of the vicious cycle. The presence of excessive nutritional factors mainly favours the proliferation of *Clostridium perfringens* and *Clostridiaceae* and disfavours *Lactobacilli* group. In **step 3**, this disruption of a very fine balance in gut microbial constellation may shift intestinal immune tolerance towards pathological inflammation reactions and oxidative stress in the gut wall, so morphological and functional alterations in the intestine occur. In case of overgrowth of *Clostridium perfringens spp.* producing Netβ toxin, these alterations even results in necrotic enteritis, as Netβ toxin directly destroys the intestinal lining. **Step 4** of the vicious cycle of BE is characterised by poor digestion of feed and poor absorption of nutrients, as the damaged intestine is not able to fulfill its functions. The above described 4 steps of the vicious cycle, result in a less functioning gut, which in turn leads to further oversupply of nutrients in the intestinal lumen, so that the spiral of the vicious cycle of BE continues.

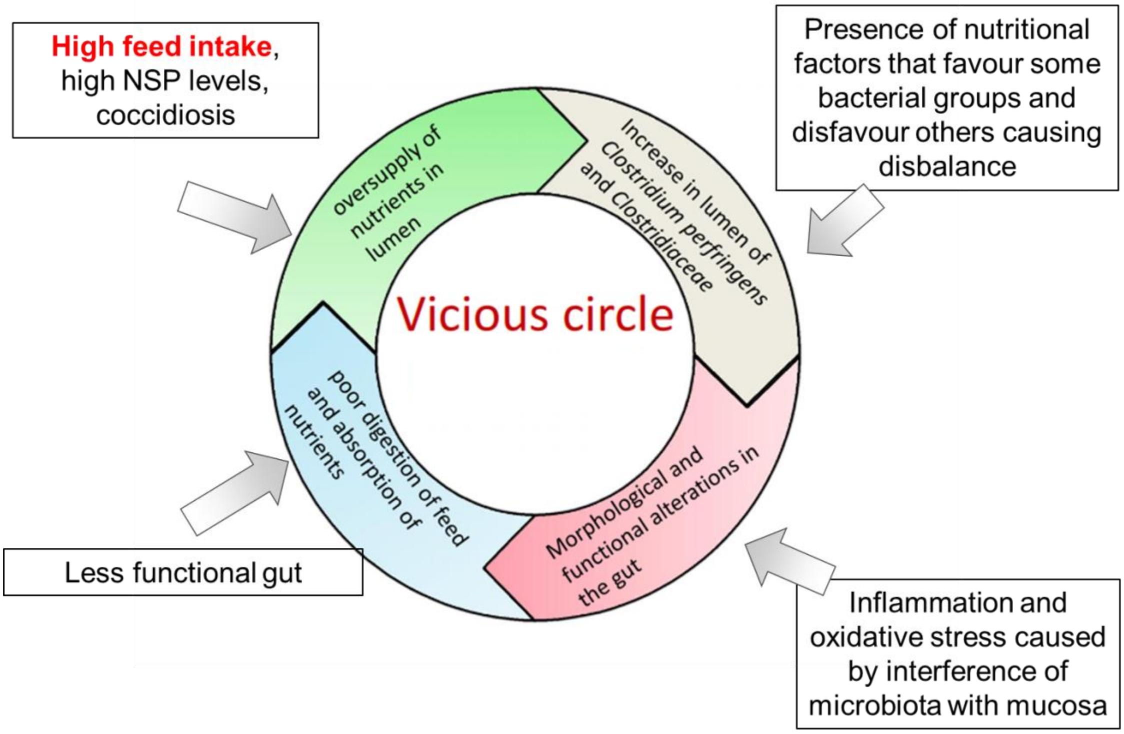

Figure : Bacterial Enteritis Vicious Circle (De Gussem, 2010)

Use of modern molecular techniques has led to a better understanding of the role of microbiota in oral tolerance and physiological functions of a healthy gut and has helped a lot to disqualify simplistic views such as the existing of 'good' *Lactobacillus spp*. and 'bad' *Clostridium spp*. bacteria. Nowadays, microbiota is considered as a gene tool box that is complementing the gene pool of the host. The research is focusing on unravelling the complex interactions of what kind of gene pool is linked with good gut health and understanding how genes, both from the gut and its microbiota, can be switched on and off with different diet types, in order to reach the best performance with lowest level of inflammation, best digestive and absorptive properties. What we know so far, is that the composition of intestinal microbiota is changing throughout the life cycle, becoming quantitatively and qualitatively more complex with the age. Also environmental factors, such as stocking density, diet composition and feeding practice, management, housing conditions, pathogen load in the environment, use of antibiotics can modify intestinal microbiota. Feed withdrawal, especially over longer time, causes reduction in the number of detected bacterial species. Also from one segment of the gastro-intestinal tract to the other, bacterial populations of the gut vary significantly. In the small intestine of a healthy bird, *Lactobacillaceae spp*. are dominant, whereas in caeca *Clostrideaceae spp*. (families *Lachnospiraceae*, *Ruminococcaceae* and *Erysipelotrichaceae*) are prevailing, which is connected with different pH and physiologic functions of these intestinal segments.

There are some members of the mucosa-associated microbial community that are considered to be especially crucial for a healthy status of the gut. These are bacteria producing short chain fatty acids, like acetic, propionic and butyric acid, during the fermentation process of dietary carbohydrates. Production of butyrate near the epithelial cells and in close association with invading and histotoxic pathogens promotes development and recovery of the villi, stimulates the expression of the tight junction proteins, limits invasion of pathogens such as *E. coli* and *Salmonella* and further promotes a beneficial microbial ecosystem, which leads to an overall increased tissue health. On the contrary, mucin desulphating bacteria and sulphate reducers create hydrogen sulphide, which enhances some pathogens and causes tissue damage

Early Feeding

The goal in poultry production is to make the most of the high genetic potential of the broiler. Epigenetics is the rising science of programming gene expression during critical developmental periods, which subsequently allows an animal to metabolically or physiologically adapt to specific dietary or environmental conditions. Feeding behaviour, nutrition and brooding conditions can affect metabolism and development of the intestines, muscle, skeleton and immune system. Epigenetic programming of the chick can be done during incubation and the perinatal period. Early feeding can be done before hatch, by in ovo injection in the amnion, during transfer at 18 days of incubation, or post hatch, by feeding in the hatcher, during transport or as soon as possible after arrival at the farm or when hatching on the farm. This early feeding is important, not only to improve the nutritional status and intestinal development, but also to program and train the host immune system to react in a tolerant way to nutrients and commensal microbiota and to recognize pathogens.

Strategic use of alternatives

The choice of best alternative solutions should be tailor made for each operation, looking at the 4 steps of the vicious circle and what contributing factors are causing damage to intestinal health. Alternative solutions work on different parts of the circle and some products have a synergistic effect.

It is important to give the chick a good start with early feeding, to support early enteric development and a balanced microbial ecosystem. During critical periods like high coccidiosis challenge, feed changes, vaccinations and other stress factors, after antibiotic use, additives can be used to restore balance in the microbial community and recovery of damaged intestinal mucosa.

Conclusions

In poultry production, intestinal health is capital for performance. Since the ban of antimicrobial growth promoters more than 10 years in EU, research has demonstrated the importance for general health of the intestinal microbial community and the complex interaction with the host. Intestinal health can be improved by early feeding for early enteric development and with feed composition and additives to maintain a rich and diverse microbial community, and to control the host reaction through dietary immunomodulation.

No microbiota transmitted from mother hen in the hatchery