Whitepaper:

Gut Health Solutions

A complementary and holistic approach for sustainable animal protein production and economic success

Written by Evonik's Research Manager for Poultry Nutrition, Dr. Nadia Yacoubi.

Introduction

The business program Gut Health Solutions, part of Sustainable Healthy Nutrition at Evonik Operations GmbH, has developed a new gut health concept for broilers, layers, and swine. It combines Evonik's amino acid and probiotic portfolios with its AMINO services program, and provides a holistic solution for animal health and livestock production. The new concept aims to link gut health to economic success by serving customer needs along the value chain of livestock production.

The Gut Health Solutions (GHS) business program has recognized the increasingly complex and interdependent requirements for livestock production and the importance of gut health as a key aspect of economic success. Customers will learn how Evonik's low crude protein diet concept, amino acid and probiotic portfolios, and AMINO services interact. GHS Product Management works towards creating a holistic picture of gut health, oriented towards customer needs. The concept focus lies on the key applications poultry and swine, while other applications such as aquaculture and pet food need to be further investigated. Ultimately, the concept will demonstrate to the customer the advantages of supporting the intestinal ecosystem with solutions from Evonik. The combination of products and services indicates a complementary and holistic approach to tackle challenges and to contribute towards sustainable animal protein production.

For the purpose of this white paper, we have focused on gut health solutions for poultry.

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The challenge

In modern broiler production, producers face a multifactorial problem including challenging environmental conditions, feed quality and intestinal health. The interaction between these elements is key for the development of the morphology and the function of the gastrointestinal tract (GIT). This is essential for nutrient digestibility and absorption, but it is also the first line of defense against pathogens, viruses, and parasites. When building our gut health system solutions, we investigated the causes of these challenges and worked on finding solutions. This included looking into the main topics of environmental conditions such as heat stress, feed nutritional values and quality, parasites, antibiotic growth promoter (AGP) replacement, and the main pathogenic bacteria.

All these issues have a direct impact on the GIT, especially when one, or many of them, leads to an imbalance in the system. The intestinal ecosystem is a complex and interconnected network. It can be defined as a system, or a group of interconnected elements, formed by the interaction of a community of organisms with their environment, in the intestine (Martín et al., 2014). When the ecosystem is in balance, the different components of the system are working in perfect harmony, also called homeostasis (Honda and Littman, 2016). This dynamic state of equilibrium is the condition of optimal functioning for the organism including microbiome (bacteria, viruses, fungi and protozoa) composition, metabolites, host epithelial cells, physical and chemical conditions in the gastrointestinal tract, etc. If this homeostasis status is disturbed or destroyed, it results in dysfunction of the system, impaired interactions with the host and, thus, reduced performance of livestock. One of the key elements of the intestinal ecosystem is the microbiota. Any alterations in the ecosystem will lead to an alteration in the microbiota and vice versa. The amplitude of this alteration and imbalance depends on the causes and its severity. In the following section we will focus on microbiota imbalance, also called dysbiosis, its causes, symptoms and effects, and how we provide potential solutions in poultry.

> **"Dysbiosis is often defined as an 'imbalance' in the gut microbial community that is associated with disease. This imbalance could be due to the gain or loss of community members or changes in relative abundance of microbes."**
> Messer and Chang, 2018

Dysbiosis is generally defined as an undesirable alteration of the microbiota resulting in an imbalance between protective and harmful bacteria (Chan et al., 2013). The definition of harmful bacteria is though not yet fully established. Pathogenic bacteria and harmful bacteria are usually considered synonymous terms. However, we know that some commensal bacteria may become harmful when conditions allow them to overgrow. The intestinal microbiota is composed of different commensal bacteria with different functions working together to maintain homoeostasis (Ducatelle et al., 2015). If the balance and synergy between these bacteria is altered, it will lead to an overgrowth of one population over the others and the consequence is dysbiosis (Ari et al., 2016). For example, the microbiota contains saccharolytic bacteria, carbohydrates degrading bacteria and proteolytic bacteria that degrade protein working together in balance, and an overgrowth of one or the other disrupts the balance, and the consequence is dysbiosis (Van Immerseel et al., 2019).

The causes of dysbiosis are related to various factors and lead to different severity of effects.

1. Antibiotics

Antibiotics are the most common and significant cause of alteration of the microbiota (Hawrelak and Myers, 2004; Singh et al., 2013; Khan et al., 2019). In many countries, the ban on the use of antibiotics as growth promotors due to the development of antibiotic resistance, means they are only allowed for therapeutic treatment. Recent studies have shown that even when used for curative purposes, antibiotics can cause dysbiosis and lead to decreased growth performance in livestock (Le Roy et al., 2019). In this study they suggested that host metabolic response to antibiotic treatment resulted from a co-occurring modification of the gut microbiota composition and steroid hormones metabolism.

2. Pathogenic bacteria and parasites

Pathogenic bacteria are part of the intestinal ecosystem, but in homeostasis they are usually in low concentration or below detection level when using common microbiological methods. When disbalance occurs, it may lead to an overgrowth of these populations (Ma et al., 2016). These pathogens will first compete for nutrients with the host and with other commensal bacteria (Lacey et al., 2018). They will then produce metabolites and toxins that lead to more severe dysbiosis, evolving into enteritis (Toor et al., 2019). The symptoms and effects of these pathogens depend on the strains and concentration of these bacteria in the gut, but also the presence of parasites.

Parasites, namely *Eimeria* spp., are intracellular protozoa that cause coccidiosis in chickens (Yun et al., 2000). Coccidiosis causes intestinal lesions, malnutrition (Tyzzer, 1929) and mobilization of the immune system to fight against these parasites (Chapman, 2014; Toor et al., 2019). As a result, coccidiosis is one of the most important stress factors leading to decreased growth performance.

In general, most of the pathogenic bacteria produce toxins and metabolites that increase gut motility, increase fermentation with gas production, change the gut pH, irritate the mucosa, cause inflammation, and increase secretion of mucus (Hawrelak and Myers, 2004; Toor et al., 2019; Khan et al., 2019). This process reduces digestibility and absorption of nutrients and water. However, the most costly condition for animal production is the chronic inflammatory responses of the animal to constant minor dysbiosis (Oviedo-Rondón, 2019).

The list of avian specific pathogens is long but, in this section, we focus only on key pathogens that cause the biggest impact on modern poultry production: *Salmonella spp., Escherichia coli, Clostridium perfringens and Eimeria spp*.

a *Salmonella spp:* These are mainly foodborne pathogens which will not always have a direct effect on the chicken. The birds act as a reservoir of this pathogen that can cause illness and even be lethal to humans. In general, economic losses are associated with the rejections of contaminated birds at the slaughter house, veterinary interventions, addition of feed additives and management measures to reduce salmonella, etc (Wigley, 2014; Likotrafiti and Rhoades, 2016; Yang et al., 2018). Some of the most redoubtable foodborne pathogens are *Salmonella Enteritidis* and *Salmonella Typhimurium*. These strains usually cause asymptomatic intestinal infections but acute outbreaks can lead to high mortality (Dunkley et al., 2009). Some other *Salmonella spp*. are animal-specific pathogens which will have a direct impact on the animals. The symptoms are specific and different to each pathogen leading mainly to high flock mortality. As an example, *Salmonella gallinarum* is one of the major avian pathogens which results in severe morbidity and mortality for broilers (Foley et al., 2011).

To limit the impact of *Salmonella spp*. there is no silver bullet. A holistic program is recommended to control *Salmonella* and its many sources of contamination (Figure 1).

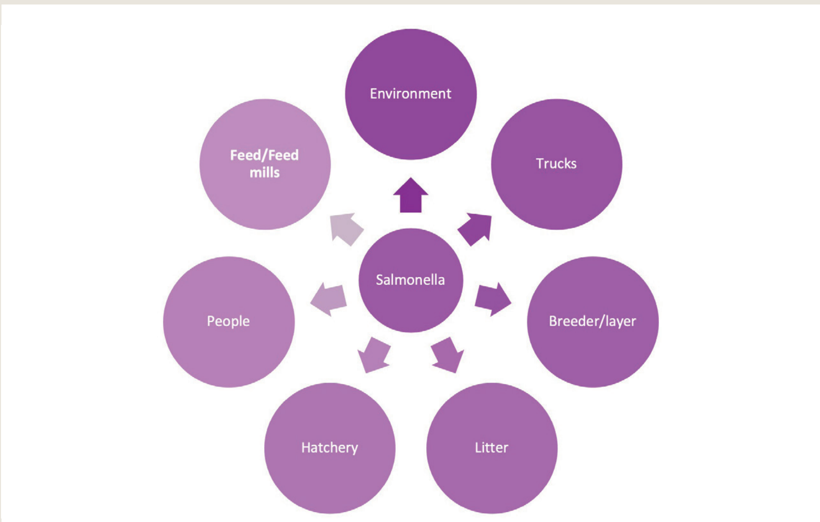

Figure 1: Main *Salmonella spp* contamination sources (Vetworks, 2018).

To control *Salmonella spp* we need to make sure to control and keep all contamination sources free from it as proven by the Danish strategy (Wegener et al., 2003). The use of vaccines has been shown to be an effective tool to control and/or prevent infection in livestock (Zhang-Barber et al., 1999; Desin et al., 2013). Vaccination programs mainly focus on the layers/or breeder flocks. Probiotics and other feed additives like organic acids have also been shown to be effective against Salmonella and an efficient alternative in the prevention program (Tellez et al., 2012; Koutsoumanis et al., 2019).

b Escherichia coli (*E. coli*): a gram-negative bacterium normally present in the environment and poultry intestinal ecosystem. A imbalance of other parameters from the ecosystem leads to conditions that are favorable for an overgrowth of *E. coli*. Depending on the specific strain (enterotoxigenic, verotoxigenic, or necro toxigenic) and the bacteria load in the intestine, the symptoms and severity of the infection can be different. The pathologies related to *E. coli* infections are mainly colibacillosis associated with cellulitis and respiratory disease, enterocolitis, omphalitis, arthritis, osteomyelitis and osteonecrosis (Kaper et al., 2004; Daud et al., 2014; Mohamed et al., 2018). *E. coli* is also one of the main foodborne pathogens conveyed by animal products and by-products and represents a major concern for human health (The European Parliament and of the Council, 2003; EFSA, 2007).

c Clostridium Perfringens (Cp): classified according to their toxin type into five classes (A, B, C, D and E). Pathogenic strains of *Cp* are responsible for necrotic enteritis in poultry by producing toxins that create lesions in epithelial cells membrane (Broom, 2017). Even though Cp are part of the intestinal microbial community, dysbiosis can create ecosystem conditions that are ideal for the overgrowth of pathogenic strains which leads to a condition known as Necrotic Enteritis (Lacey et al., 2018). Necrotic enteritis is considered as one of the major poultry diseases and the impact increased after the ban of antibiotics as growth promoters (Van Immerseel et al., 2016).

d *Eimeria spp*. infections. Eimeria are obligatory protozoans and the main cause of avian coccidiosis (Abbas et al., 2012). These protozoan develop in different regions in the gut causing mild to severe lesion affecting the mucosa integrity (Tyzzer, 1929). Depending on the severity and the infection site (Figure 2), coccidiosis will result in nutrient malabsorption and fluid losses (E. *acervulina* and *E. mitis*), inflammation of the intestinal wall with pinpoint hemorrhages and sloughing of epithelia (Eimeria brunetti and E. maxima), or complete villi destruction resulting in extensive hemorrhage and death (E. necatrix and E. tenella) (Chapman, 2014). The lesion caused by Eimeria spp. also favors the development of other pathogens like *Clostridium perfringens* resulting in a more severe necrotic enteritis and/or bacterial translocation that will lead to infections in other organs (Berg, 1999).

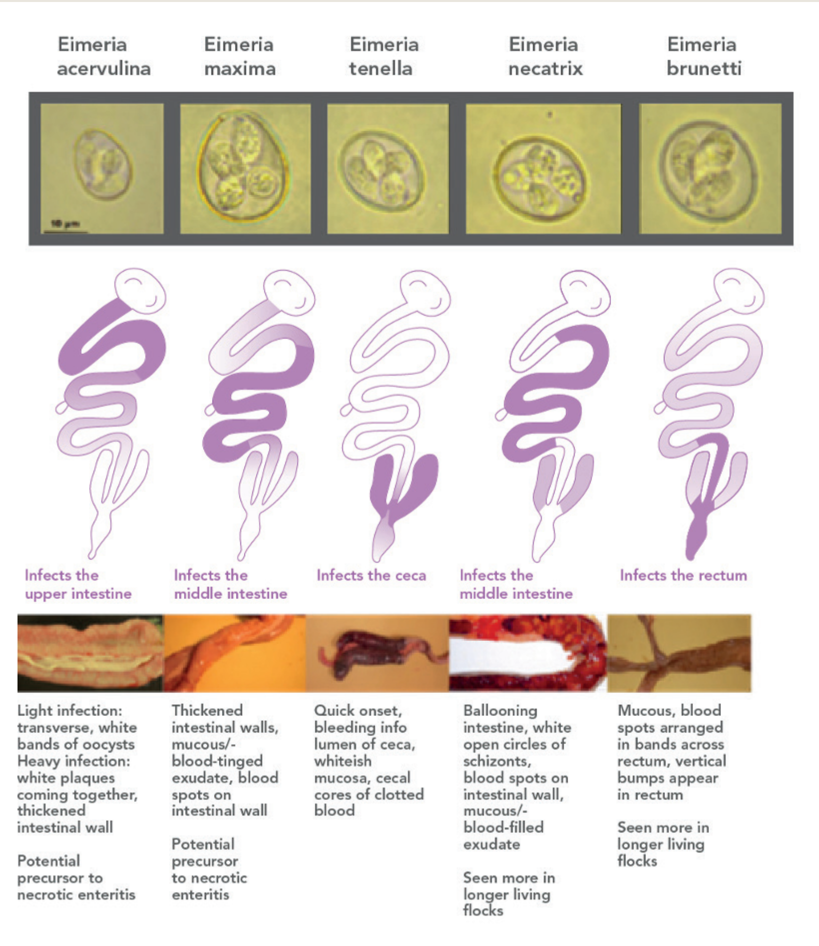

Figure 2: The five most important species of Eimeria (source: backyardchickens.com).

Probiotics are efficient feed additives against *Clostridium* perfringens and necrotic enteritis. Recent studies show that supplementing probiotics like GutCare® (Sokale et al., 2019; Whelan et al., 2019; Bortoluzzi et al., 2019; Menconi et al., 2020) and Ecobiol® (De Oliveira et al., 2019) in broiler feed inhibited pathogen growth in the intestine and compensated negative effects from the disease on growth performance.

Several mechanisms by which probiotic bacteria inhibit the gut colonization have been documented, including increasing the lactic acid bacteria to pathogenic bacteria ratio. Probiotic bacteria composed of B. *amyloliquefaciens* are known to produce α-Amylase enzyme, which hydrolyses starch (Gangadharan et al., 2008). The degradation of starch by the enzymatic activity of these bacteria produces maltose and glucose. In anaerobic conditions, glucose is degraded through the glycolytic pathway by anaerobia bacteria – such as those from streptococci and lactobacilli strains – and results in lactic acid production. The effect of the supplementation of B. *amyloliquefaciens* in the feed has been reported to increase the concentration of *Lactobacillus spp*. (An et al., 2008; Mallo et al., 2010) and reduce the concentration of pathogens like E. coli (Mallo et al., 2010) in the cecal digesta of broilers.

The change of the microbiota towards lactic acid bacteria is not only important for the control of potential pathogenic bacteria. Butyric-acid-producing bacteria, such as the members of the family *Ruminococcaceae* and *Lachnospiraceae*, exhibit such properties. Butyric acid is an important organic acid with anti-inflammatory properties and is an important signaling molecule in the gastrointestinal tract (Eeckhaut et al., 2011). The reduction of this bacterial family is observed during the induction of necrotic enteritis (Antonissen et al., 2016), resulting in impaired performance in broilers. Bortoluzzi et al. (2019) also observed the reduction of Ruminococcus in cecum after the inoculation with *Cp* in broilers (Figure 3). Cp inoculation increased the relative abundance of Bacteroides (21% in uninfected vs. 35% in infected group) and reduced the relative abundance of *Ruminococcus* (14.3% in uninfected vs. 7.7% in infected group), and *Ruminococcaceae* (7.9% in uninfected vs. 3.5% in infected group). However, *B. subtilis* DSM 32315 supplementation partially returned the relative abundance of Bacteroides (28.3%) to a similar value as that observed in uninfected birds, and restored the frequency of *Ruminococcus* (12.4%) and member of the family *Ruminococcaceae* (6.4%). Therefore, the dietary inclusion of B. subtilis DSM32315 contributed to the reestablishment of the gut microflora to a similar level as the healthy uninfected animals, overcoming the imbalance caused by *Cp*.

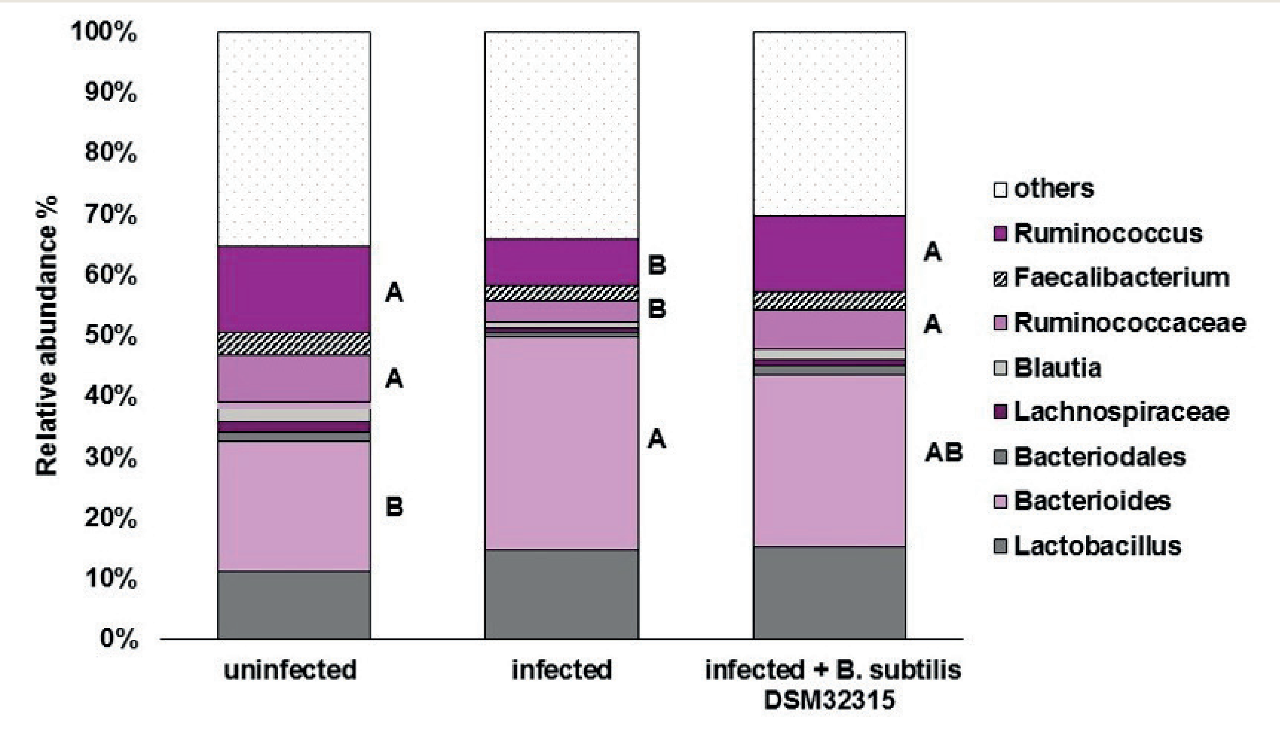

Figure 3. Relative abundance (%) of the main bacterial groups present in the cecal microbiota of broilers challenged with Cp and supplemented with B. subtilis DSM32315.

3. Feed contaminants

Feed contaminants or toxic materials such as toxins, mycotoxins (Levasseur et al., 2011; Miedaner et al., 2015), pesticides, chemical residues, biogenic amines (Ladero et al., 2010) and others can also cause dysbiosis.

a Pesticides and chemical residues coming from feed ingredients represent a potential danger for the animals ingesting them, leading to modifications in the physico-chemical properties of the gut (D'Mello, 2004).

b Biogenic amines are compounds produced by bacteria from fermentation of protein-rich raw materials, particularly from animal origins and are the causative agents in many food poisoning occurrences. The most relevant biogenic amines in food and feed toxicity are histamine, putrescine, cadaverine, tyramine, tryptamine, β-phenylethylamine, spermine, and spermidine (Shalaby, 1996). Biogenic amines can lead to important loss of weight and mortality when ingested in high concentrations. The main source of biogenic amines are fish and meat by-products used as feed ingredient. The toxicity of some biogenic amines is increased by the presence of other amines and nitrites to form carcinogenic nitrosamines (Shalaby, 1996).

Biogenic amines can lead to gizzard erosions (Fossum et al., 1988). This erosion results in altered gizzard function, impaired digestion and increases the risk of bacterial infections (Janssens, 1971). The ingestion of histamine has been observed to cause pathological changes in the digestive tract associated with tissue oedema and splenic atrophy, resulting in impaired growth (Shifrine et al., 1959). One of the solutions proposed is to quantify 11 biogenic amines using HPLC via our service AminoLab® biogenic amines.

c Mycotoxins are defined by the World Health Organization as 'toxic compounds that are naturally produced by certain types of molds (fungi).' The mold can grow on various feed ingredients such as cereals before and/or after harvest, dried fruits and fruits by-products. Among several hundred identified mycotoxins, aflatoxins, ochratoxin A, patulin, fumonisins, zearalenone and nivalenol/deoxynivalenol are the most relevant for human and animal health. Although these contaminants are from different origins and have different classifications, they share common symptoms. Feed contaminants exert anti-nutritional effects and lead to impaired performance. Mycotoxins are secondary metabolites of fungi that impair animal health through different modes of action. The topic has been extensively studied. For more information you can consult AminoNews® Dietary Mycotoxins: Impact on Gut Health and Performance of Poultry).[1]

d Plant toxins. This category can be divided into 2 sub-groups heat-stable (e.g. tannins, quinolizidine alkaloids, glucosinolates, saponins) and heat sensitive (e.g. lectins, proteinase inhibitors and cyanogens) (Osman et al., 2013).

4. Unbalanced diet

Diets containing high protein/energy which creates an imbalance between energy and protein requirement, will lead to an excess of undigested protein reaching the ceca. This will, in turn, lead to an overgrowth of proteolytic bacteria. The latter will produce ammonia and Hydrogen sulfide (H2S) (Immerseel et al., 2004; Ducatelle et al., 2018).

When the diet is well balanced, the microbiota is also more likely to be balanced to work in harmony to degrade the undigestible fraction from carbohydrate and protein as shown in Figure 2. Many studies showed that when we have an excess of protein in the diet the consequence on the microbiota is expressed through decrease of butyrate producers, an increase of the production of H2S and an overgrowth of Proteobacteria and Enterobacteriaceae population, leading to a performance decrease (Figures 3a and 3b, Van Immerseel et al., 2017).

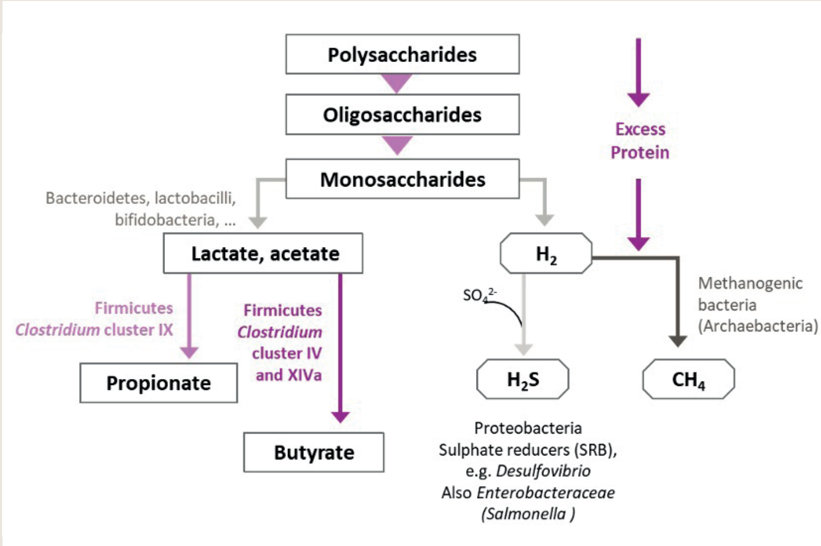

Figure 3a: Undigestible carbohydrate fraction pathway and microbiota involved in this process (Ducatelle et al., 2016).

Protein level and quality are crucial for broiler production for many reasons. One is for environmental and legal constraints related to the nitrogen excretion set by countries. With the current level of protein in the diets these levels are often exceeded, and in the future the farmers might face penalties. On the other hand, such crude protein amount (up to 23% in the starter phase and 19% in the finisher phase) is needed to cover the AA requirements of the animals to optimize performance. During the past year's extensive work has been conducted to determine nutritional recommendations for poultry species and growth stages. This research was utilized by Evonik to develop AminoChick®, a software program that calculates amino acid recommendations for broilers based on the sex of the birds, the energy level in the diet, the pellet quality, and the rearing period. Evonik has also worked to determine the ileal digestibility of amino acids (SID) in several raw materials with an extensive database present in the AMINOdat 5.0. By balancing the diet on the base of AA and energy, ideal digestibility can be maintained and growth performance optimized. Studies have shown that reducing crude protein and maintaining performance is achievable through efficient feed formulation and the use of free amino acids. For more details about the topic, have a look at AminoNews® There is room for protein reduction in broiler diets without compromising performance.[2]

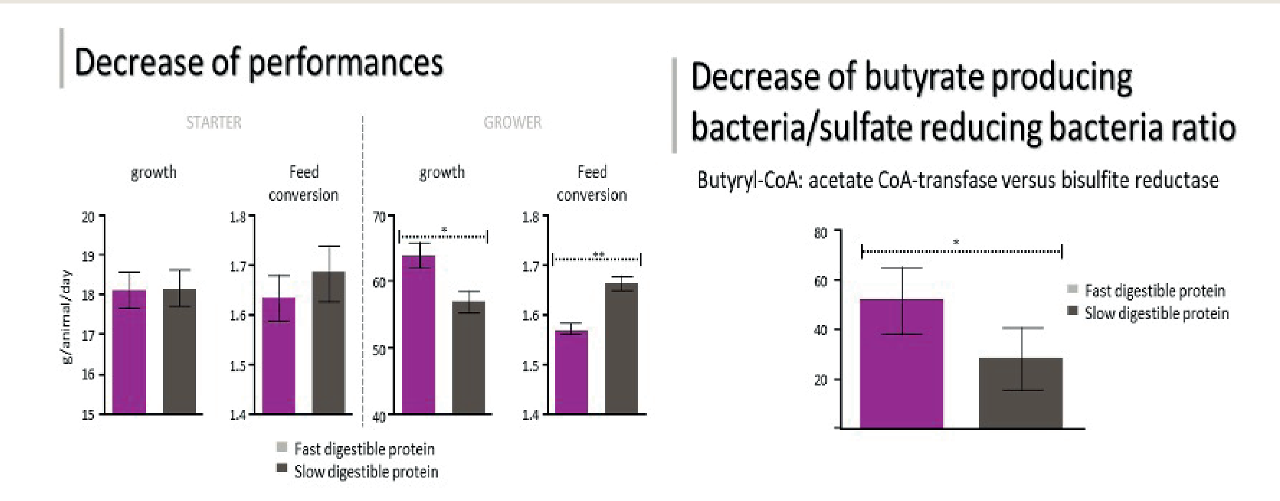

Figure 3b: Impact of protein excess in the broiler diet (Ducatelle et al., 2016).

5. Anti-nutritional factors and poorly digestible ingredients

When cellulose, non-starch polysaccharides (NSP), and phytate fractions are at a high level in feed, they will alter the physico-chemical properties of the intestinal ecosystem. Many papers have discussed and reviewed the impact of undigestible fractions of the diet on the digestibility and physico-chemical properties of the GIT as shown in Figure 4. These anti-nutritional factors are responsible for the modification of the physico-chemical conditions in the intestine such as mucus composition and secretion, the gastric acidity, pancreatic secretion of bacteriostatic peptides, mucus secretion when associated with focal ulceration and inflammation of the mucosa results in a reduced nutrient absorption and a shift in the microbial composition and metabolite compositions (Figure 4; Scott et al., 2013).

Diets are formulated according to databases that are compiled using standard amino acids digestibility coefficients. These databases do not account for variations in quality between batches of the same ingredient. During the past decade, many papers and reviews have shown that nutritional values from feed ingredients vary according to the varieties, soil, climate conditions, storage, and other factors. Evonik has developed a prediction tool based on NIR technology (AMINONIR®, AMINOProx® and AMINONRG®) to better predict the nutritional value of ingredients, which allows greater precision when formulating diets.

In addition to varying nutrient densities, feed ingredients have other properties and components that may impair their nutritional value, known as anti-nutritional factors. Examples of anti-nutritional factors are soluble and insoluble fibers, phytates, pectin and lignin, for example. Soybean quality is another example of a potential anti-nutritional factor which is related to its processing. Raw soybean contains trypsin inhibitors that decrease pancreatic enzyme activity, leading to an increase in the size of the pancreas and a decrease in fat absorption in the intestine (Mohan et al., 2015). These factors can be destroyed by heat treatment. Feed ingredients that are end products of different transformation processes (e.g. oil extraction and bioethanol production) can have lower nutritional values because of heat damage. For a better qualification of these damages and anti-nutritional factors, our AMINORED® service can assess the damage and adjust the nutritional value of these feed ingredients. Using NIR spectroscopy AMINORED® allows the effects of processing conditions on soybean meal, soybean expeller, full-fat soybean meal, raw full-fat soybeans, corn-based DDGS, as well as reactive lysine and anti-nutritional factors to be predicted. Accordingly, AMINORED® allows the adjustment of the nutritional values of these ingredients, particularly digestible amino acids.

Ecobiol® GutCare® MetAMINO® GuanAMINO®

AMINOChick® AMINOLab® AMINONIR®RED

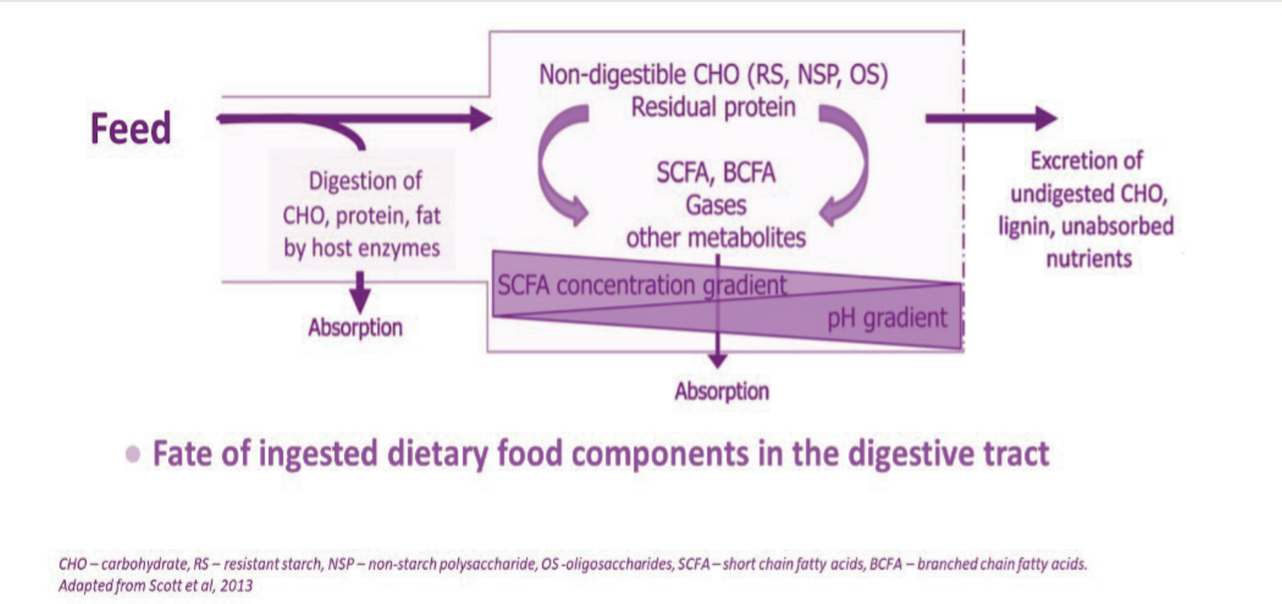

Figure 4: Fate of indigested feed in the digestive tract (Scott et al., 2013).

6. Feed structure and particle size

Coarse particle size is closely related to fiber composition and has been reported to improve gut health and feed utilization (Kheravii et al., 2018). However, the challenge with particle size is reaching the optimal feed particle size (Ali, 2018). Feed particle size is an important factor and is mainly related to the production process. Usually, it is a cost relevant factor, but it also has a significant impact on animal performance, as well as the development of the broiler GIT and intestinal health as reviewed in the AminoNews® "Influence of Particle Size and Feed Form on Growth Performance and Development of Gastrointestinal Tract in Modern Broilers[3] and in the AminoTec® Feed Structure and Production Processes impact on Poultry Live Production".[4]

Mill type, as well as screen size, have a significant effect on particle size of mash feed (Table 1) and pelleted feed (Table 2) and by consequence on animal performance. (Abdollahi, 2020, AminoNews).

Table 1: Influence of particle size on the feed intake (FI, g/bird), weight gain (WG, g/bird) and feed per gain (F/G, g/g) of broilers in mash diets.

Grain type	Age (d)	Mill type/ Screen size	Particle size (µm)		FI	WG	F/G	Reference
			GMD	GSD				
Maize	7-21	H	769	1.63	725	522a	1.37b	Nir et al. (1994)
		H	871	2.05	716	463b	1.54a	
		H	1260	2.08	740	473b	1.60a	
Sorghum	1-49	H	628	1.88	4536b	2187b	2.08a	Nir et al. (1995)
		R	1413	1.76	4728a	2347a	2.02b	
Wheat	1-21	H (3-mm)	NR	NR	777b	453b	1.717a	Amerah et al. (2007)
		H (7-mm)	NR	NR	877a	539a	1.629b	
Wheat	1-21	H (3-mm)	618	2.63	1102	810	1.370	Amerah et al. (2008)
		H (7-mm)	882	2.42	1079	786	1.370	
Maize	1-21	H (3-mm)	611	2.44	871	642b	1.359	Amerah and Ravindran (2009)
		H (7-mm)	849	2.40	902	677a	1.379	
Maize	1-21	H (2-mm)	382	3.50	1145	911	1.257b	Naderinejad et al. (2016)
		H (5-mm)	452	3.80	1179	932	1.279a	
		H (8-mm)	513	3.90	1173	918	1.290a	

a,b Within each reference, values in a column with different superscripts are significantly different ($P < 0.05$).
H, hammer mill; R, roller mill; NR, not reported.

Table 2. Influence of particle size on the feed intake (FI, g/bird), weight gain (WG, g/bird) and feed per gain (F/G, g/g) of broilers fed pelleted diets

Grain type	Age (d)	Mill type/ Screen size	Particle size (µm)		FI	WG	F/G	Reference
			GMD	GSD				
Maize	1-42	H (3.18-mm)	679	2.22	3576	1884a	1.898b	Reece et al. (1986b)
		H (6.35-mm)	987	2.43	3549	1852b	1.916a	
		H (9.53-mm)	1289	2.48	3566	1881a	1.897b	
Maize	1-21	H (3.18-mm)	716	NR	1048	749a	1.40b	Lott et al. (1992)
		H (9.59-mm)	1196	NR	1032	729b	1.42a	
Wheat	1-21	H (3-mm)	NR	NR	1271	834	1.525	Amerah et al. (2007)
		H (7-mm)	NR	NR	1253	824	1.521	
Wheat	1-21	H (1-mm)	NR	NR	1357	888	1.528	Amerah et al. (2008)
		H (7-mm)	NR	NR	1262	872	1.467	
Maize	1-21	H (1-mm)	NR	NR	1191	823	1.448	Amerah et al. (2008)
		H (7-mm)	NR	NR	1173	870	1.360	
Maize	1-21	H (2-mm)	253	3.60	1379	1139	1.219	Naderinejad et al. (2016)
		H (5-mm)	275	3.80	1373	1143	1.204	
		H (8-mm)	299	3.80	1368	1138	1.203	

H, hammer mill; NR, not reported.

7. Environmental conditions

Environmental conditions like heat or cold stress usually lead to alteration in the gastrointestinal physiology and/or immunity which can also lead to lower nutrient absorption and altered microbiota.

Relatively few papers have studied the effect of environmental conditions like heat or cold stress on the microbiota of broilers. Although the results show that heat stress impacts feed intake and growth performance of the birds, and by consequence the physico-chemicals properties of the GIT, that will lead to a modification of the microbial community (Zhang et al., 2017).

Probiotics can play an important role in maintaining intestinal integrity and performance levels during environmental stressors like above optimal heat. This was observed in a study conducted in Thailand where Ecobiol® helped overcome the negative impact of heat stress (Dorigam et al., 2019). Under heat stress, the feed intake and protein digestion and absorption were decreased. The probiotic supplementation allowed this to be rebalanced and for the same performance as the thermoneutral control group to be achieved. On the other hand, the probiotic allowed the activity of the immune system to be maintained and for a decrease in the *E. coli* count in the cecal samples.

Conclusion

Taking into consideration all the factors listed above, we can see that any minor shift in intestinal ecosystem of broilers can lead to a chain of events that will lead to a more severe infection, growth performance losses, morbidity and in the worst case, mortality. To maintain a balanced intestinal ecosystem, we need more than a single product. Solutions are needed that take into consideration all the key components of this ecosystem and bring them all to perfect homeostasis. With Evonik's large panel of services, products, scientific and technical know-how, we can help you develop a solution that will allow your flock to maintain optimal performance while keeping your production sustainable and ethical.

Acronyms
GIT - gastrointestinal tract
NIR - near-infrared
NSP - non-starch polysaccharides

References (available on request).

[1] https://kiosk.purplemanager.com/aminonews#/main/presenter/ab41da9a-9398-45c7-9eef-1b4644fc3faf
[2] https://kiosk.purplemanager.com/aminonews#/main/presenter/630c60bd-cebe-457a-b1ba-42fcff5f2528
[3] https://kiosk.purplemanager.com/aminonews#/main/presenter/2e07d478-8e5e-4998-b7c1-76f6bc26013c
[4] https://kiosk.purplemanager.com/aminonews#/main/presenter/4143aced-f0da-4292-8f65-3953766996ff