Phytobiotics in poultry and swine nutrition – a review

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ABSTRACT
The trend in the use of phytobiotics in animal feed has been increased during last two decades. Investigations showed that excessive use of in-feed antibiotics will intensify the potential risks of increasing resistance in human pathogens. Bacterial resistance and antibiotic residues in animal products led to raising the concern in using antibiotics as growth promoters and finally resulted in the ban on using in-feed antibiotics in most of the developed countries. As an alternative, phytobiotics were recommended by researchers and nutritionists. Plenty of studies have been done using phytobiotics in poultry and swine nutrition so far. They have mostly shown the anti-microbial, antioxidant, anti-inflammatory and growth promoting effects of phytobiotics. Antioxidative function of phytobiotics can positively affect the stability of animal feed and increase animal’s products quality and storage time. Generally, the available documents indicate the positive effects of phytobiotics on poultry and swine performance. Due to the contradictions in published results, further research and investigations are still necessary to elucidate various nutritional aspects of phytobiotics. In the following context, the authors try to provide an overview of the recently published results on application of phytobiotics and possible mode of actions as an alternative for in-feed antibiotics in poultry and swine nutrition.

Introduction
Developments in the production of antibiotics and their effectiveness on livestock performance have resulted in intensive use of these synthetic substances. Antibiotic growth promoters (AGPs) have been used widely in livestock production for almost 50 years. However, public awareness of the potential health risks and environmental problems caused by the excessive use of synthetic pharmaceuticals including in-feed antibiotics as growth promoters and growth hormones and also public demand for organic foods have gradually changed the attitude toward these synthetic antibiotics (Greathead 2003; Rochfort et al. 2008). Investigations have led to increased concern about the incidence of microbial resistance among human pathogens due to continuous use of antibiotics as performance enhancers in animals, ultimately resulting in the ban on using AGP in livestock feeding in developed countries at early 2000s. Elimination of AGPs has significantly increased the incidence of infections by pathogens, consequently having detrimental effect on the performance of commercial animals. Therefore, the trend of finding available alternatives has increased.

Phytophogenic feed additives (PFAs) are also known as herbs or phytobiotics used in traditional treatments. They could be used as alternatives to antibiotics. Some of the most commonly used species of PFA in traditional European animal healthcare are listed in Table 1 (Franz et al. 2010). Using PFA in poultry and swine nutrition has recently gained increasing interest. Compared to non-AGPs such as organic acids and probiotics well established in animal nutrition, phytobiotics are relatively new feed additives. Our knowledge about their modes of action and aspects of application is still rather limited.

Phytobiotics includes a wide range of plant-derived products such as essential oils, herbs and oleoresins. They can be added to the diet of commercial animals to improve their productivity through enhancing feed properties, promoting animals’ production performance, and improving the quality of products derived from these animals (Windisch et al. 2008). In addition to the above-mentioned definition, Windisch et al.
(2008) have recommended some other commonly used terms to classify different phytogenic compounds based on their origin and processing, including herbs (flowering, non-woody and non-persistent plants), spices (herbs with an intensive smell or taste commonly added to human food), essential oils (volatile lipophilic compounds) and oleoresins (extracts derived by non-aqueous solvents).

The content of active substances and the chemical composition of phytobiotics in the final products may vary widely depending on the plant parts used (seeds, leaves, etc.), geographical origins, and harvesting season (Burt 2004; Bakkali et al. 2008; Windisch et al. 2008). It has also been suggested that the benefits of the use of essential oils of oregano is often also variable because it depends on all the constituents working together (Giannenas et al. 2013). However, plenty of studies have indicated the growth promoting effects, antimicrobial activity, antioxidant activity and anti-inflammation activity of phytobiotics. Based on the literature, it has been hypothesised that the most possible mode of action of PFA is the modulation of gut environment and intestinal morphology in poultry and swine (Stein and Kil 2006; Li et al. 2012). However, reviewing published documents has revealed that some results are contradictory (Table 2; Franz et al. 2010). Herein, we focus on the use of phytobiotics as feed additives in the diet of poultry and swine in terms of their antioxidant role, antimicrobial action, beneficial impact on growth efficacy, and their effect on gut functions.

### Growth promoting effect

Plenty of PFAs have been investigated during the last two decades. It has been mostly reported that addition of herbal products to diets has growth promoting effect on poultry and swine (Wenk 2003; Kim et al. 2010; Mohammadi Gheisar et al. 2015a,b). Li et al. (2012) compared the performance of pigs fed with the diets supplemented with essential oils and reported weight gain and digestibility of dry matter and crude protein were improved by 10.3, 2.9 and 5.9%, respectively. They suggested that improved performance of pigs was the result of improvement of the intestinal morphology and consequently improvement of nutrients digestibility. Yan et al. (2010) have conducted an experiment feeding growing-finishing pigs with diet supplemented with essential oils (thyme, rosemary, oreganum extracts) and reported that the average daily gain (ADG) and feed conversion ratio (FCR) significantly improved during the growing period.

### Table 1. Most commonly used phytobiotics in traditional animal health care and livestock production (Franz et al. 2010).

| Latin name | Common name | Parts/products used |
|------------|-------------|---------------------|
| Achillea millefolium s.l. | Yarrow | Infusion |
| Arnica montana | Amica | Extract |
| Boswellia sacra | Frankincense | Resin |
| Carum carvi | Caraway | Seed, essential oil |
| Citrus sp. | Citrus oil | Essential oil |
| Curcuma longa | Curcuma | Rhizome |
| Foeniculum vulgare | Fennel | Seed |
| Matricaria recutita | Camomile | Infusion, essential oil |
| Mentha sp. | Mint | Infusion, essential oil |
| Pimpinella anisum | Aniseed | Seed, essential oil |
| Pinus sp. | Turpentine | Essential oil, (oleo) resin |
| Salvia officinalis | Sage | Infusion, essential oil |
| Syzygium aromaticum | Cloves | Buds, essential oil |
| Zingiber officinale | Ginger | Rhizome |

### Table 2. Effect of aromatic herbs and essential oils as feed additives on the performance in poultry and swine (adapted from Franz et al. 2010).

| Animals/feed additive | Feed intake | Body weight | Feed conversion ratio | Reference |
|-----------------------|-------------|-------------|-----------------------|-----------|
| **Poultry**            |             |             |                       |           |
| Carvacrol             | −2          |             | −1                    | Lee et al. (2003) |
| Cinnamaldehyde        | −2          |             | 0                     | Lee et al. (2003) |
| Rosemary              | 0−/2        | −1−/4       | 0−/3                  | Basmacioglu et al. (2004) |
| Thymol                | +1−/−5      | −1−/−3      | 0−/3                  | Lee et al. (2003) |
| Garlic                | −5          | +4          | −3                    | Sarica et al. (2005) |
| Essential oil blend   | 0           | +3          | −3.5                  | Mohammadi Gheisar et al. (2015a) |
| Phytogenic blend      | 0           | 0           | 0                     | Mohammadi Gheisar et al. (2015b) |
| Artemisia annua        | 0           | 0           | 0                     | Cherian et al. (2013) |
| **Swine**              |             |             |                       |           |
| Cinnamon              | −5          | 0           | −5                    | Wald et al. (2001) |
| Oregano               | 0           | +5          | −5                    | Wald et al. (2001) |
| Peppermint            | −9          | −3          | −7                    | Wald et al. (2001) |
| Coriander             | +4          | +7          | −3                    | Schuhmacher et al. (2002) |
| Thyme                 | +4          | +6          | −3                    | Schuhmacher et al. (2002) |
| Essential oil blend   | 0           | +5          | 0                     | Yan et al. (2010) |
| Houttuynia cordata    | −7          | +4.5        | 0                     | Yan et al. (2011) |
| Tanacetum officinale  | +5.5        | +3          | 0                     | Yan et al. (2011) |
| Phytogenic blend      | 0           | 0           | 0                     | Yan et al. (2012) |
They have also reported that the ADG was significantly improved during the overall experimental period without affecting other growth performance parameters. Yan et al. (2011) have reported that adding a herb extract blend (containing buckwheat, thyme, curcuma, black pepper and ginger) to the diet of growing pigs resulted in increases in average daily feed intake (ADFI) and final body weight (BW, Figure 1). Mohammadi Gheisar et al. (2015a) reported that feeding broiler chickens with diet containing 0.075% of a phytogenic blend led to 3.9% and 3.4% improvement in BWG and FCR, respectively (Figure 2). Results of another study on meat-type ducks have indicated 2.6% and 3.5% improvement in BWG and FCR, respectively (Mohammadi Gheisar et al. 2015b, Figure 2). Researchers have suggested different modes of action for phytobiotics. Stimulating the secretion of digestive enzymes, improving palatability and flavour of feed, increasing feed intake, and increasing antimicrobial activity are some of the main modes of action that might have led to the improved growth performance of poultry and swine (Jang et al. 2004; Czech et al. 2009). Reviewing the literature shows that removal of in feed antibiotics has been resulted in significantly negative effects on the performance of pigs and poultry. Yakhkeshi et al. (2011) studied the effects of different natural growth promoters in broiler chickens to compare the results with the groups feeding the diets with/without antibiotics. Their results indicated that feeding the birds with the diets containing antibiotic alternatives alleviated the negative effects of removing antibiotics from the diet of commercial poultry.

**Influence on palatability and gut function**

Phytobiotics are mostly claimed to be beneficially effective on the flavour and palatability of feed, thus enhancing the production performance (Windisch et al. 2008). Results of some studies have shown that feeding pigs with essential oils extracted from fennel and caraway or extracted from thyme and oregano resulted in dose-related detrimental effect on palatability (Jugl-Chizzola et al. 2006; Schone et al. 2006). Some other reports have shown that addition of phytobiotics to the diet of broiler chickens and laying hens resulted in significant depression in feed intake (Maass et al. 2005; Roth-Maier et al. 2005). On the other hand, there is evidence showing improvements in feed intake by adding PFA to swine diet (Kyriakis et al. 1998; Kroismayr et al. 2008).

Chrubasik et al. (2005) have reported that a wide range of phytobiotics (including herbal plants and their extracts) are known to have beneficial impacts on the digestive tract (such as laxative and spasmylytic effects). In addition, they can prevent flatulence. Furthermore, Platel and Srinivasan (2004) have suggested that phytobiotics can stimulate digestive secretions such as saliva and bile. They have reported that improving enzyme activity is the main mode of nutritional action of PFA. Rao et al. (2003) have reported that the in vitro activities of rat pancreatic lipase and amylase are significantly enhanced when they were in contact with various spices and spice extracts. Researchers have also found greater enzyme activities in pancreatic homogenates and pronounced bile acid flow in rats fed with PFA (Platel and Srinivasan 2000). Similarly, other researchers have reported that supplementing the diet of broiler chickens with essential oils can enhance the activities of trypsin, maltase and pancreatic amylase (Lee et al. 2003; Jang et al. 2004; Jang et al. 2007). Kreydiyyeh et al. (2003) have shown that
feeding rats with a diet containing anise oil enhanced the absorption of glucose from the small intestine. Furthermore, Manzanilla et al. (2004) reported that the diet of swine supplemented with a blend of essential oils and capsaicin can lower the gastric emptying rate. Jamroz et al. (2006) suggested that feeding broilers with a diet supplemented with PFA resulted in stimulating the secretion of mucus in the intestine of broilers. This effect was assumed to reduce the adhesion of pathogens, thus stabilising microbial eubiosis in the gut of animals. Brenes and Roura (2010) in a review reported that chickens may respond to low levels of spices in feed by increasing digestive secretions without significantly rejecting feed (i.e. decreasing feed intake), as opposed to mammals responding with a higher degree of feed refusal.

There is also some evidence showing that spices are effective on the metabolism of lipids. Leung (2008) reported that addition of capsaicin to the diet of rodents reduced the weight of visceral fat and it may be attributed to an increase in the expression of transient receptor potential vanilloid type (TRPV1).

### Antimicrobial action

The antimicrobial activity (either bactericidal or bacteriostatic) of phytogenic compounds against foodborne organisms such as protozoa and fungi has been investigated by several researchers (Chao et al. 2000; Burt 2004; Si et al. 2006; Stein and Kil 2006; Michiels et al. 2009; Panghal et al. 2011; Giannenas et al. 2013). Most of these investigations have shown that phenolic substances such as thymol, carvacrol, phenylpropane, limonene, geraniol and citronellal are the most active compounds that have antimicrobial function. In a recently published review, Yang et al. (2015) suggested that the antimicrobial action of PFAs vary by the location of their functional hydroxyl or alkyl groups. It has been reported that the hydroxyl group of the phenolic terpenoids and the presence of delocalised electrons are important elements for their antimicrobial action. For example, studies have showed some of the common terpenoids (e.g. carvacrol and thymol), have similar antimicrobial effects but their action against G⁺ or G⁻ bacteria is different based on the locations of one or more functional groups in their molecules (Lambert et al. 2001; Ultee et al. 2002). Burt (2004) reported that the plant family of Labiatae has received the greatest interest, including thyme, oregano and sage as the most popular representatives. They suggested that the ability of hydrophobic essential oils to intrude into the cell membrane of pathogens, consequently disintegrating their membrane structures and causing ion leakage as a possible explanation of the antimicrobial activity of PFA. Decreasing the count of pathogens (e.g. *Escherichia coli*) in the guts of host animals can lead to increased count of beneficial bacteria (e.g. *Lactobacillus*) in the guts. There is some evidence showing that adding 0.075% of essential oils blend (75 g/kg of feed; containing thymol and vanillin) to the diet of broiler chickens resulted in increased population of *Lactobacillus* (Mohammadi Gheisar et al. 2015a, Table 3). High antibacterial activities have also been reported for a variety of non-phenolic substances, including limonene and compounds from *Sanguinaria canadensis* (Newton et al. 2002; Burt 2004). Some studies with broiler chickens demonstrated the in vivo antimicrobial efficacy of essential oils against *E. coli* and *Clostridium perfringens* (Jamroz et al. 2003, 2006; Mitsch et al. 2004). Some PFAs have been shown to have activities against *Eimeria* species after experimental challenge (Giannenas et al. 2003, 2004; Hume et al. 2006; Oviedo-Rondon et al. 2006). Another implication of antimicrobial action of PFA is that they can improve the microbial hygiene of carcases. Indeed, there is evidence showing the beneficial effect of adding 0.1% oregano essential oils (*Origanum onites*, 15 g/kg of commercial product) to the diet on the microbial load of total viable bacteria or specific pathogens (e.g. *Salmonella*) on broiler carcases (Aksit et al. 2006). However, available data are still limited to allow reliable conclusions on the possible efficacy of certain PFA in improving carcass hygiene.

### Antioxidant and anti-inflammatory action

The antioxidant activity of phytobiotics is another biological property of great interest. Their ability of scavenging free radicals may play an important role in preventing some diseases caused by free radicals, such as cancer and heart diseases (Kamatou and Viljoen 2010; Miguel 2010). Some studies have successfully used essential oils, especially those from the Labiatae plant family, as natural antioxidants in human food and feed of companion animals (Cuppett and Hall 1998). The ability of donating hydrogen or an electron to free radicals and also delocalising the unpaired electron within the aromatic structure are the main mechanisms of protecting other biological molecules...
against oxidation, that previous researchers have been suggested (Fernandez-Panchon et al. 2008; Giannenas et al. 2013). Researchers have investigated the potential effect of PFAs from the Labiatae plant family containing phenolic compounds on improving the oxidative stability of pork (Janz et al. 2007) and poultry meat (Botsoglou et al. 2003; Young et al. 2003; Basmacioglu et al. 2004; Giannenas et al. 2005; Florou-Paneri et al. 2006). Brenes and Roura (2010) have reported that a wide range of herbs and their extracts have potential antioxidant functions, especially those products derived from the plant family Labiatae such as rosemary, oregano, and thyme. Mohammadi Gheisar et al. (2015b) have supplemented the diet of meat-type ducks with PFA blend containing thyme and reported that the thiobarbituric acid reactive substances (TBARS) value of breast meat was significantly reduced by the PFA blend (Figure 3). Cherian et al. (2013) reported that feeding broiler chickens with PFA (Artemisia annua) resulted in a significant reduction in TBARS value in breast and thigh meat. They suggested that the reduction in TBARS value could be due to individual or combined antioxidant properties of polyphenolic compounds or vitamin E in Artemisia annua. Cuppett and Hall (1998) have suggested that the antioxidative activity of Labiatae family plants is due to their contents of phenolic terpenes (e.g. rosmarinic acid and rosmarol). On the other hand, there is some evidence suggesting that the antioxidant activity of phytobiotics is not only caused by their phenolic substances, but also their non-phenolic compounds. Placha et al. (2014) have demonstrated that supplementing the diet of broiler chickens with thymol can reduce the oxidation of fatty acids indicated by the lower malondialdehyde level in duodenal mucosa. Franz et al. (2010) have suggested that phytobiotics can beneficially affect some antioxidant enzymes such as glutathione peroxidase and superoxide dismutase, consequently affecting lipid metabolism in animals.

Other plant species such as ginger, curcuma, anise, coriander and plants that are rich in flavonoids (such as green tea) or anthocyanins (e.g. many fruits) also have antioxidant activities (Nakatani 2000; Wei and Shibamoto 2007). There is also evidence showing that black pepper (Piper nigrum), red pepper (Capsicum annuum L.) and chilli (Capsicum frutescens; Nakatani 2000) also have antioxidant activities. The pungent taste and the odour of active substances of most of these plants can restrict their use in animal feeding, especially for swine. The active compounds of phytobiotics may have protective roles for feed lipids against oxidative damage, similar to antioxidants such as α-tocopheryl acetate or butylated hydroxy toluene that is usually added to diets.

Inflammation is a normal protective response induced by tissue injury or infection to combat invaders in the body (microorganisms) and to remove dead or damaged host cells (Stevenson and Hurst 2007). Miguel (2010) stated that some essential oils have the ability to scavenge free radicals. In addition, they can also act as anti-inflammatory agents because one of the inflammatory responses is oxidative burst in diverse cells. There is some evidence showing that some essential oils have anti-inflammatory activities. For instance, chamomile essential oil has been used traditionally for centuries as an anti-inflammatory drug to alleviate symptoms associated with eczema, dermatitis and other pronounced irritations (Kamatou and Viljoen 2010). It has been also reported that rosmarinic acid, oleanolic acid and ursolic acid are the major non-volatile secondary metabolites found in Origanum spp. essential oils with strong anti-inflammatory properties (Shen et al. 2010). Other essential oils (eucalyptus, rosemary, lavender, millefolia) and other plants (pine, clove and myrrh) have been used in mixed formulations as anti-inflammatory agents (Darsham and Doreswamug 2004).

**Conclusions**

Different aspects of PFAs have been studied in the last two decades. Growth promoting effect, antimicrobial activity, antioxidant activity and anti-inflammation activity are some of the functions that have been investigated. According to the literature, phytobiotics have positive effects in improving the performance of poultry and swine. Some researchers have suggested that the improving effects of dietary supplementation with PFA are partially associated with enhanced feed consumption probably due to improved palatability of

![Figure 3. Effect of phytogenic feed additives on TBARS value in meat-type ducks.](image-url)
the diet. Regarding the antimicrobial activity, there is some evidence supporting the assumption that the general mode of action of PFA is by modulating gut microflora and reducing intestinal pathogen pressure. Comparing antimicrobial feed additives and organic acids with PFAs that are currently being used in poultry and swine feed, shows similar modulation effects for relevant gastrointestinal factors such as microbiota, fermentation products (including undesirable or toxic substances), nutrients digestibility, gut tissue morphology, and reactions of the gut-associated lymphatic system. However, due to the wide variety of available phytogenic products, the recommended effective dosage vary. Furthermore, some studies have shown that phytobiotics can enhance the digestive enzyme activity and absorption capacity. In addition, the results of some studies have demonstrated that phytogenic products may be able to stimulate intestinal mucus production which may further contribute to the relief from pathogen pressure through inhibiting adherence to the mucosa. Since most experimental results are available only for commercial products containing blends of phytogenic substances, there is still a need of using a systematic approach to explain the efficacy and the mode of action for each type of PFA and the dose of active substances. Nevertheless, the available documents to date in feeding such compounds to swine and poultry seem to justify the assumption that PFA may have the potential to promote production performance and productivity as non-AGPs.

Disclosure statement

No potential conflict of interest was reported by the authors.

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