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USE OF HERBS AND SPICES AND THEIR EXTRACTS IN ANIMAL NUTRITION

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The ban on nutritive antibiotic use in Europe and the increased awareness of the consumers triggered a need for natural and safe feed additives to achieve better production results of farm animals. Plant extracts are used in animal nutrition as appetite and digestion stimulants, stimulants of physiological functions, for prevention and treatment of certain pathological conditions, as colorants and antioxidants. This article is a review of present literature data on the usage of plant extracts in poultry, pig and ruminant nutrition.

Key words: animal husbandry / pigs / ruminants / poultry / animal nutrition / herbs / spices / plant extracts

Uporaba zelišč in začimb ter njihovih ekstraktov v prehrani živali

Prepoved uporabe nutritivnih antibiotikov v prehrani živali v Evropi in naraščajoča zavest potrošnikov je sprožila potrebo po uporabi naravnih in zdravih prehranskih dodatkov za doseganje boljših proizvodnih rezultatov. Rastlinske izvlečke v prehrani živali uporabljamo kot stimulatorje apetita in prebave, za preprečevanje in zdravljenje nekaterih bolezenskih stanj, za stimuliranje fizioloških funkcij, kot barvila in kot antioksidante. Predstavljen članek je pregled dosedanjih znanstvenih dognanj o uporabi rastlinskih ekstraktov v prehrani perutnine, prašičev in prežvekovalcev.

Ključne besede: živinoreja / prašiči / prežvekovalci / perutnina / prehrana živali / zelišča / začimbe / rastlinski izvlečki

1 INTRODUCTION

Only quality feed together with proper hygiene, potable water and management can ensure the production of nutritious animal products with desired organoleptic properties (Saxena, 2008). Keeping farm animals healthy is necessary to obtain healthy animal products. For the last decade the use of additives of natural origin in animal and human nutrition has been encouraged. Numerous researches focused on the clarification of the biochemical structures and physiological functions of various feed additives like probiotics, prebiotics, organic acids and plant extracts.

Herbs, spices and their extracts were already used thousands of years ago in Mesopotamia, Egypt, India, China and old Greece, where they were appreciated for their specific aroma and various medicinal properties (Greathead, 2003). When discussing the use of herbs and spices as feed additives, we can hardly rely only on old believes about health impact of certain herbs and spices or their active components. We need a scientific proof of their beneficial effect on health and performance of the animals to justify their use. The technological progress enables us to more easily determine the structure and function of yet unidentified active molecules of plant origin.

To gain advantageous effects of herbs and spices, they can be added to feed as dried plants or parts of plants and as extracts. The composition of extracts from the same plant depends on the method of extraction and

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the properties of the extraction solvent used. Depending on the chemical characteristics of extraction solvents we can extract only certain molecules. There is also a difference between purified and unpurified extracts. Unpurified extracts contain a number of different molecules extracted with certain solvent, which can affect the action of each other, while purified extracts contain only one active component. The purified active molecules extracted from plants can be sometimes substituted by synthetic naturally identical molecules. Plants mainly contain one or some predominant active molecules (secondary metabolites), which are responsible for certain biological effects. The amount of these molecules varies depending on the variety of plant, growing conditions, harvest time etc. When we need the effect of a specific active component, it is more efficient to use a purified molecule alone than a dried plant or unpurified extract. But we have to be aware, that the potency of an unpurified extract often exceeds the potency of a purified one because of synergistic effect among the molecules in it. When talking about plant extracts, we must mention also essential oils. These are extracts of vaporous oils of strong taste and smell, which are still usually extracted by distillation with steam. Essential oils are very potent molecules and must be used in small quantities. Adversaly they can affect the function of intestinal microflora, can cause allergies, suppress feed intake and can be stored in tissues. With the proper usage, most of essential oils are recognized as GRAS (generally recognized as safe). Today the market offers different extracts of certain aromatic plants, combinations of extracts of different plants, purified active components or combinations of purified active components and synthesized active molecules (naturally identical) (Indresh, 2007).

The effect of active components from herbs and spices depends largely on the dosage used. No effect

Table 1: *Often used plants, its active components and functions (Loo and Richard, 1992; Charalambous, 1994; Kamel, 2000)*
Preglednica 1: *Pogosto uporabljene rastline, njihove aktivne komponente in funkcije (Loo in Richard, 1992; Charalambous, 1994; Kamel, 2000)*

Plant	Used parts	Mayor active component	Function
Aromatic spices			
Nutmeg	Seed	Sabinene	Digestion stimulant, antidiarrhoeic
Cinnamon	Bark	Cimetaldehyde	Appetite and digestion stimulant, antiseptic
Cloves	Cloves	Eugenol	Appetite and digestion stimulant, antiseptic
Cardamom	Seed	Cineol	Appetite and digestion stimulant
Coriander	Leaves, Seed	Linalol	Digestion stimulant
Cumin	Seed	Cuminaldehyde	Digestive, carminative, galactagogue
Anise	Fruit	Anethol	Digestion stimulant, galactagogue
Celery	Fruit, Leaves	Phtalides	Appetite and digestion stimulant
Parsley	Leaves	Apiol	Appetite and digestion stimulant, antiseptic
Fenugreek	Seed	Trigonelline	Appetite stimulant
Pungent spices			
Capsicum	Fruit	Capsaicin	Digestion stimulant
Pepperr	Fruit	Piperine	Digestion stimulant
Horsradish	Root	Allyl izotiocianat	Appetite stimulant
Mustard	Seed	Allyl izotiocianat	Digestion stimulant
Ginger	Rizom	Zingerone	Gastric stimulant
Garlic	Bulb	Allicin	Digestion stimulant, antiseptic
Herbs			
Rosemary	Leaves	Cineol	Digestion stimulant, antiseptic, antioxidant
Thyme	Whole plant	Thymol	Digestion stimulant, antiseptic, antioxidant
Sage	Leaves	Cineol	Digestion stimulant, antiseptic, carminatif
Laurel	Leaves	Cineol	Appetite and digestion stimulant, antiseptic
Mint	Leaves	Menthol	Appetite and digestion stimulant, antiseptic

whatever can be observed at small doses; on the other hand, large amounts can be even toxic.

The search for nutritive antibiotic alternatives in EU and increased awareness and concern of the consumers, further encouraged the precise researches on the possibilities of plant extract use in animal nutrition. The main scope in animal husbandry – to ensure good performance of farm animals and get quality animal products, can be achieved only with the effort to keep the animals healthy. In this aspect, herbs and spices are not just appetite and digestion stimulants, but can, with impact on other physiological functions, help to ensure good health and welfare of the animals, what can positively affect their performance.

2 POSSIBLE USE OF HERBS AND SPICES

2.1 HERBS AND SPICES AS APPETITE AND DIGESTION STIMULANTS

When considering supplementing the feed with herbs and spices or their extracts to stimulate the appetite, we have to know the taste preferences of different animal species. Janz *et al.* (2007) found that pigs preferred the feed supplemented with garlic or rosemary over the feed supplemented with oregano or ginger. Furthermore, Jugl-Chizzola *et al.* (2006) noticed that weaned pigs consumed significantly less feed if it was supplemented with thyme or oregano. If pigs in this experiment had the possibility to choose among feed with or without above mentioned spices, they had chosen the unsupplemented feed. The spices known for their appetite stimulant effect are cinnamon, cloves, cardamom, laurel and mint (Loo and Richard, 1992).

Due to the wide variety of active components, different herbs and spices affect digestion processes differently. Most of them stimulate the secretion of saliva. Curcuma, cayenne pepper, ginger, anis, mint, onions, fenugreek, and cumin enhance the synthesis of bile acids in the liver and their excretion in bile, what beneficially effects the digestion and absorption of lipids. Most of the prelisted spices stimulate the function of pancreatic enzymes (lipases, amylases an proteases), some also increase the activity of digestive enzymes of gastric mucosa (Srinivasan, 2005). Besides the effect on bile synthesis and enzyme activity, extracts from herbs and spices accelerate the digestion and shorten the time of feed/food passage through the digestive tract (Platel and Srinivasan, 2001; Suresh and Srinivasan, 2007).

2.2 ANTIMICROBIAL ACTION OF HERBS AND SPICES

Feed supplements with growth promoting activity increase stability of feed and beneficially influence the gastrointestinal ecosystem mostly through growth inhibition of pathogenic microorganism's growth. Due to improved health status of digestive system, animals are less exposed to the toxins of microbiological origin. Consequently herbs and spices help to increase the resistance of the animals exposed to different stress situations and increase the absorption of essential nutrients, thus improving the growth of the animals (Windisch *et al.*, 2008).

Numerous secondary metabolites formed by plants serve as defence agents against physiological and environmental stressors, predators and pathogenic microorganisms. Several *in vitro* studies showed strong antimicrobial activity of certain plant extracts against Gram– and Gram+ bacteria. Pasqa *et al.* (2006) found a change in long chain fatty acid profile in the membranes of *E. coli* grown in the presence of limonene or cinnamaldehyde. Similar observations were made with *Salomonella enterice* grown in the presence of carvacrol or eugenol and with *Bronchotrix thermosphacta* grown in the presence of either limonene, cinnamaldehyde, carvacrol or eugenol. In the case of *Pseudomonas fluorescens* in *Staphylococcus* aureus none of the tested phytochemicals changed the fatty acid profile. The changes in fatty acid composition can affect surviving ability of microorganisms.

The studies measuring hydrophobicity of *E. coli* (test for measuring the ability of microbial attachment) showed a large increase of hydrophobicity of *E. coli* grown in the presence of St. John's wort or Chinese cinnamon and a moderate increase when medium was supplemented with thyme or Ceylon cinnamon. The differences in hydrophobicity were in good correlation with MIC_{50} values (minimal inhibitory concentration). This confirms the fact that herbs and spices act as antimicrobial agents by changing the characteristics of cell membranes, and causing ion leakage, thus making microbes less virulent (Windisch *et al.*, 2008). The exact antimicrobial action of herbs and spices in *in vivo* situations is hard to evaluate, because of the very complex and balanced microbial populations in gastrointestinal tract and the interaction of active components from herbs and spices with other nutrients. Castillo *et al.* (2006) reported that the mixture of cinnamaldehyde, capsicum oleoresin and carvacrol enhances the growth of lactobacilli, and so increases the ratio of lactobacilli to enterobacteria. So herbs and spices do not posses only the antimicrobial activity, but also modulate the composition of microbial population by prebiotic activity.

2.3 ANTI-INFLAMMATORY ACTION

Extracts of curcuma, red pepper, black pepper, cumin, cloves, nutmeg, cinnamon, mint and ginger showed anti-inflammatory effect in the studies on rats (Srinivasan, 2005; Manjunatha in Srinivasan, 2006). The major active molecules with anti-inflammatory action are terpenoids and flavonoids. These molecules suppress the metabolism of inflammatory prostaglandins. The most known herbs and spices with anti-inflammatory potential in our area are chamomile, marigold, liquorice and anis (Craig, 2001).

2.4 ANTIOXIDATIVE ACTION

Many active components of herbs and spices can prevent lipid peroxidation through quenching free radicals or through activation of antioxidant enzymes like superoxide dismutase, catalase, glutathione peroxidase and glutathione reductase. Main molecules responsible for the antioxidative properties of herbs and spices are phenolic substances (flavonoids, hydrolysable tannins, proanthocianidins, phenolic acids, phenolic terpenes) and some vitamins (E, C and A). Often used herbs rich in phenolics are: rosemary, thyme, oregano, sage, green tea, chamomile, ginko, dandelion and marigold (Halliwell *et al.*, 1995; Craig, 2001; Ćetković *et al.*, 2004; Škerget *et al.*, 2005; BakIrel *et al.*, 2008; Fasseas *et al.*, 2008).

Herbs and spices can protect the feed against oxidative deterioration during storage. This is a widely used practice in pet food and human food industry. The herb commonly used for feed/food preservation is rosemary (*Rosmarinus officinalis*). It can be used alone or in combination with tocopherols or synthetic antioxidants (Jacobsen *et al.*, 2008).

2.5 IMMUNOSTIMULANT FUNCTION

The immune system generally benefits from the herbs and spices rich in flavonoids, vitamin C and carotenoids. The plants containing molecules which possess immunostimulatory properties are echinacea, liquorice, garlic and cat's claw. These plants can improve the activity of lymphocytes, macrophages and NK cells, they increase phagocytosis or stimulate the interpheron synthesis (Craig, 1999).

3 THE USE OF HERBS AND SPICES IN NUTRITION OF DIFFERENT ANIMAL SPECIES

3.1 POULTRY

How to replace antibiotic growth promoters is also a question for the poultry industry. Some studies on plant extracts are showing promising results. Çabuk *et al.* (2006) measured production parameters of broilers which were supplemented by a mixture of oregano, laurel, sage, anis and citrus essential oils. The mixture of essential oils significantly improved feed conversion, what can be attributed to more effective availability of nutrients due to the changes in intestinal ecosystem.

Lippens *et al.* (2005) tested the efficacy of a mixture of cinnamon, oregano, thyme, cayenne pepper and citrus extracts and a mixture of plant extracts and organic acids in comparison to nutritive antibiotic avilamicin in broiler chickens. Chickens supplemented with plant extracts reached significantly higher body weight than the ones in the control or avilamicin group. Higher body weight was a consequence of increased feed consumption. Feed conversion in group fed plant extracts was 0.4% better than in the group with avilamicin and 2.9% better than in the control group. The authors noticed no synergistic effect between plant extracts and organic acids.

Resistance of coccidia to currently used coccidiostatics to treat coccidiosis represents a serious problem in poultry industry. The use of plant extracts to treat coccidiosis is not a new approach. When searching for the best natural extract to treat coccidiosis, we have to take into account that the extract needs to be at least partially soluble in lipids to penetrate the cellular membrane, because coccidia are located inside the cells. Two Chinese plants, *Dichroa febrifuga* and *Sophora flavescens* are rich in alkaloids which are effective in treating coccidiosis (Youn in Noh, 2001). As infections with *Emeria tenela* include also lipid peroxidation in the intestine, herbs and spices with strong antioxidant potency may represent a good supportive treatment. In one of the latest studies Naidoo *et al.* (2008) studied the capacity of four African plants which would be appropriate to treat coccidiosis: leaves of *Combretum woodii*, leaves and stem of Artemisia afra, a whole plant and seeds of *Vitis vinifera*. Extracts of all chosen plants improved the feed conversion to the same extent as coccidiostatic toltrazuril. The best effect was seen with *Tulbaghia violacea*, which also partially lowered the shedding of oocysts.

The use of herbs and spices as antioxidants is not important only for the health of the animals, but also for the oxidative stability of their products. The effect of oregano essential oil on oxidative stability of chicken and

turkey meat was well studied in the past. Supplementation of turkeys with 200 mg/kg of oregano essential oil significantly decreased lipid peroxidation of cooked and fresh meat during refrigerated storage (Botsoglou *et al.*, 2003b). Essential oil of oregano also efficiently preserved the quality of chicken meat during frozen storage (Botsoglou *et al.*, 2003a). Extracts from herbs and spices in combination with vitamins C and E even more effectively prevent lipid peroxidation in tissues, what was shown in the studies on chickens and turkeys (Papageorgiou *et al.*, 2003; Young *et al.*, 2003). At this time the use of plant extracts instead synthetic or semi-synthetic antioxidants represents higher economical costs, however, this could be avoided with systematic intensified growing of needed plants and new technological processes of extraction.

The colorants for increasing yolk colour in laying hens or skin colour in broilers in intensive production can be of natural (carotenoids) or synthetic origin. Often used forage plants rich in carotenoids are maize and alfalfa. Besides these there are several other plants used for isolation of natural pigments like tagetes and red pepper. The main yellow pigments in tagetes are zeaxantin and lutein, while red pepper contains two important red pigments – capsantin and capsorubin. The extract from tagetes colours the yolk three times less effectively in comparison with the synthetic apo-ester of carotenic acid. Pigments from natural origin also degrade during the feed storage up to 30% (Sirri *et al.*, 2007). Nevertheless, pigments obtained from tagetes or calendula species and red pepper are very suitable as yolk colorants in organic farming.

3.2 PIGS

In the pig production, most problems can be expected in the time of weaning. Weaning can be accompanied by infections, especially with enterotoxic *Escherichia coli*. The use of herbs and spices in piglet nutrition can reduce the incidence of infections. Results from Roselli *et al.* (2007) showed that alicin from garlic protects intestinal cells from increased permeability of membrane in pigs infected with *E. coli*. Garlic also contains active substances which suppress the action of fungi and viruses (Zigger, 2001) and improve the feed intake and daily weight gain of piglets (Janz *et al.*, 2007). Cinnamaldehyde, an active component of cinnamon, possesses antibacterial properties. Zigger (2001) observed larger feed intake and live weight gain of weaned pigs fed feed supplemented with garlic and cinnamon extracts. The mortality due to intestinal disorders dropped from 3.9 to 1.2%. Namkung *et al.* (2004) found that a mixture of cinnamon, thyme and oregano extracts inhibited the growth of coliform bacteria. A brown algae *Ascophyllum nodosum* could be a good feed supplement with growth promoting activity of pigs infected with *E. coli* (Turner *et al.*, 2002).

Table 2: *Lymphocyte DNA damage and urinary 8-OHdG excretion of pigs fed a high PUFA diet with or without Calendula off. extracts*
Preglednica 2: *Poškodbe DNA limfocitov in količina s sečem izločenega 8-OHdG, pri prašičih, krmljenih z visoko vsebnostjo PUFA v krmi z oziroma brez dodatka ekstrakta Calendula off.*

Group	% DNA in the tail of the comet	OTM	8-OHdG (µg/24 h)
Control	7.8[a]	1.74[a]	149.9[ab]
Oil	12.0[b]	4.68[b]	269.4[b]
Calendula off. 1	6.8[a]	1.46[a]	138.9[a]
Calendula off. 2	8.2[a]	2.05[a]	150.6[ab]
Vitamin E	6.6[a]	1.54[a]	216.5[b]
SEM	0.65	0.372	31.44
P-value	< 0.01	< 0.01	0.02

[abc] LS-means – without the same superscript differ significantly, P < 0.05; OTM – Olive tail moment; 8-OHdG – 8-hidroxy-deoxyguanosine.

Combination of carvacrol, cinnamaldehyde and capsicum oleoresin beneficially effected gastrointestinal ecosystem and gastric emptying of weaned pigs (Manzanilla *et al.*, 2004). The same mixture was tested for its antioxidative properties in our laboratory. The mixture effectively protected pig's blood lymphocytes against oxidative DNA damage at the concentration of 271.2 mg/kg of feed. Its effect was comparable to that of 90.4 mg/kg of vitamin E. The concentration of spice mixture supplemented to pigs in this study was not sufficient to fully prevent lipid peroxidation induced by high intake of lightly oxidizable PUFA.

Frankič *et al.* (in press) studied antioxidant capacity of propylene glycol extracts of *Calendula officinalis* (*Calendula off.* 1 – extract from petals, 3 ml/day; *Calendula off.* 2 – extract from whole flowers tops, 3 ml/day) and vitamin E (38.4 mg/day) in the case of oxidative stress induced by high PUFA intake in pigs. The extracts effectively prevented oxidative DNA damage in peripheral lymphocytes (measured as % DNA in the tail of the comet and OTM (Olive tail moment), but did not prevent lipid peroxidation, measured by 8-OHdG (8-hidroxy-deoxyguanosine) (Table 2).

Although most studies concerning the effect of herbs and spices in pig production have been conducted on piglets, Allan *et al.* (2005) carried out an experiment on swine. Swine were fed 1000 ppm of dried oregano leaves and flowers enriched with 500 g/kg of oregano essential oil. Observed beneficial effects of oregano supplementation were: lower mortality rate, less culling during

lactation period, shorter service interval, more live born and less stillborn piglets.

3.3 RUMINANTS

Herbs and spices have been introduced also to ruminant nutrition. Microbial ecosystem in the rumen is composed from complex anaerobic microbial population of bacteria, fungi, protozoa, methanogeneous arhea and bacterifagi. Numerous metabolites produced in rumen during microbial fermentation affect the basic digestive and metabolic functions and productivity of the host. Researchers have been searching for new possibilities to modulate the microbial fermentation in the rumen. The main goal of manipulating the rumen fermentation is to increase the effectiveness of digestion and metabolism of nutrients, to increase the productivity of the animals and to suppress the undesirable processes as methanogenesis. In intensive farming systems the feed additives, including antibiotics, were used to increase the production of milk, meat and wool. The ban on antibiotic use in Europe increases the production costs what triggered the need to search for antibiotic alternatives also in ruminant nutrition.

There are numerous studies showing beneficial effects of herbs and spices on feed intake, immune functions and health, rumen fermentation and productivity of calves, dairy cows, heifers and also beef cattle (Kraszewski *et al.*, 2002; Greathead, 2003; Wawrzynczak *et al.* 2000; Cardozo *et al.* 2006). There are some data of the positive effect of plant supplements in nutrition of sheep and goats (Butter *et al.*, 1999). Extracts of yucca plant contain saponnins and glico-components which are responsible for the increase of rumen fermentation and in some cases for reduction of ammonium synthesis (Ryan, P. and Quinn, T.: http://www.irishscientist.ie/P175.htm). Kudke *et al.* (1999) supplemented calves with powder of *Azadirachta indica* tree. Supplemented calves had higher weight gain than unsupplemented ones. The unsupplemented group had much higher incidence of parasite infections.

Gladine *et al.* (2007) tested the antioxidant effect of marigold, grape, rosemary and citrus extracts in sheep. Lipid peroxidation was induced by continuous infusion of linseed oil into the duodenum. The extracts were applied directly into rumen through the rumen cannula. The results showed that all tested plant extracts kept their antioxidant capacity *in vivo* in sheep. The most bioefficient in limiting lipid peroxidation was marigold extract.

Cardozo *et al.* (2006) studied the effect of alfalfa extract, anise, capsicum, and a mixture of cinnamaldehyde end eugenol on ruminal fermentation in beef heifers. The results indicated that tested concentrations of cinnamaldehyde and eugenol mixture, anise oil and capsicum oil may be used as modifiers of rumen fermentation in beef production systems. Same authors tested six natural plant extracts (garlic, cinnamon, anise, yucca, oregano and capsicum extract) and three secondary plant metabolites (cinnamaldehyde, eugenol, anethole) at five doses and two different pH (7.0 and 5.5) to determine their effect on *in vitro* microbial fermentation using ruminal fluid of heifers (Cardozo *et al.*, 2005). Results demonstrated that the effect of herbs and spices on ruminal fermentation in beef cattle may differ depending on ruminal pH. At pH 5.5, garlic, capsicum, yucca and cinnamaldehyde altered ruminal fermentation in favour of propionate, which is more energetically efficient.

Results obtained in the research of Benchaar *et al.* (2007) showed limited effects of 750 mg/day of essential oil mixture (thymol, eugenol, vanillin, guaiacol and limonene) on nutrient utilization, ruminal fermentation, and milk performance of cows fed diets containing alfalfa or corn silage as a sole forage source. Polish researchers showed that 2% of mixture of *Urtica dioica*, *Pradix teraxci*, *Agrimonia eupatoria*, *Fructus carvi* and *Matrica Chamonilla* improves the quality of milk (Kraszewski *et al.*, 2002).

Tannins, the secondary plant metabolites found in stem, wood, leaves, fruits and seeds of many plant species can positively affect the protein digestion in ruminants. Tannins bind to proteins and form complexes which pass trough the rumen undegraded. These proteins which pass the microbial degradation in the rumen are then successfully utilized by the animal and provide the proteins necessary especially in the special physiological states (like early lactation) and in the cases when feed is not of the best quality (Waghorn *et al.*, 1990). Tannins also prevent bloat of the rumen (Butter *et al.*, 1999) and possess antihelmitic properties (Barry and McNabb, 1999).

Extracts from herbs and spices help to prevent and alleviate different kinds of health problems. They are effective in treatment of endometritis (inflammation of the endometrium) in cows. Esparza-Borges and Ortiz-Márquez (1996) evaluated the effect of extrats of garlic (*Allium sativum*, L), eucalypt (*Eucalyptus globulus*, Labill.) and *Gnaphalium conoideum* on acute endometritis of Holstein cows. The most effective of all extracts was the garlic extract, however, also eucalypt worked beneficially.

4 CONCLUSIONS

The main scope of animal production is to ensure the high productivity, healthy animals and quality animal products, which are stable and appropriate for fur-

ther processing. In this aspect, herbs and spices are not just appetite and digestion stimulants, but can, with impact on other physiological functions, help to sustain good health and welfare of the animals and improve their performance. Current studies show promising results regarding the use of phytochemicals as growth and production promoters. There is still a need to clarify the phytochemical composition and the mechanisms of action for many herbs, spices and their extracts and furthermore, to assess the appropriate dose that should be safely used in specific circumstances and animal species.

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