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Use of phytogenic products as feed additives for swine and poultry

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ABSTRACT: This article summarizes experimental knowledge on efficacy, possible modes of action, and aspects of application of phytogenic products as feed additives for swine and 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 palatability of feed has not been confirmed yet by choice feeding studies. Although numerous studies have been demonstrating 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 suggested similar effects on the gut, such as reduced bacterial colony counts, less fermentation products (including ammonia and biogenic amines), less activity of the gut-associated lymphatic system, and a greater pre-cecal 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 swine and 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 non-antibiotic growth promoters, such as organic acids and probiotics, for use in livestock. However, a systematic approach on the efficacy and safety of phytogenic compounds used as feed additives for swine and poultry is still missing.

Key words: Antimicrobial, botanical, essential oils, herbs, phytogenic, swine, poultry

INTRODUCTION

Phytogenic feed additives are plant-derived products used in animal feeding in order to improve 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 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 due to speculated risk for generating antibiotic-resistance in pathogenic microbiota. In this context, phytogenic feed additives are discussed to possibly add to the set of non-antibiotic growth promoters, such as organic acids and probiotics, which are already well established in animal nutrition. Phytogenics, however, are a relatively new class of feed additives and we are still rather limited in knowledge regarding modes of their action and aspects of their application. Further complications arise because phytogenic feed additives may vary widely with respect to botanical origin, processing, and composition. Most studies comprise blends of various active compounds and report effects on production performance rather than physiological impacts. In this context, the following will provide an overview about recent knowledge on the use of phytogenic feed additives in piglets and poultry diets, possible modes of action, as well as safety implications.

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 productivity of livestock through amelioration of feed properties, promotion of the animals’ production performance, as well as improving quality of food derived from those animals. While 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, non-woody and non-persistent plants), spices (herbs with intensive smell or taste commonly added to human food), essential oils (volatile lipophilic compounds derived by cold expression and(or) steam or alcohol distillation), or oleoresins (extracts derived by non-aqueous solvents). Within phytogenic feed additives, the content of active substances in products may vary widely, depending upon the plant part used (e.g., seeds, leaf, root, and bark), harvesting season, and geographical origin. The technique of processing (e.g., cold expression, steam distillation, extraction with non aqueous solvents, etc.) modifies the active substances and associated compounds within the final product.

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 identity and traceability of the entire commercial product, efficacy of the claimed nutritional effects including absence of possible interactions with other feed additives, as well as 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 *Regulation (EC) No 1831/2003* of the European Parliament and of the Council). Problems with feed additive legacy may, therefore, arise especially with phytogenic feed additives addressed to explicit health claims or in case of plant derived substances suspected to modulate metabolism (e.g., through a phyto-hormonal mode of action). For these reasons, the following discussion will focus on 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., Craig, 1999; Cuppett and Hall, 1998; 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. Its 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), Umbelliferae (e.g., anise and coriander) are also described to exert antioxidative properties as well as plants rich in flavonoids (e.g., green tea) and anthocyans (e.g., many fruits) (Nakatani, 2000; Wei and Shibamoto, 2007). Furthermore, pepper *(Piper nigrum)*, red pepper *(Capsicum annuum L.)*, and chilli *(Capsicum frutescene)* contain antioxidative components (Nakatani, 1994). In many of these plants, a part of the active substances are highly odorous and(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 like antioxidants usually added to diets [e.g., α-tocopheryl acetate or butylated hydroxytoluene (**BHT**)]. Although this aspect has not been explicitly investigated for piglet and poultry feeds, there is wide practice of using successfully essential oils especially from the Labiatae plant family as 'natural' antioxidants in human food (Cuppett and Hall, 1998), as well as in feed of companion animals.

The principal potential of feed additives containing herbal phenolic compounds from Labiatae plant family to improve 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., 2004a), and eggs (Botsoglou et al., 2005). Oxidative stability was shown to be improved also with other herbal products (Botsoglu et al., 2004b, Schiavone et al., 2007). Nevertheless, it remains unclear whether these phytogenic antioxidants are able to replace 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 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 thyme and oregano herbs (Jugl-Chizzola et al., 2006; Schöne et al., 2006). On the other hand, there are numerous reports on an improved feed intake through phytogenic feed additives in swine (see subsequent section on growth promoting efficacy). 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 to untreated controls (Freitag et al., 1998). Therefore, the assumption that herbs, spices and their extracts improve 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, as well as enhanced enzyme activity is 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 pronounced bile acid flow in rats fed those substances (Platel and Srinivaran, 2000a,b). Similarly, essential oils used as feed additives for broilers were shown to enhance 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 which was assumed to impair adhesion of pathogens and thus to contribute to stabilize the microbial eubiosis in the animals' gut (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 *Yucca schidigera* extracts that lower intestinal urease activity and enzymes involved into metabolic urea cycle (Killeen et al., 1998; Duffy, 2001). Reduced intestinal and faecal urease activities were found also in broiler fed such extracts (Nazeer et al., 2002). However, yucca extracts were reported to contain sub-fractions 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 to 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 feed conversion ratio, but it depressed significantly 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 principle active components (Burt, 2004). Again, the plant family of Labiatae 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 reported also from a variety of non-phenolic 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 et al., 2004). This may indicate that 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 *E. coli* and *Clostridium perfringens* (Jamroz et al., 2003; Mitsch et al., 2004; Jamroz et al., 2005). In swine, however, the few studies available thus far failed to demonstrate efficacy of phytogenic compounds on specific pathogen shedding (Jugl-Chizzola et al., 2005; Hagmüller et al., 2006). In total, available literature suggests that, at least for broilers, an overall antimicrobial potential of phytogenic compounds *in vivo* cannot be generally 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-Rodon et al., 2006).

Another implication of 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 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 is still too limited to allow reliable conclusions on possible efficacy of certain phytogenic feed additives to improve carcass hygiene.

GROWTH PROMOTING EFFICACY

During 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 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 animals' production cycle characterized by high susceptibility to digestive disorders, such as the weaning phase of piglets or early in life of poultry. Due to 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 increases 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 Rodehutscord and Kluth (2002) vary 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; Namkung et al., 2004; Straub et al., 2005;

Hagmüller et al., 2006; Manzanilla et al., 2006; Nofrarias et al., 2006; Schöne et al., 2006; Kroismayr et al., 2007a; Lien et al., 2007). For poultry, the data appears to be clearer. As shown in Table 1, the majority of experimental results indicate reduced feed intake at largely unchanged weight gain or final body weight, leading to an improved feed conversion when feeding phytogenic compounds. Of course, the wide variation in biological effects induced by phytogenics reflects the experimental approaches to test suitability of these substances for use as growth promoting feed additives to swine and poultry and includes also failures in selecting 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 a growth-promoting activity in swine and poultry. Nevertheless, the limited data available at present does not allow assessing this potential systematically in view of botanical origin and active principles, the more so as 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. (2007a) 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 terminal ileum, cecum, and colon for both feed additives, as was obvious from reduced bacterial colony counts and reduced chyme contents of volatile fatty acids as well as of biogenic amines. Comparable observations for herbal essential oils and oleoresins on activity of intestinal microbiota were found also in other studies with pigs and broilers (Jamroz et al., 2003; Manzanilla et al., 2004; Mitsch et al., 2004; Namkung et al., 2004; Jamroz et al., 2005; 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 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 volatile fatty acids counteracts stabilization of 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 due to the fact that biogenic amines are produced mainly by decarboxylation of limiting essential amino acids (e.g., cadaverine from lysine, scatol from tryptophan). Consequently, relief from microbial fermentation in the small intestine may improve supply status of limiting essential nutrients (e.g., Roth et al., 1998).

Morphological changes in gastrointestinal tissues due to phytogenic feed additives may provide further information on possible benefits on the digestive tract; however, the literature available does not provide a consistent picture. Available reports show 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, 2006; Kroismayr et al., 2007b). These results do not allow for conclusions 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).

Manzanilla et al. (2006) and Nofrarias et al. (2006) observed diminished number of intraepithelial lymphocytes in jejunum of pigs treated with antibiotic or phytogenic feed additives. Kroismayr et al. (2007b) reported smaller Peyers' Patches in the ileum of swine fed either an antibiotic or a phytobiotic feed additive. Simultaneously, the mRNA abundance of the pro-inflammatory cytokine nuclear factor-kappa B was decreased in mesenterial lymph nodes whereas expression of tumor necrosis factor-α and caspase-3 remained fairly unchanged. These observations seem to reflect a reduced activity of relevant tissues of the gut associated lymphatic system, presumably as an indirect consequence of the relief from microbial activity and related by-products through phytogenic 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 pre-cecal digestive capacity reduces the flux of fermentable matter into the hind gut and, thus, lessens the postileal microbial growth and the excretion of bacterial matter in feces, respectively. Becasue bacterial protein is the dominant fraction of total fecal protein, an improved pre-cecal digestive capacity may result indirectly in an increased apparent digestibility of dietary protein (calculated as 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 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 phytogenic feed additives may stabilize digestive functions.

FURTHER CONSIDERATIONS TO THE USE OF PHYTOGENIC FEED ADDITIVES

Besides efficacy, application of phytogenic 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 case of an accidental overdose. In case of the user (e.g., feed manufacturer, farmer), the handling of pure formulations of such feed additives usually needs protective measures because they are potentially irritating and can cause allergic contact dermatitis (Burt, 2004). With respect to consumer safety, the phytogenic feed additives cannot be releived 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 sulphate metabolites of rosmarinic essential oils (Baba et al., 2005). However, metabolic activity (e.g., absorption, potential to accumulate in edible tissues) differs widely among phytogenic compounds and, thus, safety needs to be assessed separately for each individual phytogenic feed additive.

Another consideration of using phytogenic feed additives is possible interactions with other feed additives. Many of the feeding trials investigating the efficacy of phytogenic 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 phytogenic feed additives with enzyme preparations (e.g., phytase, enzymes degrading non-starch-polysaccharides, etc.) are very limited. For example, Sarica et al. (2005) reported lack or negative interactions of garlic and thyme with non-starch-polysaccharides degrading enzymes in broiler. Phytogenic feed additives containing components with adstringent properties, however, were reported to negatively interact with proteinaceous feed additives through partial denaturation (Anadon et al., 2005).

CONCLUSIONS

Phytogenic feed additives are claimed to exert antioxidative, antimicrobial, and growth promoting effects in livestock, actions which are partially associated with an enhanced feed consumption supposedly due to an improved palatability of the diet. Whereas available results do not support a specific amelioration of palatability, the antioxidative efficacy of some phytogenic compounds to protect 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 for the general potential of phytogenic feed additives to contribute to a final reduction of intestinal pathogen pressure. When compared with antimicrobial feed additives and organic acids, the phytogenic substances currently used in practice seem to similarly 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 phytogenic compounds. In addition, phytogenic 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 phytogenic substances. Therefore, there is still a lack of a systematic approach to explain efficacy and mode of action for each of type and dose of active compounds, as well as possible interactions with other feed ingredients. Nevertheless, the current experience in feeding such compounds to swine and poultry seems to justify the assumption that phytogenic feed additives may have the potential to promote production performance and productivity, and thus add to the set of non-antibiotic growth promoters, such as organic acids and probiotics.

LITERATURE CITED

Adam, K., A. Sivropoulou, S. Kokkini, T. Lanaras, and M. Arsenakis. 1998. Antifungal activities of Origanum vulgare subsp. hirtum, Mentha spicata, Lavandula angustifolia, and Salvia fruticosa essential oils against human pathogenic fungi. J. Agric. Food. Chem. 46:1739-1745.

Aksit, M., E. Goksoy, F. Kok, D. Ozdemir, and M. Ozdogan. 2006. The impacts of organic acid and essential oil supplementations to diets on the microbiological quality of chicken carcasses. Arch. Geflugelkd. 70:168-173.

Alcicek, A., M. Bozkurt, M, and M.Cabuk. 2003. The effect of an essential oil combination derived from selected herbs growing wild in Turkey on broiler performance. S. Afr. J. Anim. Sci. 33, 89-94.

Alcicek, A, M. Bozkurt, and M. Cabuk. 2004. The effect of a mixture of herbal essential oils, an organic acid or a probiotic on broiler performance. S. Afr. J. Anim. Sci. 34:217-222.

Anadon, A., M. Abroix Arzo, G. Bories, P. Brantom, J. Brufau de Barbera, A. Chesson, P.S. Concconcelli, J. de Knecht, N. Dierick, G. Flachowsky, A. Franklin, J. Gropp, A.K. Haldorsen, I. Halle, A. Mantovani, K. Peltonen, G. Rychen, P. Sanders, A. Soares, P. Wester, and W. Windisch. 2005. Opinion of the FEEDAP Panel on the safety and efficacy of the product Farmatan for rabbits and piglets. The EFSA Journal. 222:1-20.

Baba, S., N. Osakabe, M. Natsume, A.Yasuda, Y. Muto, K. Hiyoshi, H. Takano, T. Yoshikawa, and J. Terao. 2005. Absorption, metabolism, degradation and urinary excretion of rosmarinic acid after intake of Perilla frutescens extract in humans. Eur. J. Nutr. 44:1-9.

Bampidis, V.A., V. Christodoulou, P. Florou-Paneri, E. Christaki, P.S. Chatzopoulou, T. Tsiligianni, and A.B. Spais. 2005. Effect of dietary dried oregano leaves on growth performance, carcase characteristics and serum cholesterol of female early maturing turkeys. Br. Poult. Sci. 46:595-601.

Basmacioglu, H., O. Tokusoglu, and M. Ergul. 2004. The effect of oregano and rosemary essential oils or alpha-tocopheryl acetate on performance and lipid oxidation of meat enriched with n-3 PUFA's in broilers. S. Afr. J. Anim. Sci. 34:197-210.

Botsoglou, N.A., P. Florou-Paneri, E. Christaki, D.J. Fletouris, and A.B. Spais. 2002. Effect of dietary oregano essential oil on performance of chickens and on iron-induced lipid oxidation of breast, thigh and abdominal fat tissues. Br. Poult. Sci. 43:223-230.

Botsoglou, N.A., S.H. Grigoropoulou, E. Botsoglou, A. Govaris, and G. Papageorgiou. 2003a. The effects of dietary oregano essential oil and alpha-tocopheryl acetate on lipid oxidation in raw and cooked turkey during refrigerated storage. Meat Sci. 65:1193-1200.

Botsoglou, N.A., A. Govaris, E. Botsoglou, S.H. Grigoropoulou, and G. Papageorgiou. 2003b. Antioxidant activity of dietary oregano essential oil and alpha-tocopheryl acetate supplementation in long-term frozen stored turkey meat. J. Agric. Food. Chem. 51:2930-2936.

Botsoglou, N.A., P. Florou-Paneri, E. Christaki, I. Giannenas, and A.B. Spais. 2004a. Performance of rabbits and oxidative stability of muscle tissues as affected by dietary supplementation with oregano essential oil. Arch. Anim. Nutr. 58:209-218.

Botsoglou, N.A., E. Christaki, P. Florou-Paneri, I. Giannenas, G. Papageorgiou, and A.B. Spais. 2004b. The effect of a mixture of herbal essential oils or alpha-tocopheryl acetate on performance parameters and oxidation of body lipid in broilers. S. Afr. J. Anim. Sci. 34:52-61.

Botsoglou, N.A., P. Florou-Paneri, E. Botsoglou, V. Dotas, I. Giannenas, A. Koidis, and P. Mitrakos. 2005. The effect of feeding rosemary, oregano, saffron and alpha-tocopheryl acetate on hen performance and oxidative stability of eggs. S. Afr. J. Anim. Sci. 35:143-151.

Burt, S. 2004. Essential oils: their antibacterial properties and potential applications in food - a review. Int. J. Food Microbiol. 94:223-253.

Cabuk, M., M. Bozkurt, A. Alcicek, Y. Akbas, K. Kücükyilmaz. 2006. Effect of a herbal essential oil mixture on growth and internal organ weight of broilers from young and old breeder flocks. S. Afr. J. Anim. Sci. 36:135-141.

Castillo, M., S.M. Martin-Orue, M. Roca, E.G. Manzanilla, I. Badiola, J.F. Perez, and J. Gasa. 2006. The response of gastrointestinal microbiota to avilamycin, butyrate, and plant extracts in early-weaned pigs. J. Anim. Sci. 84:2725-2734.

Cho, J.H., Y.J. Chen, B.J. Min, H.J. Kim, O.S. Kwon, K.S. Shon, I.H. Kim, S. Kim, and A. Asamer. 2006. Effects of essential oils supplementation on growth performance, IgG concentration and fecal noxious gas concentration of weaned pigs. Asian Australas. J. Anim. Sci. 19(1):80-85.

Chrubasik, S., M.H. Pittler, and B.D. Roufogalis. 2005. Zingiberis rhizome: A comprehensive review on the ginger effect and efficacy profiles. Phytomedicine 12:684-701.

Craig, W.J. 1999. Health promoting properties of common herbs. Am. J. Clin. Nutr.

70(suppl):491S-499S.

Cuppett, S.L., and C.A. Hall. 1998. Antioxidant activity of Labiatae. Adv. Food Nutr. Res. 42:245-271.

Demir E., S. Sarica, M.A. Özcan, and M. Suicmez. 2005. The use of natural feed additives as alternative to an antibiotic growth promoter in boiler diets. Arch. Geflugelkd. 69:110-116.

Denli, M., F. Okan, and A.N. Uluocak. 2004. Effect of dietary supplementation of herb essential oils on the growth performance, carcass and intestinal characteristics of quail (Coturnix coturnix japonica). S. Afr. J. Anim. Sci. 34:174-179.

Dorman, H.J.D., and S.G. Deans. 2000. Antimicrobial agents from plants: antibacterial activity of plant volatile oils. J. Appl. Microbiol. 88:308-316.

Duffy, C.F., G.F. Killeen, C.D. Connolly, and R.F. Power. 2001. Effects of dietary supplementation with Yucca schidigera Roezl ex Ortgies and its saponin and non-saponin fractions on rat metabolism. J. Agric. Food. Chem. 49:3408-3413.

Eckel, B., F.X. Roth, M. Kirchgessner, and U. Eidelsburger.1992. Zum Einfluß von Ameisensäure auf die Konzentration an Ammoniak und biogenen Aminen im Gastrointestinaltrakt. 4. Mitteilung: Untersuchungen zur nutritiven Wirksamkeit von organischen Säuren in der Ferkelaufzucht. J. Anim. Physiol. Anim. Nutr. 67:198-205.

Florou-Paneri, P., I. Giannenas, E. Christaki, A. Govaris, and N.A. Botsoglou. 2006. Performance of chickens and oxidative stability of the produced meat as affected by feed supplementation with oregano, vitamin C, vitamin E and their combinations. Arch. Geflugelkd. 70:232-240.

Francis, G., Z. Kerem, H.P.S. Makkar, and K. Becker. 2002. The biological action of saponins in animal systems: a review. Br. J. Nutr.88:587-605.

Freitag, M., H.U. Hensche, H. Schulte-Sienbeck, and B. Reichelt. 1998. Kritische Betrachtung des Einsatzes von Leistungsförderern in der Tierernährung. Forschungsbericht des Fachbereichs Agrarwirtschaft Soest. ISBN 3-00-003331-9. Universität-Gesamthochschule Paderborn, Germany.

Gabert, V.M., and W.C. Sauer. 1994. The effect of supplementing diets for weanling pigs with organic acids. J. Anim. Feed Sci. 3:73-87.

Giannenas, I.A., P. Florou-Paneri, M. Papazahariadou, E. Christaki, N.A. Botsoglou, and A.B. Spais. 2003. Effect of dietary supplementation with oregano essential oil on performance of broilers after experimental infection with Eimeria tenella. Arch. Anim. Nutr. 57:99-106.

Giannenas, I.A., P. Florou-Paneri, M. Papazahariadou, N.A. Botsoglou, E. Christaki, and A.B. Spais. 2004. Effect of diet supplementation with ground oregano on performance of broiler chickens challenged with Eimeria tenella. Arch. Geflugelkd. 68:247-252.

Giannenas, I.A., P. Florou-Paneri, N.A. Botsoglou, E. Christaki, and A.B. Spais. 2005: Effect of supplementing feed with oregano and(or) alpha-tocopheryl acetate on growth of broiler chickens and oxidative stability of meat. J. Anim. Feed Sci. 14:521-535.

Govaris, A., N. Botsoglou, G. Papageorgiou, E. Botsoglou, and I. Ambrosiadis. 2004. Dietary versus post-mortem use of oregano oil and(or) alpha-tocopherol in turkeys to inhibit development of lipid oxidation in meat during refrigerated storage. Int. J. Food Sci. Nutr. 55:115-123.

Güler, T., O.N. Ertaş, M. Ciftci, and B. Dalkılıc. 2005. The effect of coriander seed (*Coriandrum sativum* L.) as diet ingredient on the performance of Japanese quail. S. Afr. J. Anim. Sci.

35:261-267.

Guo, F.C., R.P. Kwakkel, J. Soede, B.A. Williams, and M.W.A. Verstegen. 2004. Effect of a Chinese herb medicine formulation, as an alternative for antibiotics, on performance of broilers. Br. Poult. Sci. 45:793-797.

Hagmüller, W., M. Jugl-Chizzola, K. Zitterl-Eglseer, C. Gabler, J. Spergser, R. Chizzola, and C. Franz. 2006. The use of Thymi Herba as feed additive (0.1%, 0.5%, 1.0%) in weanling piglets with assessment of the shedding of haemolysing E-coli and the detection of thymol in the blood plasma. Berl. Munch. Tiararztl. 119:50-54.

Hammer, K.A., C.F. Carson and T.V. Riley. 1999. Antimicrobial activity of essential oils and other plant extracts. J. Appl. Microbiol. 86:985-990.

Hernandez, F., J. Madrid, V. Garcia, J. Orengo, and M.D. Megias. 2004. Influence of two plant extracts on broilers performance, digestibility, and digestive organ size. Poult. Sci. 83:169-174.

Hume, M.E., S. Clemente-Hernandez, and E.O. Oviedo-Rondont. 2006. Effects of feed additives and mixed Eimeria species infection on intestinal microbial ecology of broilers. Poult. Sci. 85:2106-2111.

Jamroz, D., I. Orda, C. Kamel, A. Wiliczkiewicz, T. Wertelecki, and I. Skorupinska. 2003. The influence of phytogenic extracts on performance, nutrient digestibility, carcass characteristics, and gut microbial status in broiler chickens. J. Anim. Feed Sci. 12:583-596.

Jamroz, D., A. Wiliczkiewicz, T. Wertelecki, J. Orda, and J. Skorupinska. 2005. Use of active substances of plant origin in chicken diets based on maize and locally grown cereals. Br. Poult. Sci. 46:485-493.

Jamroz, D., T. Wertelecki, M. Houszka, and C. Kamel. 2006. Influence of diet type on the inclusion of plant origin active substances on morphological and histochemical characteristics of the stomach and jejunum walls in chicken. J. Anim. Physiol. Anim. Nutr. 90:255-268.

Jang, I.S., Y.H. Ko, H.Y. Yang, J.S. Ha, J.Y. Kim, S.Y. Kang, D.H. Yoo, D.S. Nam, D.H. Kim, and C.Y. Lee. 2004. Influence of essential oil components on growth performance and the functional activity of the pancreas and small intestine in broiler chickens. Asian Australas. J. Anim. Sci. 17:394-400.

Janz, J.A.M., P.C.H. Morel, B.H.P. Wilkinson, and R.W. Purchas. 2007. Preliminary investigation of the effects of low-level dietary inclusion of fragrant essential oils and oleoresins on pig performance and pork quality. Meat Sci. 75:350-355.

Jugl-Chizzola, M., J. Spergser, F. Schilcher, J. Novak, A. Bucher, C. Gabler, W. Hagmuller, and K. Zitterl-Eglseer. 2005. Effects of Thymus vulgaris L. as feed additive in piglets and against haemolytic E-coli in vitro. Berl. Munch. Tierarztl. 118:495-501.

Jugl-Chizzola, M., E. Ungerhofer, C. Gabler, W. Hagmuller, R. Chizzola, K. Zitterl-Eglseer, and C. Franz. 2006. Testing of the palatability of Thymus vulgaris L. and Origanum vulgare L. as flavouring feed additive for weaner pigs on the basis of a choice experiment. Berl. Munch. Tierarztl. 119:238-243.

Killeen, G.F., C.R. Connolly, G.A. Walsh, C.F. Duffy, D.R. Headon, and R.F. Power. 1998. The effects of dietary supplementation with Yucca schidigera extract or Fractions thereof on nitrogen metabolism and gastrointestinal fermentation processes in the rat. J. Sci. Food. Agric. 76:91-99.

Kirchgessner, M., W. Windisch, and F.X. Roth. 1995. Zum Einfluss von Avilamycin und

Tylosin auf die Umsetzbare Energie in der Anfangs- und Endmast von Schweinen. Arch. Anim. Nutr. 48:63-70.

Kreydiyyeh S.I., J. Usta, K. Knio, S. Markossian, and S. Dagher. 2003. Aniseed oil increases glucose absorption and reduces urine output in the rat. Life Sci. 74:663-673.

Kroismayr A., J. Sehm, M. Pfaffl, C. Plitzner, H. Foissy, T. Ettle, H. Mayer, M. Schreiner, and W. Windisch. 2006a. Effects of essential oils or Avilamycin on gut microbiology and blood parameters of weaned piglets. Journal for Land Management, Food and Environment, accepted.

Kroismayr A., J. Sehm, M. Pfaffl, and W. Windisch. 2006b. Effects of Avilamycin and essential oils on mRNA expression of apoptotic and inflammatory markers and gut morphology of piglets. J. Anim. Pysiol. Anim. Nutr., accepted.

Lee, K.W., H. Everts, H.J. Kappert, M. Frehner, R. Losa, and A.C. Beynen. 2003. Effects of dietary essential oil components on growth performance, digestive enzymes and lipid metabolism in female broiler chickens. Br. Poult. Sci. 44:450-457.

Lien, T.F., Y.M. Horng, and C.P. Wu. 2007. Feasibility of replacing antibiotic feed promoters with the Chinese traditional herbal medicine Bazhen in weaned piglets. Livest. Prod. Sci. 107:92-102.

Maass, N., J. Bauer, B.R. Paulicks, B.M. Bohmer, and D.A. Roth-Maier. 2005. Efficiency of Echinacea purpurea on performance and immune status in pigs. J. Anim. Physiol. Anim. Nutr. 89:244-252.

Manzanilla, E.G., J.F. Perez, M. Martin, C. Kamel, F. Baucells, and J. Gasa. 2004. Effect of plant extracts and formic acid on the intestinal equilibrium of early-weaned pigs. J. Anim. Sci. 82:3210-3218.

Manzanilla, E.G., M. Nofrarias, M. Anguita, M. Castillo, J.F. Perez, S.M. Martin-Orue, C. Kamel, and J. Gasa. 2006. Effects of butyrate, avilamycin, and a plant extract combination on the intestinal equilibrium of early-weaned pigs. J. Anim. Sci. 84:2743-2751.

Mitsch, P., K. Zitterl-Eglseer, B. Kohler, C. Gabler, R. Losa, and I. Zimpernik. 2004. The effect of two different blends of essential oil components on the proliferation of Clostridium perfringens in the intestines of broiler chickens. Poult. Sci. 83:669-675.

Nakatani, N. 1994. Antioxidants from Spices and Herbs. In: Ho, C.-T., T. Osawa, M.-T. Huang, and R.T. Rosen (Eds.): Food Phytochemicals for Cancer Prevention II, Teas, Spices and Herbs. ACS Symposium Series 547. American Chemical Society, 1994, Washington, DC.

Nakatani, N. 2000. Phenolic antioxidants from herbs and spices. BioFactors 13:141-146.

Namkung, H., M. Li, J. Gong, H. Yu, M. Cottrill, and C.F.M. de Lange. 2004. Impact of feeding blends of organic acids and herbal extracts on growth performance, gut microbiota and digestive function in newly weaned pigs. Can. J. Anim. Sci. 84:697-704.

Nazeer, M.S., T.N. Pasha, S. Abbas, and Z. Ali. 2002. Effect of yucca saponin on urease activity and evelopment of ascites in broiler chicken. Int. J. Poult. Sci. 1:174-178.

Newton, S.M., C. Lau, S.S. Gurcha, G.S. Besra, and C.W. Wright. 2002. The evaluation of forty-three plant species for in vitro antimycobacterial activities; isolation of active constituents from Psoralea corylifolia and Sanguinaria Canadensis. J. Ethnopharmacol. 79:57-67.

Nofrarias, M., E.G. Manzanilla, J. Pujols, X. Gilbert, N. Majo, J. Segales, and J. Gasa. 2006. Effects of spray-dried porcine plasma and plant extracts on intestinal morphology and on leukocyte cell subsets of weaning pigs. J. Anim. Sci. 84:2735-2742.

Oetting, L.L., C.E. Utiyama, P.A. Giani, U.D. Ruiz, and V.S. Miyada. 2006. Effects of herbal extracts and antimicrobials on apparent digestibility, performance, organs morphometry and intestinal histology of weanling pigs. Braz. J. Anim. Sci. 35:1389-1397.

Oviedo-Rondon, E.O., M.E. Hume, C. Hernandez, and S. Clemente-Hernandez. 2006. Intestinal microbial ecology of broilers vaccinated and challenged with mixed Eimeria species, and supplemented with essential oil blends. Poult. Sci. 85.854-860.

Özer, H., M. Sökmen, M. Güllüce, A. Adigüzel, F. Sahin, A. Sökmen, H. Kilic, and Ö. Baris. 2007. Chemical Composition and Antimicrobial and Antioxidant Activities of the Essential Oil and Methanol Extract of *Hippomarathum microcarpum* (Bieb.) from Turkey. J. Agric. Food Chem. 55:937.942.

Papageorgiou, G., N.A. Botsoglou, A. Govaris, I. Giannenas, S. Iliadis, and E. Botsoglou. 2003. Effect of dietary oregano oil and alpha-tocopheryl acetate supplementation on iron-induced lipid oxidation of turkey breast, thigh, liver and heart tissues. J. Anim. Physiol. Anim. Nutr. 87:324-335.

Platel, K. and K. Srinivasan. 2000a. Influence of dietary spices and their active principles on pancreatic digestive enzymes in albino rats. Food 44:41-46.

Platel, K., and K. Srinivasan. 2000b. Stimulatory influence of select spices on bile secretion in rats. Nutr. Res. 20, 1493-1503.

Platel, K., and K. Srinivasan. 2004. Digestive stimulant action of spices: A myth or reality? Indian J. Med. Res. 119:167-179.

Rao R.R., K. Platel, and K. Srinivasan. 2003. In vitro influence of spices and spice-active principles on digestive enzymes of rat pancreas and small intestine. Food 47:408-412.

Regulation (EC) No 1831/2003 of the European Parliament and of the council of 22 September

2003 on additives for use in animal nutrition. Official Journal of the European Union. L 268:29-43.

Rodehutscord M., and H. Kluth. 2002. Tierfütterung ohne antibiotisch wirkende Leistungsförderer. Zuchtungskunde 74:445-452.

Roth, F.X., and M. Kirchgessner. 1998. Organic acids as feed additives for young pigs: nutritional and gastrointestinal effects. J. Anim. Feed Sci, 8:25-33.

Roth F.X., W. Windisch, and M. Kirchgessner. 1998. Effect of potassium diformiate (FormiTM LHS) on nitrogen metabolism and nutrient digestibility in piglets at graded dietary lysine supply. Agribiol. Res. 51:167-175.

Roth, F.X., G.G. Gotterbarm, W. Windisch, and M. Kirchgessner. 1999. Whole-body protein turnover and nitrogen balance in growing pigs supplied with antibiotic feed additive (Avilamycin). J. Anim. Physiol. Anim. Nutr. 82:88-93.

Roth-Maier, D.A., B.M. Bohmer, N. Maass, K. Damme, and B.R. Paulicks. 2005. Efficiency of Echinacea purpurea on performance of broilers and layers. Arch. Geflugelkd. 69:123-127.

Sarica, S., A. Ciftci, E. Demir, K. Kilinc, and Y. Yildirim. 2005. Use of an antibiotic growth promoter and two herbal natural feed additives with and without exogenous enzymes in wheat based broiler diets. S. Afr. J. Anim. Sci. 35:61-72.

Schiavone, A., F. Righi, A. Quarantelli, R. Bruni, P. Serventi, and A. Fusari. 2007. Use of *Sibyllum marianum* fruit extract in broiler chicken nutrition: influence on performance and meat quality. J. Anim. Physiol. Anim. Nutr. 91:256-267.

Schöne, F., A.Vetter, H. Hartung, H. Bergmann, A. Biertumpfel, G. Richter, S. Müller, and G. Breitschuh. 2006. Effects of essential oils from fennel (Foeniculi aetheroleum) and caraway (Carvi aetheroleum) in pigs. J. Anim. Physiol. Anim. Nutr. 90:500-510.

Seskeviciene, J., J. Jankowski, and K. Kozlowski. 2005. Effect of probiotic preparation and phytogeneous feed additive on digestibility of nutrients, metabolizibility of gross energy and content of metabolizable energy of a practical feed ration for fattening turkeys. Arch. Geflugelkd. 69:107-109.

Si, W., J. Gong, R. Tsao, T. Zhou, H. Yu, C. Poppe, R. Johnson, and Z. Du. 2006. Antimicrobial activity of essential oils and structurally related synthetic food additives towards selected pathogenic and beneficial gut bacteria. J. Appl. Microbiol. 100:296-305.

Smith-Palmer, A., J. Stewart, and L. Fyfe. 1998. Antimicrobial properties of plant essential oils and essences against five important food-borne pathogens. Lett. Appl. Microbiol. 26:118.122.

Stoni, A., K. Zitterl-Egelseer, A. Kroismayr, W. Wetscherek, W. Windisch. 2006. Tissue recovery of essential oils used as feed additive in piglet feeding and impact on nutrient digestibility. Proc. Soc. Nutr. Physiol. 15, 60

Straub, R., S. Gebert, C. Wenk, and M. Wanner. 2005. Growth performance, energy, and nitrogen balance of weanling pigs fed a cereal-based diet supplemented with Chinese rhubarb. Livest. Prod. Sci. 92:261-269.

Wei, A., and T. Shibamoto. 2007. Antioxidant Activities and Volatile Constituents of Various Essential oils. J. Agric. Food Chem. 55:737-1742.

Yeo, J., and K.I. Kim. 1997. Effect of feeding diets containing an antibiotic, a probiotic, or yucca extract on growth and intestinal urease activity in broiler chicks. Poult. Sci. 76:381-385.

Young, J.F., J. Stagsted, S.K. Jensen, A.H. Karlsson, and P. Henckel. 2003. Ascorbic acid, alpha-tocopherol, and oregano supplements reduce stress-induced deterioration of chicken meat quality. Poult. Sci. 82:1343-1351.

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

Phytobiotic feed additive	Dietary dose (g/kg)	Treatment effects, % difference to untreated control				References
		Feed intake	Body weight	Daily weight gain	Feed conversion rate	
A) Broilers						
Plant Extracts						
Oregano	0.15	-6		-2	-4	Basmacioglu et al., 2004
Oregano	0.3	-3		+1	-2	Basmacioglu et al., 2004
Rosemary	0.15	0		-1	-1	Basmacioglu et al., 2004
Rosemary	0.3	-2		+1	-4	Basmacioglu et al., 2004
Thymol	0.1	+1		+1	-1	Lee at al., 2003
Cinnamaldehyde	0.1	-2		-3	0	Lee at al., 2003
Thymol	0.2	-5		-3	-3	Lee at al., 2003
Carvacol	0.2	+2		+2	-1	Lee at al., 2003
Yucca extract	2.0	-1		+1	-6	Yeo et al., 1997
Essential oil blend	0.024	-4	-0		-4	Cabuk et al., 2006
Essential oil blend	0.048	-5	0		-6	Cabuk et al., 2006
Plant extracts[1]	0.2		-2	0	-2	Hernandez et al., 2004
Plant extracts[1]	5.0		+2	+3	-4	Hernandez et al., 2004
Plant extracts[1]	0.5	0	-2	-2	+2	Botsoglou et al., 2004
Plant extracts[1]	1.0	+2	-1	0	+2	Botsoglou et al., 2004
Essential oil blend	0.075	-7		-3	-4	Basmacioglu et al., 2004b
Essential oil blend	0.15	-7		-1	-1	Basmacioglu et al., 2004b
Essential oil blend	0.036	+3	-8		-5	Alcicek et al., 2004
Essential oil blend	0.048	+2	-8		-4	Alcicek et al., 2004
Plant extracts[1]	0.1	+1		+1	0	Lee at al., 2003
Essential oil blend	0.024	-2	0		-2	Alcicek et al., 2003
Essential oil blend	0.048	0	+14		-12	Alcicek et al., 2003
Essential oil blend	0.072	-2	+8		-9	Alcicek et al., 2003
Herbs and spices						
Oregano	5.0	+5		+7	-2	Florou-Paneri et al., 2006
Thyme	1.0	+1	+2		-1	Sarica et al., 2005
Garlic	1.0	-5	-5		0	Sarica et al., 2005
Herb mix	0.25	0		+2	-2	Guo et al., 2004
Herb mix	0.5	+5		+2	+3	Guo et al., 2004
Herb mix	1.0	+2		+1	+1	Guo et al., 2004
Herb mix	2.0	+1		+1	0	Guo et al., 2004
B) Turkeys						
Herbs and spices						
Oregano	1.25	-5	+2			Bambidis et al., 2005
Oregano	2.5	-6	+1			Bambidis et al., 2005
Oregano	3.75	-9	+1			Bambidis et al., 2005
C) 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	+1	Guler et al., 2005
Coriander	10.0	+3		+5	-1	Guler et al., 2005
Coriander	20.0	+4		+8	-4	Guler et al., 2005
Coriander	40.0	+5		+4	+1	Guler et al., 2005

[1] Entire product