Herbs and Spices: Options for Sustainable Animal Production

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Abstract
Herbs and spices and a host of other plant derivatives used in animal feeding as feed additives are referred to as phytogenic feed additives. This class of feed additives is increasingly gaining popularity in livestock production. A number of studies have demonstrated antioxidative and antimicrobial efficacy in vitro. Methane reducing effects of some herbs and spices in ruminants have also been reported. Studies show that some of these plant materials improved the palatability of feed. There are suggestions that they may specifically enhance activities of digestive enzymes and nutrient absorption. Experimental comparisons of these phytogenic additives with antibiotics and organic acids have suggested similar effects on the gut. This include reduced bacterial colony counts, fewer fermentation products, greater nutrient digestion and probably reflecting an overall improved gut equilibrium. In addition, some of the herbs and spices or their derivatives have been reported to promote intestinal mucus production. This effect may explain improved production performance after including these phytogenic feed additives. In general, available literature suggests that phytogenic feed additives such as herbs and spices may add to the set of non-antibiotic growth promoters for use in livestock like organic acids and probiotics. However, a systematic approach toward the efficacy and safety of phytogenic materials used as feed ingredients or additives is needed. There should also be studies to show the possible interaction of these plant materials with other feed ingredients in vivo. There is also the need to study herbs and spices which are indigenous to the tropics for their utilization in livestock production.
Keywords: Herbs, Spices, Antimicrobial, Antioxidant, Phytogenic Feed Additive, Performance.

1. Introduction

Livestock farmers are generally faced with the challenge of improving livestock performance in order to ensure more net returns (Pervez, 1992). A lot of research and production strategies have been employed, including the use of antibiotics to achieve this aim (Kehinde *et al.,* 2010). Although antibiotics achieved good performance, their potential side effects became a real public health concern globally (Donoghue, 2003) and eventually led to the ban of the products especially in the western world (Nweze and Nwankwagu, 2010). This triggered an explosion of interest in the use of herbs and spices and their products as supplements in animal rations (Bunyapraphatsra, 2007; Owen, 2011; Anyanwu, 2010). Odoemelam *et al.,* (2013) reported that up to one third of all commercial swine and chicken rations in Europe now use mixtures of herbs and spices to accelerate growth and maintain health.

Herbs are flowering, non-woody and non-persistent plants and spices are herbs with an intensive smell and taste commonly added to human foods. They have been reported to possess antimicrobial, antioxidative, anti-inflammatory and immuno-modulatory properties (Sofowora, 1993). Herbs and spices fall into the class of feed additives currently referred to as “Phytogenics”. They are strongly being considered as addition to the set of non-antibiotic growth promoters, such as organic acids and probiotics which are already well established in animal nutrition (Windisch *et al.,* 2007). Their usefulness lies in some chemical substances that produce definite physiological actions in the body of the animals (Oko and Agiang, 2009). The most important bioactive constituents include alkaloids, tannins, flavonoids, saponins and phenolic compounds.

Some of the useful herbs and spices are indigenous to Africa and include ginger (*Zingiber officinale*), garlic (*Allium sativium*), scent leaf (*Ocimum gratissimum*), bitter leaf (*Vernomnia amygdalia*), they have been reported to enhance the performance of livestock animals (Muhmmad *et al.,* 2009).

This article discusses the roles of these herbs and spices in improvement of livestock performance through their antioxidative action, antimicrobial action, Impact on palatability and gut function and reduction of methane emission in ruminants.

2. Antioxidative Action

An antioxidant is any substance that when present at low concentration compared to those of an “oxidizable substrate” significantly delays or prevents oxidation of that “substrate” (Aruoma *et al.,* 1997; Imark *et al.,* 2000). While antioxidants are associated primarily with inhibition of lipid peroxidation, free radicals can also cause damages in other components thus, “oxidizable substrate” includes almost everything found in feeds and in living tissues such as protein, lipids, carbohydrates and DNA (Eskin and Robinson, 2000). Antioxidants are often added to delay the onset or slow the development of rancidity due to oxidation (Imark, *et al.,* 2000). Just as oxidation can cause rust and deterioration in metals, oxidation in feeds and feedstuff can result in rancidity, destruction of vitamins, A, D, E, pigmenters and amino acids with resultant lowered biological value (Harris, 1970; Talbot, 2004).

Oxidative rancidity is a chemical reaction in which oxygen attacks a weak point (double bond) in the fat, forming peroxides (Talbot, 2004). These peroxides attack fat molecules leading to the destruction of fat soluble vitamins and other nutrients (Talbot, 2004). Similarly, unsaturated fatty acids undergo a loss of hydrogen, resulting in the formation of free radicals at the site of unsaturation (Nwabugwu, 2010).

If the feed material in which this reaction is taking place does not contain some effective antioxidants the free radical is quickly converted to a fatty acid peroxide free radical and fatty acid hydroxperoxide (Nwachukwu, 2009). An antioxidant can block this peroxidation by supplying a hydrogen in the first free radical formed, thereby reconverting it to the original fatty acid. If the hydroperoxides are allowed to form they continue to decompose by breaking down into variety of aldehydes and ketones (Nwachukwu, 2009). These chemical processes generates highly reactive molecules resulting in rancidity in feeds which are responsible for producing unpleasant and obnoxious odour and reducing palatability and metabolizable energy of feeds and fats (Young and Mcenergy, 2001; Talbot, 2004). The study of the various problems resulting from uncontrolled oxidation and ways of bringing these oxidation processes under control has remained a concern in food and feed management.

2.1 Modes of Action and Evaluation of Antioxidant Activity

Antioxidants can act in cell membranes or food products by; scavenging free radicals which initiates oxidation, removing reactive oxygen species such as oxygen radicals, breaking the initiated chain of reaction (Manson, 1997), Quenching/scavenging singlet oxygen (Budason, 2000), destroy peroxides to prevent radical formation and removing oxygen or decreasing local oxygen concentration/pressure (Pryor, 1993; Eskin and Robinson, 2000; Benzenic, 2003).

Herb and spices have been shown to exert antioxidative properties (Cuppett and Hall, 1998; Nakatani, 2000). The antioxidant property of many phytogenic compounds can contribute to protection of feed lipids from oxidative damage. Among a variety of plants bearing antioxidative constituents, the volatile oils from the Labiatae family (Mint plants) have been attracting the greatest interest. Their antioxidative activity arises from phenolic terpenes, such as rosmarinic acid and rosmarol (Cuppett and Hall, 1998; Windisch *et al.,* 2007). Other Labiatae species with significant antioxidative properties are thyme and oregano. Other plant species like ginger, scent leaf, garlic and *Monodora myristica* as well as other plants rich in flavonoids have been described as exerting antioxidative properties (Nakatani, 2000; Nwachukwu, 2009).

The antioxidative activities of some spices have been tested by evaluating the peroxide value of a lipid containing extracts of these plants over time (Aruoma *et al.,* 1997; Nwachukwu, 2009). Peroxide value is used to monitor the development of rancidity through the evaluation of the quantity of peroxides generated in the products (substrate). Peroxide value is usually less than 10 mEq/kg when a fat sample is fresh. Rancid taste and smell begins to show up when the peroxides value is between 20 and 40 mEq/kg (Onwuka, 2005). Peroxide value of oil is also a measure of its content of oxygen.

Peroxide values of soyabean oil treated with different spice extracts over a given period have been determined (Table 1 and Table 2). Peroxide value of soyabean oil treated with *Ocimum gratissimum* and *Monodora myristica* extracts decreased with increasing concentration of the extracts. The rate of increase of peroxide value also increased with duration of storage (days) however, this rate dropped significantly after 21 days (Nwabugwu, 2010; Ukachukwu, *et al.,* 2012). Aruoma *et al.,* (1997) indicated an increasing peroxidation inhibition with increasing concentration of ginger and garlic extracts (Table 3). An implication of the peroxidation inhibition action of herbs, spices and their products in livestock feeds may be in improving feed intake and weight gain by preventing problems of reduced palatability and metabolizeable energy associated with the chemical process of peroxidation or rancidity. Yen e*t al.,* (2011) reported a higher weight gain and feed intake ($P<0.05$) for pigs fed garlic treated diets compared to non garlic treated diets.

Other ways of investigating the antioxidant activity of a potential antioxidant include assessing its chelating ability (Decker and Welch, 1990), scavenging effect (Muller, 1995; Nagai *et al.,* 2001) and Reducing power (Onyaizu, 1986) and comparing it with a standard antioxidant.

3. Anti microbial Action

Herbs and spices are well known to exert antimicrobial actions against important pathogens, including fungi (Adam *et al.,* 1998; Smith-palmer *et al.,* 1998; Junaid *et al.,* 2006). The active substances are largely the same responsible for antioxidative properties with phenolic compounds being the principal active components (Burts, 2004). The antimicrobial mode of action is considered to arise mainly from the potential of the hydrophobic essential oils in these plants to intrude into the bacterial cell membrane, disintegrate membrane structures and cause ion leakage (Lee *et al.,* 2004; Windisch *et al.,* 2007). High anti-bacterial activities have also been observed in a variety of non-phenolic substances e.g. Limonene and compounds from Black pepper and nutmeg (Newton *et al.,* 2002).

The antimicrobial activity of a variety of herbs and spices has been reported (Junaid *et al.,* 2006; Anyanwu, 2010). Junaid *et al.,* (2006) indicated the antimicrobial efficacy of *O. gratissimum* leaf extracts on some bacterial isolates like *Aeromonas hydrophila, Bacillus cereus, E.coli, Salmonella typhimurium* and *Yersinia enterocolitica* (Table 6) . Cold H_2O fresh leaf extract gave Minimum bactericidal concentration (MBC) of 3.13, 12.5 25, 25 and 25 mg/ml for *E. coli, B. cereus, A. hydrophila, S. typhimurium* and *Y. enterocolitica.*

The use of herbs and spices as well as their products in rations is aimed primarily at harnessing their antimicrobial potentials to boost performance. Their use in broiler and swine production has been reported (Hassan *et al.,* 2004; Al-harthi, 2006; Odoemelam *et al.,* 2013). At least for broilers, an overall antimicrobial potential of phytogenic compounds in vivo cannot be ruled out (Windisch *et al.,* 2007; Muhammad *et al.,* 2009). Studies with boilers demonstrated in vivo antimicrobial efficacy of essential oils from plants against *Escherichia coli* and *Clostridium perfringens* (Jamoz *et al.,* 2003: Mitsch *et al.,* 2004).

Evans *et al.,* (2001) investigated the effect of a mixture of essential oils from clove (1.0%) thyme (0.1%), peppermint (0.1%) and lemon (0.1%) on *Coccidia* oocytes output and the number of *Clostridium perfringens* in broilers chicks when artificially inoculated. They observed that chicks fed the diets containing the essential oil blend showed a reduced oocyte excretion compared to those fed the non-supplemented diet.

It would be expected that the intake of herbs and spices or their products affects the gastro intestinal micro flora composition and population thus, controlling potential pathogens (Roth and Kirchgessner, 1998). As a result of this more stabilized intestinal health, animals are less exposed to microbial toxins and other undesired microbial metabolites such as ammonia and biogenic amines (Eckel *et al.,* 1992). They are also relatively relieved from immune defense stress during critical situations as well as increased availability of essential nutrients for absorption, thereby helping the animals to grow better within the framework of their genetic potential. According to Muhammed *et al.,* (2009) who investigated the effect of aqueous extract of plant mixture (*Zingiber officinale, Carum apticum, Withania somnifera, Trigonella Foenum-Graecum, Silybum marianum, Allium sativum* and *Berberis lyceum)* on performances and carcass quality of broiler chicks, improvements were recorded with increasing levels of the extracts of plant mixture (Table 7).

3.1 Impact on Palatability, Gut Function and Digestion

There are suggestions that spices and herbs can positively affect food digestion (Mellor, 2000; Pradeep *et al.,* 1991). A wide range of spices, herbs and their extract are known from medicine to exert beneficial actions within the digestion tract, such as, laxative acid spasmolytic effects and prevention of flatulence (Chrubasik *et al.,* 2005). Studies have reported the effect of spices or their active components on bile salt secretion (Bhat *et al.,* 1984; Sambaiah and Srinivasan, 1991). Platel and Srinivasan (2004) reported that stimulation of digestive secretions e.g. saliva, bile and mucus and enhanced enzyme activity are their core mode of nutritional action. In vitro activities of rat pancreative lipase and amylase were shown to be significantly enhanced when brought into contact with various spices and spice extracts (Rao *et al.,* 2003). Similarly, essential oils used as feed additives for broilers were shown to enhance the activities of trypsin and amylase (Lee *et al.,* 2003; Jang *et al.,* 2004). They were also reported to stimulate intestinal secretion of mucus in broilers an effect that was assumed to impair adhession of pathogens and thus stabilizing the microbial eubiosis in the gut of the animals (Jamroz *et al.,* 2006). On the other hand Kreydiyyeh *et al.,* (2000) observed that Cinnamaldehyde and eugenol, a main component of clove essential oils, when fed at high concentrations significantly impaired the absorption of alanine by rat jejenum. They postulated that these materials inhibited the activity of Na^+- K^+- ATPase located in the enterocyte and consequently impair transport processes in the intestine. In addition, in vitro results showed that IC^{50} values which is the concentration that inhibited the activity of intestinal Na^+- K^+- ATPase by 50% were 1.1 and 1.4 mg/mg of protein for cinnamaldelyhde and eugenol, respectively. It can thus be expected that high doses of these substances when introduced into the chicken diet could inhibit the digestion process.

Herbs and spices or their products are often indicated to improve the flavor and palatability of feed, thus helping the animal to achieve a better performance. Experiments validating these claims are quite limited. Dose-related depressions of palatability in pigs fed essential oils from fennel and caraway as well as thyme and Oregano have been reported (Jugl-chizzolla *et al.,* 2006; Windisch *et al.,* 2007). On the other hand, there are numerous reports on improved feed intake through the use of phytogenic feed additives in swine (Yen *et al.,* 2011; Windisch *et al.,* 2007) The specific effects of flavors on chickens' performance have not received much attention possibly because poultry may not acutely respond to flavor when compared to pigs (Moran, 1982). Also Moran, (1982) indicated that the effects of flavors on poultry performances are regarded as negligible. There is evidence however, that flavor could affect feed intake (Deyoe *et al.,* 1962). The characteristic flavor of spices can also be advantageous in standardizing tastes and smells of the diet especially if the ingredients in the diets are changed such as the weaning transitions of piglets (Lee *et al.,* 2004; Anonymous, 1998).

3.2 Effect on Methane Emission in Ruminants

Ruminant producers are seeking to identify and promote good management practices that reduce production of atmospheric greenhouse gases, particularly those that reduce methane emissions from enteric fermentation (Beauchemin and McGinn, 2006). Although, methane does not exist in the same quantity as carbon dioxide, it is more than 20 times more powerful in terms of contributing to the greenhouse effect (Kavanagh 2010). Through belching a single sheep emits about 0.7 ft^3 of methane per day. Cows are much more an ecological nuisance, each belching emits nearly 18 ft^3 of methane into the air per day (Kavanagh, 2010). Also, reducing methane production can be of direct economic benefit because it coincides with greater energy-use efficiency of the feed by the animal. Energy lost as methane from cattle for instance ranges from 2 - 12% of Gross energy intake (Johnson and Johnson, 1995). Dean and Ritchie, (1987) have suggested that Plant essential oils and spice extracts contain antimicrobial properties that may inhibit methanogenesis by affecting ruminal bacteria. There are some in vitro studies showing inhibitory effects of spices and herbs (Table 8), essential oil mixtures or extracts derived from herbs on methanogenesis (Tatsouka *et al.,* 2008; Agarwal *et al.,* 2009). Juniper berry essential oil and cinnamon oil (Chaves *et al.,* 2008) and Peppermint oil (Tatsouka *et al.,* 2008) have shown to have strong inhibitory effect on methanogenesis. The active component of Cinnamon oil *i.e.* cinnamaldehyde caused a depression of methane production to the extent of 94% at 5 mM (Macheboeuf, *et al.,* 2008). In vivo study of Beauchemin and McGinn, (2006) indicated that adding Canola oil to the diet of cattle decreased total daily methane emissions by 32% and tended to decrease methane emissions as a percentage of gross energy intake by 21%, however, this was also associated with decreased feed intake. Wang *et al.* (2009) also showed in an in vivo study that inclusion of 0.25 g day^{-1} of essential oil from Oregano plants in the diet of sheep for 15 days lowered methane production. Herbs and spices and their products seem to hold a lot of promise as a natural option to embrace to cut back on methane emission in livestock production. Introducing spices to livestock feed could be an effective natural means of reducing methane production. Chaudhry (2010) revealed that the spices; coriander, turmeric, cumin, clove and cinnamon act as natural antibiotics, killing methane-producing bacteria, while allowing less harmful bacteria to act in its place. In a test at Newcastle University involving the five curry spices, it was discovered that ground up coriander added to an in-vitro solution mirroring that found in the stomach of sheep and cows caused a 40% reduction in methane production.

Since antibiotics were banned the hunt has been on for new, safe cheap ways to reduce methane production in ruminants. Plants like coriander appear to be an ideal solution especially in parts of the world where expensive treatments are not an option (Table 8).

There is still need to explore other species and herbs common and indigenous in the tropics.

5. Conclusion

There are strong indications that herbs, spices and their products exert antioxidative, antimicrobial and growth promoting effects in livestock. The antioxidative efficacy of some of the herbs and spices in protecting the quality of feed as well as that of food derived from animals fed these substances cannot be ruled out. For antimicrobial actions, observations in vivo supports the assumption that they possess the potential to contribute to the final reduction of intestinal pathogen pressure. This action compares with the role played by some other antimicrobial feed additives and organic acids. Furthermore, studies reveal that they contribute to an enhanced digestive enzyme activity and absorption capacity. They also stimulate intestinal mucus production, which contributes to relieve pathogen pressure through inhibition of adherence to the mucosa. However, products containing blends or mixtures of phytogenic compounds appear to produce these results.

There is therefore the need for a systematic approach to explain the efficacy and mode of action of herbs and spices as well as dose of the active compound especially those indigenous to the tropics. There should also be studies to show the possible interaction of these plant materials with other feed ingredients.

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Table 1: Peroxides Value of Soyabean oil treated with *Ocimum gratissimum* extracts.

		Peroxide value (mEq/kg)			
Treatments	Day 0	Day 7	Day 14	Day 21	Day 28
C0	6.85	8.31 (0.21)*	15.49 (1.03)*	20.62 (0.73)*	23.65 (0.43)*
C1	6.85	7.78 (0.12)*	12.32 (0.66)*	19.47 (1.02)*	22.45 (0.50)*
C2	6.85	7.57 (0.11)*	11.87 (0.61)*	18.79 (0.98)*	22.30 (0.50)*
C3	6.85	7.41 (0.08)*	11.77 (0.62)*	17.63 (0.84)*	21.58 (0.56)*
C4	6.85	7.30 (0.06)*	10.86 (0.51)*	17.52 (0.95)*	19.82 (0.33)*
C5	6.85	7.19 (0.05)*	10.24 (0.44)*	16.60 (0.91)*	19.27 (0.38)*

C1 = Concentration of *O. gratissimum* extract at 2000 ppm; C2 = Concentration of *O. gratissimum* extract at 4000 ppm; C3=Concentration of *O. gratissimum* at 6000 ppm; C4 = Concentration of *O. gratissimum* extract at 8000 ppm; C5= Concentration of *O. gratissimum* extract at 10000; C0 = control (test oil without *O. gratissimum* extracts)
*Rate of increase of peroxide value (*m*Eq/Kg/day)
(Source: Nwabugwu, 2010)

Table 2: Peroxides value of Soyabean oil treated with *Monodora myristica* seed extract

		Peroxide values (*m*Eq/Kg)			
Treatments	Day 0	Day 7	Day 14	Day 21	Day 28
C0	8.30	10.07(0.25)*	16.47(0.19)*	22.67(0.89)*	22.87(0.68)*
C1	8.30	9.73(0.20)*	15.17(0.85)*	21.73(0.87)*	21.80(0.64)*
C2	8.30	9.67(0.20)*	15.13(0.78)*	21.47(0.91)*	21.27(0.63)*
C3	8.30	8.53(0.03)*	13.73(0.74)*	20.40(0.95)*	20.53(0.58)*
C4	8.30	8.83(0.08)*	12.47(0.52)*	19.07(0.94)*	19.47(0.53)*

C1 = Concentration of *M. myristica extract at* 2000 ppm; C2 = Concentration of *M. myristica* extract at 4000 ppm; C3 = Concentration of *M. myristica* extract at 6000 ppm; C4 = Concentration of *M. myristica* at 8000 ppm; C0 = Control (Test oil without *M. myristica* extracts).
*Rate of increase of peroxide value (*m*Eq/kg/day)
(Source: Ukachukwu,*et al.,* 2012).

Table 3: Inhibition of Phospholipid Liposome Peroxidation by Ginger and Garlic.

	Inhibition of Peroxidation (%)	
Concentrations(mg/ml)	Ginger	Garlic
0.10	36	-
0.50	38	8
1.0	47	9
2.0	63	18
4.0	70	34
5.0	74	43

(Source :Aruoma *et al.,* 1997)

Table 4: Minimum bactericidal concentrations (MBC) of leaf extracts of *Ocimium gratissimum*

	Concentrations of extracts mg/ml												
Isolates	200	150	100	50	25	12.5	6.25	3.13	1.56	0.78	0.39	Extracts	MBC
A.h	-	-	-	-	-	+	+	+	+	++	++	CH_20F	25
A.h	-	-	-	-	+	+	+	+	++	++	++	HexF	50
B.c	-	-	-	-	-	+	+	+	++	++	++	CH_20F	12.5
B.c	-	-	-	-	+	+	+	+	++	++	++	HexF	25
E.c	-	-	-	-	-	-	-	-	+	+	++	CH_20F	3.13
E.c	-	-	-	-	-	-	+	+	+	++	++	HexF	12.5
E.c	-	-	-	+	+	+	++	++	++	++	++	HH_20F	100
E.c	-	-	-	-	+	+	+	++	++	++	++	METF	50
STM	-	-	-	-	-	+	+	++	++	++	++	CH_20F	25
STM	-	-	-	-	-	+	+	+	++	++	++	HexF	50
Y.e	-	-	-	-	-	+	+	+	++	++	++	CH_20F	25
Y.e	-	-	-	-	-	+	+	+	++	++	++	HexF	25

- No growth; + Growth; ++ Heavy growth; CH_20F-Cold H_20 Fresh; HH_20F- Hot H_20 Fresh; MET F- Methanol Fresh; Hex F – Hexane Fresh (A.h - *Aeromonas hydrophila;* B.c - *Bacillus cereus*; E.c - *E.coli;* STM - *Salmonella typhimurium;* Y.e - *Yersinia enterocolitica*)
(Source: Junaid *et al.,* 2006).

Table 5: Effect of aqueous extract of plant mixture on performances and carcass quality of broiler chicks.

Parameter	Levels of Plant mixture			
	0 ml	5 ml	10 ml	15 ml
Body weight (g)	916 ± 11.23^d	1101 ± 10.98^c	1396.08 ± 6.56^a	1169.22 ± 8.34^b
Feed intake (g)	1883.5 ± 15.45^a	1809.82 ± 19.87^c	1825.28 ± 15.89^b	1825.0 ± 21.13^b
FCR	2.05±0.29	1.73±0.21	1.31±0.34	1.56±0.65
Dressing percent(%)	51.11 ± 1.76^d	55.4 ± 2.21^b	62.3 ± 1.78^a	54.33 ± 2.25^c
Breast weight(g)	170.5 ± 3.54^c	193.33 ± 2.23^b	203.16 ± 3.76^a	190 ± 1.43^b
Thigh(g)	44.5±6.45	50.1±3.87	52.16±3.21	46.33±2.94
Leg(g)	40.8 ± 1.21^b	40.83 ± 1.56^b	50.16 ± 2.32^a	41.21 ± 1.32^b

a b,c,d=means with the same superscript in a row do not differ significantly ($P<0.05$)
(Source: Muhammed *et al.,* 2009).

Table 6: Percentage reduction of methane emission from ruminant: Effect of some spices

Species	Methane Reduction (%)
Coriander	40
Turmeric	30
Cumin	22
Clove	NG
Cinnamon	NG

NG: Negligible.
(Sources: Chaudhry, 2010).