

Use of phytogetic products as feed additives for swine and poultry¹

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ABSTRACT: This article summarizes the experimental knowledge on efficacy, possible modes of action, and aspects of application of phytogetic products as feed additives for swine and poultry. Phytogetic feed additives comprise a wide variety of herbs, spices, and products derived thereof, and are mainly essential oils. The assumption that phytogetic compounds might improve the palatability of feed has not yet been confirmed by choice-feeding studies. Although numerous studies have demonstrated antioxidative and antimicrobial efficacy *in vitro*, respective experimental *in vivo* evidence is still quite limited. The same applies to the supposition that phytogetic compounds may specifically enhance activities of digestive enzymes and nutrient absorption. Nevertheless, a limited number of experimental comparisons of phytogetic feed additives with antibiotics and organic acids have suggested similar

effects on the gut, such as reduced bacterial colony counts, fewer fermentation products (including ammonia and biogenic amines), less activity of the gut-associated lymphatic system, and a greater prececal nutrient digestion, probably reflecting an overall improved gut equilibrium. In addition, some phytogetic compounds seem to promote intestinal mucus production. Such effects may explain a considerable number of practical studies with swine and poultry reporting improved production performance after providing phytogetic feed additives. In total, available evidence indicates that phytogetic feed additives may add to the set of nonantibiotic growth promoters for use in livestock, such as organic acids and probiotics. However, a systematic approach toward the efficacy and safety of phytogetic compounds used as feed additives for swine and poultry is still missing.

Key words: antimicrobial, botanical, essential oil, herb, phytogetic, swine

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INTRODUCTION

Phytogetic feed additives are plant-derived products used in animal feeding to improve the performance of agricultural livestock. This class of feed additives has recently gained increasing interest, especially for use in swine and poultry, as can be derived from a significant increase in the number of scientific publications since 2000. This appears to be strongly driven by the ban on most of the antibiotic feed additives within the European Union in 1999, a complete ban enforced in 2006, and ongoing discussions to restrict their use outside the European Union because of speculated risk for generating antibiotic resistance in pathogenic microbiota. In this context, phytogetic feed additives are discussed

possibly to add to the set of nonantibiotic growth promoters, such as organic acids and probiotics, which are already well established in animal nutrition. Phytogetics, however, are a relatively new class of feed additives and our knowledge is still rather limited regarding their modes of action and aspects of their application. Further complications arise because phytogetic feed additives may vary widely with respect to botanical origin, processing, and composition. Most studies investigate blends of various active compounds and report the effects on production performance rather than the physiological impacts. In this context, the following provides an overview of recent knowledge on the use of phytogetic feed additives in piglet and poultry diets, possible modes of action, and safety implications.

GENERAL ASPECTS OF PHYTOGETIC FEED ADDITIVES

Phytogetic feed additives (often also called phytobiotics or botanicals) are commonly defined as plant-derived compounds incorporated into diets to improve the productivity of livestock through amelioration of feed

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properties, promotion of the animals' production performance, and improving the quality of food derived from those animals. Although this definition is driven by the purpose of use, other terms are commonly used to classify the vast variety of phytogenic compounds, mainly with respect to origin and processing, such as herbs (flowering, nonwoody, and nonpersistent plants), spices (herbs with an intensive smell or taste commonly added to human food), essential oils (volatile lipophilic compounds derived by cold expression or by steam or alcohol distillation), or oleoresins (extracts derived by nonaqueous solvents). Within phytogenic feed additives, the content of active substances in products may vary widely, depending on the plant part used (e.g., seeds, leaf, root, or bark), harvesting season, and geographical origin. The technique for processing (e.g., cold expression, steam distillation, extraction with nonaqueous solvents, etc.) modifies the active substances and associated compounds within the final product.

The use of feed additives is usually subject to restrictive regulations. In general, they are considered as products applied by the farmer to healthy animals for a nutritional purpose on a permanent basis (i.e., during the entire production period of the respective species and category), in contrast to veterinary drugs (applied for prophylaxis and therapy of diagnosed health problems under veterinarian control for a limited time period, partially associated with a waiting period). In the European Union, for example, feed additives need to demonstrate the identity and traceability of the entire commercial product, the efficacy of the claimed nutritional effects, including the absence of possible interactions with other feed additives, and the safety to the animal (e.g., tolerance), to the user (e.g., farmer, worker in feed mills), to the consumer of animal-derived products, and to the environment (for further details, refer to European Commission, 2003). Problems with feed additive legacy may therefore arise especially with phytogenic feed additives addressed to explicit health claims or in the case of plant-derived substances suspected to modulate metabolism (e.g., through a phytohormonal mode of action). For these reasons, the following discussion focuses on the use of phytogenic compounds as feed additives in swine and poultry diets in terms of claimed antioxidative and antimicrobial actions, beneficial effects on palatability and gut functions, and growth-promoting efficacy.

ANTIOXIDATIVE ACTION OF PHYTOGENIC FEED ADDITIVES

Antioxidative properties are well described for herbs and spices (e.g., Cuppett and Hall, 1998; Craig, 1999; Nakatani, 2000; Wei and Shibamoto, 2007). Among a variety of plants bearing antioxidative constituents, the volatile oils from the Labiatae family (mint plants) have been attracting the greatest interest, especially products from rosemary. Their antioxidative activity arises from phenolic terpenes, such as rosmarinic acid and

rosmarol (Cuppett and Hall, 1998). Other Labiatae species with significant antioxidative properties are thyme and oregano, which contain large amounts of the monoterpenes thymol and carvacrol (Cuppett and Hall, 1998). Plant species from the families of Zingiberaceae (e.g., ginger and curcuma) and Umbelliferae (e.g., anise and coriander), as well as plants rich in flavonoids (e.g., green tea) and anthocyanins (e.g., many fruits), are also described as exerting antioxidative properties (Nakatani, 2000; Wei and Shibamoto, 2007). Furthermore, pepper (*Piper nigrum*), red pepper (*Capsicum annum L.*), and chili (*Capsicum frutescense*) contain antioxidative components (Nakatani, 1994). In many of these plants, parts of the active substances are highly odorous or may taste hot or pungent, which may restrict their use for animal feeding purposes.

The antioxidant property of many phytogenic compounds may be assumed to contribute to protection of feed lipids from oxidative damage, such as the antioxidants usually added to diets (e.g., α -tocopheryl acetate or butylated hydroxytoluene). Although this aspect has not been explicitly investigated for piglet and poultry feeds, there is a wide practice of successfully using essential oils, especially those from the Labiatae plant family, as natural antioxidants in human food (Cuppett and Hall, 1998), as well as in the feed of companion animals.

The principal potential of feed additives from the Labiatae plant family containing herbal phenolic compounds to improve the oxidative stability of animal-derived products has been demonstrated for poultry meat (Botsoglou et al., 2002, 2003a,b; Papageorgiou et al., 2003; Young et al., 2003; Basmacioglu et al., 2004; Govaris et al., 2004; Giannenas et al., 2005; Florou-Paneri et al., 2006), pork (Janz et al., 2007), rabbit meat (Botsoglou et al., 2004b), and eggs (Botsoglou et al., 2005). Oxidative stability was also shown to be improved with other herbal products (Botsoglou et al., 2004a; Schiavone et al., 2007). Nevertheless, it remains unclear whether these phytogenic antioxidants are able to replace the antioxidants usually added to the feeds (e.g., α -tocopherols) to a quantitatively relevant extent under conditions of common feeding practice.

SPECIFIC IMPACT ON DIETARY PALATABILITY AND GUT FUNCTIONS

Phytogenic feed additives are often claimed to improve the flavor and palatability of feed, thus enhancing production performance. However, the number of studies having tested the specific effect of phytogenic products on palatability by applying a choice-feeding design is quite limited. They show dose-related depressions of palatability in pigs fed essential oils from fennel and caraway, as well as from the herbs thyme and oregano (Jugl-Chizzola et al., 2006; Schöne et al., 2006). On the other hand, there are numerous reports on improved feed intake through phytogenic feed additives in swine (see the subsequent section on growth-promoting effi-

cacy). However, an increase in feed intake in swine is a common result of the use of growth-promoting feed additives, such as antibiotics, organic acids, and probiotics, and, in the first instance, it may be considered to reflect the higher consumption capacity of animals grown larger compared with untreated controls (Freitag et al., 1998). Therefore, the assumption that herbs, spices, and their extracts improve the palatability of feed does not seem to be justified in general.

A wide range of spices, herbs, and their extracts are known from medicine to exert beneficial actions within the digestive tract, such as laxative and spasmolytic effects, as well as prevention from flatulence (Chrubasik et al., 2005). Furthermore, stimulation of digestive secretions (e.g., saliva), bile, and mucus, and enhanced enzyme activity are proposed to be a core mode of nutritional action (Platel and Srinivasan, 2004). In vitro activities of rat pancreatic lipase and amylase were shown to be significantly enhanced when brought into contact with various spices and spice extracts (Rao et al., 2003). The same group of researchers found greater enzyme activities in pancreatic homogenates and a pronounced bile acid flow in rats fed those substances (Platel and Srinivasan, 2000a,b). Similarly, essential oils used as feed additives for broilers were shown to enhance the activities of trypsin and amylase (Lee et al., 2003; Jang et al., 2004). Glucose absorption from the small intestine was accelerated in rats fed anise oil (Kreydiyyeh et al., 2003). Furthermore, Manzanilla et al. (2004) fed a combination of essential oils and capsaicin to swine and observed that gastric emptying was slowed down by these additives. Phytogenic feed additives were also reported to stimulate intestinal secretion of mucus in broilers, an effect that was assumed to impair adhesion of pathogens and thus to contribute to stabilizing the microbial eubiosis in the gut of the animals (Jamroz et al., 2006). These observations support the hypothesis that phytogenic feed additives may favorably affect gut functions, but the number of in vivo studies with swine and poultry is still quite limited.

Saponins (e.g., from *Yucca schidigera*) are proposed to reduce intestinal ammonia formation, and thus aerial pollution of housing environment, which is considered an important health stress, especially for young animals (Francis et al., 2002). Studies with rats confirmed the existence of active components in *Y. schidigera* extracts that lower intestinal urease activity and enzymes involved in the metabolic urea cycle (Killeen et al., 1998; Duffy et al., 2001). Reduced intestinal and fecal urease activities were also found in broilers fed such extracts (Nazeer et al., 2002). However, yucca extracts were reported to contain subfractions with partially antagonistic properties on intestinal urease activity and ammonia formation (Killeen et al., 1998). Thus, further research seems to be required to clarify the potential of saponins as feed additives for swine and poultry diets.

Another claim often made of phytogenic feed additives is stimulation of immune functions; however, the specific experimental verification in monogastric agricultural livestock is rather limited. For example, the use of *Echinacea purpurea* in pig feeding revealed an enhanced immune stimulation after vaccination with Swine erysipelas, followed by a slight improvement in the feed conversion ratio (F:G, which is the reciprocal of the efficiency of gain or G:F), but it significantly depressed feed intake in broilers and layers (Maass et al., 2005; Roth-Maier et al., 2005).

ANTIMICROBIAL ACTIONS

Herbs and spices are well known to exert antimicrobial actions in vitro against important pathogens, including fungi (Adam et al., 1998; Smith-Palmer et al., 1998; Hammer et al., 1999; Dorman and Deans, 2000; Burt, 2004; Si et al., 2006; Özer et al., 2007). The active substances are largely the same as mentioned previously for antioxidative properties, with phenolic compounds being the principal active components (Burt, 2004). Again, the plant family of Labiatae has received the greatest interest, with thyme, oregano, and sage as the most popular representatives (Burt, 2004). The antimicrobial mode of action is considered to arise mainly from the potential of the hydrophobic essential oils to intrude into the bacterial cell membrane, disintegrate membrane structures, and cause ion leakage. High antibacterial activities are also reported from a variety of nonphenolic substances, for example, limonene and compounds from *Sanguinaria canadensis* (Newton et al., 2002; Burt, 2004).

Microbiological analysis of minimum inhibitory concentrations (MIC) of plant extracts from spices and herbs, as well as of pure active substances, revealed levels that considerably exceeded the dietary doses when used as phytogenic feed additives (Burt, 2004). This may indicate that the antimicrobial action of phytogenics should not contribute significantly to the overall efficacy of this class of feed additives. On the other hand, some studies with broilers demonstrated in vivo antimicrobial efficacy of essential oils against *Escherichia coli* and *Clostridium perfringens* (Jamroz et al., 2003, 2005; Mitsch et al., 2004). In swine, however, the few studies available thus far have failed to demonstrate the efficacy of phytogenic compounds on shedding of specific pathogens (Jugl-Chizzola et al., 2005; Hagemüller et al., 2006). In total, the available literature suggests that, at least for broilers, an overall antimicrobial potential of phytogenic compounds in vivo cannot generally be ruled out. Furthermore, some phytogenic feed additives have been shown to act against *Eimeria* species after experimental challenge (Giannenas et al., 2003, 2004; Hume et al., 2006; Oviedo-Rondon et al., 2006).

Another implication of the antimicrobial action of phytogenic feed additives may in be improving the microbial hygiene of carcasses. Indeed, there are isolated

reports on the beneficial effects of essential oils from oregano on the microbial load of total viable bacteria, as well as of specific pathogens (e.g., *Salmonella*) on broiler carcasses (e.g., Aksit et al., 2006). However, available data are still too limited to allow reliable conclusions on the possible efficacy of certain phytogenic feed additives to improve carcass hygiene.

GROWTH-PROMOTING EFFICACY

In recent years, phytogenic feed additives have attracted increasing interest as an alternative feeding strategy to replace antibiotic growth promoters. This has occurred especially in the European Union, where antibiotics have been banned completely from use as additives in livestock feed since 2006 because of a suspected risk of generating microbiota with increased resistance to the antibiotics used for therapy in humans and animals.

The primary mode of action of growth-promoting feed additives arises from stabilizing feed hygiene (e.g., through organic acids), and even more from beneficially affecting the ecosystem of gastrointestinal microbiota through controlling potential pathogens (e.g., Roth and Kirchgessner 1998). This applies especially to critical phases of an animal's production cycle characterized by high susceptibility to digestive disorders, such as the weaning phase of piglets or early in the life of poultry. Because of a more stabilized intestinal health, animals are less exposed to microbial toxins and other undesired microbial metabolites, such as ammonia and biogenic amines (e.g., Eckel et al., 1992). Consequently, growth-promoting feed additives relieve the host animals from immune defense stress during critical situations and increase the intestinal availability of essential nutrients for absorption, thereby helping animals to grow better within the framework of their genetic potential.

Literature on the biological efficacy of phytogenic feed additives presents a scattered picture. Data on swine reviewed by Rodehutschord and Kluth (2002) varied widely from depressions in production performance to improvements similar to those observed with common growth promoters, such as antibiotics, organic acids, and probiotics. The same applies to more recent investigations (e.g., Manzanilla et al., 2004, 2006; Namkung et al., 2004; Straub et al., 2005; Hagmüller et al., 2006; Nofrarias et al., 2006; Schöne et al., 2006; Kroismayr et al., 2007; Lien et al., 2007). For poultry, the data appear to be clearer. As shown in Table 1, the majority of experimental results indicate reduced feed intake at largely unchanged BW gain or final BW, leading to an improved F:G when feeding phytogenic compounds. Of course, the wide variation in biological effects induced by phytogenics reflects the experimental approaches used to test the suitability of these substances as growth-promoting feed additives to swine and poultry and also includes failures in selecting the proper plants, active components, and efficacious dietary doses. However, numerous examples of positive experimental re-

sults among the studies mentioned above indicate that phytogenic feed additives, in general, may actually exert growth-promoting activity in swine and poultry. Nevertheless, the limited data available at present do not allow a systematic assessment of this potential in view of botanical origin and active principles, the more so because the available literature mainly presents data on commercial products containing blends of different compounds.

Recent studies with swine and poultry indicated stabilizing effects of phytogenic feed additives on the ecosystem of gastrointestinal microbiota. Kroismayr et al. (2007) compared a blend of essential oils from oregano, anise, and citrus peels with an antibiotic growth promoter and reported a decrease in microbial activity in the terminal ileum, cecum, and colon for both feed additives, as was obvious from reduced bacterial colony counts and reduced chyme contents of VFA as well as of biogenic amines. Comparable observations for herbal essential oils and oleoresins on the activity of intestinal microbiota were also found in other studies with pigs and broilers (Jamroz et al., 2003, 2005; Manzanilla et al., 2004; Mitsch et al., 2004; Namkung et al., 2004; Castillo et al., 2006). These effects are also typical for organic acids, which are known to exert a major part of their biological efficacy mainly through stabilizing the microbial eubiosis in the gastrointestinal tract (for a review, see Gabert and Sauer, 1994; Roth and Kirchgessner, 1998), including suppressed formation of biogenic amines (Eckel et al., 1992).

Relief from microbial activity and related by-products is of high relevance, especially in the small intestine, because production of VFA counteracts stabilization of the intestinal pH required for optimum activity of digestive enzymes. In addition, intestinal formation of biogenic amines by microbiota is undesirable not only because of toxicity, but also because of the fact that biogenic amines are produced mainly by decarboxylation of limiting essential AA (e.g., cadaverine from Lys, scatol from Trp). Consequently, relief from microbial fermentation in the small intestine may improve the supply status of limiting essential nutrients (e.g., Roth et al., 1998).

Morphological changes in gastrointestinal tissues caused by phytogenic feed additives may provide further information on possible benefits to the digestive tract; however, the available literature does not provide a consistent picture. Available reports have shown increased, unchanged, and reduced villi length and crypt depth in the jejunum and colon for broilers and pigs treated with phytogenic feed additives (Namkung et al., 2004; Demir et al., 2005; Jamroz et al., 2006; Nofrarias et al., 2006; Oetting et al., 2006). These results do not allow for conclusions to be drawn on the relevance of changes in intestinal morphology in view of a growth-promoting potential of phytogenic feed additives, especially because in some studies, the phytogenic formulations contained pungent principles (e.g., capsaicin) and

Table 1. Effect of phytobiotic feed additives on production performance in poultry

| Phytobiotic feed additive | Dietary dose (g/kg) | Treatment effect, % difference from untreated control | | | Reference |
|-----------------------------|---------------------|---|-----|-----|----------------------------|
| | | Feed intake | BW | ADG | |
| Broilers | | | | | |
| Plant extracts | | | | | |
| Oregano | 0.15 | -6 | | -2 | Basmacioglu et al., 2004 |
| Oregano | 0.3 | -3 | | +1 | Basmacioglu et al., 2004 |
| Rosemary | 0.15 | 0 | | -1 | Basmacioglu et al., 2004 |
| Rosemary | 0.3 | -2 | | +1 | Basmacioglu et al., 2004 |
| Thymol | 0.1 | +1 | | +1 | Lee et al., 2003 |
| Cinnamaldehyde | 0.1 | -2 | | -3 | Lee et al., 2003 |
| Thymol | 0.2 | -5 | | -3 | Lee et al., 2003 |
| Carvacol | 0.2 | +2 | | +2 | Lee et al., 2003 |
| Yucca extract | 2.0 | -1 | | +1 | Yeo and Kim, 1997 |
| Essential oil blend | 0.024 | -4 | -0 | | Cabuk et al., 2006 |
| Essential oil blend | 0.048 | -5 | 0 | | Cabuk et al., 2006 |
| Plant extracts ¹ | 0.2 | | -2 | 0 | Hernandez et al., 2004 |
| Plant extracts ¹ | 5.0 | | +2 | +3 | Hernandez et al., 2004 |
| Plant extracts ¹ | 0.5 | 0 | -2 | -2 | Botsoglou et al., 2004a |
| Plant extracts ¹ | 1.0 | +2 | -1 | 0 | Botsoglou et al., 2004a |
| Essential oil blend | 0.075 | -7 | | -3 | Basmacioglu et al., 2004b |
| Essential oil blend | 0.15 | -7 | | -1 | Basmacioglu et al., 2004b |
| Essential oil blend | 0.036 | +3 | -8 | | Alcicek et al., 2004 |
| Essential oil blend | 0.048 | +2 | -8 | | Alcicek et al., 2004 |
| Plant extracts ¹ | 0.1 | +1 | | +1 | Lee et al., 2003 |
| Essential oil blend | 0.024 | -2 | 0 | | Alcicek et al., 2003 |
| Essential oil blend | 0.048 | 0 | +14 | | Alcicek et al., 2003 |
| Essential oil blend | 0.072 | -2 | +8 | | Alcicek et al., 2003 |
| Herbs and spices | | | | | |
| Oregano | 5.0 | +5 | | +7 | Florou-Paneri et al., 2006 |
| Thyme | 1.0 | +1 | +2 | | Sarica et al., 2005 |
| Garlic | 1.0 | -5 | -5 | | Sarica et al., 2005 |
| Herb mix | 0.25 | 0 | | +2 | Guo et al., 2004 |
| Herb mix | 0.5 | +5 | | +2 | Guo et al., 2004 |
| Herb mix | 1.0 | +2 | | +1 | Guo et al., 2004 |
| Herb mix | 2.0 | +1 | | +1 | Guo et al., 2004 |
| Turkeys | | | | | |
| Herbs and spices | | | | | |
| Oregano | 1.25 | -5 | +2 | | Bampidis et al., 2005 |
| Oregano | 2.5 | -6 | +1 | | Bampidis et al., 2005 |
| Oregano | 3.75 | -9 | +1 | | Bampidis et al., 2005 |
| Quail | | | | | |
| Essential oils | | | | | |
| Thyme | 0.06 | 0 | | +6 | Denli et al., 2004 |
| Black seed | 0.06 | +1 | | +2 | Denli et al., 2004 |
| Herbs and spices | | | | | |
| Coriander | 5.0 | +3 | | +1 | Güler et al., 2005 |
| Coriander | 10.0 | +3 | | +5 | Güler et al., 2005 |
| Coriander | 20.0 | +4 | | +8 | Cüler et al., 2005 |
| Coriander | 40.0 | +5 | | +4 | Güler et al., 2005 |

¹Entire product.

significantly increased intestinal mucus production (Jamroz et al., 2006).

Manzanilla et al. (2006) and Nofrarias et al. (2006) observed a diminished number of intraepithelial lymphocytes in the jejunum of pigs treated with antibiotics or phytogetic feed additives.

Improved digestive capacity in the small intestine may be considered an indirect side effect of feed additives stabilizing the microbial eubiosis in the gut. Such

an effect has been shown in young pigs with antibiotic feed additives (Roth et al., 1999) and in broilers and swine with plant extracts (Jamroz et al., 2003; Hernandez et al., 2004). An improved prececal digestive capacity reduces the flux of fermentable matter into the hindgut, and thus lessens the postileal microbial growth and the excretion of bacterial matter in feces, respectively. Because bacterial protein is the dominant fraction of total fecal protein, an improved prececal digestive ca-

capacity may result indirectly in an increased apparent digestibility of dietary protein (calculated as the disappearance rate from intake until fecal excretion). Such an effect has been demonstrated for antibiotics and organic acids (e.g., Kirchgessner et al., 1995; Roth et al., 1998, 1999) as well as for phytogetic feed additives in pigs (Cho et al., 2006, Oetting et al., 2006; Stoni et al. 2006), broilers (Hernandez et al., 2004), and turkeys (Seskeviciene et al., 2005). These observations give further support to the hypothesis that phytogetic feed additives may stabilize digestive functions.

FURTHER CONSIDERATIONS ON THE USE OF PHYTOGETIC FEED ADDITIVES

Besides efficacy, application of phytogetic feed additives to livestock also has to be safe to the animal, the user, the consumer of the animal product, and the environment. Regarding exposed animals, adverse health effects cannot generally be excluded in the case of an accidental overdose. For the user (e.g., feed manufacturer, farmer), the handling of pure formulations of such feed additives usually requires protective measures because they are potentially irritating and can cause allergic contact dermatitis (Burt, 2004). With respect to consumer safety, the phytogetic feed additives cannot be relieved from determination of possible undesired residues in products derived from animals fed those products. For example, Stoni et al. (2006) reported almost complete absorption of carvacrol and thymol in swine fed these essential oils and detected their glucuronic and sulfate metabolites in blood plasma and kidney. Similarly, a study in humans demonstrated rapid absorption and subsequent urinary excretion of glucuronic and sulfate metabolites of rosmarinic essential oils (Baba et al., 2005). However, metabolic activity (e.g., absorption, potential to accumulate in edible tissues) differs widely among phytogetic compounds, and thus safety needs to be assessed separately for each individual phytogetic feed additive.

Another consideration when using phytogetic feed additives is possible interactions with other feed additives. Many of the feeding trials investigating the efficacy of phytogetic feed additives included other growth promoters (e.g., antibiotics, organic acids, and probiotics), as well as combinations with them, without showing antagonistic interaction among these feed additives. On the other hand, studies on interactions of phytogetic feed additives with enzyme preparations (e.g., phytase, enzymes degrading nonstarch polysaccharides, etc.) are very limited. For example, Sarica et al. (2005) reported a lack of or negative interactions of garlic and thyme with nonstarch polysaccharide-degrading enzymes in broilers. Phytogetic feed additives containing components with astringent properties, however, were reported to interact negatively with proteinaceous feed additives through partial denaturation (Anadon et al., 2005).

In conclusion, phytogetic feed additives are claimed to exert antioxidative, antimicrobial, and growth-promoting effects in livestock, actions that are partially associated with enhanced feed consumption, supposedly because of improved palatability of the diet. Whereas available results do not support a specific amelioration of palatability, the antioxidative efficacy of some phytogetic compounds to protect the quality of feed, as well as that of food derived from animals fed those substances, cannot be ruled out. With respect to antimicrobial action, some observations in vivo support the assumption that the general potential of phytogetic feed additives is to contribute to a final reduction of intestinal pathogen pressure. When compared with antimicrobial feed additives and organic acids, the phytogetic substances currently used in practice similarly seem to modulate relevant gastrointestinal variables, such as microbial colony counts, fermentation products (including undesirable or toxic substances), digestibility of nutrients, gut tissue morphology, and reactions of the gut-associated lymphatic system. Furthermore, some isolated observations seem to support the claimed enhancements of digestive enzyme activity and absorption capacity through phytogetic compounds. In addition, phytogetic products may stimulate intestinal mucus production, which may further contribute to relief from pathogen pressure through inhibition of adherence to the mucosa. Unfortunately, respective experimental results are available only from commercial products containing blends of phytogetic substances. Therefore, there is still a need for a systematic approach to explain the efficacy and mode of action for each of type and dose of active compound, as well as its possible interactions with other feed ingredients. Nevertheless, the current experience in feeding such compounds to swine and poultry seems to justify the assumption that phytogetic feed additives may have the potential to promote production performance and productivity, and thus add to the set of nonantibiotic growth promoters, such as organic acids and probiotics.

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