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Utilization of spices and herbs in ruminant and non-ruminant diet and its effects on meat quality

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ABSTRACT

The purpose of this review is to provide detailed information about the use of herbs and spices in ruminant and non-ruminant animal and its effect on meat quality. Herbs are dried leaves of any aromatic plants used to impart flavor and odour of food and spices are dried parts of any aromatic plants without leaves. Herbs and spices produced different natural and non-antibiotic phytogenic feed additives. Most usual and repeatedly used herbs and spices for phytogenic feed additives in swine, cattle and poultry production are garlic, chili, cayenne, pepper, peppermint, cinnamon, horseradish thyme, anise, rosemary sage, and oregano. Numerous useful properties of herbs and spices compounds derive from their bioactive molecules are piperine, linalool, carvacrol, capsaicin, cineole, allicin, thymol, allyl isothiocyanate and anethole. Herbs and spices have antimicrobial, antiparasitic, antiviral, antifungal, insecticidal and antitoxigenic properties. The prospective benefits of using herbs and spices in ruminant and non-ruminant nutrition are stimulate nutrient digestion and absorption, improved health status declined incidence of diseases, increased feed intake and average daily weight gain and feed conversion ratio, increased carcass yield, improved meat quality and shelf life of meat. The aim of the review is to summarize on the current knowledge on the use of herbs and spices as a feed additive in ruminant and non-ruminant animals.

INTRODUCTION

Livestock is an essential element of the diverse farming system practiced in Bangladesh for a period of hundred years. Livestock sub sector shows 12% to agricultural GDP and 3% to National economy (Mia, 2013). Ruminant, particularly cattle the key major of the livestock. Non-ruminant are also important element of this sector (BBS, 2010).Livestock are an integrate part of agriculture in Bangladesh that provides food (meat, milk), leathers, draft power and manure. About 20% of the human population is directly and 50% is partly dependent on the livestock sector (Bangladesh Economic Review, 2009). Unfortunately, default managemental practices, defective sanitation, and agro-geo-climatic ailment of Bangladesh are responsible for the occurrence of many diseases. Nutritional deficiency such as animal receiving poor amounts of macro and micro molecules lower the resistance against diseases (Onneshan, 2014). Merely, the standard feed together with proper hygiene, potable water and appropriate management can ascertain the production of nutritious animal products with adequate organoleptic characteristics (Saxena, 2008). Healthy farm animal is to provide healthy animal products. Their undesirable effects of antibiotics together with good performances became a real public health concern throughout the world (Donoghue, 2003), at last led to the inhibition of the products particularly in the western world (Nweze and Nwankwagu, 2010). Finally, as a supplements in animal rations increasing interest in the use of herbs and spices and their products (Bunyapraphatsra, 2007; Owen, 2011).

Herbs are flowering, non-woody and non-persistent plants and spices are herbs with an

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intensive smell and taste commonly added to human foods (Sofowora, 1993). Herbs and spices fall into the class of feed additives now mention to as Phytogenic. Gradually, increase the use of natural feed additives in animal nutrition. Thousands of years ago, plants and their extracts were already used in Mesopotamia, Egypt, India, China and old Greece, where they were valued because of their specific aroma and various medicinal properties (Greathead, 2003). Lots of secondary metabolites are present in plants, which are accountable for particular biological and physiological effects (Calsamiglia et al., 2007). Herbs and spices are known to have health favor such as appetite and digestion stimulants (Janz et al., 2007), anti-microbial action (Pasqua et al., 2006; Windisch et al., 2008), anti-inflammatory action (Craig, 1999, Srinivasan, 2005), anti-oxidative action (Craig, 1999; Fasseas et al., 2008) and immune-stimulant function (Craig, 1999) on animals when used as feed additives in animal nutrition. Non-ruminants (simple stomach) are able to utilize the plant materials less than the Ruminants because of a large part of the carbohydrate that contains simple sugars joined together by β-links such as cellulose (Van Soest, 1994). Recently, many researchers have diverted their attentions to the use of extracts from herbs and spices because of their possibility as substitutes to antibiotics for the purpose of manipulating rumen ecosystem in ruminant nutrition and growth (Calsamiglia et al., 2007; Jayasena & Jo, 2013; Geraci et al., 2012). The present study discusses the utilization of these herbs and spices in ruminant and non-ruminant diet for improvement of livestock performance.

Classification of spices and herbs

The spices and herbs can be classified on the basis of botanical nomenclature, useful plant part, longevity of plants, plants type, economic importance and freshness of herbs. The various ranges of herbs and spices are illustrated in Table 1 & 2.

Table 1: Botanical classification of spices

Family name	Spices	Scientific name
Piperaceae	Pepper	*Piper nigrum*
Zingiberaceae	Ginger	*Zingiber officinale*
	Cardamon	*Elettaria cardamomum*
	Turmaric	*Curcuma longa*
Apiaceae	Coriander	*Coriandrum sativum*
	Fennel	*Foeniculum vulgare*
	Cumin	*Cuminum cyminum*
Myrtaceae	Clove	*Syzygium aromaticum*
	Nutmeg	*Myristica fragrans*
Fabaceae	Fenugreek	*Trigonella foenum-graecum*
Lauraceae	Cinnamom	*Cinnamomum verum*

Table 2: Useful plant part as spices

Plant organs	Spices	Scientific name
Root spice	Angelica	*Angelica archangelica*
	Horse radish	*Armoracia rusticana*
Rhizome spice	Turmaric	*Curcuma longa*
	Ginger	*Zingiber officinale*
Bulbous spices	Onion	*Allium cepa*
	Garlic	*Allium sativum*
Bark spice	Cinnamom	*Cinnamomum verum*
	Cassia	*Cassia fistula L*
Leafy spices	Mints	*Mentha*
	Coriander	*Coriandrum sativum*
	Methi	*Trigonella foenum-graecum*
Aril Spices	Mace	*Myristica fragrans*
Seedy spices	Coriander	*Coriandrum sativum*
	Celery	*Apium graveolens*
	Methi	*Trigonella foenum-graecum*
Fruit spice	Cardamom	*Elettaria cardamomum*
	Chillies	*Capsicum frutescens*
	Pepper	*Piper nigrum*
	Allspice	*Pimenta dioica*

Effects on growth and health of mono-gastric and ruminant

The use of herbs and spices to the animal diet depends on some factors such as animal species, age and production. Each herb contains different biological substance, which produces different effect to the animal body. In the present time, increasing interest by using herbal plants as a feed additives alternative to antibiotic growth

promoters (Windisch et al., 2008; Hashemi and Davoodi, 2010). By the use of herbal plants as a supplemented feed increased feed intake and digestive secretions in animals (Windisch and Kroismayr 2006). The beneficial effect on the ecosystem of gut microflora through controlling influential pathogens are the function of phytogenic feed additives (Windisch et al., 2008). Effect of essential oil to improved growth promoter were showed at different ages of birds by Jamroz et al. (2003), Hernandez et al. (2004), and Cross et al. (2007). Essential oils may affect lipid metabolism, fat digestibility and also stimulate digestive enzymes (Platel and Srinivasan, 2000). Guo et al. (2003) indicated that herbal supplementation increased growth of immune organs. Hashemi and Davoodi (2010) showed that, so much effect of phytobiotic feed additives on production performance in poultry. Different herbal plants such as sage, thyme, rosemary and the mixture of carvacrol, cinnamaldehyde and capsaicin elevated feed digestibility in broilers was reported by Hernandez et al. (2004). Al-Kassie and Jameel (2009), was studied by the effect of thyme and cinnamon on the performance of broilers and found their positive effect on body weight, feed intake, feed conversion ratio and improvement of the health of poultry. In broiler, garlic, Peppermint, sage, echinacea, thyme, oregano, clove and cinnamon have no effect on body weight gain, feed intake, feed conversion ratio, carcass traits, final body weight, average daily gain (Arczewska-Wlosek 2012; Isabel 2009; Emami, 2012 and Kırkpınar 2011) and Oregano helps the improvement of body weight gain and feed conversion ratio (Mohiti-Asli., 2015; Roofchaee, 2011; Silva, 2009), Placha 2013 reported that Thyme EO have no effect on faecal and caecal bacterial counts and improvement of intestinal integrity and antioxidant status in rabbits. In case of pigs, thyme, rosemary, cinnamon, oregano, peppermint, anise and clove improved the average daily weight gain, feed conversion ratio, gross energy digestibility and crude protein digestibility but peppermint, anise and clove have no effect in body weight gain and feed intake (Yan 2010; Maenner, 2011; Namkung 2004).

Herbs and spices are also used ruminant diet. Legionary research among herbs and spices exibit sound effects 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). The result of Benchaar et al. (2007) showed that, thymol, eugenol, vanillin, guaiacol and limonene have limited effects on nutrient utilization, ruminal fermentation and milk performance of cows. In dairy cows Garlic and Blend of oregano, cinnamon, thyme and orange peel no effect on dry matter intake, ruminal pH, volatile fatty acid concentration, milk yield, nutrients digestibility but Improvement of feed digestibility in rumen. (Yang et al., 2007; Spanghero et al., 2009). Vakili, et al., (2013) reported that, Cinnamon and Thyme have No effect on dry matter intake, average daily gain, volatile fatty acid concentration and ruminal pH. Decrease of A: P ratio in calves but Anise extract reduce the VFA concentration and rumen parameters in beef heifers (Fandiño, et al., 2008).

In lambs and sheep, Carvacrol and Garlic have no effects on rumen parameter, dry matter intake, average daily weight, carcass characteristics and meat characteristics. On the other hand carvacrol reduce the ruminal pH and increase VFA concentration (Chaves et al., 2008; Bhatt.et al., 2011). Mixture of clove, oregano, cinnamon, and lemon in Sheep have no effect on dry matter intake, nutrients digestibility and ruminal pH. Decrease of VFA concentration, A: P ratio and ruminal protein digestibility (Lin, et. al., 2013). Gladine et al. (2007) tested the antioxidant effect of marigold, grape, rosemary and citrus extracts in sheep.

Meat quality can be described by the chemical, physico-chemical, nutritional, sensory, health and food safety characteristics that would be more preference to the consumer and a higher price in the market (Duclos et al., 2007; Dunshea et al., 2005; Farrell et al., 2003). Still now, there are many studies that evaluate the incorporation of phytochemicals into diets to improve meat quality. Hong et al., 2012 reported that, Oregano, anis and citrus peel increase tenderness and acceptability of broiler meat. Clove powder, Agronomy extract and Lemon balm increase Crude protein and sensory evaluation but decrease Fat (Marcinčák et al., 2011). Soybean isoflavone increase body weight gain, feed intake, water holding capacity,

pH and lightness of meat (Jiang et al., 2007). Genistein and hesperidin mixture helps to increase the polyunsaturated fatty acid in breast muscles of broilers. (Kamboh and Zhu 2013). Oregano essential oil significantly decreased lipid peroxidation of cooked and fresh meat during refrigerated storage and also efficiently preserved the quality of chicken meat during frozen storage (Botsoglou et al., 2003a and Botsoglou et al., 2003b). The result of (Janz et al.,2007) showed that, Essential oils and Oleoresins (rosemary, garlic, oregano and ginger) have Minimal impact on the lipid oxidation but Alarcón-Rojo et al., 2013 reported that, singly oregano decrease lipid oxidation in porcine. In porcine, Captis chinensis herb extract increase Meat color, pH, water holding capacity and unsaturated fatty acid and decrease saturated fatty acid (Zhou et al., 2003). In case of Bovine, Ferulic acid increase Tenderness, juiciness, flavor of meat and smaller increases in TBAs values (González-Ríos et al., 2016). In ovine, Cinnamaldehyde of Diet increase off-flavour intensity (Chaves et al., 2011) and Hesperidin decrease Lipid oxidation values (Simitzis et al., 2011).

Effect of plant on meat quality

Several herbs and spices as feed additive help to reduce microbial burden and immune response in animal and thus work as alternative of chemical treatment that cause health risk for human. The antibacterial, antibiotic, anti-inflammatory, antihistaminic, anti-bronchial, anti-hyperglycemic, ruminant fermentation and immune boosting actions of spices and herb in ruminant and non-ruminant diet are reported.

Antibacterial

Different types of studies showed strong antimicrobial activity of certain plant extracts against Gram-positive and Gram-negative bacteria. EOs are more effective against gram-positive bacteria because Eos contains hydrophobic compounds which can directly interact with the cell membrane of gram-positive bacteria but gram-negative bacteria is hydrophilic as a result hydrophobic compounds cannot easily penetrate into the bacterial membrane (Calo, et al., 2015; Cimanga, et al., 2002). There are four modes of action that explain how phytochemical feed additives exert their antibacterial effect: 1) inhibition of cell wall synthesis, 2) disruption of cell wall structure (altering the permeability of the cytoplasmic membrane), 3) inhibition of nucleic acid synthesis, 4) inhibition of protein synthesis and inhibition of a unique bacterial metabolic pathway. Finally lead to the collapse of cellular activities result in bacterial death (Fanning et al., 2014). Limonene or cinnamaldehyde change in long chain fatty acid in the membranes of *E. coli* found by Pasqa et al. (2006). The mixture of cinnamaldehyde, capsicum oleoresin and carvacrol enhances the growth of lactobacilli and increases the ratio of lactobacilli to enterobacteria Castillo et al. (2006). Namkung et al. (2004) reported that extract of cinnamon, oregano and thyme reduce fecal coliforms. *Thymus vulgaris* inhibit the growth of *S. typhimurium* and *E. coli* (Aktug and Karapinar, 1986; Marino et al., 1999). Mixtures of essential oils such as thymol, eugenol and carvacrol have high antimicrobial activity against pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus* and *Salmonella typhimurium* (Hippenstiel et al., 2011; Bassole and Juliani, 2012). Cinnamon oil and its constituents (cinnamaledehyde and eugenol) have shown antimicrobial activity against *Escherichia coli, Pseudomonas aeruginosa, Enterococcus faecalis, Staphylococcus aureus, Staphylococcus epidermis, Klebsiella pneumoniae, Salmonella sp., and Vibrio parahaemolyticus* (Chang et al., 2001). Blend of essential oils such as black pepper, clove, geranium, nutmeg, oregano and thyme – all of them containing carvacrol – were effective against *Enterococcus faecalis, Escherichia coli, Salmunella pullorum, Staphylococcus aureus, Yersinia enterocolitica* (Dorman and Deans, 2000). Antibacterial effects have been reported for oregano, black pepper, clove, thyme and the essential oil components thymol, carvacrol and eugenol against *Escherichia coli, Staphylococcus aureus* and *Salmunella enterica* serotype *typhimurium* (Cosentino et al., 1999).

Antibiotics

The residual effect of the antibiotics found in meat and milk products that may lead to health problems and increase resistance of antibiotics in humans. So, need some safe feed additives such as

plant extracts (Casewell et al., 2003, Russell & Houlihan, 2003). Efficacy of nutritive antibiotic avilamicin and mixture of plant extracts such as cinnamon, oregano, thyme, cayenne pepper and organic acids in broiler chickens are tested by Lippens et al., (2005). Chickens supplemented with mixture of plant extracts was significantly higher body weight than supplemented with antibiotic avilamicin.

Immune boosting actions

Phytochemical feed additives increased the activity of lymphocytes, the immunoglobulin response, monocytes, macrophages, NK cells and, therefore, increasing phagocytosis and stimulating interferon synthesis when animals are in immune-suppressed conditions. (Alipour et al., 2015; Khalaji et al., 2011; Chakraborty et al., 2011; Craig et al., 1999; Frankič et al., 2009). Supplementation with essential oils thyme increase in the immunological response reported by Alipour et al. (2015). Acemannan from Aloe vera acts as an Immunostimulator found by Djeraba and Quere (2000). Guo et al. (2003) reported that, herbal supplementation of *Lentinus edodes*, *Tremella fuciformis* and *Astragalus membranaceus* increased growth of immune organs such as thymus, bursa and spleen. Zeng et al. (2015) studies have confirmed that the dietary supplementation with essential oils increased the levels of IgA and IgG.

Anti-inflammatory

Some certain plants such as black pepper, turmeric, nutmeg, cinnamon, coriander, celery, chive and parsley have antiinfammatory activity (Peter, 2006). Another most important characteristics of phytochemicals is anti-inflammatory activity it helps to suppress the metabolism of inflammatory prostaglandins (Muanda et al., 2011). Terpenoids and flavonoids are the major active molecules with anti-inflammatory action. They are so much effective in the treatment of endometritis (inflammation of the endometrium) in cows. The extracts of garlic (*Allium sativum*), eucalypt (*Eucalyptus globulus, Labill*.) and *Gnaphalium conoideum* are effective on acute endometritis of Holstein cows evaluated by Esparza-Borges and Ortiz-Márquez (1996). Rubio et al. (2013) mention that phytochemical feed additives regulate the inflammatory process by expressing antioxidant enzymes. In the intestinal lumen antioxidant and anti-inflammatory activities improve the gut morphology (Miguel et al., 2010). Turmeric, red pepper and clove induced antioxidant effects and beneficial anti-inflammatory influence in arthritis was documented by Srinivasan 2005.

Antihistaminic

Peter (2006) reported that, Ginger and tuemaric have antihistaminic property. Garlic contain Quercetin, which is a top histamine-lowering compound effective in improving the symptoms of spring allergies. quercetin found in garlic is a key ingredient among many allergy-fighting supplements and drugs. Turmaric significantly reduce and restrict allergic responses.https://billyoh.com/extra/blog/diy/herbs-for-allergies-relief. Basil and chive are expectorant. Peter KV 2006.

Anti-hyperglycemic

(Al-Kassie 2009; Kamboh et al., 2013; Hong et al., 2012) found that supplementation with thyme and cinnamon essential oil, blend of essential oil such as oregano, anise and citrus peel, genistein and hesperidin decreased the cholesterol, VLDL and triglyceride contents in serum and skeletal muscle.

Ruminant fermentation

The extracts of herbs and spices have a great potential in manipulating the process of rumen fermentation thereby reducing methane production, decreasing ammonium concentration and other rumen fermentation parameters. The use of herbs and spices depends mainly in the properties and ability to influence rumen environment (Szumacher-Strabel & Cieślak, 2010, Cieslak et al., 2013). Rezaei & Pour (2012) reported that thyme extracts reduce the degradability of soybean meal as a result gas production was reduced. Chaudhry & Khan (2012) revealed that, coriander, turmeric, cumin, clove and cinnamon act as natural antibiotics, killing methane producing bacteria in the animal's gut

which lead to reduction in methane production and it was found that coriander reduced 40% methane production. Mohammad & Moeini (2015) reported that, supplementation with ginger improved ruminal fermentation due to reduction in ammonia, reduction in methane loss, reduction in acetate to propionate ratio and beneficial changes in protozoa population. The effect of ginger (zingiber officinale) and garlic (*Allium sativum*) on gas production, energy values, organic matter digestibility and methane emission was determined by Tag El-Din et al. (2012). The research showed that the use of garlic juice and ginger improved rumen fermentation, increased gas production and reduced methane production. The findings of Kim et al. (2012b) also reported that plant extracts such as garlic, onion and ginger were reduce methane production, reduce acetate to propionate ratio, decrease methanogen population and increase fibrolytic bacteria population. The cinnamaldehyde and garlic alter ruminal nitrogen metabolism, increase propionate and reduce acetate and methane production (Kim et al., 2012a, Fraser et al., 2007, Calsamiglia et al., 2007). Arhab et al. (2013) to determine the impact of essential oils extracted from *Juniperus phoenicea*, *Satureja calamintha* and *Mentha pulegium* on methane production and rumen fermentation, the result showed that decreased methane production and also decreased ammonia concentration.

Possible uses of herbs and spices in ruminant and mono-gastric animal diets

Spices have been used in diets, mainly as flavouring and colouring agents as well as for their functional properties such as being antioxidant and antimicrobial while some spices inhibit growth of microorganisms. The combined properties of herbs and spices (effects on digestibility and antimicrobial activity) has found to be used in the feeding of animals such as pigs, chickens, sows and ruminants as a growth promoters and antibiotic replacements. Plant extract such as oregano, cinnamon, pepper and extract from sage, thyme, rosemary has been shown to improve apparent whole-tract and ileal digestibility of the feeds for broilers (Hernandez et al., 2004). The above plant extracts fed to broilers showed little growth promoter effect and live performance levels similar to an antibiotic growth promoter (Hernandez et al., 2004). Jamroz and Kamel (2002) observed improvements of 8.1% in daily gain and 7.7% in feed conversion ratios in 17-day-old poultry fed a diet supplemented with a plant extract containing capsaicin, cinnamaldehyde and carvacrol at 300 ppm.

In farms animals, various types of herbs and spices and their mixture are used to raise and maintain the milk production. Galactagogues are important for milk productions. Galactagogues helps to installation, maintenance and enhancement of milk production. There are few herbs such as *Asparagus recemosus, Leptadenia reticulate Nigella sativa* are used as a galactagogues (Gabay, 2002, Abascal and Yarnell, 2008). Lectovet is herbal combination which increase the milk production and also enhance the fat percentage of milk in dairy cows (Qureshi 1999). In dairy cows, the herbs and spices are used as a feed supplement to maintain the milk flavor. The prominence flavor of cow milk was suppressed due to dispatch of components when dried herbs were fed to lactating dairy cows (Ando et al. 2001). The milk flavor was increased by the use of many herbal galactogogue obtained by Preciado et al. (2011).

To get the nutritious animal products with desired organoleptic properties necessary to supply quality feed, potable water and to maintain good hygiene and management (Saxena, 2008). Supplementation with oregano essential oil conspicuously diminution the lipid peroxidation of cooked and fresh meat during refrigerated storage (Botsoglou et al. 2003b) and also perpetuate the quality characteristics of chicken meat during frozen storage (Botsoglou et al. 2003a). Supplementation with *Andrographis paniculata*, turmeric and vitamin E in goat results higher antioxidant activities and better sensory qualities of goat meat.
In poultry feed different types of herbs are used as a natural coloring agent. Yolk color in laying hens and skin color in broilers are increased by using some natural carotenoids. Marigold, tagetes, maize, alfaalfa and red pepper are used as a natural coloring agent. Red pepper contains two major red pigments these are capsantin and capsorubin (Sirri et al. 2007).The pigments are acquired from *Calendula officinalis* and *Cayenne pepperis* are used as a very compatible yolk coloring agent. In layer feed, *Morus nigra* leaves are good natural

coloring agents. The supplementation with mulberry leaves in layer feed ameliorate the yolk color, egg quality, shelf life and antioxidant properties of eggs conducted by the studies of Al Kirshi (2009).

Different types of herbs may exert multiple function in animal body. Herbs induce flavors in animal feed and influence eating patterns, total feed intake, secretion of digestive juice and saliva. Saliva makes swallowing easier. Improved feed digestibility in broilers by feeding the extracts of *Salvia officinalis*, *Thymus vulgaris* and *Rosmarinus officinalis* and the blend of carvacrol, cinnamaldehyde and capsaicin (Hernandez et al. 2004). Clove, coriander, cumin and garlic acts as an appetizer and digestive stimulant (Bhatt N. 2015). Herbs and herbal extracts are potentially useful as growth promoters in diets and also as therapeutic agents.Useful spices and herbs used in different livestock and poultry Speciesand response of ruminant and non-ruminant animals towards spices and herbs are presented in table 3 and 4.

Table 3: Useful spices and herbs used in different livestock and poultry Species

Plant Name	Scientific name	Useable portion	Principal Bioactive components	Usefulness and application
Pungent spices				
Capsicum	*Capsicum annuum*	Fruit	Capsaicin	Digestive complaints.
Pepper	*Piper nigrum*	Fruit	Piperine, Monoterpenes	Digestion stimulant.
Mustard	*Brassica*	Seed	Ally izotiocianat	Digestion stimulant.
Ginger	*Zingiber officinale*	Rhizome	Zingerone	Gastric stimulant.
Garlic	*Allium sativum*	Bulb	Allicin	Digestion stimulant and antiseptic.
Onion	*Allium cepa*	Bulb	Flavonoids, organosulfur,fructans	Antioxident, anticarcinogenic.
Turmeric	*Curcuma longa*	Rhizome	Beta-carotene, ascorbic acid, flavonoids	Stimulant and mild digestive, antiseptic.
Ajowan	*Trachyspermum ammi (L.)*	Seed	Thymol, carbacrol	Relief in rheumatic and neuralgic pain and used as a stimulant, carminative, and expectorant.
Jamaica pepper	*Pimenta dioica (L.) Merr.*	Berry and leaf	Eugenol (65–90%), methyl eugenol	To treat indigestion, flatulence, and diarrhea and also to stimulate appetite.
Anise Star	*Illicium verum Hook. f.*	Seeds	Anethole	Antibacterial, carminative.
Horseradish	*Armoracia rusticana*	Root, leaves	Glucosinolates	To treat bronchial conditions and urinary tract infections.
Aromatic spices				
Anise	*Pimpinella anisum*	Fruit/Fruit pulp	Anethol	Digestive properties, mild expectorent.
Cardamom	*Elettaria cardamomum*	Fruit/Fruit pulp	Cineol	Appetite and digestion stimulant.
Cloves	*Syzygium aromaticum*	Flower bud	Eugenol, eugenol acetate	Increase carcass weight.
Cinnamom	*Cinnamomum verum*	Stem bark	Cinnamldehyde, eugenol	Reduce cholesterol and blood suger.
Coriender	*Coriandrum sativum*	Leaves, Seed	Linalol	Kill certain fungi and bacteria, anti-inflammatory effects, digestive properties.
Cumin	*Cuminum cyminum*	Seed	Cuminaldehyde	Digestive properties, relieve flatulence and colic, increase lactation.
Celery	*Apium graveolens*	Fruit, Leaves	Phtalides	Appetite and digestion stimulant.
Fenugreek	*Trigonella foenumgraecum*	Seed	Trigonelline	Increase milk production.
Parsley	*Petroselinum crispum*	Leaves	Apiol	
Nutmeg	*Myristica fragrans*	Kernel/Fruit seed	Sabinene	Anti-inflammatory, antimicrobial.

Caraway	*Carum carvi L*	Seeds	D -carvone (40–60%) and d -limonene (30–50%)	Antibacterial and larvicidal properties.
Chervil	*Anthriscus cerefolium L*	Leaves	Methyl chavicol	Expectorant.
Curry Leaf	Murraya koenigii Spreng.	Leaves	Caryophyllene, alkaloids	Antibacterial, anthelmintic.
Fennel	*Foeniculum vulgare Mill.*	Seed	Trans -anethole.	Anti-inflammatory.
Lavender	*Lavandula angustifolia*	Leaves	Linalyl acetate, linalool	Antidepressant.
Herbs				
Rosemary	*Salvia rosmarinus*	Leaf	1,8-cineol	Increase feed intake.
Thyme	*Thymus*	Whole plant	Thymol	Improved average daily gain.
Sage	*Salvia officinalis*	Leaves	Cineol	Increage body weight.
Laurel	*Laurus nobilis*	Leaves	Cineol	Appetite and digestion stimulant.
Mint	*Mentha*	Leaf	Mrnthol, 1,8-cineole	Helps to maintain feed conversion ratio, antiseptic.
Oregano	*Origanum vulgare*	Leaf	Carbacrol, Thymol	Increase meat tenderness and acceptability.
Basil	*Ocimum basilicum L.*	Leaves	Methyl chavicol, cineole	Digestive purposes.
Lemongrass	*Cymbopogon citratus*	Whole plant	Geranial	-

Table 4: Response of ruminant and non-ruminant animals towards spices and herbs

Name of spices and herbs	Principal bioactive component	Dose	Overall responses	Species	Reference
Ajowan	Thymol(35-60%) Carbacrol	2%, 4% and 6%	Used as a stimulant, carminative, and expectorant.	-	Charles ,2013
Jamaica pepper	Eugenol (65–90%), methyl eugenol	-	To treat indigestion, diarrhea and also to stimulate appetite.	Broilers Bovines	Charles ,2013
Thyme and cinnamon	Cinnamaldehyde, Thymol	100 and 200 ppm	Increase body weight gain and feed intake, Decrease abdominal fat.	Broilers	Al-Kassie (2009)
Thyme extract	Thymol	50, 100, 200, or 400 ppm	Increase Body weight gain.	Broilers	Alipour et al. (2015)
Organo essential oil	Carvacrol 84.0%; thymol 1.8%	300mg/kg	Improvement of Feed conversion ratio.	Broilers	Alp et al. (2012)
Organo essential oil	Carvacrol 84.0%; thymol 1.8%	2.5 to 6.25 mL/kg	Effect on E.coli	Broilers	Horosava et al. (2006)
Garlic EO	2-propenyl thioacetonitril 43.2%, trisulfide methyl 2-propenyl 23.4%, disulfide di-2-propenyl 20.9%	300mg/kg		Broilers	Kirkpinar et al. (2011)
Thyme EO	Thymol 44.1%, p-cymene 32.0% terpineol 9.6%, linalol 4.6%	1g/kg	Increase of Body weight gain and Feed intake	Broilers	Cross et al. (2007)
Ginger EO	β-Bisabolene 9.9%;	75mg/kg	Gastric stimulant	Broilers	Habibi et al. (2014)
Blend of essential oils	Thymol, eugenol and piperine	100–200 mg/kg	No effect on growth performance and Feed conversion ratio.	Broilers	Abildgaard L et al. (2010)
Blend of essential oils	Carvacrol, thymol, eucalyptol, lemon	125–500 mg/kg	Improvement of Body weight gain and feed conversion ratio.	Broilers	Alali et al. (2013)
Blend of essential oils	Cinnamaldehyde and thymol	100 mg/kg	Improvement of feed conversion ratio.	Broilers	Amerah et al. (2011)

Blend of essential oils		1g/kg	No effect on body weight gain, feed intake and feed conversion ratio.	Broilers	Arczewska-Wlosek et al. (2012)
Blend of essential oils	Clove and cinnamon	100 mg/kg	Increase carcass weight.	Broilers	Isabel et al. (2009)
Blend of essential oils		100mg/kg	Improvement of feed conversion ratio.	Broilers	Rinttila et al. (2013)
Blend of essential oils		30mg/kg	Improvement of average daily gain and feed conversion ratio.	Broilers	Khattak et al. (2014)
Capsicum	Capsaicin	5–20 mg/kg	Reduction of Salmonella Typhimurium counts.	Broilers	Orndorff et al. (2005)
Peppermint EO	Mentha	400mg/kg	Helps to maintain feed conversion ratio, antiseptic.	Broilers	Emami et al. (2013)
Pepper	Piperine	0, 60, 120, and180 mg/kg	Increase feed conversion ratio.	Broilers	Cardoso et al. (2012)
Oregano and vitamin E	Carbacrol, Thymol	100 mg/kg of feed	No effect in feed intake.	Broilers	Avila-Ramos et al. (2012)
Blend of essential oils	Rosemary and oregano	50 and 100 mg	Increase feed intake.	Broilers	Mathlouthi et al. (2012)
Blend of essential oils	Oregano, clove, cinnamon, red pepper	100ppm		Broilers	Barreto et al. (2008)
Thyme EO	Thymol (30–75%)	60mg/kg	Improvement of body weight gain and feed conversion ratio.	Quails	Denli et al. (2004)
Thyme	Thymol	30mg/kg	Improvement of body weight gain and feed conversion ratio	Turkey	Ginnenas et al. (2014)
Blend of essential oils	Thymol, eugenol, piperine	30mg/kg	Improvement body weight gain, antioxidant status.	Turkey	Giannenas et al. (2014)
Juniper berry EO	Monoterpene hydrocarbons	2g/day	Improvement of feed digestibility in rumen.	Bovine	Yang et al. (2007)
Cinnamon	Cinnamaldehyde	-	Increase feed intake.	Bovine	Yang et al. (2010)
Cloves	Eugenol	50mg/kg DM	Stimulate appetite.	Bovine	Benchaar et al. (2012)
Garlic EO	Allicin	5g/day	Improvement of feed digestibility in rumen.	Bovine	Yang et al. (2007)
Blend of essential oils		0.32, 0.64,96g/day	No effect on dry matter intake.	Bovine	Spanghero M et al. (2009)
Oregano leaves	Carbacrol, Thymol	500g/day	No effect on volatile fatty acid concentration and ruminal pH, Decrease methene production.	Bovine	Tekippe et al. (2011)
Mixture of essential oils		2 g/day	Increase of ruminal pH.	Bovine	Benchaar et al. (2006)
Mixture of essential oils	Eugenol, geranyl acetate and coriander	1g/day	Decrease of body condition scoring.	Bovine	Santos et al. (2010)
Anise extract	Anethol	500mg/day	Reduction of volatile fatty acid concentration and rumen parameter.	Bovine	Fandino et al. (2008)
Anise	Anethole (up to 90%)	500mg/day	Decrease cramp and colic in infants,improve appetite, and promote lactation.	Bovine	Charles, 2013
Thyme E O	Thymol	5 G/day	No effect on volatile fatty acid concentration and ruminal pH.	Calves	Vakili et al. (2013)
Oregano	Carvacrol	200mg/kg DM	Reduction of ruminal pH and increase of Volatile fatty acid concentration.	Lambs	Chaves et al. (2008)
Cinnamon	Cinnamaldehyde	200mg/kg DM	Reduction of ruminal pH and increase of Volatile fatty acid concentration.	Lambs	chaves et al. (2008)
Garlic	Allicin	200Mg/kg DM	Improvement of feed digestibility in rumen.	Lambs	Chaves et al. (2008)
Juniper berry	Monoterpene hydrocarbons	200Mg/kg DM	No effect on ruminal pH, Decrease of methene production.	Lambs	Chaves et al. (2008)

Garlic EO	Allicin	5g /kg DM	No effect on dry matter intake and methene production.	Sheep	Klevenhusen et al. (2011)
Mixture of essential oils	Clove, oregano, cinnamon, and lemon	1 g/day	Decrease of volatile fatty acid concentration.	Sheep	Lin et al. (2013)
Mixture of essential oils		1 g/day	Decrease of volatile fatty acid concentration.	Sheep	Lin et al. (2013)
Cinnamon	Cinnamaldehyde	100, 200 and 400 mg/kg of Diet	Increase off flavour intensity.	Goat	Chaves et al. (2011)
Extract of cinnamon, oregano and thyme	cinnamaldehyde (60–80%), Carbacrol, Thymol thymol (30–75%)	7.5 g/kg	Reduction in fecal coliforms. No immunostimulatory effect	Swine	Namkung et al. (2004)
Thyme	Thymol (30–75%)	10 g/kg	No effect on hemolytic E.coli shed	Swine	Jugl-Chizzola et al. (2005)
Fennel	Fennel were obtained bysteam distillation from fennel seeds	100mg/k g	Anti-inflammatory	Swine	Schone et al. (2006)
Caraway	Caraway were obtained bysteam distillation from caraway seeds	100mg/kg	Antibacterial	Swine	Schone et al. (2006)
Blend of essential oils	Thymol and cinnamaldehyde	0.1-0.15mg/kg	Improvement of average daily gain and feed conversion ratio.	Weaner pig	Li et al. (2012)
Blend of essential oils	Peppermint, anise and clove	300mg/kg	Improvement of feed conversion ratio and amino acids digestibility.	Weaner pig	Maenner et al. (2011)
Blend of essential oils		200mg/kg	Increase of ileal lactobacilli:enterobacteria ratio.	Swine	Manzanilla et al. (2009)
Blend of essential oils	Carvacrol and thymol	500-1500mg/kg	No effect on body weight gain, feed intale and feed conversion ratio.	Swine	Muhl and Liebert (2007)
Blend of essential oils	Rosemary, garlic, oregano and ginger	0.05%	Increase feed intake.	Swine	Janz et al. (2007)
Oregano	Carbacrol	1000, 2000 or 3000ppm	-	Swine	Alarcón-Rojo et al. (2013)
Thyme EO	Thymol (30–75%)	0.5 g/kg	Improvement of intestinal integrity and antioxidant status.	Rabbits	Placha et al. (2013)

CONCLUSION

Herbs and spices can be used as a natural non-antibiotic growth promoters. Herbs and spices have antimicrobial, antioxidative, growth promoting and immune stimulating effects on ruminant, non-ruminant and poultry. The herbs and spices have a potential antimicrobial effects to promote to a concluding decline of intestinal pathogen burden through inhibition of adherence to the mucosa. It has a pronounced role in intensification of digestive enzyme action and absorption capability. Herbs and spices have valuable effects on normal gut function, the feed intake, feed conversion ratio, nutrient digestibility, body weight gain, carcass characteristics, meat quality and egg production in poultry. Herbs and spices also have positive effects on growth performance and meat quality in swine and cattle. Herbs and spices help to endure good health and welfare of the animals and improve their performance. Herbs and spices extracts have an ample potential in manipulating rumen fermentation process by decreasing methane production, ammonium concentration and rumen fermentation.

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