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Phytogenics As Animal Feed Additive

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Abstract

This article summarizes the experimental knowledge on efficacy, possible modes of action, and aspects of application of phytogenic products as feed additives for poultry. Phytogenic feed additives comprise a wide variety of herbs, spices, and products derived thereof, and are mainly essential oils. The assumption that phytogenic 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 phytogenic compounds may specifically enhance activities of digestive enzymes and nutrient absorption. Nevertheless, a limited number of experimental comparisons of phytogenic 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 phytogenic compounds seem to promote intestinal mucus production. Such effects may explain a considerable number of practical studies with poultry reporting improved production performance after providing phytogenic feed additives. In total, available evidence indicates that phytogenic 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 phytogenic compounds used as feed additives for poultry is still missing.

Introduction

Phytogenics, sometimes also referred to as “botanicals”, and commonly defined as plant based feed additives, represent a group of natural substances used in animal nutrition, and solely derived from herbs, spices, and their extracts, such as essential oils respectively. Owing to their wide range of substances and manifold active agents, phytogenics offer much more than only flavouring properties! Included into livestock diets they are able to enhance properties of feed and food quality and even improve the animals´ productivity and performance.Driven by the economic priority to improve efficiency and profitability by means of animal feeding, various phytogenic products are used in livestock nutrition. Though, additives applied should not only contribute to profitability and superior quality of animal-derived products, but also be in line with the steadily increasing food safety and agricultural regulations. Therefore, feed additives of natural plant origin have the potential for a more than promising prospective in animal nutrition.

Nature – tested and proven

The power of nature in terms of plants has been constituting an inherent part in human nutrition and human medicine for many years, and still does. The positive effect of some plants on our soundness has been known for many decades. First records of the usage of plant derived substances were found in Mesopotamia and date back to 2600 BC. But herbal substances were not only interesting for human purpose - throughout history, many essential oil-plants and spices have been used in veterinary treatment and animal health management likewise. Known for their holistic and broad spectrum efficacy, their application in livestock industry started many years ago. In recent times, mainly since the complete ban on antibiotic growth promoters in the EU in 2006, phytogenic products have been on the rise in animal production and - be it for reasons of public awareness of the potential health risk, environmental problems, trends towards “more natural, sustainable food production” or a sort of response to customers pressure in order to eliminate all kind of contaminants from livestock and thus also from the food chain - they are steadily gaining popularity.

GENERAL ASPECTS OF PHYTOGENIC FEED ADDITIVES

Phytogenic 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 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).

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 anthocyans (e.g., many fruits), are also described as exerting antioxidative properties (Nakatani, 2000; Wei and Shibamoto, 2007). Furthermore, pepper (*Piper nigrum*), red pepper (*Capsicum annuum L.*), and chili (*Capsicum frutescene*) 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.

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;O¨ zer 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 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).

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. 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).

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 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 poultry feeding revealed an enhanced immune stimulation after vaccination, 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).

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 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. For poultry, the data appear to be clearer. 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 poultry and also includes failures in selecting the proper plants, active components, and efficacious dietary doses. However, numerous examples of positive experimental results among the studies mentioned above indicate that phytogenic feed additives, in general, may actually exert growth-promoting activity 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 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 promotant 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 on 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 (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 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 significantly increased intestinal mucus production (Jamroz et al., 2006). 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 broilers 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 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 phytogenic feed additives in broilers (Hernandez et al., 2004), and turkeys (Seskeviciene et al., 2005). These observations give further support to the hypothesis that phytogenic feed additives may stabilize digestive functions.

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