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REVIEW ARTICLE

Use of Cinnamon in Diet of Broiler Chicken - A Review

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Abstract

It can be concluded that use of cinnamon in the diet of broiler chicken at various level will have positive impact on the performance in terms of body weight gain, feed intake and FCE, overall performance index, carcass characteristics as well as net profit per birds over control group. It will also show significant impact on blood profile. So, dietary supplementation of cinnamon in no chemical era will be very effective particularly for the antioxidant, antimicrobial, anti-inflammatory, anticancer and antidiabetic activities occur indirectly via receptor-mediated mechanisms. The significant health benefits of numerous types of cinnamon may be explored.

Keywords: Cinnamon, Anti-inflammatory, Anti-cancerous, Anti-oxidants, Anti-diabete.

1. Introduction

The term ‘‘poultry’’ originated from the French/Norman word *poule*, itself derived from the Latin word *pullus*, which means small animals. Poultry farming refers to the raising of domesticated birds such as chickens, turkeys and geese for the purpose of meat or eggs. Poultry are farmed in great numbers with chickens being the most numerous. More than 50 billion chickens are raised annually as a source of food, for both their meat and eggs. Poultry farming has made a tremendous progress during the last few decades. It has developed the meagre backyard venture to a full-fledged, well-organized, scientific and techno-commercial industry. Poultry is the second most widely consumed meat in the world, accounting for about 30 per cent of total meat production worldwide compared to pork at 38 percent. Poultry industry has registered growth of 8-10 percent per annum as compared to agricultural crops (1.5-2% per annum) and ranked 5th in egg production (Mehta and Nambiar, 2013). Poultry is the most organised sector in animal agriculture, worth rupees one lakh crores (Kotaiah, 2016). The poultry business in India provides the employment to around 1.6 million people in which 80 percent are directly employed, while the rest 20 percent is engage with its allied areas like feed, pharmaceuticals, equipment and other services required by the poultry industry (Ketharaj and Jeyakumar, 2009). Currently India is the 3rd largest producer of eggs in the world next to China and USA producing 45.2 billion eggs annually (Mehta and Nambiar, 2013). In India, Andhra Pradesh, Haryana, Tamil Nadu, Punjab, Maharashtra and West Bengal are the major egg producing states that accounts for more than 60-70 percent of the eggs produced in the country. Egg consumption in India has increased dramatically over the past 30 years. The poultry meat production increased 18 folds from 81,000 t in 1961 to 2.19 million tons in 2006 (Mehta and Nambiar, 2013). While in India, broiler production grew at an annual growth rate of 8.35 percent from 2001 to 2010 with a production of 1.25 million metric tons to 2.65 million metric tons (USDA, 2011). Currently, India is producing 2.75M tons of chicken meat. India ranks 6th in broiler production and is among the top 5 chicken meat producing countries in the world. The largest poultry meat producers are USA, China, Brazil and Mexico. As per the 19th Livestock census, total poultry population in the country increased from 307.07 million in 1992 to 729.21 million during 2012, in which 95 percent consist of fowl. Per capita consumption of poultry meat has grown from 1.22 kg in 2001 to 2.26 kg in 2010 against the ICMR recommendation of 10.8 kg (USDA, 2011). Poultry utilizes substantial quantities of non-edible agricultural and industrial by-products and converts into high quality nutritious protein rich food. It helps to bridge the gap between requirement and availability of high quality protein diet for the human population in the country. Eggs and meat are the cheapest source of animal protein. Further, poultry manure is one of the alternatives for chemical fertilizers. The poultry sector also provides a great employment opportunity even to

unskilled labourers and women thereby providing income to the vulnerable group. In broiler production, feed accounts for 65-70 percent of the cost of production, which is the major constraint in broiler enterprise. Therefore, every effort is directed to maintain feed quality, reducing the feed cost in order ensure maximum conversion of feed to food of high biological value. To curtail the feeding cost, wastage of nutrients and to reduce soil pollution due to loss of the nutrients through excreta, it requires efficient utilization of raw materials, establishment of various nutrients updating nutritional establishments to keep up with genetic improvement and ensuring efficient utilization of nutrients through feed processing and use of feed additives. Presently use of feed additives in poultry feeding have assumed a position of prime importance and has become obligatory as it improves feed efficiency and growth rate which generally results in lowering the cost of egg or meat production. Besides, it also improves the physical appearance, consistency, nutritive quality, shelf life and texture of meat. Thus, feed additives are an ideal tool to boost the profits of poultry farmers. All over the world, studies are being undertaken for utilization of traditional and promising medicinal herb to test their efficacy in optimizing livestock and poultry production. Antibiotics have been used widely as growth promotant in poultry industry. However, keeping in mind the harmful effects of antibiotic residues in poultry products, the use of antibiotics is widely discouraged which necessitated for exploring a safe and effective alternative to antibiotics (Hashemi and Davoodi, 2010). Therefore, natural products have been studies to serve as alternatives to synthetic compounds with objective to provide safe and wholesome food to mankind. The natural antioxidants have been found effective in extending the shelf life and to increase the acceptability of meat by the consumers (Fellenberg and Speisky, 2006). Further, due to the health risks associated with animal fat, consumers demand carcasses and poultry meat with less fat contents. In these circumstances, search for safe growth promotants and carcass modifiers has become a priority research area. Natural medicinal products originating from herbs, spices have been used as feed additives for farm animals (Guo, 2003). Herbs, spices and various plant extracts have been received particular attention as possible alternatives to antibiotic growth promotants (Hernandez *et al*., 2004). Being natural, non-toxic, residue-free and easy availability makes them highly acceptable as natural feed additives for poultry. Natural products have been found to have beneficial effects viz. appetizer, increased digestive enzymes secretion, immuno-stimulant, bactericidal, antiviral and antioxidants in animals (Singh *et al*., 2014).

Cinnamon (*Cinnamomum zeylanicum*) commonly known as "dalchini" is one of the oldest medicinal plants and widely used as condiment in India. It is a valued spice which is being used all over the world. *C. zeylanicum* is indigenous to Sri Lanka and South India (Jakhetia *et al.,* 2010). Various parts of the cinnamon are widely used Ayurvedic and ethno-medicine. Cinnamon is mainly used in the aroma and essence industries due to its fragrance, which can be incorporated into various foodstuffs, perfumes and medicinal product (Huang *et al.,* 2007). The principal chemical constituents of cinnamon are cinnamaldehyde, trans-cinnamaldehyde (Cin) and euginol, which are present in the essential oil and contribute to the fragrance and various biological activities (Chang *et al.,* 2013). One of the major constituents of essential oil extracted from C. *zeylanicum* named (E)-cinnamaldehyde has an anti-tyrosinase activity (Marongiu *et al.,* 2007), while cinnamaldehyde is the principle compound responsible for this activity (Chou *et al.,* 2013). Cinnamon bark contains procyanidins and catechins (Nonaka *et al.,* 1983). Cinnamon consists of a variety of resinous compounds, including cinnamaldehyde, Cinnamate, Cinnamic acid and numerous essential oils (Senanayake *et al.,* 1978). The presence of a wide range of essential oils such as *trans*-cinnamaldehyde, cinnamyl acetate, euginol, L-borneol, Caryophyllene oxide, b-caryophyllene, L-bornyl acetate, E-nerolidol, a-thujene, has been reported (Chang *et al*., 2008).

Studies have shown that Cinnamon possess appetite and digestion-stimulant properties (Taback *et al.,* 1999), anti-bacterial properties (Chang *et al.,* 2001), antioxidant properties (Singh *et al.,* 2007) and other medicinal properties like anti ulcer, anti-diabetic, anti-inflammatory (Jakhetia *et al.,* 2010). Recent studies have shown that cinnamon powder, cinnamaldehyde alone or in combination with other essential oils had a wide array of beneficial effects in poultry. Some of those effects include increased feed intake (Al-Kassie, 2009), improved growth performance and improved meat quality (Sang-Oh *et al.,* 2013), improved performance and feed efficiency (Isabel and Santos, 2009; Al-Kassie, 2009; Kamel, 2001), increased pancreatic and intestinal lipase activity (Kim *et al*., 2010), increased breast meat yield (Isabel and Santos, 2009), improvement in health status (Al-Kassie, 2009; Kamel, 2001), protection against pathogens such as *Escherichia coli*, *Pseudomonas aeruginosa, Enterococus faecalis, Staphylococcus aureus, Staphylococcus epidermis, Salmonella sp*., *Helicobacter pylori* and *Parahemolyticus* (Chang *et al*., 2001; Taback *et al*., 1999). Medicinal plants are -

Table 1: Chemical constituents of different parts of cinnamon (Vangalapati *et al.*, 2012)

Parts of the plant	Compound
Leaves	Cinnamaldehyde (1.0 - 5.0%), Euginol (70.0 - 95.0%)
Bark	Cinnamaldehyde (65.0 - 80.0%), Euginol (5.0 - 10.0%)
Root bark	Camphor (60.0%)
Fruit	*Trans-Cinnamyl* acetate (42.0 - 54.0%), Caryophyllene (9.0 - 14.0%)
C. zeylanicum buds	Terpene hydrocarbons (78.0%), *Alpha*-Bergamotene (27.38%) *Alpha*-Copaene (23.05%), Oxygenated terpenoids (9.0%)
C. zeylanicum flowers	(E)-Cinnamyl acetate (41.98%), Trans-alpha-Bergamotene (7.97%) Caryophyllene oxide (7.20%)

important for pharmacological research and drug development. One fifth of all the plants found in India are used for medicinal purpose. Bark of Cinnamon is one of most widely used as spice due to its distinct odour of essential oils. Cinnamon was found very safe and can be used as spice for longer period. Several reports have been dealt with the numerous properties of cinnamon in the forms of bark, essential oils, bark powder, phenolic compounds, flavonoids and isolated components. The antioxidant and antimicrobial activities may occur through the direct action on oxidants or microbes, whereas the anti-inflammatory, anticancer, and antidiabetic activities occur indirectly via receptor-mediated mechanisms. The significant health benefits of numerous types of cinnamon have been explored. Since the informations on benefits of cinnamon as poultry feed additives are sparsely available, the present reviews entitled "Use of cinnamon in the diet of broiler chicken" was done on following headings:

2. Body Weight and Growth Rate

Lee *et al.* (2003) found that the feeding of thymol, cinnamaldehyde or CRINA poultry did not affect growth performance, micronutrient digestibility or plasma lipids in female broiler chickens. Lee *et al*. (2004) reported that the addition of cinnamon to the diet of broilers improved their growth performance. Mull and Liebert (2007) found no significant effects of 2 commercial PFA containing 5% carvacol, 3% cinnamaldehyde and 2% capsicum oleoresin, or the alkaloids sanguinarin and chelerythrin on the growth performance in broiler chickens. Chang *et al*. (2008); Park (2008) reported that cinnamon extract supplementation had significantly higher daily gain and lower feed to gain ratio. Al-Kassie (2009) found positive effect of ground thyme and cinnamon on the live weight gain and improvement of the health of broiler chickens, in addition to the other performance traits, feed conversion ratio and feed intake. Al-Kassie (2009) reported that chicks fed with 200 ppm EO derived from thyme and cinnamon had significantly ($P<0.05$) higher body weight gain followed by chicks fed with 100 ppm EO derived from thyme and cinnamon and the least with control group chicks. Koochaksaraie *et al*. (2011) reported that addition of cinnamon at 500 to 2000 mg/kg diet had no effect on growth of the broiler chicken. Toghyani *et al*. (2011) reported that dietary inclusion of cinnamon @ 2 g/kg diet improved body weight significantly and suggested that it could be as alternative to antibiotic growth promoters in broilers. Ebrahimi *et al*. (2013) found that the body weight of the broilers was significantly higher in the group supplemented with cinnamon diet. Sang-Oh *et al*. (2013) reported that growth performance and meat quality improved significantly when diets were supplemented with 3, 5 and 7 percent of cinnamon powder compared to the control birds. Sampath and Atapattu (2013) found that supplementation of cinnamon powder had no effect on final live body weight of the broiler chickens. Najafi and Taherpour (2014) found that the inclusion of ginger *(Zingiber officinale*) and cinnamon (*Cinnamomum*) in addition to the broiler diet enhanced the growth and could also improve the health statue. Safa-Eltazi (2014) reported that dietary inclusion of cinnamon at 5% had significantly ($P<0.05$) higher body weight gain, feed intake and best feed conversion ratio. Singh *et al*. (2014) reported that the dietary inclusion of cinnamon might improved the growth performance of broilers. Symeon *et al*. (2014) reported that body weight, feed intake and feed conversion ratio of broiler chicken had no significant effect with cinnamon oil supplementation. Shirzadegan (2014) observed that supplementing different concentrations of cinnamon powder in the diet (especially at a level of 0.50%) increased the final body weight of broiler chickens.

3. Feed Intake and Feed Conversion Efficiency

Jamroz and Kamel (2002) reported that broilers fed with combination of essential oils like capsaicin, carvacrol and cinnamaldehyde showed higher weight

gain and better feed conversion ratio. Hernandez *et al*. (2004) reported no difference in the feed intake or FCR in broilers fed 200 mg/kg of diet with essential oils extracted from oregano, cinnamon and pepper or 5000 mg/kg of diet with a labiates extract from sage, thyme and rosemary. Jamroz *et al.* (2005) showed that the supplementation of feed mixtures with plant extract consisting of capsaicin, cinnamaldehyde and carvacrol improved feed conversion by 4.1% with a maize diet and 2.0% with a wheat and barley diet, whereas the BW was not affected. Garcia *et al*. (2007) reported that the dietary supplementation with a blend of oregano, cinnamon and pepper essential oil (200 ppm) improved the FCR (0-42 days). Al-Kassie (2009) study showed that the supplementation of 200 ppm oil extract derived from thyme and cinnamon in broiler diets significantly improved the live weight gain and feed conversion ratio during a growing period of 6 weeks. Toghyani *et al.* (2011) found no difference in feed intake and FCR of broilers after the dietary incorporation of cinnamon powder. Sampath and Atapattu (2013) found that supplementation of dietary CNPW tends (P=0.09) to increase the feed intake and feed conversion ratio (FCR) but had no effects on final live weight, weight gain, visceral organ weight, and gizzard, cloaca and total fat contents or serum cholesterol level. Hossain *et al.* (2014) found significantly (P<0.005) better FCR and body growth on supplementation with 1% cinnamon, 1% black cumin and 1% chilli powder. Shirzadegan (2014) found that the administration of cinnamon powder (CP) had significant effects (P<0.05) on final body weight, body weight gain, feed intake, feed conversion ratio (FCR), liver weight, glucose level, thiobarbituric acid (TBA) and breast fat percentage of broiler chicks. Najafi and Taherpour (2014) showed that broilers birds supplemented with feed additives decreased (P<0.05) feed intake and body weight gain, but improved (P<0.05) feed conversion ratio as compared to the control group during the whole experimental period (1-42 days).

4. Carcass Traits and Organ Weight

Lee *et al*. (2003) reported no significant differences in the internal organs of the broiler chickens when incorporated with cinnamaldehyde (100 ppm). Hernandez *et al*. (2004) concluded that the Labiatae extract and the blend of carvacrol, cinnamaldehyde and capsaicin improved the digestibility of the feeds but no effects were noted on organ weight. Garcia *et al*. (2007) observed that a blend of oregano, cinnamon and pepper oil (200 ppm) had no influence on carcass weight of broilers. However, breast weight (% of carcass) appeared to increase after the incorporation of a plant extract based on a blend of clove and cinnamon oil (100 ppm). Byung-Sung (2008) reported that the sensory evaluation of the taste and savour in fried and boiled chicken meat were better from broiler chicken fed with diets containing cinnamon powder. Al-Kassie (2009) found that different levels of oil extract derived from thyme and cinnamon had significant effects on dressing percentage, abdominal fat, and internal organs percentage (liver, heart and gizzard). Ciftci *et al*. (2009) reported that supplementation of cinnamon oil (500, 1000 ppm) in diet decreased the cholesterol levels of serum and chicken meat. But they also suggested that dietary cinnamon supplementation would improve the nutritional quality of chicken meat as cinnamon oil plays an important role as an endogenous antioxidant and could be applicable as a protective agent against tissue damage. Isabel and Santos (2009) found no effect on dietary supplementation with plant extract based on a blend of clove and cinnamon oil (100 ppm). Stefan *et al*. (2009) did not observe any effect of cinnamon on the concentration of MDA in the liver and kidney tissues. Koochaksaraie *et al*. (2011) revealed that supplementation of cinnamon powder at the dose of 250 to 2000 mg/kg broiler diets did not have any influence on the carcass parameters. Toghyani *et al*. (2011) observed no impact of diets on carcass parameters supplemented with 2 and 4 g/kg of cinnamon powder in broilers. He also found that the sensory evaluation showed no change in meat flavour and odour intensity or desirability after the dietary supplementation. Sampath and Atapattu (2013) reported that the dietary supplementation of CNPW at 0.1 and 0.4 percent increased the abdominal fat content as compared to control. It was concluded that dietary CNPW used had no growth promoting or fat reducing effects in broiler chicken. Sang-Oh *et al*. (2013) reported that dietary supplementation of cinnamon powder at 5 percent level to broilers improved the quality of chicken meat including colour, flavour, texture and overall acceptability and shelf life. Safa-Eltazi (2014) reported that the broiler chicken fed with cinnamon showed significantly (P<0.05) higher flavour scores for breast and thigh meat and also improved the dressing percentage significantly (P<0.05). Singh *et al.* (2014) reported that the supplementation of dietary cinnamon improved (P<0.05) the sensory attributes of the meat as compared to control group. Symeon *et al*. (2014) reported that carcass and meat characteristics of the broilers chickens had no significant effect with cinnamon oil supplementation at the concentrations of 0.5 and 1 ml/kg feed. Shirzadegan (2014) observed that the addiction of CP to the diets of broiler chicks had no significant effects (P>0.05) on cholesterol, triglyceride, low density lipoproteins (LDL), abdominal fat, gizzard and heart weights and on breast protein percentage. Najafi and Taherpour (2014) reported no significant

effect (P>0.05) on the relative weights of spleen, bursa of Fabricius and thymus with dietary treatment of cinnamon.

5. Economics

Safa-Eltazi (2014) reported that the highest profitability ratio was obtained by the diet supplemented with 5% cinnamon powder in the broiler diet. Singh *et al*. (2014) revealed that dietary inclusion of cinnamon powder at 0.5 percent level had the potential to act as a natural alternative to antibiotic growth promoters in respect of cost. Hossain *et al.* (2014) concluded that addition of cinnamon powder at 1 percent dose resulted in significantly (P<0.05) higher BCR than the control.

6. Conclusion

It can be concluded that use of cinnamon in the diet of broiler chicken at various level has positive impact on the performance in terms of body weight gain, feed intake and FCE, overall performance index, carcass characteristics as well as net profit per birds over control group. It has positive impact on blood profile and is also effective for the antioxidant, antimicrobial, anti-inflammatory, anticancer and antidiabetic activities via receptor mediated mechanisms.

References

Al-Kassie GA (2009). Influence of two plant extracts derived from thyme and cinnamon on broiler performance. *Pakistan Veterinary Journal*, 29(4): 169-173.

Byung SP (2008). Effects of dietary cinnamon powder on savour and quality of chicken meat in broiler chicken. *Journal of Korean Society of Food Science and Nutrition*, 37: 618-624.

Chang ST, Chen PF and Chang SC (2001). Antibacterial activity of leaf essential oils and their constituents from *Cinnamomum osmophloeum. Journal of Ethnopharmacology*, 77: 123-127.

Chang ST, Yeh FH, Luo YC, Lin YC, Cheng SS and Hsu RY (2013). Methods for thermal stability enhancement of leaf essential oils and their main constituents from indigenous Cinnamon (*C. osmophloeum*). *Journal of Agricultural and Food Chemistry*, 61(26): 6293-698.

Chang ST, Chang LW, Chang WC and Cheng SS (2008). Antibacterial activities of plant essential oils against *Legionella pneumophila*. *Water Research*, 42(1-2): 278-286.

Chou ST, Chang LW, Chang TC, Hsu LS, Lin CY and Shih Y (2013). *Cinnamomum cassia* essential oil inhibits alpha-MSH-induced melanin production and oxidative stress in murine B16 melanoma cells. *International Journal of Molecular Sciences*, 14(9): 19186-19201.

Ciftci M, Dalkilic B, CerciI H, Guler T, Ertas ON and Arslan O (2009). Influence of dietary cinnamon oil supplementation on performance and carcass characteristics in broilers. *Journal of Applied Animal Research*, 36: 125-128.

Ebrahimi M, Hoseini A, Palizdar MH, Mohamadian-Tabrizi HR and Porelmi MR (2013). Effect of cinnamon, red pepper, ginger and cumin on broiler performance. *Research Opinions in Animal and Veterinary Sciences*, 3(5): 131-135.

Fellenberg MA and Speisky H (2006). Antioxidants: Their effects on broiler oxidative stress and its meat oxidative stability. *World Poultry Science Journal*, 62: 53-57.

Garcia V, Catala-Gregori, Hernandez F, Megias MD and Madrid J (2007). Effect of formic acid and plant extracts on growth, nutrient digestibility, intestine mucosa morphology and meat yield of broilers. *Journal of Applied Poultry Research*, 16: 555-562.

Guo FC (2003). Mushroom and herb polysaccharides as alternative for antimicrobial growth promoters in poultry. Ph.D Dissertation, Wageningen University, The Netherlands.

Hashemi SR and Davoodi H (2010). Phytogenic as new class of feed additive in poultry industry. *Journal of Animal and Veterinary Advances*, 9: 2295-2304.

Hernandez F, Madrid J, Garcia V, Orengo J and Megias MD (2004). Influence of two plants extracts on broilers performance, digestibility and digestive organ size. *Poultry Science*, 83: 169-174.

Hossain MM, Howlader AJ, Islam MN and Beg MAH (2014). Evaluation of locally available herbs and spieces on physical, biochemical and economical parameters on broiler production. *International Journal of Plant, Animal and Environment Sciences*, 4: 317-323.

Huang CT, Fu YH, Ho TC, Tan D, Huang TY and Pan HM (2007). Induction of apoptosis by cinnamaldehyde from indigenous cinnamon (*Cinnamomum osmophloeum)* Kaneh through reactive oxygen species production, glutathione depletion, and caspase activation in human leukaemia K562 cells. *Food Chemistry*, 103(2): 434-443.

Isabel B and Santos Y (2009). Effects of dietary organic acids and essential oils on growth performance and carcass characteristics of broiler chickens. *Journal of Applied Poultry Research*, 18: 472-476.

Jakhetia V, Patel R, Khatri P, Pahuja N, Garg S, Pandey A and Sharma S (2010). Cinnamon: a pharmacological review. *Journal of Advanced Scientific Research*, 1: 19-23.

Jamroz D and Kamel C (2002). Plant extracts enhance broiler performance. *Journal of Animal Science*, 80-141.

Jamroz D, Wiliczkiewicz A, Wertelecki T, Orda J and Skorupinska J (2005). Use of active substances of plant origin in chicken diets based on maize and locally grown cereals. *British Poultry Science*, 46: 485-493.

Kamel C (2001). Tracing modes of action and roles of plant extracts in non-ruminants. *Recent Advances in Animal Nutrition*, 135-150.

Ketharaj M and Jeyakumar S (2009). The silver lining in the stagnant agriculture sector. *Poultry Farming*. http://www.ffymag.com. Accessed on 15 January 2010.

Kim DK, Lillehoj HS, Lee SH, Jang SI and Bravo D (2010). High throughout gene expression analysis of intestinal intraepithelial lymphocytes after oral feeding of carvacrol, cinnamaldehyde or capsicum oleoresin. *Poultry Sciences,* 89: 68-81.

Koochaksaraie RR, Irani M and Gharavysi S (2011). The effects of cinnamon powder feeding on some blood metabolites in broiler chicks. *Brazilian Journal of Poultry Science,* 13: 197-101.

Kotaiah T (2016). Poultry production in India - The current scenario. http://fnbnews.com. Accessed on 30 may 2017.

Lee KW, Everts H, Kappert HJ, Frehner M, Losa R and Beynen AC (2003). Effects of dietary essential oil components on growth performance, digestive enzymes and lipid metabolism in female broiler chickens. *British Poultry Science,* 44(3): 450-457.

Lee KW, Everts H and Beynen AC (2004). Essential oil in broiler nutrition. *International Journal of Poultry Science*, 3: 738-752.

Marongiu B, Piras A and Porcedda S (2007). Supercritical CO_2 extract of *Cinnamomum zeylanicum:* chemical characterization and antityrosinase activity. *Journal of Agricultural and Food Chemistry,* 55(24): 10022-10027.

Mehta R and Nambiar RG (2013). Poultry industry in India. http://www.fao.org. Accessed on 10 March 2016.

Mull A and Liebert F (2007). Growth nutrient utilization and threonine requirement of growing chicken fed threonine-limiting diets with commercial blends of phytogenic feed additives. *Japanese Poultry Science,* 44: 297-304.

Najafi S and Taherpour K (2014). Effects of dietary Ginger (*Zingiber officinale*), Cinnamon (*Cinnamonum*), Synbiotic and antibiotic supplementation on performance of broilers. *Journal of Animal Sciences Advances,* 4(1): 658-667.

Nonaka IG, Morimoto S and Nishioka I (1983). Tannins and related compounds. Part 13. Isolation and structures of trimeric, tetrameric, and pentameric proanthicyanidins from cinnamon. *Journal of the Chemical Society, Perkin Transactions,* 1: 2139-2145.

Park BS (2008). Effect of dietary cinnamon powder on savour and quality of chicken meat in broiler chickens. *Journal of Korean Society of Food Science and Nutrition*, 37: 618-624.

Safa-Eltazi MA (2014). Effect of using cinnamon powder as natural feed additive on performance and carcass quality of broiler chickens. *International Journal of Innovative Agriculture and Biology Research,* 2(3): 1-8.

Sampath HKR and Attapattu NSBM (2013). Effects of cinnamon (*Cinnamon zeylanicum*) bark powder on growth performance, carcass fat and serum cholesterol levels of broiler chicken. In: Proceedings of 3rd International Symposium. Held from 6-7 July at SEUSL, Oluvil, Sri Lanka.

Sang-Oh P, Chae MR, Byung-Sung P and Jong H (2013). The meat quality and growth performance in broiler chickens fed diet with cinnamon powder. *Journal of Environmental Biology*, 34: 127-133.

Senanayake MU, Lee HT and Wills RBH (1978). Volatile constituents of cinnamon (*Cinnamomum zeylanicum*) oils. *Journal of Agricultural and Food Chemistry,* 26(4): 822-824.

Shirzadegan K (2014). Reactions of modern broiler chickens to administration of cinnamon powder in the diet. *Iranian Journal of Applied Animal Sciences,* 4(2): 387-371.

Singh G, Maurya S, Cesar MP and Catalan AM (2007). A comparison of chemical, antioxidant and antimicrobial studies of cinnamon leaf and bark volatile oils, oleoresins and their constituents. *Food and Chemical Toxicology,* 45: 1650-1661.

Singh J, Sethi APS, Sikka SS, Chatli MK and Kumar P (2014). Effect of cinnamon (*C. Cassia*) powder as a phytobiotic growth promoter in commercial broiler chickens. *Animal Nutrition and Feed Technology,* 14: 471-479.

Stefan F, Placha ZFI and Koppel J (2009). Effect of *Cinnamomum Zeylanicum* essential oil on oxidative status in broiler chickens. *Acta Veterinarian Brunensis,* 78: 411-417.

Symeon GK, Athanasiou A, Lykos N, Charismiadou MA, Goliomytis M, Demiris N, Ayoutanti A, Simitzis PE and Deligeorgis SG (2014). The effects of dietary cinnamon (*Cinnamomum zeylanicum*) oil supplementation on broiler feeding behaviour, growth performance, carcass traits and meat quality characteristics. *Annals of Animal Sciences,* 14(4): 883-895.

Taback M, Armon R and Neeman I (1999). Cinnamon extracts inhibitory effect on *Helicobacter pylori*. *Journal of Ethnopharmacology,* 67: 269-277.

Toghyani M, Gheisari A, Ghalamkari G and Eghbalsaied S (2011). Evaluation of cinnamon and garlic as antibiotic growth promoter substitutions on performance, immune responses, serum biochemical and haematological parameters in broiler chicks. *Livestock Science,* 138(1): 167-173.

USDA (2011). Indian egg and poultry production. http://www.poultryworld.net. Accessed on 26 August 2011.

Vangalapati M, Sree Satya M, Surya PD and Avanigadda S (2012). A review on pharmacological activities and clinical effects of cinnamon species. *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* 3(1): 653-663.