

Respiratory Challenges: Breathing Space for Antibiotic Reduction?



Sub-therapeutic doses of antibiotic growth promoters (AGPs) were used for more than 50 years in poultry production to achieve performance targets – until growing concerns arose regarding antibiotic resistance (Kabir, 2009) and decreasing efficacy of antibiotics for medical purposes (Dibner & Richards, 2005).

Isolates of ESBL-producing *E.coli* from animals, farmworkers, and the environment were found to have identical multidrug resistance patterns (A. Nuangmek et al., 2018). There is also evidence that AMR strains of microorganisms spread from farm animal to animal workers and beyond. Global AMR fatalities are increasing and might reach 10 million by 2050 (Mulders et al., 2010, Trung et al., 2017, Huijbers et al., 2014).

In light of this, certain AGPs have already been banned, and there is a strong possibility of future restrictions on their use worldwide. Bans are effective: the MARAN report 2018 shows that lower antibiotics usage following the EU ban on AGPs has reduced resistant *E.coli* in broilers. Another positive consideration is the market opportunities that exist for antibiotic residue-free food.

However, the key element that poultry producers need to get right for antibiotic reduction to be successful is [respiratory health management](#). This article looks at why respiratory health is a particular challenge – and how phyto-genic solutions can help.

A closer look at the chickens' respiratory system

The respiratory tract is equipped with a functional mucociliary apparatus consisting of a protective mucous layer, airway surface liquid layer, and cilia on the surface of the ciliated cells. This apparatus produces mucus, which traps the inhaled particles and pathogens and propels them out of the airways. This mechanism, called the mucociliary clearance, is the primary innate defense mechanism of the respiratory system.

High stocking density combined with stressful environmental factors can negatively influence birds' immune systems (Heckert et al., 2002; Muniz et al., 2006), making them more susceptible to respiratory disease. When a bird suffers from respiratory disease, which is nowadays usually complicated by a co-infection or secondary bacterial infection, there is an excess production of mucus that results in ciliostasis and, therefore, in an impaired mucociliary clearance. The excess mucus in the tract obstructs the airways by forming plaques and plugs, resulting in dyspnea (hypoxia) and allowing the invasive bacteria to adhere and colonize the respiratory system.

The build-up of mucus in the respiratory tract severely reduces oxygen intake, causing breathlessness, reduced feed intake, and a drop in the birds' energy levels, which negatively impacts weight gain and egg production. Respiratory problems can result from infection with bacteria, viruses, and fungi, or exposure to allergens. The resultant irritation and inflammation of the respiratory tract leads to sneezing, wheezing, and coughing – and, therefore, the infection rapidly spreads within the flock.



Relatively high stocking density is the norm in poultry production

Low or no antibiotics: how to

manage respiratory disease?

Unsurprisingly, respiratory diseases in poultry are a major cause of mortality and economic loss in the poultry industry. For Complicated Chronic Respiratory Disease (CCRD), for instance, although the clinical manifestations are usually slow to develop, *Mycoplasma gallisepticum* (MG), in combination with *E. coli*, can cause severe airsacculitis. Beside feed and egg production reduction, these problems are of high economic significance since respiratory tract lesions can cause high morbidity, high mortality, and significant carcass condemnation and downgrading.

Producers need to pre-empt the spread of respiratory pathogens, react quickly to alleviate respiratory distress and maintain the mucociliary apparatus' functionality. Traditionally, treatment options are based on antiviral, anti-inflammatory, and antibiotic drugs. Can the poultry industry limit losses from respiratory infections without excessive recourse to antibiotics?

Indeed, a sudden reduction in antibiotic usage comes with a risk of impaired performance, increased mortality, and impaired animal health and welfare. The impact has been quantified as a 5% loss in broiler meat production per sq. meter (Gaucher et al., 2015). Effective antibiotics reduction requires a combination of innovative products and suitable consultancy services to manage poultry gut health, nutrition, flock management, biosecurity, and, particularly, respiratory health.

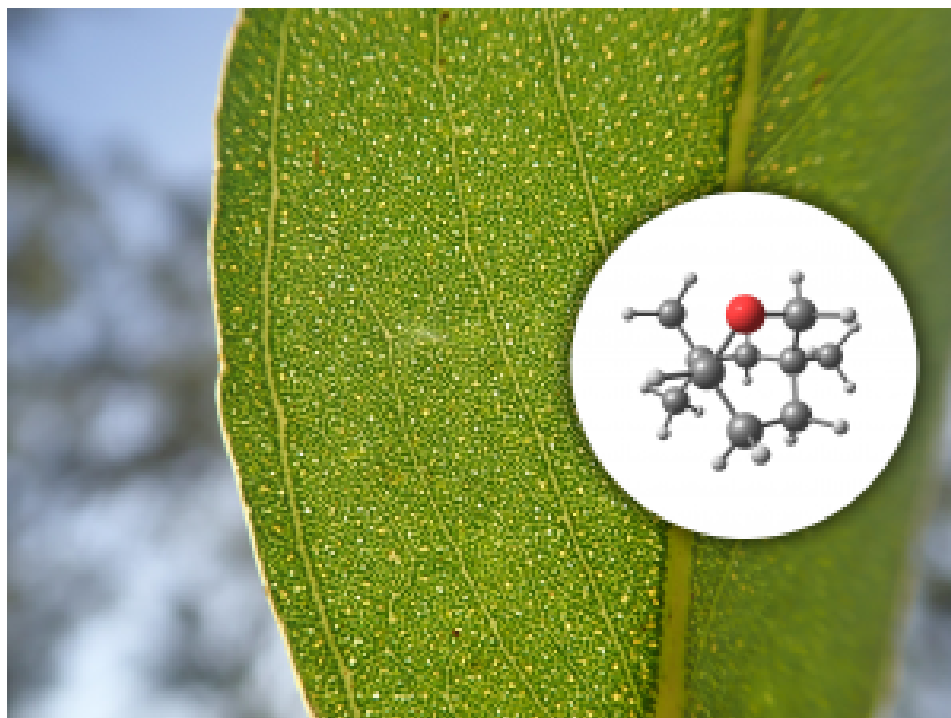
Non-antibiotic alternatives to control diseases and promote broiler growth, such as organic acids (Vieira et al., 2008), probiotics (Mountzouris et al., 2010), prebiotics (Patterson & Burkholder, 2003), and essential oils (Basmacioğlu Malayoğlu et al., 2010) have been the subject of much research in recent years.

Phytogenic solutions: proven efficacy

Essential oils, which are extracted from plant parts, such as flowers, buds, seeds, leaves, twigs, bark, wood, fruits, and roots, have a particularly well-established track record of medicinal applications. Efforts have centered on phytomolecules, the biologically active secondary metabolites that account for the properties of essential oils (Hernández et al., 2004; Jafari et al., 2011).

Studying these properties is challenging: essential oils are very complex natural mixtures of compounds whose chemical compositions and concentrations are variable. For example, the concentrations of the two predominant phytogenic components of thyme essential oils, thymol and carvacrol, have been reported to range from as low as 3% to 60% of the whole essential oil (Lawrence and Reynolds, 1984).

Another well-researched example is eucalyptus oil. The essential oils of eucalyptus species show antibacterial, anti-inflammatory, diaphoretic, antiseptic, analgesic effects (Cimanga et al., 2002) and antioxidant properties (Lee and Shibamoto, 2001; Damjanović Vratnica et al., 2011). The oils are mainly composed of terpenes and terpene derivatives in addition to some other non-terpene components (Edris, 2007). The principal constituent found in eucalyptus is 1,8-cineole (eucalyptol); however, other chemotypes such as α -phellandrene, p-cymene, γ -terpinene, ethanone, and spathulenol, among others, have been documented (Akin et al., 2010).



Close-up of eucalyptus leaf oil glands and the molecular structure of eucalyptol $C_{10}H_{18}O$ (red = oxygen; dark grey = carbon; light grey = hydrogen)

Antimicrobial activity

In modern intensive broiler production, bacterial diseases such as salmonellosis, colibacillosis, mycoplasmosis, or clostridia pose serious problems for the respiratory system and other areas. Analyses of the antibacterial properties of essential oils have been carried out by multiple research units (Ouweland et al., 2010; Pilau et al., 2011; Solorzano- Santos and Miranda-Novales, 2012; Mahboubi et al., 2013; Nazzaro et al., 2013; Petrova et al., 2013).

Phenols, alcohols, ketones, and aldehydes are clearly associated with antibacterial activity; the exact mechanisms of action, however, are not yet fully understood (Nazzaro et al., 2013). Essential oils' [antimicrobial activity](#) is not attributable to a unique mechanism but instead results from a cascade of reactions involving the entire bacterial cell (Nazzaro et al., 2013). However, it is accepted that antimicrobial activity depends on the lipophilic character of the components.

The components permeate the cell membranes and mitochondria of the microorganisms and inhibit, among others, the membrane-bound electron flow and thus the energy metabolism. This leads to a collapse of the proton pump and draining of the ATP (adenosine triphosphate) pool. High concentrations may also lead to lysis of the cell membranes and denaturation of cytoplasmic proteins (Nazzaro et al., 2013; Gopi et al., 2014).

According to current knowledge, lavender, thyme, and eucalyptus oil, as well as the phytomolecules they contain, show enhanced effects when combined with other essential oils or synthetic antibiotics (Sadlon and Lamson, 2010; Bassole and Juliani, 2012; Sienkiewicz, 2012; de Rapper et al., 2013; Zengin and Baysal, 2014).

Minimum inhibitory concentration (MIC) of some essential oil components against microorganisms *in vitro*

Compounds	Microorganisms	MIC (µg/ml) or (%v/v)*	Reference
Carvacrol	<i>Bacillus subtilis</i>	0.125	Soković et al., 2010 Bajpai et al., 2012 Krishan and Narang, 2014
	<i>Candida albicans</i>	113.0–200.0	
	<i>Enterobacter cloacae</i>	0.5	
	<i>Escherichia coli</i>	0.5–225.0	
	<i>Mycobacterium avium</i>	72.0	
	<i>Pseudomonas aeruginosa</i>	1.0	
	<i>Salmonella typhimurium</i>	0.25–0.5	
1,8-cineole	<i>Staphylococcus aureus</i>	0.25–450.0	Soković et al., 2010
	<i>Bacillus subtilis</i>	4.0	
	<i>Enterobacter cloacae</i>	6.0	
	<i>Escherichia coli</i>	6.0	
	<i>Listeria monocytogenes</i>	5.0	
Cinnamaldehyde	<i>Staphylococcus aureus</i>	5.0	Bajpai et al., 2012 Krishan and Narang, 2014
	<i>Candida albicans</i>	200.0	
	<i>Escherichia coli</i>	396.0	
Eugenol	<i>Salmonella sp.</i>	500	Bajpai et al., 2012
Linalol	<i>Salmonella typhimurium</i>	0.5–16	
	<i>Bacillus subtilis</i>	4.0	Soković et al., 2010
	<i>Enterobacter cloacae</i>	6.0	
	<i>Escherichia coli</i>	6.0	
	<i>Listeria monocytogenes</i>	5.0	
	<i>Pseudomonas aeruginosa</i>	9.0	
Menthol	<i>Aspergillus niger</i>	125.0	Soković et al., 2010 Mahboubi et al., 2013
	<i>Bacillus cereus</i>	250.0	
	<i>Bacillus subtilis</i>	0.5	
	<i>Candida albicans</i>	125.0	
	<i>Enterobacter cloacae</i>	2.0	
	<i>Escherichia coli</i>	1.0–250.0	
	<i>Pseudomonas aeruginosa</i>	3.0	
Terpinen-4-ol	<i>Staphylococcus aureus</i>	1.0–125.0	Kurekci et al., 2013
	<i>Campylobacter jejuni</i>	0.05*	
Thymol	<i>Bacillus subtilis</i>	0.25	Soković et al., 2010 Bajpai et al., 2012 Krishan and Narang, 2014
	<i>Enterobacter cloacae</i>	1.0	
	<i>Escherichia coli</i>	1.0–450.0	
	<i>Pseudomonas aeruginosa</i>	1.5	
	<i>Salmonella typhimurium</i>	0.05–56.0	
	<i>Staphylococcus aureus</i>	0.25–225.0	

Immune system boost I: improved production of antibodies

Some essential oils were found to influence the avian immune system positively, since they promote the production of immunoglobulins, enhance the lymphocytic activity, and boost interferon- γ release (Awaad et al., 2010; Faramarzi et al., 2013; Gopi et al., 2014; Krishan and Narang, 2014). Placha et al. (2014) showed that the addition of 0.5g of thyme oil per kg of feed significantly increased IgA levels.

Awaad et al. (2010) experimented on birds vaccinated with the inactivated H5N2 avian influenza vaccine. The experiment revealed that adding eucalyptus and peppermint essential oils to the water at a rate of 0.25 ml per liter resulted in an enhanced cell-mediated and humoral immune response.

Saleh et al. (2014), who applied thyme and ginger oils in quantities of 100mg and 200mg per kg of feed, respectively, observed an improvement in chickens' immunological blood profile through increased antibody production. Rehman et al. (2013) stated that the use of herbal products containing eucalyptus oil and menthol in broilers showed consistently higher antibody titers against NDV (Newcastle disease virus), compared to untreated broilers.

Immune system boost II: better vaccine responses and anti-inflammatory effects

Essential oils are also used as immunomodulators during periods when birds are exposed to stress, acting protectively and regeneratively. Importantly, the oils alleviate the stress caused by vaccination (Barbour et al., 2011; Faramarzi et al., 2013; Gopi et al., 2014). The study by Kongkathip et al. (2010) confirmed the antiviral activity of turmeric essential oil.

In recent years studies have been carried out on the use of essential oils in conjunction with vaccination programs, including those against infectious bronchitis (IB), Newcastle disease, and Gumboro disease. The results of the experiments show that essential oils promote the production of antibodies, thus enhancing the efficacy of vaccination (Awaad et al., 2010; Barbour et al., 2010; Barbour et al., 2011; Faramarzi et al., 2013).

Essential oils contain compounds that are known to possess strong anti-inflammatory properties, mainly terpenoids, and flavonoids, which suppress the metabolism of inflammatory prostaglandins (Krishan and Narang, 2014). Also, other compounds found in essential oils have anti-inflammatory, pain-relieving, or edema-reducing properties, for example, linalool from lavender oil, or 1,8-cineole, the main component of eucalyptus oil (Peana et al., 2003).

Immune system boost III: antioxidant effects and radical scavenging

An imbalance in the rate of production of free radicals or removal by the antioxidant defense mechanisms leads to a phenomenon referred to as oxidative stress. A mixture of Oregano (carvacrol, cinnamaldehyde, and capsicum oleoresin) was found to beneficially affect the intestinal microflora, absorption, digestion, weight gain and also to have an antioxidant effect on chickens (Bassett, 2000).

Zeng et al. (2015) indicated the positive effect of essential oils on the production of digestive secretions and nutrient absorption. They reduce pathogenic stress in the gut, exert antioxidant properties, and reinforce the animal's immune status.

Inside the cell, essential oils can serve as powerful scavenger preventing mutations and oxidation (Bakkali et al., 2008). Studies have demonstrated the concentration-dependent free radical scavenging ability of oils from eucalyptus species (Kaur et al., 2010; Marzoug et al., 2011; Olayinka et al., 2012). Some authors attribute the strong antioxidant capacity of essential oils to their phenolic constituents and synergistic effect between tannins, rutin, thymol, and carvacrol, and probably 1, 8-cineole. Moderate DPPH radical scavenging activity reported by Edris(2007), El-Moein et al. (2012), and Kaur et al. (2011).

Vázquez et al. (2012) have demonstrated the potential of the phenolic compounds in eucalyptus bark as a source of antioxidant compounds. The study showed that eucalyptus had ferric reducing antioxidant power in the ranges 0.91 to 2.58 g gallic acid equivalent (GAE) per 100 g oven-dried bark and 4.70 to 11.96 mmol ascorbic acid equivalent (AAE) per 100 g oven-dried bark, respectively (see also Shahwar et al., 2012). Moreover, Eyles et al. (2004) were able to show superoxide dismutase (SOD)-like activity for different compounds and fractions isolated from wood extracts.

Last but not least: positive effects on the respiratory system

In poultry production houses, especially in summer, high temperatures and low humidity increase the amount of air dust. Under such conditions, respiratory tract disorders in broiler chickens, including the deposition of particulates, become more frequent and more severe.



Clinical signs of respiratory disease in chickens include coughing, sneezing, and rales

Thyme oil, thanks to the phytochemicals thymol and carvacrol, supports the treatment of respiratory disorders. These substances smooth tightened muscles and stimulate the respiratory system. An additional advantage lies in their expectorant and spasmolytic properties (Edris, 2007).

These properties are also seen in essential oils such as eucalyptus and peppermint, which contain eucalyptol and menthol. They thin out the mucus and facilitate its removal from the airways. As a result, the airways are cleared and breathing during inflammation becomes easier (Durmik and Blache, 2012).

Another positive effect of the terpenoid compounds used in commercial preparations for poultry is that they disinfect the bronchi, preventing respiratory infections (Awaad et al., 2010; Barbour et al., 2011; Mahboubi et al., 2013). Barbour and Danker (2005) reported that the essential oils of eucalyptus and peppermint improved the homogeneity of immune responses and performance in MG/H9N2-infected broilers.

Grippozon: the phytogenic solution for respiratory health

[Grippozon](#) is a liquid composition with a high content of essential oils, which are combined to systematically prevent and ease respiratory diseases. The formulation is derived from the research on essential oils' effectiveness against respiratory pathogens that are common in animal farming. Grippozon exhibits a synergistic action of all its components to optimally support animal health. It contains a high concentration of active components; both their quantity and quality are guaranteed to deliver results.

Application of Grippozon

Grippozon application can be flexibly adapted to most common housing systems. It is fully water-soluble for use in the drinking line and it is also possible to nebulize a diluted solution in air.

The dose recommendation in drinking water usually amounts to 100ml to 200ml per 1000 liters of drinking

water (Grippozon administration has not been reported to affect water consumption). The active substances in Grippozon adhere to mouth mucosa and become volatile in the breathing air later on. Therefore Grippozon can enter the respiratory system indirectly as well. The volatile compounds also spread into the whole barn air and, thus, indirectly via breathing into the respiratory system (and farmers notice the smell of essential oils when Grippozon is applied through in the waterline)

Grippozon can also be used as a spray at a rate of 200ml/10 liters of water for 2000 birds, twice daily on 2-3 days a week. This produces a very effective nebulization effect and offers faster respiratory relief to birds.

Grippozon is an impactful tool for managing respiratory problems. Thanks to its effective mucolytic and relaxant activity, Grippozon gives symptomatic relief to the birds during high-stress periods of respiratory diseases. Mucus in the trachea works as media for the proliferation of bacteria and viruses, so by thinning the mucus, Grippozon slows down the proliferation of bacteria and the spread of disease. Grippozon helps in improving air quality and air intake. It can also be used to stimulate the immune response during vaccination.

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References available on request

Do we have the tools to reduce antibiotics in swine production?



The global swine industry is going through unprecedented challenges. On the one hand, the threat of the African Swine Fever virus is global, despite the fact it hasn't arrived in all markets. The virus is today alive among the wild boars in the Polish and Belgian forests. Every day it keeps gaining a few more meters to

the border, threatening the German swine industry, one of the largest in the European Union.

If this happens, we might be seeing important changes to the pork supply chain on the meat market worldwide – in Europe in addition to current issues in the USA meat plants. The profitability of swine businesses depends in many ways on the export capacity of large corporations based in Germany, Spain, Denmark, etc.

On the other hand, the presence of COVID-19 in most countries is changing human behavior, meat consumption at home, and the way we look at the future. Perhaps a virus overload via the news, some “fake news” conveying wrong messages on what’s coming, and suddenly we feel the future will never be the same.

The future of the swine industry

At least for the swine industry, the future will indeed never be exactly the same. We will be facing different challenges. Some of these will be structural, such as the issue of decreased manpower and how to substitute manpower by machines, through the implementation of Precision Livestock Farming, for instance.

We are also facing important health challenges to our animals: not just ASF, but also new and more aggressive PRRS strains, among other pathogens. Our sows’ production capacity is increasing annually, yet in some cases 25% of the new-born piglets are lost from birth to market. Increasingly, we may start to see increased levels of mortality not only in the nursery but in fattening pigs and sows as well.

It is becoming clearer all the time: the future of the global swine industry lies in producing more pigs with reduced antibiotics. To stay the course, we need to take further action and implement corrective measures.

Why we should remove antibiotics in pig production

Pressure from stakeholders and regulators

There is, and there will be, increasing pressure from many stakeholders worldwide to work toward pig production with reduced or no antibiotics. Meat suppliers, slaughterhouses and processors, governments at different levels, and, of course, the European Union – all are demanding reductions in the level of antibiotics in livestock production.

There is also an increasing awareness at the global societal level regarding [antimicrobial resistance](#) related to antibiotic usage in farming production. Consumer pressure will grow exponentially as the terrible COVID-19 experience will be “digested” by the global population.

Pressure to accede to the pork market

There is yet another important reason to start working in that direction: the global swine meat market. Today, China’s pork meat shortage is opening the market. Now any producer could potentially sell meat, either to China or to any other country. We are starting to see moves from companies in the USA or Brazil banning the use of Ractopamine in their operations because they want to get access to the ractopamine-free market (Europe & Asia, over 70% of the global population).

According to M. Pierdon (AASV 2020 Proceedings), there will be two types of markets: the “Niche ABFree” and the “Commodity ABFree”. Companies will have to analyse what their future is on the meat market. Not all the producers may be willing to enter this new phase, but for sure many will try.

Strategies for antibiotic reduction

In Europe, the time has arrived. Zinc oxide will be banned in June 2021 and there is now more than a trend in production with less or no antibiotic use. In some cases, there is a need; in others, this is simply profitable.

Challenges to antibiotic reduction

Producing pigs completely without antibiotics is not easy, and not affordable for all. Initially we may have to give up some performance parameters in order to achieve the balance between what we want and what we can achieve in animal performance. But the time will arrive when these two objectives will converge; there is no alternative.

To that end, we will have to include in our pig production strategy all the available tools and technologies: genetic selection, immunization against some key pathogens, environmental control (mandatory but often forgotten), early detection of diseases, etc.

In this new era we are entering, nutrition and feed additives will play a key role. It will be crucial to find solutions targeting the microbiome's stabilization and diversification, creating and maintaining healthy farms and achieving all the performance parameters.

Do we have the tools for antibiotic reduction?

Even today there are companies able to produce completely antibiotic-free pigs – proof that **yes, the tools are already in place**.

Nevertheless, for most producers, the answer to – **Can we produce without antibiotics?** is most likely “probably not”. This will require a holistic approach, given the specific case of piglets.

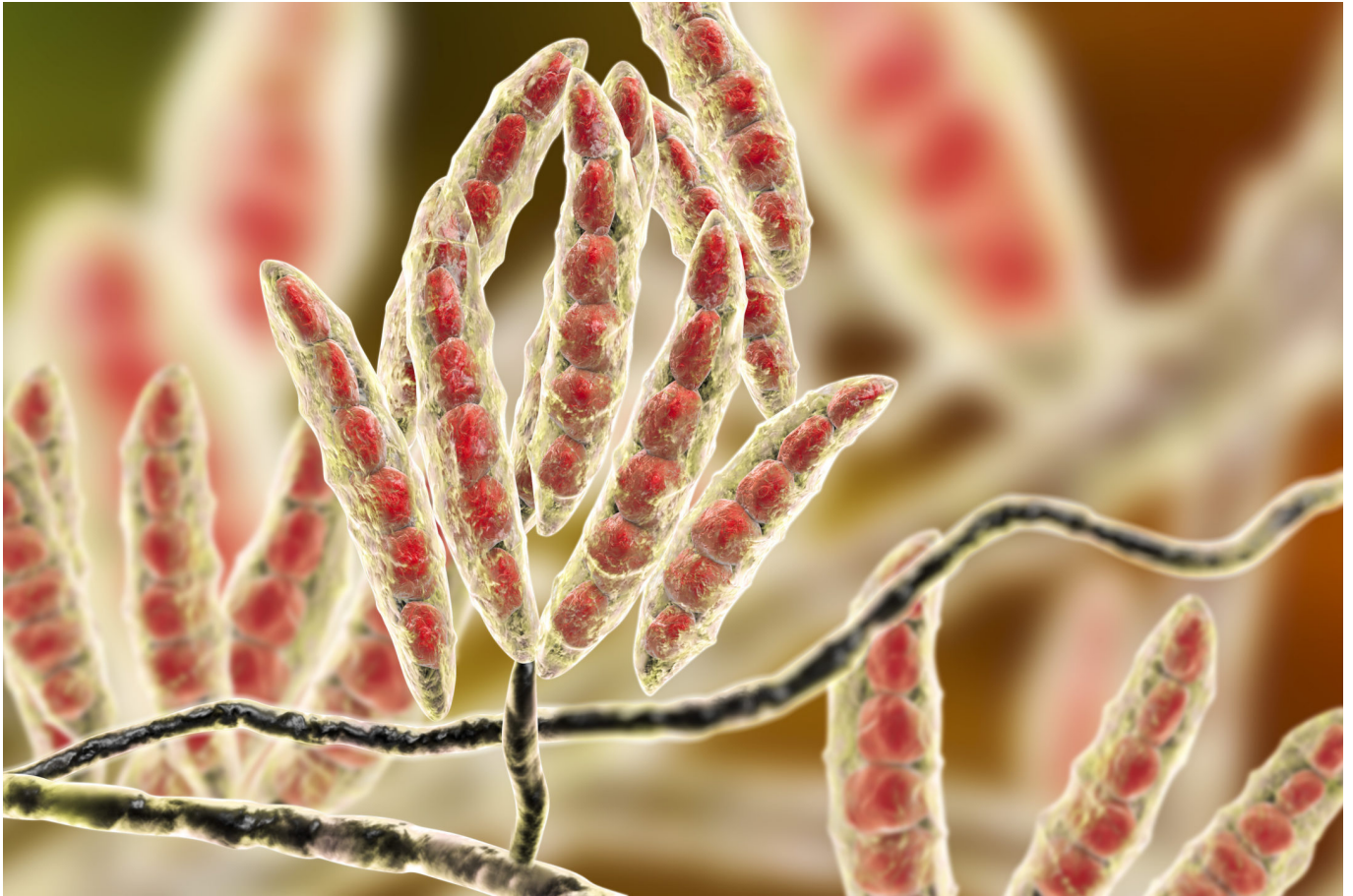
The microbiome of the piglet is strongly influenced by birth and the subsequent weeks. What, then, are the elements that will be part of this new game that comprises a new approach?

- The colostrum intake & the management of the piglets
- Antibiotic usage and its influence on the gut
- The piglets' microbiome and its evolution during the periweaning period
- The weaning process, appetite, and water intake
- Zinc oxide removal and its influence on the microbiome
- The immune system and the relationship with the GIT status
- Inflammation and its modulation at the gut level
- The health status and the effect on the concomitant infections: which ones are key and which ones are secondary pathogens
- The all-important biosecurity, management, and hygiene

To summarize: there is no one tool, but rather a **holistic approach** to face this new challenge that the swine industry is facing nowadays. The answer is not a silver bullet, but a journey that we all must undertake.

Available in Spanish [here](#).

A complex battlefield: mycotoxins in the gastrointestinal tract



Most grains used as feed raw materials are susceptible to mycotoxin contamination. These toxic secondary metabolites are produced by fungi before or after harvest and cause severe economic losses all along agricultural value chains. For livestock, negative consequences include acute effects such as impaired liver and kidney function, vomiting, or anorexia, as well as chronic effects such as immunosuppression, growth retardation, and reproductive problems. Mycotoxin management is, therefore, of the utmost priority for animal producers worldwide.

But how is it that mycotoxins cause such damage in the first place? This article delves into the complex processes that take place when mycotoxins come into contact with the gastrointestinal tract (GIT). The intestinal epithelium is the first tissue to be exposed to mycotoxins, and often at higher concentrations than other tissues. A deeper understanding of how mycotoxins affect the GIT allows us to appreciate the cascading effects on animal health and performance, why such damage already occurs at contamination levels well below official safety thresholds – and what we can do about it.

The intestinal epithelium: the busy triage

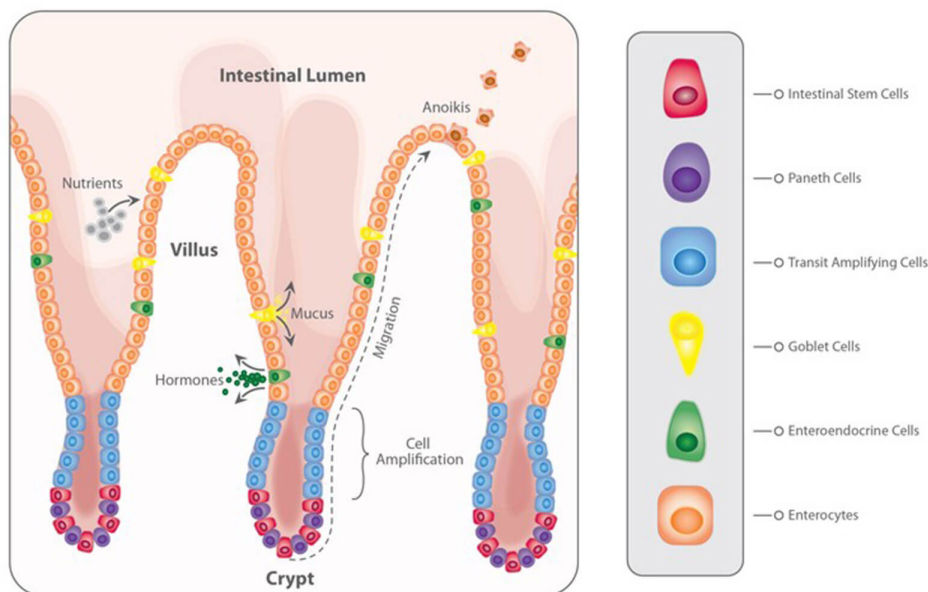
site for nutrients and harmful substances

When mycotoxins are ingested, they encounter the GIT's intestinal epithelium (Figure 1). This single layer of cells lining the intestinal lumen serves two conflicting functions: firstly, it must be permeable enough to allow the absorption of nutrients. On the other hand, it constitutes the primary physiological barrier against harmful agents such as viruses, microorganisms, and toxins.

Within the intestinal epithelium, several types of highly specialized cells are involved in epithelial regeneration, nutrient absorption, innate defense, transport of immunoglobulins, and immune surveillance. The selective barrier function is maintained due to the formation of complex networks of proteins that link adjacent cells and seal the intercellular space. Besides, the intestinal epithelium is covered with mucus produced by goblet cells, which isolates its surface, preventing the adhesion of pathogens to the enterocytes (intestinal absorptive cells).

Due to its dual involvement in digestive and immune processes, the intestinal epithelium plays a pivotal role in the animal's overall health. Importantly, the epithelium is directly exposed to the entire load of ingested mycotoxins. Hence their effects can be problematic even at low concentrations.

Figure 1: The intestinal epithelium



Problematic effects of mycotoxins on the intestinal epithelium

Most mycotoxins are absorbed in the proximal part of the gastrointestinal tract (Table 1). This absorption can be high, as in the case of aflatoxins (~90%), but also very limited, as in the case of fumonisins (<1%); moreover, it depends on the species. Importantly, a significant portion of unabsorbed toxins remains within the lumen of the [gastrointestinal tract](#).

Some of the mycotoxins that enter the intestinal lumen can be [bio-transformed into less toxic compounds](#) by the action of certain bacteria. This action, however, predominantly happens in the large intestine – therefore, no detoxification takes place before absorption in the upper parts of the GIT. Part of the absorbed mycotoxins can also re-enter the intestine, reaching the cells from the basolateral side via the bloodstream. Furthermore, they re-enter through [enterohepatic circulation](#) (the circulation of substances between the liver and small intestine). Both actions increase the gastrointestinal tract's overall exposure

to the toxins.

Table 1: Rate and absorption sites of different mycotoxins

Mycotoxin	Primary absorption sites	Absorption rate in poultry	Absorption rate in swine	Observations
Aflatoxin	Duodenum / Jejunum	~90%	~80%	Subject to enterohepatic circulation
DON	Duodenum / Jejunum	Up to 20%	Up to 60%	Subject to enterohepatic circulation and to biotransformation in the large intestine
Fumonisin	Duodenum / Jejunum	Less than 1%	Less than 5%	Subject to enterohepatic circulation
Ochratoxin	Jejunum	~40%	~60%	Subject to enterohepatic circulation and to biotransformation in the large intestine
Zearalenone	Small & large intestine	~10%	~80%	Subject to enterohepatic circulation

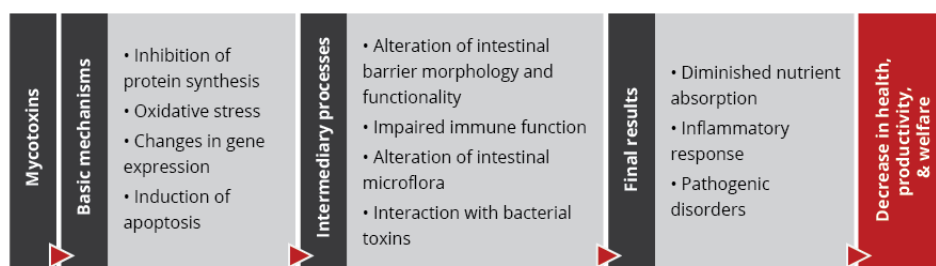
Adapted from: [Biehl et al., 1993](#); [Bouhet & Oswald, 2007](#); [Devreese et al., 2015](#); [Ringot et al., 2006](#)

The damaging impact of mycotoxins on the intestinal epithelium initially occurs through:

- A decrease in protein synthesis, which reduces barrier and immune function ([Van de Walle et al., 2010](#))
- Increased oxidative stress at the cellular level, which leads to lipid peroxidation, affecting cell membranes ([Da Silva et al., 2018](#))
- Changes in gene expression and the production of chemical messengers (cytokines), with effects on the immune system and cellular growth and differentiation ([Ghareeb et al., 2015](#))
- The induction of programmed cell death (apoptosis), affecting the reposition of immune and absorptive cells ([Obremski & Poniatowska-Broniek, 2015](#))

Importantly, studies based on realistic mycotoxin challenges (e.g., [Burel et al., 2013](#)) show that the mycotoxin levels necessary to trigger these processes are lower than the [levels reported as safe](#) by EFSA, the Food Safety Agency of the European Union. The ultimate consequences range from diminished nutrient absorption to inflammatory responses and pathogenic disorders in the animal (Figure 2).

Figure 2: Mycotoxins' impact on the GIT and consequences for monogastric animals



1. Alteration of the intestinal barrier's morphology and functionality

The mycotoxins DON, fumonisin, and T2 induce [a reduction in the rate of epithelial cell proliferation and differentiation](#). This causes a decrease in the height and the surface of the intestinal villi, which in turn leads to a reduction in nutrient absorption. Additionally, some [nutrient transporters](#) are inhibited by the action of mycotoxins such as DON and T2, for example, negatively affecting the transport of glucose.

Several studies indicate that mycotoxins such as aflatoxin B1, DON, fumonisin B1, ochratoxin A, and T2, can increase the permeability of the intestinal epithelium of poultry and swine (e.g. [Pinton & Oswald, 2014](#)). This is mostly a consequence of the inhibition of protein synthesis. As a result, there is an increase in the passage of antigens into the bloodstream (e.g., bacteria, viruses, and toxins). This increases the animal's susceptibility to infectious enteric diseases. Moreover, the damage that mycotoxins cause to the intestinal barrier entails that they are also being absorbed at a higher rate.

2. Impaired immune function in the intestine

The intestine is a very active immune site, where several immuno-regulatory mechanisms simultaneously defend the body from harmful agents. [Immune cells are affected by mycotoxins](#) through the initiation of apoptosis, the inhibition or stimulation of cytokines, and the induction of oxidative stress. Studies demonstrate that aflatoxin, DON, fumonisin, T2, and zearalenone interact with the intestinal immune system in such a manner that the animal's susceptibility to viral and bacterial infections increases (e.g., [Burel et al., 2013](#)). Moreover, by increasing their fecal elimination, the horizontal transmission of pathogens is extended.

For poultry production, one of the most severe enteric problems of bacterial origin is [necrotic enteritis](#), which is caused by *Clostridium perfringens* toxins. Any agent capable of disrupting the gastrointestinal epithelium – e.g. mycotoxins such as DON, T2, and ochratoxin – promotes [the development of necrotic enteritis](#). The inhibition of the intestinal immune system caused by mycotoxins such as aflatoxin, DON, and T2 also collaborates with the development of this disease.

3. Alteration of the intestinal microflora

The gastrointestinal tract is home to a diverse community of bacteria, fungi, protozoa, and viruses, which lines the walls of the distal part of the intestine. This microbiota prevents the growth of pathogenic bacteria through competitive exclusion and the secretion of natural antimicrobial compounds, volatile fatty acids, and organic acids.

Recent studies on the effect of various mycotoxins on the intestinal microbiota show that [DON and other trichothecenes favor the colonization of coliform bacteria in pigs](#). DON and ochratoxin A also induce a [greater invasion of *Salmonella*](#) and their translocation to the bloodstream and vital organs in birds and pigs – even at non-cytotoxic concentrations. It is known that fumonisin B1 may induce changes in the balance of sphingolipids at the cellular level, including for gastrointestinal cells. This facilitates the adhesion of pathogenic bacteria, increases in their populations, and prolongs infections, [as has been shown for the case of *E. coli*](#).

From the perspective of human health, the colonization of the intestine of food-producing animals by pathogenic strains of *E. coli* and *Salmonella* is of particular concern. Mycotoxin exposure may well increase the transmission of these pathogens, posing a risk for human health.

4. Interaction with bacterial toxins

When mycotoxins induce changes in the intestinal microbiota, this can lead to an increase in the endotoxin concentration in the intestinal lumen. Endotoxins or lipopolysaccharides (LPS) are fragments of Gram-negative bacteria's cell walls. They are released during bacterial cell death, growth, and division. Hence endotoxins are always present in the intestine, even in healthy animals. [Endotoxins promote the release of several cytokines](#) that induce an enhanced immune response, causing inflammation, thus reducing feed consumption and animal performance, damage to vital organs, sepsis, and death of the animals in some cases.

The synergy between mycotoxins and endotoxins can result in an overstimulation of the immune system. The interaction between endotoxins and estrogenic agents such as zearalenone, for example, generates [chronic inflammation and autoimmune disorders](#) because immune cells have estrogen receptors, which are stimulated by the mycotoxin. The combination of DON at low concentrations and endotoxins in the intestine, on the other hand, has been shown to engender [a decrease in transepithelial resistance](#) and to

alter the balance of the microbiota.

What to do? Proactive toxin risk management

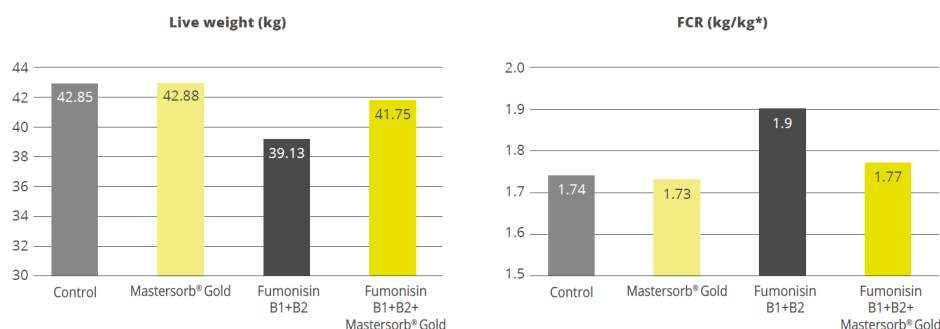
To prevent the detrimental consequences of mycotoxins on animal health and performance, proactive solutions are needed that support the intestinal epithelium's digestive and immune functionality and help maintain a balanced microbiome in the GIT. Moreover, it is crucial for any anti-mycotoxin product to feature both anti-mycotoxin and anti-bacterial toxin properties and that it supports the organs most targeted by mycotoxins, e.g., the liver. EW Nutrition's Mastersorb Gold premix is based on the synergistic combination of natural clay minerals, yeast cell walls, and phytomolecules. Its efficacy has been extensively tested, including as a means for dealing with *E. coli* endotoxins.

Mastersorb Gold: anti-mycotoxin activity stabilizes performance and strengthens liver health

A field trial conducted in Germany on male Ross 308 broilers showed that for broilers receiving a diet contaminated with DON and zearalenone, adding 1kg of Mastersorb Gold per ton of feed to their diet led to significant performance enhancements. Not only did they recuperate the mycotoxin-induced weight loss (6% increase relative to the group receiving only the challenge), but they gained weight relative to the control group (which received neither the challenge nor Mastersorb Gold). Feed conversion also improved by 3% relative to the group challenged with mycotoxins.

A scientific study of crossbred female pigs showed that Mastersorb Gold significantly reduced the deleterious effects of fumonisin contamination in the feed. The decrease in weight gain and the decline of feed conversion could be mitigated by 6.7% and 13 FCR points, respectively (Figure 3). Also, the sphinganine/sphingosine (Sa/So) ratio, a biomarker for fumonisin presence in the blood serum, could be decreased by 22.5%.

Figure 3: Mastersorb Gold boosts performance for pigs fed a fumonisin-contaminated diet



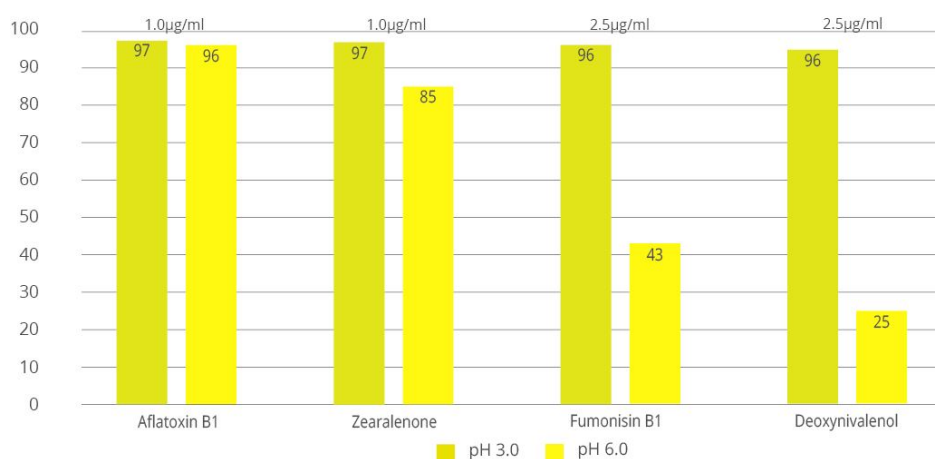
Another study of crossbred female piglets, carried out at a German university, investigated whether Mastersorb Gold could support performance as well as liver health under a naturally occurring challenge of ZEA (~ 370ppb) and DON (~ 5000ppb). Mastersorb Gold significantly improved weight gain and feed conversion in piglets receiving the mycotoxin-contaminated diet: daily body weight gain was 75g higher than that of a group receiving only the challenge, and the FCR improved by 24% (1.7 vs. 2.25 for the group without Mastersorb Gold). Moreover, Mastersorb Gold significantly improved the liver weight (total and relative) and the piglets' AST levels (aspartate aminotransferase, an enzyme indicating liver damage). A tendency to improve spleen weight and GGT levels (gamma-glutamyl transferase, another enzyme indicative of liver issues) was also evident, all of which indicate that Mastersorb Gold effectively

counteracts the harmful impact of mycotoxin contamination on liver functionality.

In-vitro studies demonstrate Mastersorb Gold's effectiveness against mycotoxins as well as bacterial toxins

Animal feed is often contaminated with two or more mycotoxins, making it important for an anti-mycotoxin agent to be effective against a wide range of different mycotoxins. Besides, to prevent mycotoxins damaging the GIT, an effective product should ideally adsorb most mycotoxins in the first part of the animal's intestine (under acidic conditions). In-vitro experiments at an independent research facility in Brazil showed that an application of 0.2% Mastersorb Gold binds all tested mycotoxins at rates from 95 to 97% at a pH level of 3, using realistic challenges of 1000ppb (Aflatoxin B1 and ZEA) and 2500ppb (Fumonisin B1 and DON). The binding results achieved for Fumonisin and DON, which are often considered outright "nonbinding," under challenging close to neutral conditions (pH 6), are particularly encouraging.

Figure 4: Mastersorb Gold binding capacity against different mycotoxins (%)



Concerning its efficacy against endotoxins, an *in vitro* study conducted at Utrecht University, among other studies, has shown Mastersorb Gold to be a strong tool against the LPS released by *E. coli*. For the test, four premium mycotoxin binders were suspended in a phosphate buffer solution to concentrations of 0.25% and 1%. *E. coli* LPS were suspended to a final concentration in each sample of 50ng/ml. Against this particularly high challenge, Mastersorb Gold achieved a binding rate of 75% at an inclusion rate of 1%: clearly outperforming competing products, which at best showed a binding rate of 10%.

Conclusion

A healthy gastrointestinal tract is crucial to animals' overall health: it ensures that nutrients are optimally absorbed, it provides effective protection against pathogens through its immune function, and it is key to maintaining a well-balanced microflora. Even at levels considered safe by the European Union, mycotoxins can compromise different intestinal functions such as absorption, permeability, immunity, and microbiota balance, resulting in lower productivity and susceptibility to disease.

To safeguard animal performance, it is important to continually strive for low levels of contamination in feed raw materials – and to stop the unavoidable mycotoxin loads from damaging the intestinal epithelium through the use of an effective anti-mycotoxin agent, which also supports animals against [endotoxins](#) and boosts liver function. Research shows that [Mastersorb Gold](#) is a powerful tool for proactive producers seeking stronger animal health, welfare, and productivity.

By Marisabel Caballero, Global Technical Manager Poultry, EW Nutrition

Challenging times for broilers? Phytomolecules, not antibiotics, are the answer



by **Ajay Bhoyar**, Global Technical Manager, EW Nutrition

Anyone working with today's fast-growing broiler chicken knows that it is a sensitive creature – and so is its gut health. Thanks to continuous improvements in terms of [genetics and breeding](#), nutrition and feeding, as well as general management strategies, broiler production has tremendously upped performance and efficiency over the past decades. It is estimated that, between 1957 and 2005, the [broiler growth rate increased by over 400%, while the feed conversion ratio dropped by 50%](#).

These impressive improvements, however, have come at the cost of intense pressure on the birds' digestive system, which needs to process large quantities of feed in little time. To achieve optimal growth, a broiler's [gastrointestinal tract \(GIT\)](#) needs to be in perfect health, all the time. Unsurprisingly, enteric diseases such as [necrotic enteritis](#), which severely damages the intestinal mucosa, hamper the intestines' capacity to absorb nutrients and induce an inflammatory immune response.

The modern broiler's gut – a high-performing, but sensitive system

However, in a system as high performing as the modern broiler's GIT, much less can lead to problems. From when they are day-old chicks up to slaughter, broilers go through several challenging phases during which they are more likely to show impaired gut functionality, e.g. after vaccinations or feed changes. [Good management practices go a long way towards eliminating unnecessary stressors](#) for the animals, but some challenging periods are unavoidable.

The transition from starter to grower diets is a classic situation when nutrients are very likely to not be well digested and build up in the gut, fueling the proliferation of harmful microbes. Immunosuppressive stress in combination with an immature intestinal microflora results in disturbances to the bacterial microbiota. At “best”, this entails temporarily reduce nutrient absorption, in the worst case the birds will suffer serious intestinal diseases.

Phytomolecules – the intelligent alternative to antibiotics

To safeguard performance during stressful periods, poultry producers need to anticipate them and proactively provide effective gut health support. For many years, this support came in the form of antibiotic growth promoters (AGP): administered prophylactically, they were effective at keeping harmful enteric bacteria in check. However, due to grave concerns about the [development of antimicrobial resistance](#), non-therapeutic antibiotics use has been banned in many countries. Alternatives need to focus on improving feed digestibility and strengthening gut health, attacking the root causes of why the intestinal microflora would become unbalanced in the first place.

Phytomolecules are secondary metabolites active in the defense mechanisms of plants. Studies have found that certain phytomolecules [stimulate digestive enzyme activities](#) and stabilize the gut microflora, “leading to improved feed utilization and less exposure to growth-depressing disorders associated with digestion and metabolism” ([Zhai et al., 2018](#)). With other trials showing [positive effects on broilers' growth performance and feed conversion](#), the research indicates that phytomolecules might also specifically support chickens during challenging phases.

The effect of phytomolecules on broilers during a challenging phase

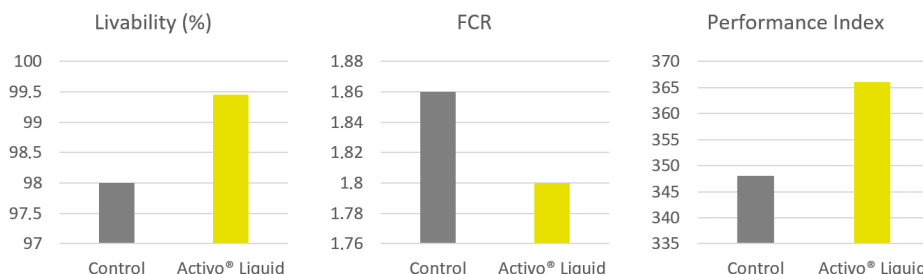
A study was conducted over a period of 49 days on a commercial broiler farm of an AGP-free integration operation in Japan. The farm reported gut health challenges in the second and third week of the fattening period due to vaccinations and changes to the animals' diets. The trial included 15504 Ross 308 broilers, divided into two groups. The negative control group included a total of 7242 birds, kept in another house.

All the birds were fed the standard feed of the farm. The trial group (8262 birds) received Activo Liquid,

which contains a synergistic combination of phytomolecules, administered directly through the drinking water. Activo Liquid was given at an inclusion rate of 200ml per 1000L of water (3.3 US fl oz per gallon of stock solution, diluted at 1:128), from day 8 until day 25, for 8 hours a day.

The results are summarized in Figure 1:

Figure 1: Improved broiler performance for Activo Liquid group (day 49)



The Activo Liquid group clearly showed performance improvements compared to the control group. Livability augmented by 1.5%, while the feed conversion rate improved by 3.2%. This resulted in a more than 5% higher score in terms of the performance index.

Challenging times? Tackle them using phytomolecules

Poultry producers take great care to eliminate unnecessary sources of stress for their birds. Nonetheless, during their lifecycle, broiler chickens face challenging periods during which the balance of the intestinal microflora can easily become disturbed, with consequences ranging from decreased nutrient absorption to full-blown enteric disease.

The trial reviewed here showed that, after receiving Activo Liquid, broilers raised without AGPs showed encouraging performance improvements during a challenging phase of feed changes and vaccinations. Likely thanks to the activation of digestive enzymes and a stabilization of the gut flora, the broilers showed improved livability and feed conversion, thus delivering a much more robust performance during a critical phase of their lives. In times where the non-therapeutic use of antibiotics is no longer an option, phytomolecules allow poultry farmers to effectively support their animals during challenging times.

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Photo Source: [Aviagen](#)

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Phytomolecules: A tool against antibiotic-resistant *E. coli*



Diseases caused by *E. coli* entail use of antibiotics in animal production

E. coli infections are a major problem in pig production. Especially young animals with an incompletely developed immune system are often unable to cope with the cavalcade of pathogens. In poultry, *E. coli* are responsible for oedema, but also for [respiratory diseases](#). In young piglets, *E. coli* cause diarrhoea, oedema, endotoxic shock and death. In order to cure the animals, antibiotics often must be applied. Besides this curative application, antibiotics were and in many countries still are used prophylactically and as growth promoters.

The excessive use of antibiotics, however, leads to the [occurrence of antimicrobial resistance](#) (AMR): due to mutations, resistance genes are created which enable enterobacteria such as *Salmonella*, *Klebsiella* and *E. coli* to produce enzymes (β -lactamases) in order to withstand β -lactam antibiotics. In case of an antibiotic treatment, the resistant bacteria survive whereas the other bacteria die.

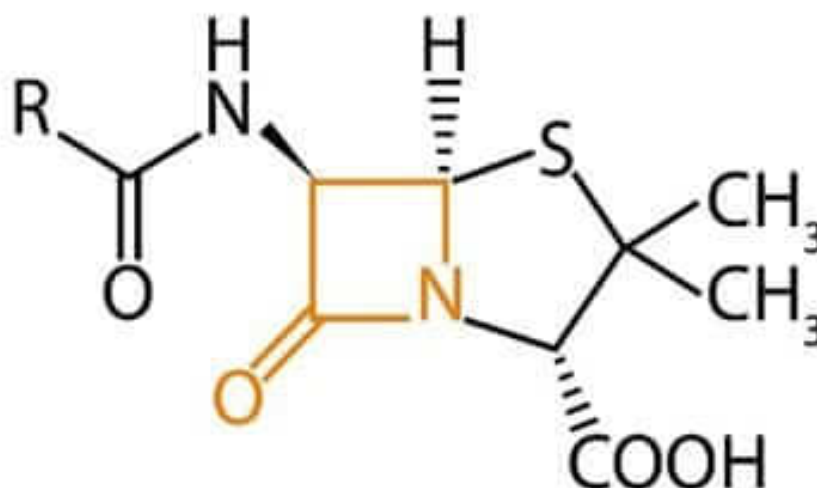
The major problem here is that these resistance genes can be transferred to other bacteria. Harmless bacteria can thus transfer resistance genes to dangerous pathogens, which then cannot be combatted with

antibiotics anymore. In this article we explore in detail how AMR happens and how phytomolecules, which have antimicrobial properties, could be a key tool to reduce the need for antibiotics in animal production.

How β -lactam antibiotics work

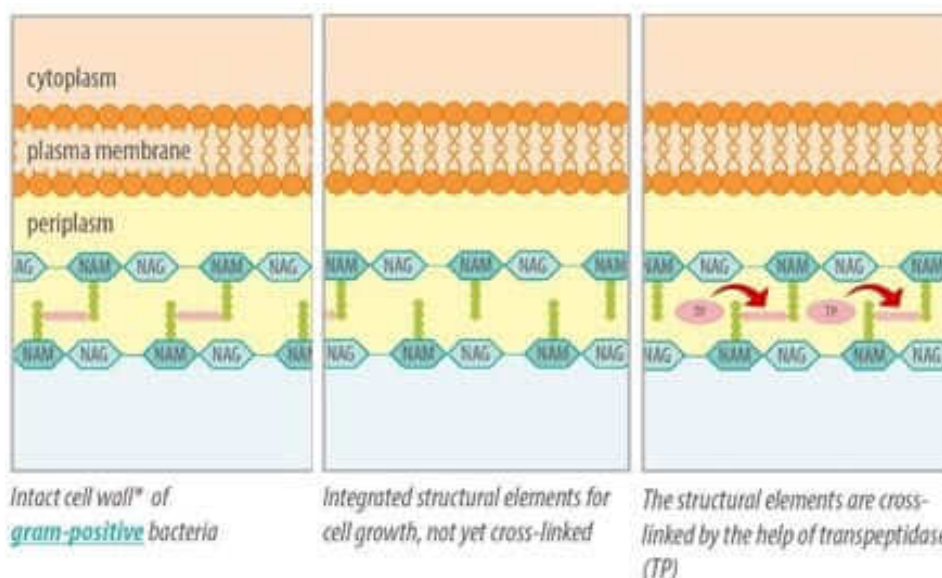
The group of β -lactam antibiotics consists of penicillins, cephalosporins, monobactams, and carbapenems. These antibiotics are characterised by their lactam ring (Figure 1).

Figure 1: An antibiotic with a β -lactam ring (in orange)



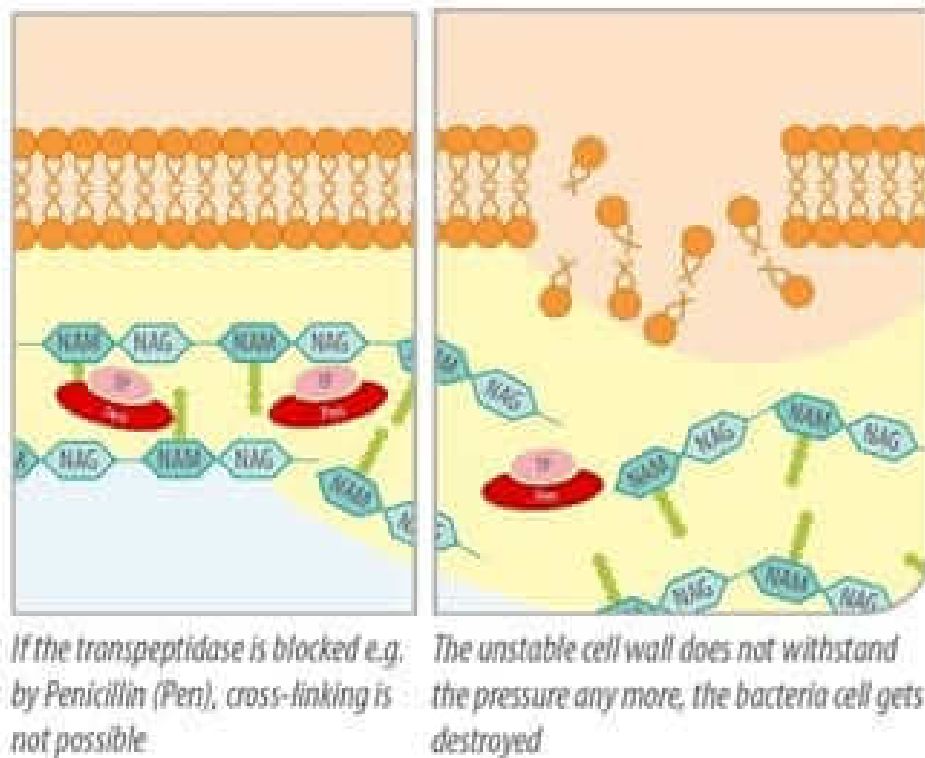
If bacteria are growing, the cell wall also has to grow. For this purpose existing conjunctions are cracked and new components are inserted. In order for the cell wall to remain a solid barrier, the new components must be interconnected by crosslinks. For the creation of these crosslinks an enzyme is essential, the transpeptidase (figure 2).

Figure 2: building up a stable cell wall with the help of transpeptidase



Due to their structure, β -lactam-antibiotics also fit as binding partner for transpeptidase. They bind to the enzyme and block it (Kohanski et al., 2010). The crosslinks cannot be created and the stabilization of the cell wall is prevented. Disturbance of cell wall stability leads to the death of the bacterial cell, hence β -lactam antibiotics act bactericidal.

Figure 3: blocked by β -lactam antibiotics, transpeptidase cannot serve as enzyme for building the cell wall



The challenge: *E. coli* producing β -lactamases

Resistant bacteria, which are able to produce β -lactamases – enzymes that destroy the β -lactam ring – prevent their own destruction. Divers point mutations within the β -lactamase genes lead to the occurrence of “extended-spectrum-beta-lactamases” (ESBL). ESBL are able to inactivate most of the β -Lactam-antibiotics.

Another mutation leads to so-called AmpC (aminopenicillin and cephalosporin) β -lactamases. They enable the *E. coli* to express a resistance against penicillins, cephalosporins of the second and third generation as well as against cephamycins.

Phytomolecules - an alternative?

One approach to reduce the use of antibiotics is the utilization of phytomolecules. These secondary metabolites are produced by plants to protect themselves from moulds, yeasts, bacteria and other harmful organisms.

The use of plants and their extracts in human and veterinary medicine is well-established for centuries. Besides digestive and antioxidant characteristics they are well known for their bacteriostatic and bactericidal effects.

Consisting of a high number of chemical compounds, they attack at diverse points and their antimicrobial effect is not caused by only one single specific mechanism. This is crucial because it is therefore very unlikely that bacteria can develop resistances to phytomolecules like they do to antibiotics.

How phytomolecules work

Mostly, phytomolecules act at the cell wall and the cytoplasm membrane level. Sometimes they change the whole morphology of the cell. This mode of action has been studied extensively for thymol and carvacrol, the major components of the oils of thyme and oregano.

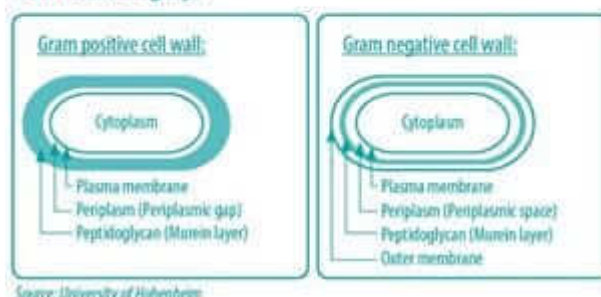
They are able to incorporate into the bacterial membrane and to disrupt its integrity. This increases the permeability of the cell membrane for ions and other small molecules such as the energy carrier ATP (Adenosin-tri-phosphate). It leads to the decrease of the electrochemical gradient above the cell membrane and to the loss of energy equivalents of the cell.

A special challenge: gram-negative bacteria

Gram-negative bacteria such as *E. coli* and *Salmonella* pose a special challenge. The presence of lipopolysaccharides in the outer membrane (OM) provides the gram-negative bacteria with a hydrophilic surface ([Nikaido, 2003](#); [Nazarro et al., 2013](#)) (see also blue infobox).

Gram-positive bacteria and gram-negative bacteria:
Bacteria differ in the construction of their cell walls. The Danish bacteriologist Hans Christian Gram (1853–1938) developed a colouring method to differentiate the bacteria. It is not possible to assign all bacteria to both groups. There are also gram-variable and gram-indefinite species.

Cell wall (roughly):



The cell wall therefore only allows the passage of small hydrophilic solutes and is a barrier against macromolecules and hydrophobic compounds such as hydrophobic antibiotics and toxic drugs. The bypassing of the OM therefore is a prerequisite for any solute to exert bactericidal activity toward gram-negative bacteria (Helander et al., 1998).

Based on their trial results Helander et al. (1998) (1998) concluded that trans-cinnamaldehyde and partly also thymol and carvacrol gain access to the periplasm and to the deeper parts of the cell. Nikaido (1996) also concluded that OM-traversing porin proteins allow the penetration of lipophilic probes at significant rates.

Evaluating phytomolecules I - in vitro trial, Scotland

A trial conducted in Scotland evaluated the effects of Activo Liquid, a mixture of selected phytomolecules and citric acid, on ESBL-producing *E. coli* as well as on *E. coli* that generate AmpC.

Material and methods

For the trial two strains for each group were isolated from the field, a non-resistant strain of *E. coli* served as control. Suspensions of the strains with 1×10^4 CFU/ml were incubated for 6-7 h at 37°C (98.6°F) together with diverse concentrations of Activo Liquid or with cefotaxime, a cephalosporin. The cefotaxime group served as a control for differentiating resistant and non-resistant *E. coli*.

The suspensions were put on LB agar plates and bacteria colonies were counted after further 18-22h incubation at 37°C.

Results

The antimicrobial efficacy of the blend of phytomolecules depended on the concentration at which they were used (see table 1). A bacteriostatic effect could be shown at dilutions up to 0.1 %, a bactericidal effect at higher concentrations.

Table 1: Effect of phytomolecules against resistant *E. coli* producing ESBL and AmpC in poultry

Poultry Microbiology Laboratory, Edinburgh, Scotland	Cefotaxime	Phytomolecules (Activo® Liquid)			
	30 µg / ml	0.1 %	0.2 %	0.4 %	0.5 %
<i>E. coli</i> ESBL 1 (Poultry)	-	+	++	++	++
<i>E. coli</i> ESBL 2 (Poultry)	-	+	++	++	++
<i>E. coli</i> AmpC 1 (Poultry)	-	+	++	++	++
<i>E. coli</i> AmpC 2 (Poultry)	-	++	++	++	++
<i>E. coli</i> non-resistant	+	+	++	++	++
- no effect + growth inhibiting (bacteriostatic) ++ bactericidal					

Evaluating phytomolecules II - in vitro trial, Germany

A further trial was conducted in Germany (Vaxxinova, Münster), confirming the preceding results.

Material and methods

Four ESBL producing *E. coli* all isolated from farms and a non-resistant reference strain as control were tested concerning their sensitivity against Activo Liquid. Every bacteria strain (Conc.: 1×10^4 CFU/ml) was subjected to a bacterial inhibition assay in an appropriate medium at 37°C for 6-7 hours.

Results

In this trial Activo Liquid also showed a dose-dependent efficacy, with no or just a bacteriostatic effect up to a concentration of 0.1 %, but bactericidal effects at a concentration of ≥ 0.2 % (table 2).

Table 2: Effect of phytomolecules against resistant ESBL producing *E. coli* in pig and in poultry

Vaxxinova GmbH, Münster	Phytomolecules (Activo® Liquid)			
	0.1 %	0.2 %	0.4 %	1 %
<i>E. coli</i> ATCC25922	+	++	++	++
<i>E. coli</i> ESBL 1 (Pig)	-	++	++	++
<i>E. coli</i> ESBL 2 (Pig)	+	++	++	++
<i>E. coli</i> ESBL 3 (Poultry)	+	++	++	++
<i>E. coli</i> ESBL 4 (Poultry)	-	++	++	++
- no effect + growth inhibiting (bacteriostatic) ++ bactericidal				

Phytomolecules: a promising outlook

E. coli infections have devastating effects on animals, from diarrhea to edema, enterotoxic shock and even death. Antibiotic treatments have long been the only practicable answer. However, their excessive use– for instance, the metaphylactic application to thousands of animals in a flock– has led to the development of resistant strains. There is evidence that a reduction of antibiotic use reduces the occurrence of resistances ([Dutil et al., 2010](#)).

The results of the two in vitro trials in Scotland and Germany demonstrate the bactericidal effects of [phytomolecules](#) on *E. coli* that produce ESBL and AmpC. Using phytomolecules could thus reduce the use of antibiotics and therefore also the occurrence of AMR.

While it is theoretically possible for bacteria to also become resistant against phytomolecules, the probability of this happening is very low: unlike antibiotics, phytomolecules contain hundreds of chemical components with different modes of action. This makes it exceedingly difficult for bacteria to adapt and develop resistance. To tackle the problem of antibiotic-resistant *E. coli*, antimicrobial phytomolecules therefore offer a promising, sustainable and long-term solution.

By Dr. Inge Heinzl, Editor, EW Nutrition

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Phytomolecules: Boosting Poultry Performance without Antibiotics



Antimicrobial resistance (AMR) is a major threat to global public health. It is largely caused by the overuse of antibiotics in human medicine and agriculture. In intensive poultry production most antibiotics are used as antimicrobial growth promoters and/or used as prophylactic and metaphylactic treatments to healthy animals. Reducing such antibiotic interventions is crucial to lowering the incidence of AMR. However, antibiotic reduction often results in undesirable performance losses. Hence alternative solutions are needed to boost poultry performance. Phytomolecules have antimicrobial, digestive, anti-inflammatory and antioxidant properties, which could make them key to closing the performance gap.

Poultry performance depends on intestinal health

Poultry performance is to a large extent a function of intestinal health. The intestines process nutrients, electrolytes and water, produce mucin, secrete immunoglobulins and create a barrier against antigens and pathogens.

In addition, it is an important component of the body's immune defense system. The intestine has to identify pathogens and reject them, but also has to tolerate harmless and beneficial microorganisms. If the intestines do not function properly this can lead to food intolerance, dysbiosis, infections and diseases. All of these are detrimental to feed conversion and therefore also to animal performance.

Antibiotics reduce the number of microorganisms in the intestinal tract. From a performance point of view this has two benefits: first, the number of pathogens is reduced and therefore also the likelihood of diseases; second, bacteria are eliminated as competitors for the available nutrients. However, the overuse of antibiotics not only engenders AMR: antibiotics also eliminate probiotic bacteria, which negatively impacts the digestive tracts' microflora.

Products to boost poultry performance may be added to their feed or water. They range from pre- and probiotics to medium chain fatty acids and organic acids to plant extracts or phytomolecules. Especially the latter have the potential to substantially reduce the use of antibiotics in poultry farming.

Phytomolecules are promising tools for antibiotic reduction

Plants produce phytomolecules to fend off pathogens such as moulds, yeasts and bacteria. Their antimicrobial effect is achieved through a variety of complex mechanisms. Terpenoids and phenols, for example, disturb or destroy the pathogens' cell wall. Other phytomolecules inhibit their growth by influencing their genetic material. Studies on broilers show that certain phytomolecules reduce the adhesion of pathogens such as to the wall of the intestine. Carvacrol and thymol were found to be effective against different species of *Salmonella* and *Clostridium perfringens*.

There is even evidence that secondary plant compounds also possess antimicrobial characteristics against antibiotic resistant pathogens. In-vitro trials with cinnamon oil, for example, showed antimicrobial effects against methicillin resistant *Staphylococcus aureus*, as well as against multiresistant *E. coli*, *Klebsiella pneumoniae* and *Candida albicans*.

Importantly, there are no known cases to date of bacteria developing resistances to phytomolecules. Moreover, phytomolecules increase the production and activity of digestive enzymes, they suppress the metabolism of pro-inflammatory prostaglandins and they act as antioxidants. Their properties thus make them a promising alternative to the non-therapeutic use of antibiotics.

Study design and results

In order to evaluate the effect of phytomolecules on poultry performance, multiple feeding studies were conducted on broilers and laying hens. They were given a phytogenic premix ([Activo](#), EW Nutrition GmbH) that contains standardized amounts of selected phytomolecules.

To achieve thermal stability during the feed processing and a targeted release in the birds' [gastrointestinal tract](#), the product is microencapsulated. For each , the studies evaluated both the tolerance of the premix and the efficacy of different dosages.

Study I: Evaluation of the dose dependent efficacy and tolerance of Activo for broilers

Animals: 400 broilers; age: 1-35 days of age

Feed: Basal starter and grower diets

Treatments:

- No supplement (negative control)
- 100 mg of Activo /kg of feed
- 1.000 mg of Activo /kg of feed
- 10.000 mg of Activo /kg of feed

Parameters: weight gain, feed intake, feed conversion ratio, health status, and blood parameters

Results: The trial group given the diet supplemented with 100 mg/kg [Activo](#) showed significant improvements in body weight gain during the starter period (+4%) compared to the control group.

Additional significant improvements in feed conversion ratio (FCR) in the growing period (+4%) resulted in an overall improvement in FCR of 3%. At a 1.000 mg/kg supplementation, a significant improvement in FCR of 6% was observed over the entire feeding period. Hematological parameters were within the reference range of healthy birds when feeding up to 10,000 Activo/ kg of feed.

Study II: Evaluation of the dose depending efficacy and tolerance of Activo for laying hens

Animals: 200 hens; age: 20 to 43 weeks

Feed: basal diet for laying hens

Treatments:

- No supplement (negative control)
- 100 mg of Activo/ kg of feed
- 250 mg of Activo/ kg of feed
- 500 mg of Activo/ kg of feed
- 5.000 mg of Activo/ kg of feed

Parameters: weight gain, feed intake, feed conversion ratio, health status, and blood parameters

Results: Inclusion levels from 100 mg/kg of Activo onwards improved laying performance, egg mass and egg weight and reduced FCR compared to the control group. Results recorded for hematological parameters were within the reference range of healthy birds when feeding up to 5.000 mg Activo/ kg of feed.

Study III: Evaluation of the dose-dependent effects of Activo for coccidiosis vaccinated broilers

Animals: 960 broiler chickens; age: 42 days

Feed: Standard starter and finisher feed

Treatments:

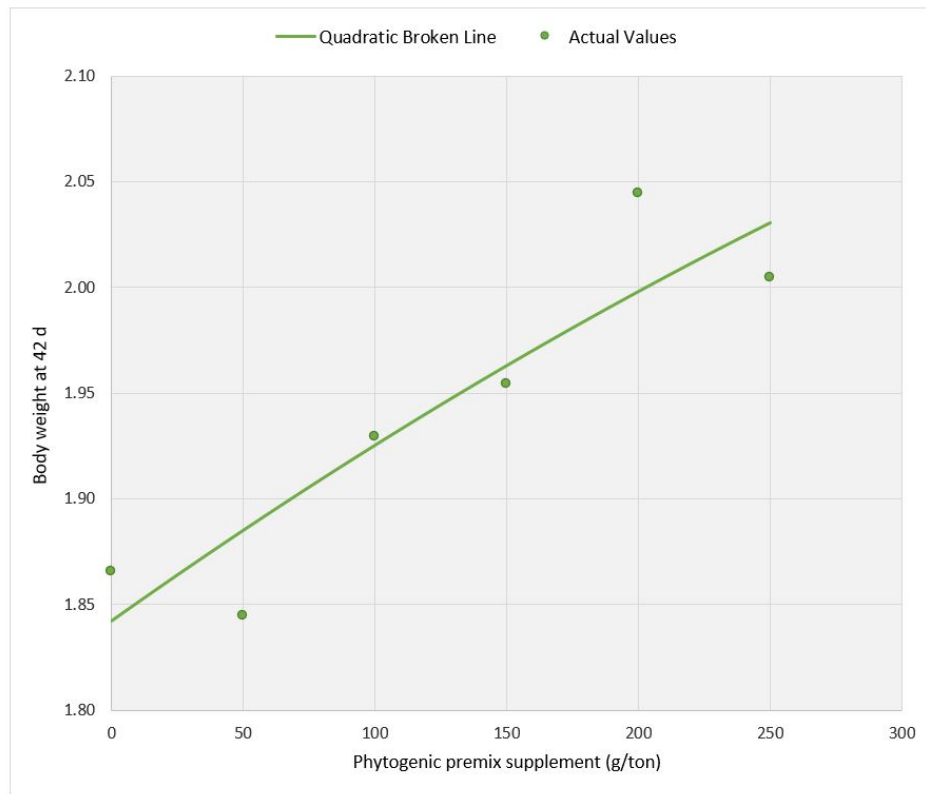
- No supplement (negative control)
- 50 g of Activo /US ton of feed
- 100 g of Activo /US ton of feed
- 150 g of Activo /US ton of feed
- 200 g of Activo /US ton of feed
- 250 g of Activo /US ton of feed
- Antibiotic growth promoter (AGP)(positive control)

Parameters: weight gain, feed efficiency

Specific: In order to represent field conditions, the birds were challenged with used, homogenized litter.

Results: A clear dose response for both body weight gain and feed efficiency was observed (see Figure 1): the more phytogenic premix given, the better the birds' performance. The group with 200g of Activo /US ton of feed showed similar performance levels than the positive control group supplemented with AGP.

Figure 1: Dose-dependent effects of for coccidiosis vaccinated broilers



Study IV: Evaluation of the dose-dependent effects of Activo for laying hens

Animals: 40 hens; age: week 20 to 43

Feed: basal diet for laying hens

Treatments:

- No supplement (negative control)
- 100 mg of Activo/ kg of feed
- 250 mg of Activo/ kg of feed
- 500 mg of Activo/ kg of feed
- 5.000 mg of Activo/ kg of feed

Parameters: weight gain, feed intake, egg production, feed conversion ratio, health status

Duration: 168 days of feeding period

Results: The laying hens showed a higher laying rate when fed with a higher concentration of phytomolecules (Figure 2). Similarly improved results were observed for the feed efficiency. The more phytogetic premix added to their diet the better feed efficiency (Figure 3).

Figure 2: Dose-dependent effects of Activo on laying rate in laying hens

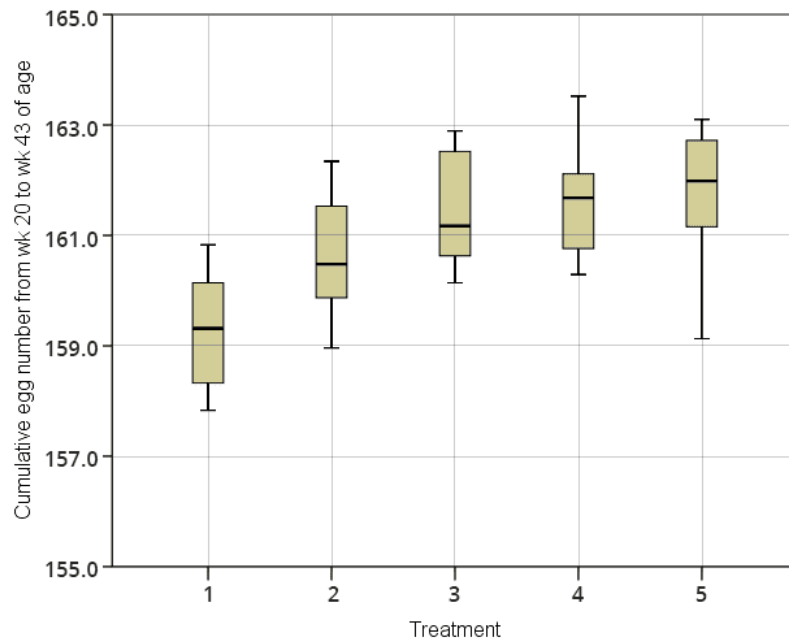
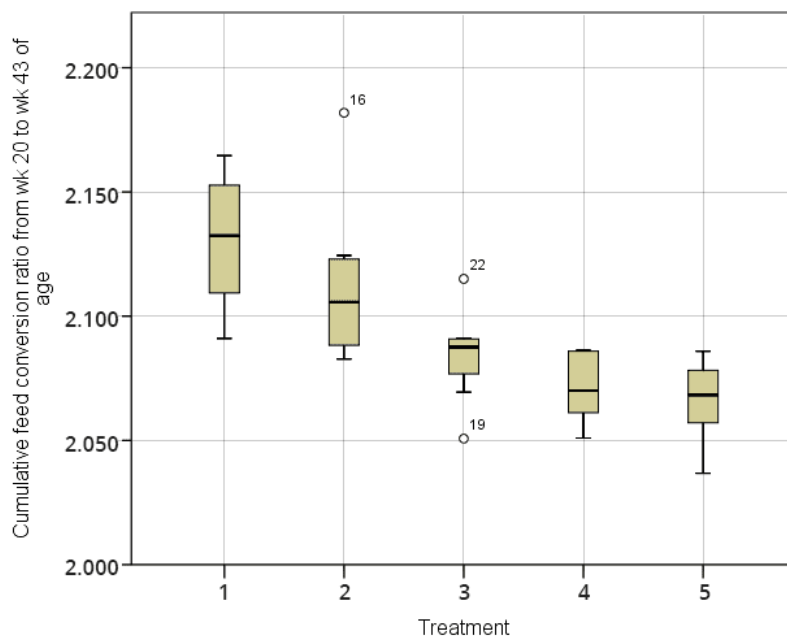


Figure 3: Dose-dependent effects of Activo on feed efficiency in laying hens



In conclusion, all four studies indicate that the inclusion of phytochemicals in broilers' and laying hens' diet improves their performance. Increasing levels of a phytochemical premix (Activo) significantly increased the production parameters for both groups. These improvements might bring performance in antibiotic-free [poultry production](#) on par with previous performance figures achieved with antimicrobial growth promoters.

The studies also showed that microencapsulated phytochemical premixes are safe when used in dose ranges recommended by the suppliers. No negative effects on animal health could be observed even at a 100 fold / 50 fold of the recommended inclusion rate in diets for broiler or laying hens, respectively. Thanks to their positive influence on intestinal health, phytochemicals thus boost poultry performance in a safe and effective way.

By Technical Team, EW Nutrition

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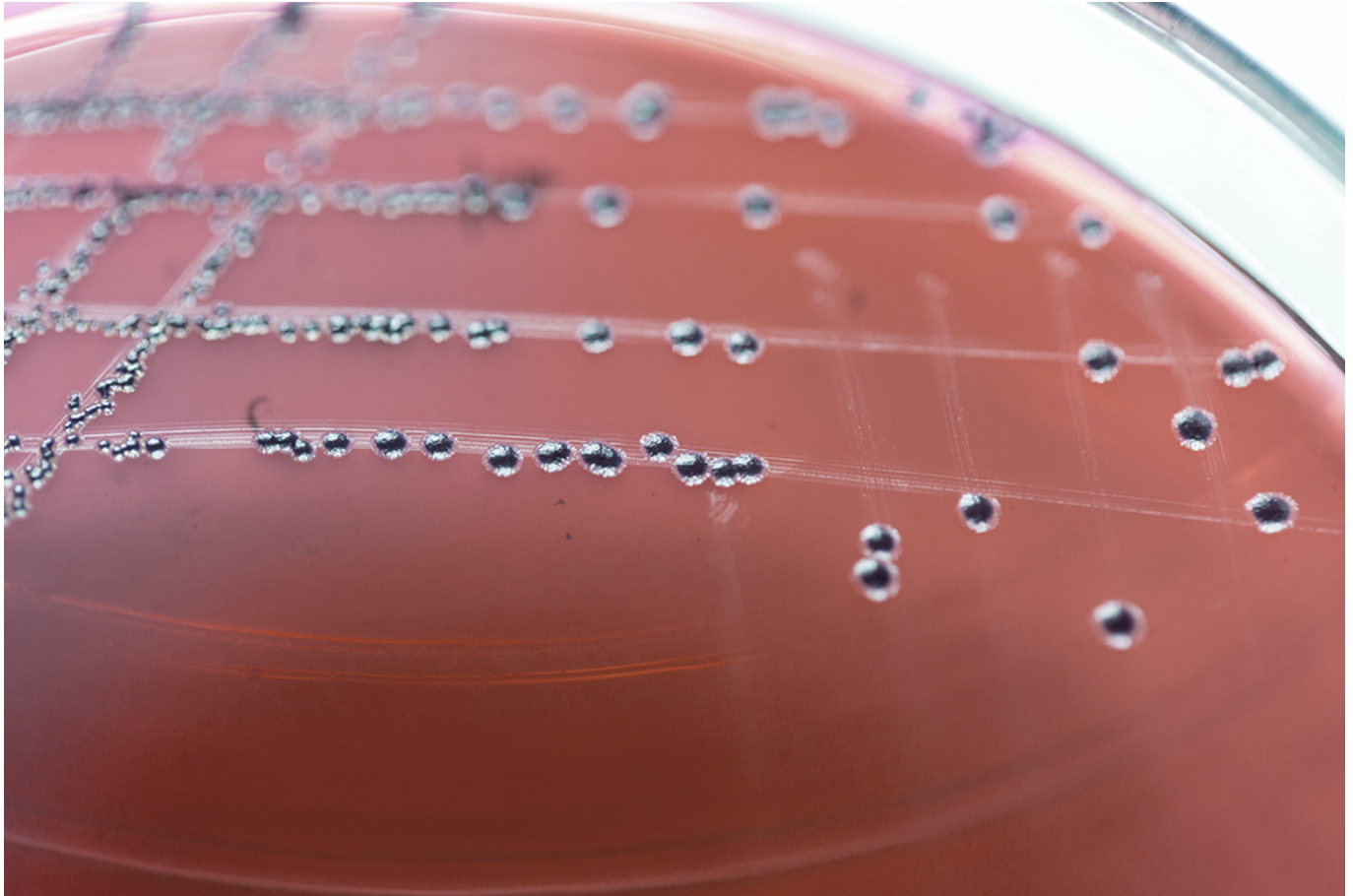
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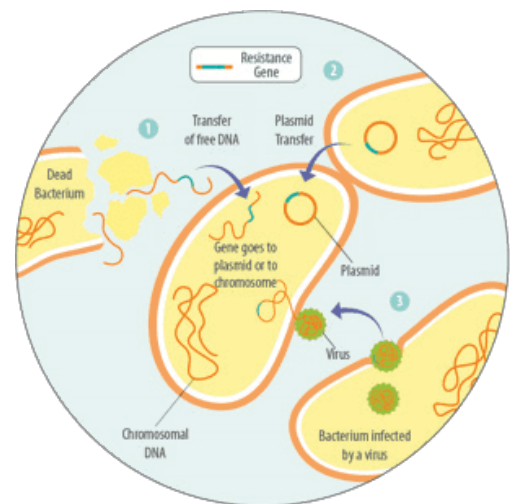
Photo source: [Aviagen](#)

Secondary Plant Compounds (SPC's) to reduce the use of antibiotics?



Initial in vitro trials give reason for hope

Antibiotic Resistance



Some bacteria, due to mutations, are less sensitive to certain antibiotics than others. This means that if certain antibiotics are used, the insensitive ones survive. Because their competitors have been eliminated, they are able to reproduce better. This resistance can be transferred to daughter cells by means of „resistance genes“. Other possibilities are the intake of free DNA and therefore these resistance genes from dead bacteria 1, through a transfer of these resistance genes by viruses 2 or from other bacteria by means of horizontal gene transfer 3 (see figure 1). Every application of antibiotics causes a selection of resistant bacteria. A short-term use or an application at a low dosage will give the bacteria a better chance to adapt, promoting the generation of resistance (Levy, 1998).

Antibiotics are promoting the development of resistance:

- Pathogenic bacteria possessing resistance genes are conserved and competitors that do not

- possess these genes are killed
- Useful bacteria possessing the resistance genes are conserved and serve as a gene pool of antibiotic resistance for others
- Useful bacteria without resistance, which probably could keep the pathogens under control, are killed

Reducing the use of antibiotics

Ingredients from herbs and spices have been used for centuries in human medicine and are now also used in modern animal husbandry. Many SPC's have antimicrobial characteristics, e.g. Carvacrol and Cinnamon aldehyde. They effectively act against *Salmonella*, *E. coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, Enter- and *Staphylococcus*, and *Candida albicans*. Some compounds influence digestion, others act as antioxidants. Comprehensive knowledge about the single ingredients, their possible negative but also positive interaction (synergies) is essential for developing solutions. Granulated or microencapsulated products are suitable for addition to feed, liquid products would be more appropriate for an immediate application in the waterline in acute situations.

	(Activo* Liquid)		
	10%	2%	1%
<i>Central Poultry Diagnostic Laboratory, Kondapur, Hyderabad (India)</i>			
<i>E. coli</i> (reference strains)	++	+	+
<i>Proteus vulgaris</i> (reference strains)	+	+	+
<i>Pseudomonas fluorescens</i>	++	+	-
<i>Salmonella pulmorum</i>	++	++	+
<i>Salmonella gallinarum</i>	++	++	+
<i>Staphylococcus aureus</i> (reference strains)	+++	++	++
+++	22 – 29 mm ZOI (zone of inhibition)		
++	15 – 21 mm ZOI		
+	10 – 14 mm ZOI		
-	< 10 mm ZOI		

SPC's (Activo Liquid) against livestock pathogens in vitro

In "agar diffusion tests", the sensitivity of different strains of farm-specific pathogens was evaluated with different concentrations of Activo Liquid. The effectiveness was determined by the extent to which they prevented the development of bacterial overgrowth. The larger the bacteria-free zone, the higher the antimicrobial effect.

In this trial, Activo Liquid showed an antimicrobial effect on all bacteria tested. The degree of growth inhibition positively correlated with its concentration.

Table 1: Inhibition of field isolated standard pathogens by different concentrations of Activo Liquid

Activo Liquid against antibiotic resistant field pathogens in vitro

It cannot be excluded that resistant pathogens not only acquired effective weapons to render antibiotics harmless to them but also developed general mechanisms to rid themselves of otherwise harmful substances. In a follow-up laboratory trial, we evaluated whether the Activo Liquid composition is as effective against ESBL producing *E. coli* and Methicillin resistant *S. aureus* (MRSA) as to non-resistant members of the same species.

Laboratory: Vaxxinova, Muenster, Germany	SPC's (Activo® Liquid)			
	0.1%	0.2%	0.4%	1%
<i>E.coli</i> reference ATCC25922	+	++	++	++
ESBL 1 (Pig)	-	++	++	++
ESBL 2 (Pig)	+	++	++	++
ESBL 3 (Poultry)	+	++	++	++
ESBL 4 (Poultry)	-	++	++	++
<i>S. aureus</i> reference ATCC29213	-	+	+	++
MRSA 1 (Pig)	-	+	+	++
MRSA 2 (Pig)	-	+	+	++

- no effect
+ growth inhibiting
++ bactericide

Trial Design: Farm isolates of four ESBL producing *E. coli* and two MRSA strains were compared to nonresistant reference strains of the same species with respect to their sensitivity against Activo Liquid. In a Minimal Inhibitory Concentration Assay (MIC) under approved experimental conditions (Vaxxinova Diagnostic, Muenster, Germany) the antimicrobial efficacy of Activo Liquid in different concentrations was evaluated.

The efficacy of SPC's (Activo Liquid) against the tested strains could be demonstrated in a concentration-dependent manner with antimicrobial impact at higher concentrations and bacteriostatic efficacy in dilutions up to 0,1% (ESBL) and 0,2% (MRSA)(table 2).

Conclusion:

To contain the emergence and spread of newly formed resistance mechanisms it is of vital importance to reduce the use of antibiotics. SPC's are a possibility to [decrease antibiotic use](#) especially in pro- and metaphylaxis, as [they show good efficacy against the common pathogens](#) found in poultry, even against resistant ones.

I. Heinzl

Secondary plant compounds are the new frontier in poultry nutrition



Why should you read another story about phytogenics? Or, is it botanicals, spices, herbs, and extracts? No matter what we call them, scientists have named them [“secondary plant compounds”](#), and if we are to follow the American tradition we can call them SPC. Then, here is the first interesting thing we can discuss about this plant-derived class of active compounds. They are “secondary” in nature, but not insignificant. They play no role in normal metabolism, but they help plants (and now animals) survive under adverse conditions. Perhaps, this is why some experts consider them as the next frontier in poultry nutrition. With [poultry](#) that are raised in less than ideal conditions, especially when we consider the movement towards antibiotic reduction (for growth promoting reasons, not complete removal of all medicines), we understand that such natural compounds can be of significant help.

As it happens, the majority of poultry specialists in Europe and increasingly in the Americas consider SPC as an almost-essential element in diets for broilers and layers (and turkeys, ducks, and all poultry for that matter) when birds are raised without antibiotics. Some go even further and use them along with antibiotics because, as we all know, antibiotics are never 100% efficient as bacteria sooner or later develop some form of resistance. Such resistance has not yet been observed with SPC. So if one is to use SPC in poultry feds, which ones to buy? A quick glance at the market will reveal more commercial products than can possibly be imagined. Some must be better than the rest, but how can we separate the wheat from the chaff? Price alone is not always a good indicator. A high quality product must be expensive – for there is no such thing as a free lunch – but all expensive products are not always of the highest possible quality!

There are three basic criteria, which we can mention briefly here:

1. **SPC are volatile** – at least most of them. As such, unprotected products will soon evaporate if left in the open air as it happens with feed prepared in commercial farms. So, some form of protecting SPC is essential.
2. **SPC are innumerable** – so finding the right mix for the job required is important. You cannot get the same results with any kind of mix. So, in designing an SPC mix, the manufacturer must declare and have knowledge of the target to be accomplished.
3. **SPC are powerful** – meaning you cannot just keep adding as much as possible. Here finding the exact dosage for the right purpose is a difficult balancing exercise. So, the right mix and the right dosage must be combined, otherwise animals will refuse the feed (worst case scenario) or just fail to benefit from SPC inclusion.

There is so much more to learn about this exciting class of compounds that can replace the growth promoting action of antibiotics that it is worth spending time learning more about them.

Secondary plant compounds against antibiotic-resistant *E. coli*

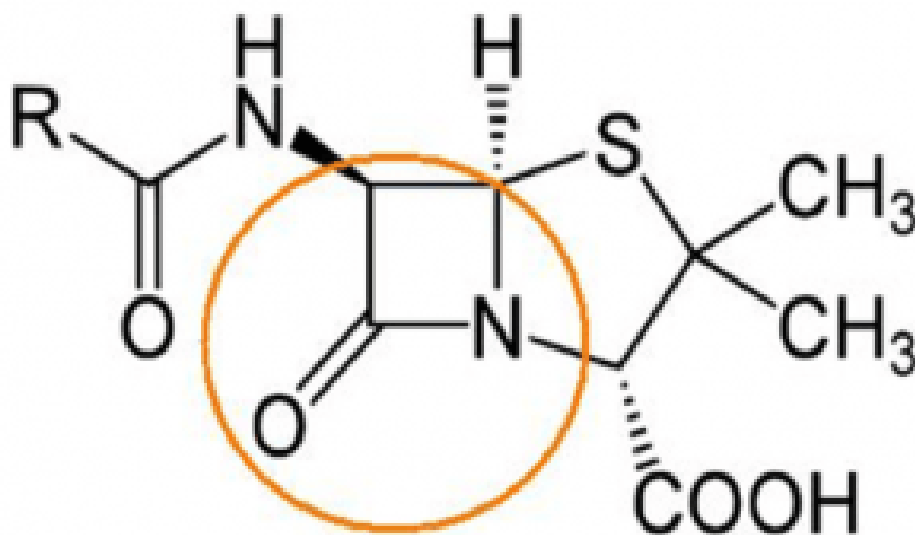


Due to incorrect therapeutic or preventive use of antibiotics in animal production as well as in human medicine, occurrence of antibiotic resistant pathogens has become a widespread problem. Enterobacteria in particular (e.g. *Salmonella*, *Klebsiella*, *E. coli*) possess a special mechanism of resistance. By producing

special enzymes (β -lactamases), they are able to withstand the attack of so-called β -lactam antibiotics. The genes for this ability (resistance genes) can also be transferred to other bacteria resulting in a continuously increasing problem. Divers point mutations within the β -lactamase genes lead to the occurrence of „Extended-Spectrum-Beta-Lactamases“ (ESBL), which are able to hydrolyse most of the β -Lactam-antibiotics. AmpC Beta-Lactamases (AmpC) are enzymes, which express a resistance against penicillins, cephalosporins of the second and third generation as well as cephamycins.

What are β -lactam antibiotics?

The group of β -lactam antibiotics consists of penicillins, cephalosporins, monobactams and carbapenems. A characteristic of these antibiotics is the lactam ring (marked in orange):

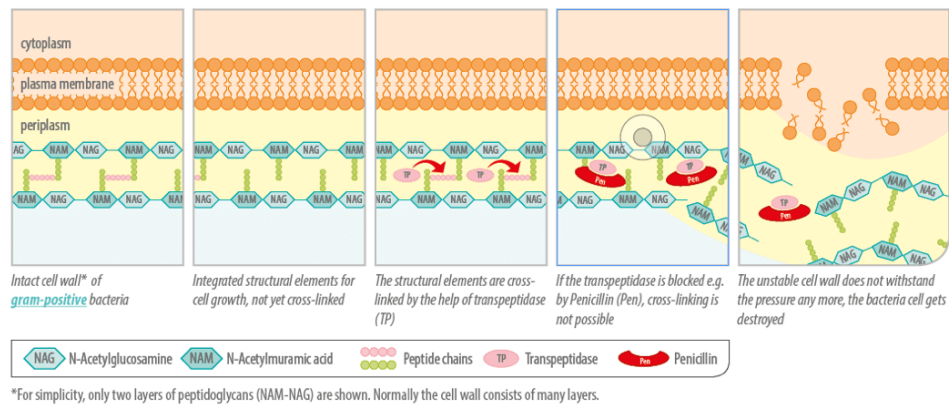


Mode of action of β -lactam antibiotic

If a bacterial cell is growing, the cell wall also has to grow. For this purpose, existing conjunctions are cracked and new components are inserted. β -lactam-antibiotics disturb the process of cell wall construction by blocking an enzyme needed, the transpeptidase. If crosslinks necessary for the stability of the cell wall cannot be created, the bacteria cannot survive. Resistant bacteria, which are able to produce β -lactamases, destroy the β -lactam antibiotics and prevent their own destruction.

Secondary plant compounds

[Secondary plant compounds and their components](#) are able to prevent or slow down the growth of moulds, yeasts, viruses and bacteria. They attack at various sites, particularly the membrane and the cytoplasm. Sometimes they change the whole morphology of the cell. In the case of gram-negative bacteria, secondary plant compounds (hydrophobic) have to be mixed with an emulsifier so that they can pass the cell wall which is open only for small hydrophilic solutes. [The modes of action of secondary plant compounds](#) depend on their chemical composition. It also depends on whether single substances or blends (with possible positive or negative synergies) are used. It has been observed that extracts of spices have a lower antimicrobial efficacy than the entire spice.



The best explained mode of action is the one of thymol and carvacrol, the major components of the oils of thyme and oregano. They are able to incorporate into the bacterial membrane and to disrupt its integrity. This increases the permeability of the cell membrane for ions and other small molecules such as ATP leading to the decrease of the electrochemical gradient above the cell membrane and to the loss of energy equivalents of the cell.

Trial (Scotland)

Design

Two strains of ESBL-producing and AmpC respectively, isolated from the field, a non-resistant strain of *E. coli* as control. Suspensions of the strains with 1×10^4 KBE/ml were incubated for 6-7 h at 37°C together with different concentrations of [Activo Liquid](#) or with cefotaxime, a cephalosporin. The suspensions were then put on LB-Agar plates and bacteria colonies were counted after a further 18-22h incubation at 37°C. Evaluation of the effects of Activo Liquid on ESBL-producing as well as on *E. coli* resistant for aminopenicillin and cephalosporin (AmpC)

Results

The antimicrobial efficacy of the blend of secondary plant compounds depended on concentration with bactericidal effect at higher concentrations and bacteriostatic at dilutions up to 0,1%. It is also possible that bacteria could develop a resistance to secondary plant compounds; the probability is however relatively low, due to the fact that essential oils contain hundreds of chemical components (more than antibiotics) making it difficult for bacteria to adapt.

Phytogenics can positively influence the efficacy of

antibiotics



Many veterinary antibiotics are applied via the waterline, [where they are dosed in combination with other feed additives](#). Amongst those are mixtures of secondary plant compounds with a proven antimicrobial efficacy against veterinary pathogenic bacteria. However, little research has been done to evaluate any effect that antibiotics and phytogenics may have on each other. A possible influence of phytogenics on the efficacy of antibiotics through the combined administration would require a change in application recommendations of antibiotics and phytogenic feed additives. In the case of no interaction, no changes would be necessary. If they were to interact in a positive way, the dosages could be lowered and if they interact in a negative way, a combined application would be avoided.

Antibiotics and SPC's in co-incubation

There are different groups of antibiotics depending on the chemical structure and on the pathogen they target. Some impair the cell wall or the cytoplasmic membrane (polymyxins, β -lactam antibiotics) and some affect protein synthesis (macrolides, Chloramphenicol, Lincospectin, tetracyclines, aminoglycosides). Others compromise DNA and RNA synthesis (fluorchinolones, ansamycines) and some disturb the metabolism of e.g. folic acid (Trimethoprim).

The intention of a trial with these different groups of antibiotics was to evaluate possible interactions they may have with a combination of secondary plant compounds. Four ESBL producing *E. coli* field isolates from poultry flocks were experimentally assessed as well as a β -lactamase positive and a β -lactamase negative reference strain as quality control strains for antimicrobial susceptibility testing.

Two-fold serial dilutions of antibiotics and the liquid product based on secondary plant compounds were co-incubated in a checkerboard assay. The highest concentration of the antibiotic was chosen according to CLSI standard recommendations. The control of the serial dilution of SPC's was made without antibiotics and vice versa.

Lowering the antibiotic dosage by the use of SPC's

In the experiment all field isolates proved resistant against the β -lactam antibiotics, two field isolates and one reference strain were resistant against tetracyclines and macrolides and one field isolate and one reference strain against aminoglycosides.

The results showed that there was no negative influence of the antibiotics on the SPC's and vice versa. Moreover, for several classes of antibiotics an additive to synergistic effect was observed to such an extent that an antibiotic effect could be achieved with half or even one quarter of the former effective dosage. The dosage of the SPC-mixture could also be reduced. Based on the results of this *in vitro* experiment it can be stated that in the case of antibiotic resistance, the option exists to apply a phytogenic product with broad antimicrobial

efficacy. Even more, for most combinations between antibiotics and [Activo Liquid](#), a defined mixture of secondary plant compounds, their combined use potentiates the individual efficacy of either compound class against *E.coli* strains *in vitro*. This adds further benefits to the improvements in animal performance and health, for which a number of [phytogenic feed additives have already proven effective](#).