

Phytogenics as New Class of Feed Additive in Poultry Industry

¹S.R. Hashemi and ²H. Davoodi

¹Department of Animal Science,

Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

²Department of Microbiology, Golestan University of Medical Sciences,
Golestan, Iran

Abstract: The aim of this study summarizes the experimental knowledge on efficacy, possible modes of activity and aspects of application of phytogenic products as feed additives for poultry. Feed additives are a group of feed ingredients that can cause a desired animal response in a non-nutrient role such as pH shift, growth or metabolic modifier. Many substances found in nature have a wide range of growth promoting, immunostimulatory or antimicrobial activity. Common feed additives used in poultry diets include antimicrobials, antioxidants, pH control agents and enzymes. Phytogenic are a relatively young class of feed additives and in recent years this feed additives have gained considerable attention in the feed industry. They are a wide variety of herbs, spices and products derived thereof and are mainly essential oils. Although, numerous reports have demonstrated antioxidative and antimicrobial and immune stimulation efficacy *in vitro*, respective experimental *in vivo* evidence is still quite limited. A limited number of experimental comparisons of phytogenic feed additives with antibiotics and acidifiers have suggested similar effects on the gut. Gut microflora has significant effects on host nutrition, health and growth performance by interacting with nutrient utilization and the development of gut system of the host. In addition, some phytogenic compounds seem to promote intestinal mucus production. However, a systematic approach toward the efficacy and safety of phytogenic compounds used as feed additives for poultry is still lacking.

Key words: Antimicrobial, botanical, essential oil, feed additive, phytogenic, poultry, broiler

INTRODUCTION

Feed additives are products used in animal nutrition for purposes of improving the quality of feed and the quality of food from animal origin or to improve the animals performance and health. The initial use of antibiotics in diets arose from the discovery in the late 1940's, in the United States that including the fermentation products of *Streptomyces aureofaciens* (a strain of bacteria) in the diets of simple-stomached animals such as pigs and poultry resulted in growth responses (Frost, 1991).

It is important to make a distinction between antibiotics used in the treatment and prevention of disease in farm animals (prescribed therapeutic and prophylactic use) which differs from their use as feed additives to enhance growth (Castanon, 2007). As feed additives, antibiotics are used at low concentrations of 2.5-50 ppm (depending on the compound used). In the next 50 years, the use of antibiotics as feed additives in

pig and poultry production became virtually universal. However, the possibility of developing resistant populations of bacteria and the side effects of using antibiotics as growth promoters in farm animals have been led to the European Union and United States ban on the use of antibiotics on farm animals as growth and health promoters.

This will have avoidable consequences for growth performance of birds in the poultry industry. Hence, an intensive search for alternatives such as probiotics, prebiotics, symbiotics, enzymes, toxin binders, organic acids, organic minerals, oligosaccharides and other feed additives has started in the last decade (Fulton *et al.*, 2002). Phytogenics are a group of natural growth promoters or non-antibiotic growth promoters, derived from herbs, spices or other plants. In this context, the present research provides an overview of recent knowledge on the use of phytogenic feed additives in poultry diets and possible modes of action and safety implications.

PLANT SECONDARY METABOLITES (PSM)

The biological or therapeutic activity of a medicinal plant is closely related to the plant chemicals in it. As Plant Secondary Metabolites (PSM) are an extremely large group of compounds, a comprehensive overview of their biochemistry, bioactivity and chemistry is not possible in a relatively short paper. PSM, also known as phytochemicals, represent a diverse group of natural products, some of which may be nutritionally valuable but many of which have no nutritional value or antinutritional properties. Although precise numbers are at best an estimate, of the >100000 different compounds of natural origin that have been described >80000 are derived from plants. These chemicals can be classified into major groups of chemicals such as essential oils, alkaloids, acids, steroids, tannins, saponins and so forth. Each one of these classes of chemicals may have a preferred effective method of extraction.

SAFETY OF PLANTS

Herbal plants and plant derived products are known for herb medicinal values for centuries. They are also extensively used, particularly in many Asian, African and other countries. It is estimated that there are 250,000-500,000 species of plants on earth (Borris, 1996). Relatively small percentages (1-10%) of these are used as

foods by both humans and other animal species (Cowan, 1999). Compared with synthetic antibiotics or inorganic chemicals, these plant-derived products have proven to be natural, less toxic, residue free and are thought to be ideal feed additives in food animal production (Hashemi *et al.*, 2008).

HERBAL PLANTS CLASSIFICATION

With respect to biological origin, formulation, chemical description and purity, phytobiotics comprise a very wide range of substances and 4 subgroups may be classified) herbs (product from flowering, non-woody and non-persistent plants) botanicals (entire or processed parts of a plant, e.g., root, leaves, bark) essential oils (hydro distilled extracts of volatile plant compounds) and oleoresins (extracts based on non-aqueous solvents) (Windisch and Kroismayr, 2006).

HERBAL PLANTS PROPERTIES

Antimicrobial (Guo *et al.*, 2004a), antioxidant (Hashemi *et al.*, 2009a), anti-stress (Chattopadhyay *et al.*, 2005), gut microflora manipulation (Hashemi *et al.*, 2009b), nutrigenomics effect (Franco-Jimenez *et al.*, 2007) and immune enhancement (Guo *et al.*, 2004b) properties probably are the major mechanisms by which herbal plants exert positive effects on the growth performance and health of animals (Fig. 1).

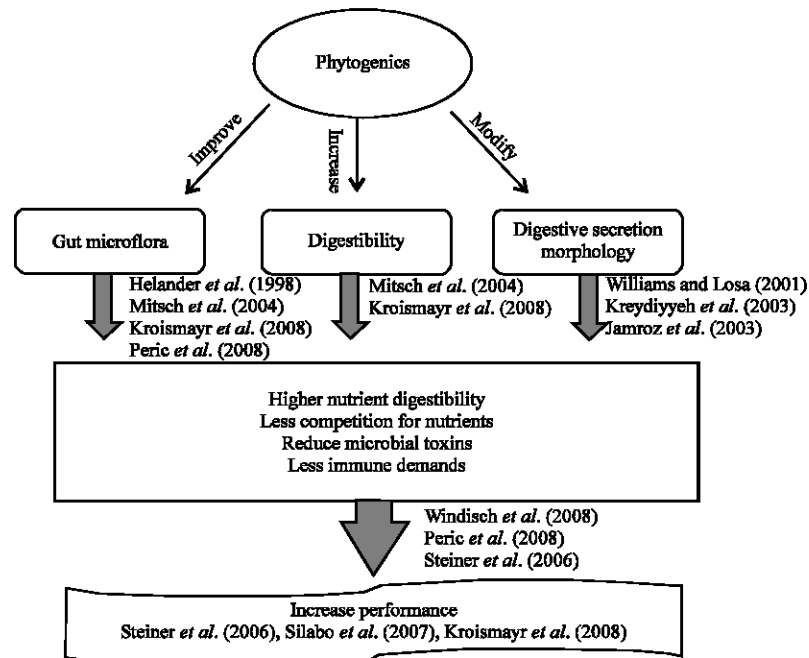


Fig. 1: Main mechanisms of herbal plants exert positive effects on the growth performance and health of animals. Tobias Steiner, BIOMIN GmbH, Herzogenburg, Austria with some modification

ANTIBACTERIAL ACTIVITY OF PHYTOBIOTICS

Herbs and spices are well known to exert antimicrobial actions *in vitro* against important pathogens including fungi (Windisch *et al.*, 2008). A common feature of phytobiotics is that they are a very complex mixture of bioactive components. For example, hawthorn fruit, a common growth-enhancing and digestion modifier has been shown to contain >70 kinds of organic chemicals along with some unidentified factors and active bio-active compounds (Wang *et al.*, 1998).

Growth enhancement through the use of phytobiotics is probably the result of the synergistic effects among complex active molecules existing in phytobiotics. Phytochemicals in phytobiotics are well known to have antimicrobial ability (Cowan, 1999). Phytochemicals exert their antimicrobial activity through different mechanisms, tannins for example act by iron deprivation, hydrogen bonding or non specific interactions with vital proteins such as enzymes (Scalbert, 1991).

Chung *et al.* (1993) showed that tannic acid inhibits the growth of intestinal bacteria such as *Bacteroides fragilis*, *Clostridium perfringens*, *E. coli* and *Enterobacter cloacae*. Alkaloid is known to be a DNA intercalator and an inhibitor of DNA synthesis through topoisomerase inhibition (Karou *et al.*, 2006). The main mechanism by which saponins display an antimicrobial activity is based on their ability to form complexes with sterols present in the membrane of microorganisms.

This causes damages in the membrane and the consequent collapse of cells (Morrissey and Osbourn, 1999). Essential oils have long been recognized for their anti-microbial activity (Lee *et al.*, 2004a) and they have gained much attention for their potential as alternatives to antibiotics in broiler chickens. Some studies with broilers demonstrated *in vivo* antimicrobial efficacy of essential oils against *Escherichia coli* and *Clostridium perfringens* (Jamroz *et al.*, 2003; Mitsch *et al.*, 2004).

The exact anti-microbial mechanism of essential oils is poorly understood. However, it has been suggested that their lipophilic property (Conner, 1993) and chemical structure (Farang *et al.*, 1989a, b) can play a role. It was suggested that terpenoids and phenylpropanoids can penetrate the membranes of the bacteria and reach the inner part of the cell because of their lipophilicity (Helander *et al.*, 1998). Moreover, structural properties, such as the presence of the functional groups (Farang *et al.*, 1989c) and aromaticity (Bowles and Miller, 1993) are also responsible for the antibacterial activity of essential oils.

PHYTOGENICS AS FEED ADDITIVES IN POULTRY

In recent years, phytogetic feed additives have attracted increasing interest as an alternative feeding strategy to replace antibiotic growth promoters. Effect of phytobiotic feed additives on production performance in poultry are shown in Table 1. Hernandez *et al.* (2004) reported that extracts from sage, thyme and rosemary and the blend of carvacrol, cinnamaldehyde and capsaicin improved feed digestibility in broilers. The researchers attributed the positive effects of plant extracts on nutrient digestibility to the appetite and digestion-stimulating properties and antimicrobial effects. Therefore they may exert multiple functions in the animal body. Increased feed intake and digestive secretions are also observed in animals offered phytobiotic-supplemented feed (Windisch and Kroismayr, 2006).

The primary mode of action of phytogetic feed additives arises from beneficially affecting the ecosystem of gastrointestinal microbiota through controlling potential pathogens. Improved digestive capacity in the small intestine may be considered an indirect side effect of phytogetic stabilizing the microbial eubiosis in the gut. Consequently, phytogetic 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.

Ground thyme has been shown to inhibit the growth of *S. typhimurium* when added to media (Aktug and Karapinar, 1986). The essential oil of the thyme has been shown to inhibit the growth of the *E. coli* in media (Marino *et al.*, 1999). However, bird growth responses to essential oil supplementation are still controversial (Table 2). No essential oil effects on growth performance were reported by Botsoglou *et al.* (2002), Zhang *et al.* (2005), Jang *et al.* (2007) whereas improved growth performance were observed at different ages of birds fed certain essential oil supplemented diet(s) by Jamroz *et al.* (2003), Hernandez *et al.* (2004) and Cross *et al.* (2007) (Table 3).

The effect of *hymus vulgaris* (thyme) and *Cinnamomum zeylanicum* (cinnamon) on the performance of broilers was studied by Al-Kassie *et al.* (2009) who found their effect on the live weight gain and the improvement of the health of poultry in addition to other performance traits, feed conversion ratio and feed intake. Guo indicated that mushroom and herb polysaccharides increased growth of immune organs such as thymus, bursa and spleen weights in both normal or immune-inhibition-treated chickens and rats. Immuno-

Table 1: Effect of phytobiotic feed additives on production performance in poultry¹

Phytobiotic feed additive	Dietary dose (g kg ⁻¹)	Treatment effect, percentage of difference from untreated control				Reference
		FI	BW	ADG	FCR	
Broilers						
Plant extracts						
Oregano	0.150	-6	-	-2	-4	Basmacioglu <i>et al.</i> , 2004
Oregano	0.300	-3	-	+1	-2	Basmacioglu <i>et al.</i> , 2004
Rosemary	0.150	0	-	-1	-1	Basmacioglu <i>et al.</i> , 2004
Rosemary	0.300	-2	-	+1	-4	Basmacioglu <i>et al.</i> , 2004
Thymol	0.100	+1	-	+1	-1	Lee <i>et al.</i> , 2003
Cinnamaldehyde	0.100	-2	-	-3	0	Lee <i>et al.</i> , 2003
Thymol	0.200	-5	-	-3	-3	Lee <i>et al.</i> , 2003
Carvacol	0.200	+2	-	+2	-1	Lee <i>et al.</i> , 2003
Yucca extract	2.000	-1	-	+1	-6	Yeo and Kim, 1997
Essential oil blend	0.024	-4	0	-	-4	Cabuk <i>et al.</i> , 2006
Essential oil blend	0.048	-5	0	-	-6	Cabuk <i>et al.</i> , 2006
Plant extracts ²	0.200	-	-2	0	-2	Hernandez <i>et al.</i> , 2004
Plant extracts ²	5.000	-	+2	+3	-4	Hernandez <i>et al.</i> , 2004
Plant extracts ²	0.500	0	-2	-2	+2	Botsoglou <i>et al.</i> , 2004a
Plant extracts ²	1.000	+2	-1	0	+2	Botsoglou <i>et al.</i> , 2004a
Essential oil blend	0.075	-7	-	-3	-4	Basmacioglu <i>et al.</i> , 2004
Essential oil blend	0.150	-7	-	-1	-1	Basmacioglu <i>et al.</i> , 2004
Essential oil blend	0.036	+3	-8	-	-5	Alcicek <i>et al.</i> , 2004
Essential oil blend	0.048	+2	-8	-	-4	Alcicek <i>et al.</i> , 2004
Plant extracts ¹	0.100	+1	-	+1	0	Lee <i>et al.</i> , 2003
Essential oil blend	0.024	-2	0	-	-2	Alcicek <i>et al.</i> , 2003
Essential oil blend	0.048	0	+14	-	-12	Alcicek <i>et al.</i> , 2003
Essential oil blend	0.072	-2	+8	-	-9	Alcicek <i>et al.</i> , 2003
Herbs and spices						
Oregano	5.000	+5	-	+7	-2	Florou-Paneri <i>et al.</i> , 2006
Thyme	1.000	+1	+2	-	-1	Sarica <i>et al.</i> , 2005
Garlic	1.000	-5	-5	-	0	Sarica <i>et al.</i> , 2005
Herb mix	0.250	0	-	+2	-2	Guo <i>et al.</i> , 2004a
Herb mix	0.50	+5	-	+2	+3	Guo <i>et al.</i> , 2004a
Herb mix	1.000	+2	-	+1	+1	Guo <i>et al.</i> , 2004b
Herb mix	2.000	+1	-	+1	0	Guo <i>et al.</i> , 2004b
Turkeys						
Herbs and spices						
Oregano	1.250	-5	+2	-	-	Bampidis <i>et al.</i> , 2005
Oregano	2.500	-6	+1	-	-	Bampidis <i>et al.</i> , 2005
Oregano	3.750	-9	+1	-	-	Bampidis <i>et al.</i> , 2005
Quail						
Essential oils						
Thyme	0.060	0	-	+6	-	Denli <i>et al.</i> , 2004
Black seed	0.060	+1	-	+2	-	Denli <i>et al.</i> , 2004
Herbs and spices						
Coriander	5.000	+3	-	+1	+1	Guler <i>et al.</i> , 2005
Coriander	10.000	+3	-	+5	-1	Guler <i>et al.</i> , 2005
Coriander	20.000	+4	-	+8	-4	Guler <i>et al.</i> , 2005
Coriander	40.000	+5	-	+4	+1	Guler <i>et al.</i> , 2005

Windisch *et al.*, 2008 ²Entire product

active polysaccharides derived from two mushrooms, *Tremella fuciformis* and *Lentinus edodes* and the herb *Astragalus membranacea* Radix seem to be potential alternatives for antimicrobial growth and health promoters.

These products were considered to play an important role in strengthening the animals defense system by improving the physical conditions of gut ecosystem and enhancing functions of the immune system of chickens. Lower population of pathogenic bacteria

may increase availability of nutrients eliminate sub-clinical infections and reduce production of growth-depressing toxins or metabolites by intestinal microflora.

However, bird growth responses to herbal plants and its derived supplementation are still controversial. While comparing the effects of various herbs and oils on broiler performance, Cross *et al.* (2007) concluded that the quality as well as the quantity of active chemicals in plant extract determines bird response. Some factors may affect

Table 2: Literature review of the effects of specific essential oil blends on live performance, carcass traits and digesta parameters

Essential oil composition	Diet, husbandry and challenge conditions	Effect of EO reference	References
Blend non specified	+20 mg kg ⁻¹ virginiamycin. Three experiment in cages	No effect on BW and FCR	Vogt, 1990, 1991
Crina® poultry	Floor pens	No effect on BW and FCR	Ristic and Damme, 2001
Oregano (carvacrol-thymol)	Wheat-soybean meal basal diet- floor pens	No effect on BW and FCR	Botsoglou <i>et al.</i> , 2002
Carvacrol and cinnamaldehyde combination		Negative effects as compared to the two fed individually	Lee <i>et al.</i> , 2004c
EO blends		Improve antioxidant activity in carcasses	Dorman <i>et al.</i> , 1995; Saricoban and Ozcan, 2004; Basmacioglu <i>et al.</i> , 2004
Apacox®		No effect on BW and FCR, retarded lipid oxidation in meat	Botsoglou <i>et al.</i> , 2004a, b
Genex® (EO+organic acids) 500-1000 ppm		Growth promoting effect compared to flavomycin	Spais <i>et al.</i> , 2002
Capsaicin, carvacrol, cinnamic aldehyde, 150-300 ppm	Wheat-barley diet	Improvement in BW (5.4, 8.1%) and feed conversion (3.1 and 7.1%). Reduced <i>E. coli</i> and <i>C. perfringens</i>	Jamroz <i>et al.</i> , 2003
Crina® Poultry; or thymol and cinnamaldehyde	Maize-maize starch-soybean meal diet in wire floored cages	No effect of BW and FCR Amilase activity improved in Crina®	Lee <i>et al.</i> , 2003
Cinnamaldehyde	Diet with carboxymethyl cellulose, rye	Reverse negative effects of high viscosity diets	Lee <i>et al.</i> , 2004 a, b
Blend from Turkey	Corn-soybean meal diets with wheat and sunflower meal in floor pens	Improved BW, FCR and carcass yield	Alcicek <i>et al.</i> , 2003
Crina® poultry and combinations with antibiotics and lactic acid		Improve BW, FCR Combination with antibiotics or lactic acid did not show any effect	Suk <i>et al.</i> , 2003
EO blend plus lactic acid		Improve BWG and increase digestive enzyme activities of the pancreas and intestinal mucosa	Jang <i>et al.</i> , 2004
Oregano (carvacrol and thymol)		Reduced feed intake and significantly improve feed efficiency	Halle <i>et al.</i> , 2004
EO blend		Improve BWG, FCR and carcass yield	Alcicek <i>et al.</i> , 2004
RepaXol™ (oregano, cinnamon, thyme and capsicum)	Corn soybean meal diets in floor pens and cages from 1-42 days	No effect on BWG, FCR or FI. Improvement of final carcass yield and Feed efficiency at 14 days but not over the course of the experiment	Zhang <i>et al.</i> , 2005
Crina® poultry and Crina® Alternate	Corn soybean meal diets in floor from 1-49 days	Improvement of FCR 13 days but not over the course of the experiment. No effect on cocci-vaccinated birds	Oviedo-Rondon, 2005d
Oregano (carvacrol and thymol)	Cocci-vaccinated birds <i>Eimeria tenella</i> infection-cages	Improve responses	Giannenas <i>et al.</i> , 2003
Oregano (carvacrol and thymol)	Mixed Eimeria vaccination	Improvement in BWG and FI	Waldenstet, 2003
Oregano (carvacrol and thymol)	Mixed Eimeria infection and induced necrotic enteritis	Improve BWG, lesion scores	Saini <i>et al.</i> , 2003a, b
Thymol, carvacrol, eugenol, curcumin and piperin.	12 field trials to test <i>Clostridium perfringens</i> Numbers	Reduced Clostridium perfringens colonization	Mitsch <i>et al.</i> , 2004
Crina® Poultry and Crina® Alternate	Mixed Eimeria vaccination and infection	Crina Alternate but not Crina Poultry improved BWG, FCR and lesion scores post-infection. No effect on cocci-vaccinated birds	Oviedo-Rondon, 2005a-c

Ferket *et al.*, 2005

Table 3: Effects of essential oils on growth performance in broilers

Item	Negative control	Antibiotic control	Essential oil treatment
Garcia <i>et al.</i> (2007)			
ADG (g bird ⁻¹)	68.90	66.50	68.80
FCR (g g ⁻¹)	1.92	1.54	1.59
Ertase <i>et al.</i> (2005)			
ADG (g bird ⁻¹)	61.30	65.80	71.30
FCR (g g ⁻¹)	1.61	1.50	1.41
Jamroz <i>et al.</i> (2003)			
ADG (g bird ⁻¹)	48.10	48.90	49.20
FCR (g g ⁻¹)	1.85	1.81	1.79

Yang *et al.*, 2009; ADG: Average Daily Gain. FCR: Feed Conversion Ratio

Table 4: Herbs products for poultry available in market

Products name and composition	Company name and address	Additional information
Aerocid Liquid composition of organic acids and herbs to be nebulized in the stables	Herbavita Bvba, Belgium	Properties • Stress-reducing • Antibacterial action
Anihom Liquid composition of extracts of plants	Herbavita bvba, Belgium	Target groups: Broilers, Layers Properties. Stimulates the immunity system, emollient for the air passages, beneficial for the intestinal tract
Aquacid Composition of organic acids and extracts from herbs	Herbavita bvba, Belgium	Target groups: Broilers, Layers Properties Promotes the appetite, stimulates the enzyme production, beneficial for a healthy digestion and feed conversion
Herban liquid Herbal extracts	KELA nv, Belgium.	Target group: calf, pig, poultry
Herban powder Herbal extracts	KELA nv, Belgium.	Target group: calf, pig, poultry
Artripul Liquid composition of extracts of plants	Herbavita bvba, Belgium	Target groups: Broilers Properties: Beneficial for the muscles, joints and the maintenance of strong bones, maintains the joints and muscles supple, beneficial to maintain strong bones
Phytobiotic growth promoter Blend of phytobiotics from quantified essential oils extracts, plant extracts from Thyme, Origanum, Rosmary, Clove and Cynnamon.	Tav veterinaria, Spain	Target group: swine poultry and calves. Properties: Growth promoter. Prevents coccidial multiplication and reduces its damage effect on the intestinal wall
Bronchimax Liquid composition of extracts of plants.	Herbavita bvba, belgium.	Target groups: Broilers Properties: Emollient for the airways and ensures efficient respiration
Ammofree-premix AmmoFree is a poly herbal formulation capable of binding ammonia and increases the utilization of ammonia nitrogen in GI tract	Indian herbs, India	Ammo Free Premix supports and enhances the intestinal enzyme system, ammo free Premix increases the utilization of ammonia nitrogen in GI tract Ammo Free Premix binds ammonia and prevents its excess release in poultry shed
Animunin	Indian herbs, India	Animunin is a herbal feed supplement which functions like a respiratory antiseptic and helps to maintain normal respiratory functions (Complicated Chronic Respiratory Disease)
Avericox® Plant extracts and additives: appetizing and aromatic substances (essential oils).	Mercordi animal care, Belgium	Avericox® can be used to combat coccidiosis as well as to optimise growth and production in poultry. The essential oils control the coccidial population
Colinex® Echinacea angustifolia Echinacea purpurea Vincetoxicum hirudinaria Survey in Euro Tier-2008	Mercordi animal care, Belgium	Colinex® LA is an extremely powerful immune stimulator and can therefore be used successfully to prevent <i>E. coli</i> infections

the effectiveness of phytobiotic additives could be include: plant parts and their physical properties, the genetic variation of plant, age of the plant, different dosage used, extraction method, harvest time and compatibility with the other ingredients which may also explain why difference in body weight gain and difference in feed conversion ratio could happen when different kinds of phytobiotics are used in chicken diet (Yang *et al.*, 2009).

In addition, the efficacy of dietary phytobiotic can be affected by intrinsic and extrinsic factors such as nutritional status of animals, infection, diet composition and environment (Giannenas *et al.*, 2003; Lee *et al.*, 2004a, b, c). Herbal products for poultry available in market are shown in Table 4. Although, phytobiotics are a group of natural additives, research into their

mechanisms of action, compatibility with diet, toxicity and safety assessment needs to be done before they can be applied more extensively in poultry feed.

CONCLUSION

There are so many advantages of using herbs than antibiotics. phytogenic feed additives may have the potential to promote production performance and productivity and thus add to the set of nonantibiotic growth promoters such as organic acids and probiotics. Even antibiotics can't be used during laying period of chickens due to residual effect in eggs. Now a day few herb products are available in market. Farmers can easily use in their layer, broiler and parent stock without any

residual effect. Even these herbs can be used during the laying period. Farmers also interested to use the herbs for their poultry. But products are not still familiar to the farmers.

REFERENCES

- Aktug, S.E. and M. Karapinar, 1986. Sensitivity of some common food-poisoning bacteria to thyme, mint and bay leaves. *Int. J. Food Microbiol.*, 3: 349-354.
- Al-Kassie, G.A.M. and Y.J. Jameel, 2009. The effect of adding *Thyme vulgaris* and *Cinnamomum zeylanicum* on productive performance in broilers. Proceeding of 9th Veterinary Scientific Conference, College of Veterinary Medicine, University Baghdad, Iraq.
- Alcicek, A., M. Bozkurt and M. Cabuk, 2003. The effect of essential oil derived herbs growing wild in Turkey on from selected broiler combination 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.
- 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, carcass 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-tocopherol acetate on performance and lipid oxidation of meat enriched with n-3 PUFA's in broilers. *South Afr. J. Anim. Sci.*, 34: 197-210.
- Borris, R.P., 1996. Natural product research: Perspective from a major pharmaceutical company. *J. Ethnopharmacol.*, 51: 29-38.
- Botsoglou, N.A., E. Christaki, P. Florou-Paneri, I. Giannenas, G. Papageorgiou and A.B. Spais, 2004a. The effect of a mixture of herbal essential oils or alfa 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. Christaki, I. Giannenas and A.B. Spais, 2004b. 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., 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.
- Bowles, B.L. and A.J. Miller, 1993. Antibouulinal properties of selected aromatic and aliphatic aldehydes. *J. Food Prod.*, 56: 788-794.
- Cabuk, M., M. Bozkurt, A. Alcicek, Y. Akbas and K. Kucuklymaz, 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.
- Castanon, J.I.R., 2007. History of the use of antibiotic as growth promoters in european poultry feeds. *Poult. Sci.*, 86: 2466-2471.
- Chattopadhyay, D., G. Arunachalam, L. Ghosh, K. Rajendran, A.B. Mandal and S.K. Bhattacharya, 2005. Antipyretic activity of *Alstonia macrophylla* Wall ex A. DC: An ethnomedicine of Andaman Islands. *Pharm. Pharm. Sci.*, 8: 558-564.
- Chung, K.T., S.E. Stevens, W.F. Jr. Lin and C.I. Wie, 1993. Growth inhibition of selected food borne bacteria by tannic acid, propyl gallate and related compounds. *Lett. Applied Microbiol.*, 17: 29-32.
- Conner, D.E., 1993. Naturally Occurring Compounds. In: *Antimicrobials in Foods*, Davidson, P. and A.L. Branen (Eds.). Marcel Dekker, Inc., New York, ISBN: 0-8247-8906-7, pp: 441-468.
- Cowan, M.M., 1999. Plant products as antimicrobial agents. *Clin. Microbiol. Rev.*, 12: 564-582.
- Cross, D.E., R.M. McDevitt, K. Hillman and T. Acamovic, 2007. The effect of herbs and their associated essential oils on performance, dietary digestibility and gut microflora in chickens from 7 to 28 days of age. *Br. Poult. Sci.*, 48: 496-506.
- 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., S.G. Deans and P. Surai, 1995. Evaluation *in vitro* of plant essential oils as natural antioxidants. *J. Essential Oil Res.*, 7: 645-651.
- Farag, R.S., A.Z.M.A. Badei, F.M. Hewedi and G.S.A. El-Baroty, 1989a. Antioxidant activity of some spice essential oils on linoleic acid oxidation in aqueous media. *J. Am. Oil Chem. Soc.*, 66: 792-799.
- Farag, R.S., Z.Y. Daw and S.H. Abo-Raya, 1989b. Influence of some spice essential oils on *Aspergillus parasiticus* growth and production of aflatoxins in a synthetic medium. *J. Food Sci.*, 54: 74-76.
- Farag, R.S., Z.Y. Daw, F.M. Hewedi and G.S. El-Baroty, 1989c. Antimicrobial activity of some Egyptian Spice essential oils. *J. Food Prot.*, 52: 665-667.

- Ferket, P.R., A.A. Santos Jr. and E.O. Oviedo-Rondon, 2005. Dietary factors that affect gut health and pathogen colonization. Proceedings of the 32nd Carolina Poultry Nutrition Conference, Oct. 26-27, Research Triangle Park, NC, pp: 1-22.
- 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. Ge?ugelkd., 70: 232-240.
- Franco-Jimenez, D.J., S.E. Scheideler, R.J. Kittok, T.M. Brown-Brandl, L.R. Robeson, H. Taira and M.M. Beck, 2007. Differential effects of heat stress in three strains of laying hens. Applied Poult. Res., 16: 628-634.
- Frost, A.J., 1991. Antibiotics and Animal Production. In: World Animal Science Microbiology of Animals and Animal Products, Woolcock, J.B. (Ed.). Elsevier, New York, pp: 181-194.
- Fulton, R.M., B.N. Nersessian and W.M. Reed, 2002. Prevention of Salmonella enteritidis infection in commercial ducklings by oral chicken egg-derived antibody alone or in combination with probiotics. Poult. Sci., 81: 34-40.
- Giannenas, I., 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.
- Guler, T., O.N. Erta, M. Ciftci and B. Dalkilic, 2005. The effect of coriander seed (*Coriandrum sativum* L.) as diet ingredient on the performance of Japanese quail. South Afr. J. Anim. Sci., 35: 261-267.
- Guo, F.C., B.A. Williams, R.P. Kwakkel, H.S. Li and X.P. Li *et al.*, 2004a. Effects of mushroom and herb polysaccharides, as alternatives for an antibiotic, on the cecal microbial ecosystem in broiler chickens. Poult. Sci., 83: 175-182.
- Guo, F.C., R.P. Kwakkel, B.A. Williams, H.K. Parmentier, W.K. Li, Z.Q. Yang and M.W. Verstegen, 2004b. Effects of mushroom and herb polysaccharides on cellular and humoral immune responses of *Eimeria tenella*-infected chickens. Poult. Sci., 83: 1124-1132.
- Halle, I., R. Thomann, U. Bauermann, M. Henning and P. Kohler, 2004. Effects of a graded supplementation of herbs and essential oils in broiler feed on growth and carcass traits. Landbauforsch. Volk, 54: 219-229.
- Hashemi, S.R., I. Zulkifli, M. Hair-Bejo, A. Farida and M.N. Somchit, 2008. Acute toxicity study and phytochemical screening of selected herbal aqueous extract in broiler chickens. Int. J. Pharmacol., 4: 352-360.
- Hashemi, S.R., I. Zulkifli, M. Hair-Bejo, M. Karami and A.F. Soleimani, 2009a. The effects of *Euphorbia hirta* and acidifier supplementation on growth performance and antioxidant activity in broiler chickens. Proceedings of the 21st Veterinary Association Malaysia (VAM) Congress, Aug. 7-9, Port Dickson, Malaysia, pp: 215-217.
- Hashemi, S.R., I. Zulkifli, Z. Zunita, M. Hair-Bejo and T.C. Loh *et al.*, 2009b. Effects of dietary supplementation with *Euphorbia hirta* and acidifier on performance and *Salmonella* colonization in broiler chickens. Proceedings of the 30th Malaysia Society of Animal Production Annual Conference, June 2-5, Kota Kinabalu, Malaysia, pp: 69-70.
- Helander, I.M., H.L. Alakomi, K. Latva-Kala, T. Mattila-Sandholm and I. Pol *et al.*, 1998. Characterization of the action of selected essential oil components on gram-negative bacteria. J. Agric. Food Chem., 46: 3590-3595.
- Hernandez, F., J. Madrid, V. Gargia, J. Orengo and M.D. Megias, 2004. Influence of two plant extracts on broiler performance, digestibility and digestive organ size. Poult. Sci., 83: 169-174.
- Jamroz, D., J. Orda, C. Kamel, A. Wiliczekiewicz, T. Wartecki and J. Skorupinska, 2003. The influence of phytochemical extracts on performance, nutrient digestibility, carcass characteristics and gut microbial status in broiler chickens. J. Anim. Feed Sci., 12: 583-596.
- Jang, I.S., Y.H. Ko, H.Y. Yang, J.S. Ha and J.Y. Kim *et al.*, 2004. Influence of essential oil components on growth performance and the functional activity of the pancreas and small intestine in broiler chickens. Asian-Aust. J. Anim. Sci., 17: 394-400.
- Jang, I.S., Y.H. Ko, S.Y. Kang and C.Y. Lee, 2007. Effect of a commercial essential oil on growth performance, digestive enzyme activity and intestinal microflora population in broiler chickens. Anim. Feed Sci. Technol., 134: 304-315.
- Karou, D., A. Savadogo, A. Canini, S. Yameogo and C. Montesano *et al.*, 2006. Antibacterial activity of alkaloids from *Sida acuta*. Afr. J. Biotechnol., 5: 195-200.

- Lee, K.W., H. Everts, H.J. Kappert and A.C. Beynen, 2004a. Growth performance of broiler chickens fed a carboxymethyl cellulose containing diet with supplemental carvacrol and/or cinnamaldehyde. *Int. J. Poultry Sci.*, 3: 619-622.
- Lee, K.W., H. Everts, H.J. Kappert, H. Wouterse, M. Frehner and A.C. Beynen, 2004b. Cinnamaldehyde, but not thymol, counteracts the carboxymethyl cellulose-induced growth depression in female broiler chickens. *Int. J. Poultry Sci.*, 3: 608-612.
- Lee, K.W., H. Everts, H.J. Kappert, J. van der Kuilen, A.G. Lemmens, M. Frehner and A.C. Beynen, 2004c. Growth performance, intestinal viscosity, fat digestibility and plasma cholesterol in broiler chickens fed a rye-containing diet without or with essential oil components. *Int. J. Poultry Sci.*, 3: 613-618.
- 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. Poultry Sci.*, 44: 450-457.
- Marino, M., C. Bersani and G. Comi, 1999. Antimicrobial activity of the essential oils of *Thymus vulgaris* L. measured using a bioimpedometric method. *Food Prot.*, 62: 1017-1023.
- Mitsch, P., K. Zitterl-Eglseder, B. Kohler, C. Gabler, R. Losa and I. Zimpf, 2004. The effect of two different blends of essential oil components on the proliferation of *Clostridium perfringens* in the intestines of broiler chickens. *Poultry Sci.*, 83: 669-675.
- Morrissey, J.P. and A.E. Osbourn, 1999. Fungal resistance to plant antibiotics as a mechanism of pathogenesis. *Microbiol. Mol. Biol. Rev.*, 63: 708-724.
- Oviedo-Rondon, E.O., M.E. Hume and S. Clemente-Hernandez, 2005a. Dynamics of duodenal and ileal microbial ecology in chickens vaccinated and challenged with mixed *Eimeria* spp. *Poultry Sci.*, 84: 164-172.
- Oviedo-Rondon, E.O., M.E. Hume, F. Salvador and S. Clemente-Hernandez, 2005b. Dynamics of duodenal and ileal microbial ecology in chickens fed diets supplemented with essential oils and challenged with mixed *Eimeria* spp. *Poultry Sci.*, 84: 100-100.
- Oviedo-Rondon, E.O., S. Clemente-Hernandez, D. Caldwell, K. Ameiss, P. Williams and R. Losa, 2005c. Essential oils to enhance gut immunity against a challenge of *Eimeria* sp. and replace growth-promotant antibiotics and ionophores. *Poultry Sci.*, 84: 47-102.
- Oviedo-Rondon, E.O., S.C. Hernandez, P. Williams and R. Losa, 2005d. Responses of broilers vaccinated against coccidia to essential oil blends supplementation: live performance in a 49 production period. *J. Applied Poultry Res.*, 14: 657-664.
- Ristic, M. and K. Damme, 2001. Changing from animal to vegetable protein at fattening: Consequences on carcass and meat quality of broilers. *Die Fleischwirtschaft*, 81: 114-116.
- Saini, R., S. Davis and W. Dudley-Cash, 2003a. Oregon essential oil reduces necrotic enteritis in broilers. *Proceedings of 52th Western Poultry Disease Conference, (WPDC'03)*, Sacramento, CA, pp: 95-97.
- Saini, R., S. Davis and W. Dudley-Cash, 2003b. Oregon essential oil reduces the expression of coccidiosis in broilers. *Proceedings of 52th Western Poultry Disease Conference, (WPDC03)*, Sacramento, CA, pp: 97-98.
- Saricoban, C. and M. Ozcan, 2004. Antioxidative activity of rosemary (*Rosmarinus officinalis* L.) and sage (*Salvia fruticosa* L.) essential oils in chicken fat. *Essential Oil Bearing Plants*, 7: 91-95.
- Scalbert, A., 1991. Antimicrobial properties of tannins. *Phytochemistry*, 30: 3875-3883.
- Spais, A.B., L.A. Giannenas, P. Fluorou-Paneri, E. Christaki and N.A. Botsoglou, 2002. Effect of Genex, a feed additive containing organic acids and herb extracts, on the performance of broiler chickens. *Hellenic Vet.*, 53: 247-256.
- Suk, J.C., H.S. Lim and I.K. Paik, 2003. Effects of blended essential oil (CRINA®) supplementation on the performance, nutrient digestibility, small intestine microflora and fatty acid composition of meat in broiler chickens. *Anim. Feed Sci. Technol.*, 45: 777-786.
- Vogt, H., 1990. The effect of a mixture of essential oils in broiler diets. *Landbauforschung Volkenrode*, 40: 157-159.
- Vogt, H., 1991. Essential oils in broiler diets. *Landbauforschung Volkenrode*, 41: 94-97.
- Waldenstet, L., 2003. Effect of vaccination against coccidiosis in combination with an antibacterial oregano (*Origanum vulgare*) compound in organic broiler production. *Acta Agric. Scandinavica*, 53: 101-109.
- Wang, R., D. Li and S. Bourne, 1998. Can 2000 years of herbal medicine history help us solve problems in the year 2000. *Proceedings of Alltech's 14th Annual Symposium, (AAS'98)*, Kentucky, USA., pp: 273-291.
- Windisch, W. and A. Kroismayr, 2006. The effects of phytobiotics on performance and gut function in monogastrics. http://en.engormix.com/MA-feed-machinery/articles/the-effect-phytobiotics-performance_285.htm.

- Windisch, W., K. Schedle, C. Plitzner and A. Kroismayr, 2008. Use of phytogetic products as feed additives for swine and poultry. *J. Anim. Sci.*, 86: 140-148.
- Yang, Y., P.A. Iji and M. Choct, 2009. Dietary modulation of gut microflora in broiler chickens: A review of the role of six kinds of alternatives to in-feed antibiotics. *Worlds Poul. Sci. J.*, 65: 97-114.
- Yeo, J. and K. 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.
- Zhang, K.Y., F. Yan, C.A. Keen and P.W. Waldroup, 2005. Evaluation of microencapsulated essential oils and organic acids in diets for broiler chickens. *Int. J. Poult. Sci.*, 4: 612-619.