Supplementation value of *Cinnamomum ceylon* powder on growth performance, serum metabolites, antioxidant activities and meat analysis of broiler chickens.

Abstract

This study examined the effect of *Cinnamomum ceylon* powder (CCP) supplementation on growth performance, serum metabolites, antioxidant activities and meat analysis of broiler chickens. A total of 128 broiler chicks were randomly allocated into 4 treatments with 4 replicates of 10 birds each as follows: Diet 1 (control) Diet 2 (diet supplemented with 0.2% *Cinnamomum ceylon* powder), Diet 3 (diet supplemented with 0.4% *Cinnamomum ceylon* powder) Diet 4 (diet supplemented with 0.6% *Cinnamomum ceylon* powder) using a Completely Randomized Design. The dietary CCP supplementation significantly (P<0.05) increased the final live-weight, bodyweight, feedintake of the broiler chickens compared to those fed the control diet during the feeding trial. The CCP supplementation significantly (P<0.05) reduced the glucose and cholesterol levels of broiler chickens fed 0.4 and 0.6% CCP supplementation compared to those fed the control diet. No significant difference were observed in the measured aspartate aminotransferase (AST), alanine aminotransferase (ALT), triglyceride and creatinine. The broiler chicken fed diets supplemented with CCP had higher (P<0.05), total serum glutathione peroxidase and catalase compared to those fed the control diet. The concentration of muscle cholesterol and lipid peroxidation reduced significantly (P<0.05) in the birds fed CCP supplemented diets compared to those fed the control diet. In conclusion, this study has shown that CCP can be used to 0.6% as an antibiotic growth promoter supplement in a broiler diet to improve the performance characteristics, antioxidant capacity to scavenge free radical and other reactive species also lower meat cholesterol level and lipid oxidation.

Keywords: Cinnamon powder, Antioxidant enzymes, lipid peroxidation, growth performance, broilers

Introduction :

The poultry industry is one of the world's most important agricultural sectors (1). Supplementing poultry diets with natural products rich in bioactive components has yielded promising results (2). Aromatic plants and essential oil extracts have antimicrobial effects on pathogens (3), which stimulate the digestive system (4). Herbs, spices, and extracts have received increased attention as potential antibiotic growth promoter (AGP) alternatives due to their natural, readily available, non-toxic, and residue-free properties. This makes them ideal as natural feed additives for poultry. However, the use of antibiotics in poultry and livestock has been linked to an increase in multidrug-resistant germs (5). Furthermore, (6) found that antibiotics used in birds on their first day of life had a negative impact on microbial colonization and intestinal function over 14 days. The prohibition on antibiotic use in farm animals has prompted researchers to investigate alternative agents such as enzymes, organic acids, and phytogenic feed additives derived from spices and herb plants (7).

Comment [P1]: Bodyweight

Comment [P2]: feedintake

Phytogenic feed additives are used in broiler feeds, and their economic impact on body weight (BW) and feed conversion ratio (FCR) varies significantly throughout the first stages of life (8). Cinnamon is a natural spice derived from the inner bark of a cinnamon tree. The tree is found all over the world and has about 250 different species (9). Cinnamon bark can be used as a phytogenic feed additive in starter diets due to its phytochemical content, including cinnamaldehyde, eugenol, caryophyllene, water, electrolytes, and phytonutrients like β-carotene, β-cryptoxanthin, lutein, and lycopene (10). So, according to studies by (11), (12), (13), (14), and others, cinnamon has antiviral, antimicrobial, antioxidant, and antidiabetic properties. Accordingly, reports suggest that cinnamon can be used as a natural preservative for food products (15), an appetite enhancer, help secrete digestive enzymes during digestion, and enhance broiler performance (16). The study aimed to investigate the effect of *Cinnamon ceylon* powder (CCP) supplementation on performance, serum biochemical indices, antioxidant status and meat cholesterol of broiler chickens.

Material and methods

Comment [P3]: Delete

Materials and methods

Location of the experimental site: The study was carried out in the Poultry unit, Teaching and Research Farm, Department of Agricultural Technology. The Federal Polytechnic, Ado, Ekiti-State, Nigeria. The state is situated in the nation's southwest. Ekiti State covers a land area of 6355km square (2,453 sqm) with a population estimated in 2010 to be 3,737,199. It enjoys a tropical climate with two different seasons
these are dry and wet season (April to October) and the rainy season (November to March) dry season. Ado-Ekiti has a temperature range between 21^{0}C to 28^{0}C.

Site Preparation: The poultry house was thoroughly washed, fumigated, and disinfected. The house was allowed to stay for two weeks before the arrival of experimental birds and proper weeding of the surrounding was carried out 2to prevent reptiles.

Test ingredients: The test ingredient *Cinnamomum ceylon* powder (CCP) supplementation used was obtained from a local market. The bark was crushed and ground using a blender to a fine powder (particle size: 0.25-0.30mm) and was packed into an airtight container.

Management of experimental birds :A total number of 128 birds of Cobb-500 breeds were used for the experiment. The birds were purchased from a reputable hatchery for this study. The chicks were brooded for two weeks for acclimatization using electric bulb as a source of light and heat in the pen. In the brooding house enough provision was made for space, ventilation, polythene were also used to cover the pen to provide warmth and protection against predators and extreme of weather. The experimental pen temperature was maintained at 31^{0}C± 2 for the first 7 days and gradually reduced by 2^{0}C after each consecutive week until the experimental house temperature was 26^{0}C±2.They were fed the experimental diet for 8weeks. Proper and adequate management practice was observed. All vaccination were given as appropriate through the period of the experiment. Feed and water were given *ad-libitum.*

Experimental diets: The composition of experimental diets were presented in table 1 below. The basal diets were formulated for broiler starter (0-28 day) and finisher (29-56 day). The experimental diets used for the study were compounded on the floor at the premises of the Teaching and Research Farm, Federal Polytechnic, Ado-Ekiti. The diets were formulated to be iso-caloric and iso-nitrogenous. Diet 1- control diet (diet without supplementation), diet 2-

contained 0.2% CCP supplementation, diet 3 contained 0.4% CCP supplementation and diet 4-contained 0.6% CCP supplementation.

Table 1 Composition of experimental diet (%) for broiler starter and finisher

Ingredients	Broiler starter	Broiler finisher
Maize	51.00	60.00
Soybean cake	23.00	15.00
Groundnut cake	16.00	16.00
Fish meal	2.00	2.00
Bone meal	4.00	3.00
Limestone	2.00	2.00
Broiler premix	0.25	0.25
Methionine	0.25	0.25
Lysine	0.25	0.25
Common salt	0.25	0.25
Vegetable oil	1.00	1.00
Total	100.00	100.00
Calculated composition		
Metabolizable Energy	2938.00	3031.00
Crude protein	24.68	19.50
Calcium	2.35	1.99
Phosphorus	0.84	0.65
Lysine	1.33	1.27
Methionine	0.60	0.58

Experimental design

A total of one hundred and twenty-eight (128) birds were used in this study. There were four experimental diets with four replicate per treatment. Eight birds were allocated per replicate amounting to 32 birds per treatments using a completely randomized design. The birds were used to assess the varying levels on the growth performance of broiler chickens.

Data collection

The test ingredient *Cinnamomum ceylon* supplementation used in this study was obtained from a local market. The bark was crushed and ground using a blender to a fine powder (particle size: 0.25-0.30mm) to produce *Cinnamomum Ceylon* powder (CCP). The CCP were analyzed for flavonoids (17), phenol (18), saponin (19), terpenoids (20), ferric-reducing antioxidant property (21) and 2,2-diphenyl-1-picrylhydrazy hydrate (22).

The growth performance: Body weight and feed intake of the experimental birds were taken weekly. The average body weight (BW) was calculated by determining the differences between the initial weights and final live weights of the birds in the experimental group. Feed conversion ratio was calculated by dividing the feed intake by the weight gain.

On day 56 of the experiment, four birds per replicate were randomly selected, weighed, stunned and sacrificed. The jugular veins in the neck region of the selected birds were cut with a sharp and clean knife. The birds' blood was allowed to flow into a plain sample bottle for serum metabolites (aspartate amino transferase, alanine amino transferase, triglycerine, creatinine, glucose and cholesterol) and serum antioxidant enzymes (catalase, glutathione peroxidase and superoxide dismutase) determination. Using a Reflectron Plus 8C79 (Roche Diagnostic, GombH Mannheim, Germany), the serum metabolites were determined. The glutathione peroxidase and superoxide dismutase were determined as described by (23) and (24), respectively. About 100g of the bird's breast meat was cut out the determination of the meat cholesterol (25) and meat lipid peroxidation (26).

Statistical Analysis:
The model: $Dny = \mu + \alpha\eta + \beta ny$, was used in this experiment, where Dny = any of the response variables ; n = the overall mean; αn = effect of the nth treatment (D= diets 1,2,3and 4) ; and βny = random error due to experimentation. The data obtained in the study were subjected to one-way analysis of variance using the SPSS software programme. The means were compared ($p<0.05$) using Duncan's Multiple Range Test (DMRT).

Results

Phytochemical composition and antioxidant activity of *Cinnamomum Ceylon* powder (CCP)
The phytochemical constituents and antioxidant activity of *Cinnamum Ceylon* powder (CCP) are presented in Table 2. The result shows that CCP possessed high flavonoid (80.54mg/g), phenol (19.02mg/g), saponin (68.25mg/g) and terpenoids (120.20mg/g) contents.
The result of the antioxidant activity revealed that CCP showed 78.25%, 2,2-diphenyl-1-picrylhydrazyl hydrate (DPPH) and 20.75mg/g ferric-reducing antioxidant property (FRAP).

Table 2: Phytochemical composition and antioxidant activity of *Cinnamomum ceylon* powder

Parameter	Quantity (mg/g)
Flavonoid	80.54
Phenol	19.02
Saponin	68.25
Terpenoids	120.20
DPPH (%)	78.25
FRAP	20.75

The result of the effect of varying levels of cinnamon on growth performance of broiler chicken is shown in Table 3. There were significant differences in final live-weight, body weight gain, feed intake and feed conversion ratio among treatments ($p<0.05$). The highest final live-weight (FLW) was recorded for birds fed 0.4% CCP supplemented diet at 3047.48g while the least FLW was recorded for birds on control diet at 2754.48g. The body weight of birds on 0.4% and 0.6% CCP supplemented diets were similar ($P>0.05$) but significantly ($P<0.05$) higher than birds on control diet and 0.2% CCP supplemented diet. The feed intake of birds on diets 3 and 4 were similar ($P>0.05$) but significantly ($P<0.05$) higher than birds on control diet and diet 2. The highest feed intake was recorded for birds on 0.4% CCP supplemented diet at 6215.18g while the lowest feed intake was recorded for birds on control diet at 5709.90g. The FCR of birds on control diet and 0.6% CCP supplemented diet were similar (P>0.05) but significantly (P<0.05) higher than the values recorded for birds on 0.2 and 0.4% CCP supplemented diet.

Table 3. Effect of varying levels of *Cinnamomumceylon* on growth performance of broiler chickens

Parameters	*Cinnamomum ceylon* inclusion (%)				SEM	*p- value*
	T1	T2	T3	T4		
	0	0.2	0.4	0.6		
Final liveweight (g)	2754.48[c]	2872.48[b]	3047.48[a]	2927.48[a]	8.9	0.02
Body weight /b/d (g)	48.55[c]	50.49[b]	53.62[a]	51.47[a]	2.37	0.03
Feed intake/b/d (g)	101.96[c]	103.49[b]	110.99[a]	109.63[a]	8.56	0.04
Feedconversion ratio	2.10[a]	2.05[b]	2.07[b]	2.13[a]	0.02	0.01

Means within a row with different letters are significantly different (P<0.05)

Comment [P4]: Liveweight

Comment [P5]: Delete space

Effect of varying levels of *Cinnamomumceylon* on serum metabolites of broiler chickens is presented in Table 4. The aspartate aminotransferase (AST), alanine aminotransferase (ALT), triglyceride, creatinine were not affected (P>0.05) by the dietary treatment. There were significant difference in glucose and cholesterol (p<0.05). The highest glucose value was recorded for birds on control diet and 0.2% CCP supplemented diets which were similar (P>0.05) but significantly higher (P<0.05) than the values recorded for birds on 0.4 and 0.6% supplemented diets. The cholesterol values of birds on 0.2, 0.4 and 0.6% CCP supplemented diets were similar (P>0.05) but significantly lower (P<0.05) than the values recorded for birds on control diet.

Table 4. Effect of varying levels of *Cinnamomumceylon* on serum metabolites of broiler chickens

Parameters	*Cinnamomum ceylon* inclusion (%)				SEM	*p- value*
	T1	T2	T3	T4		
	0	0.2	0.4	0.6		
AST (µ/l)	100.32	77.54	76.75	77.84	5.21	0.75
ALT (µ/l)	45.73	47.35	45.62	46.68	0.42	0.71
Triglyceride(mmol/l)	1.80	1.62	1.85	1.77	0.07	0.72
Creatinine(mmol/l)	18.49	21.24	24.24	23.57	1.14	0.31
Glucose(mmol/l)	8.95[a]	6.69[a]	5.12[b]	4.17[c]	0.04	0.02
Cholesterol (mmol/l)	0.42[a]	0.39[b]	0.37[b]	0.33[b]	0.02	0.01

Means within a row with different letters are significantly different (P<0.05) AST: aspartate aminotransferase ; ALT: Alanine aminotransferase

Effect of varying levels of *Cinnamomumceylon* on serum metabolites of broiler chickens is presented in Table 5. The serum catalase and glutathione peroxidase of birds fed *CinnamomumCeylon* powder supplemented diets were significantly higher (P<0.05) than those fed the control diets. The serum superoxide dismutase of birds were not significantly (P>0.05) affected by CCP supplemented diets.

The meat cholesterol level decreased significantly (P<0.050 in the birds fed the CCP supplement compared to the control diet. In the same vein, the lipid peroxidation of meat of broiler chickens fed CCP supplemented diets were significantly (P<0.05) lower compared to those fed the control diets.

Table 5. Effect of varying levels of *Cinnamomumceylon* on antioxidant activities and meat analysis of broiler chickens

Parameters	*Cinnamomum ceylon* inclusion (%)				SEM	*p- value*
	T1	T2	T3	T4		
	0	0.2	0.4	0.6		
Catalase	2.41[d]	5.31[c]	6.34[b]	7.18[a]	0.54	0.01
GPx(µg.g^{-1})	61.94[c]	75.26[b]	78.48[a]	78.59[a]	2.07	0.01
SOD (%)	63.69	63.92	64.15	64.30	0.52	0.71
Meat analysis						
Cholesterol(mg/dl)	61.54[a]	59.63[a]	28.42[b]	23.82[b]	4.25	0.01
Lipid peroxidation (mg/MDA)	4.65[a]	2.62[b]	2.19[d]	2.37[c]	0.34	0.01

Means within a row with different letters are significantly different (P<0.05)

Discussion

According to the findings of this study's phytochemical and antioxidant analysis, CCP is rich in phenols, flavonoids, saponins, and terpenoids and has a potent scavenging action on free radicals and other reactive oxygen species when added as a phytogenic feed additive. According to several studies, phytogenic feed additives are rich in polyphenols, flavonoids, saponins, terpenoids, and other bioactive compounds with antioxidant qualities that help scavenge free radicals and enhance the health and performance of chickens (27; 28). These plant-derived, non-enzymatic antioxidants that chelate metals to stop them from taking part in the metal-mediated Haber-Weiss reaction interact with reactive oxygen species either directly or indirectly. Furthermore, by stabilizing free radicals with electron donations, these non-enzymatic antioxidants derived from phytochemicals can scavenge free radicals and impede their attack on biological targets (29). This outcome is consistent with reports from other authors about cinnamon According to the findings of this study's phytochemical and antioxidant analysis, CCP is abundant in phenols, flavonoids, saponins, and terpenoids and has a potent scavenging action on free radicals and other reactive oxygen species when added as a phytogenic feed additive. According to several studies, phytogenic feed additives are rich in polyphenols, flavonoids, saponins, terpenoids, and other bioactive compounds with antioxidant qualities that help scavenge free radicals and enhance the health and performance of chickens (27, 28). These plant-derived, non-enzymatic antioxidants that chelate metals to stop them from taking part in the metal-mediated Haber-Weiss reaction interact with reactive oxygen species either directly or indirectly. Furthermore, by stabilizing free radicals with electron donations, these non-enzymatic antioxidants derived from phytochemicals can scavenge free radicals and impede their attack on biological targets (29). This finding is consistent with reports from other authors that Cinnamomum Ceylon powder has a high content of phenolic compounds (30) and has the ability to scavenge free radicals against 2,2-diphenyl-1-picrylhydrazyl hydrate (DPPH) radicals (31).

Eugenol and cinnamon aldehyde, two of CCP's active ingredients, may improve feed utilization efficiency and accelerate growth rate. Improvements in bodyweight and feed conversion ratio in birds fed 0.4% and 0.2% supplemented diet, respectively, may be explained by this. This

Comment [P6]: bodyweight

illustrates how spices and herbs can stimulate appetite, aid in digestion, and have antibacterial properties (32). Herbs with strong aromas, like cinnamon, were used to mimic the effects of a chicken's digestive tract. On the other hand, (33) found that broiler diets containing aromatic plants had the opposite effect on bodyweight. The insulin regulating mechanisms of feed intake include the lipostatic theory, thermostatic theory, glucostatic theory, and protein intake hypothesis, as demonstrated by (34). Additionally, studies revealed that hypoglycemia activates a neurological system linked to feed consumption, while hyperglycemia increases the animal brain's center of satiety. One possible explanation for the difference in feed intake between the treatment and control diet groups could be the increased levels of glucagon or the glucostatic hypothesis. The diets supplemented with 0.6% cinnamon performed the lowest (FCR) in comparison to other experimental diets. This could be as a result of the spice's constituents, which include coumarin, alkaloids, and other antinutritional elements, having potentially negative effects (33).

The results of the serum enzyme constituents are significant in determining the health status and the physiological responses of animals to treatments. In addition, the majority of serum enzymes are tissue specific, and their abnormal rise in serum concentration connotes tissue damage (35). The results of this study showed that, when compared to other treatments, CCP supplements had no discernible effect on the serum levels of creatinine, triglycerides, aspartate aminotransferase (AST), and alanine aminotransferase (ALT) in broiler chickens. The observed parallels show that the CCP supplement is safe and provides adequate nutrition for broiler chickens. Additionally, it demonstrated that the diets had comparable effects and did not harm the broiler chickens' muscles or organs (36). This established the suitability of the CCP at inclusion levels as a phytogenic feed additive for chicken production. The diet supplemented with 0.6% CCP and the control diet showed the lowest and highest glucose levels, respectively. According to (34), adding CCP caused the glucose level to drop noticeably. However, this study found that broiler chickens given CCP supplementation had significantly lower cholesterol levels. *Cinnamomum ceylon's* antioxidant properties prevented lipid peroxidation of tissue lipids, particularly polyunsaturated fatty acids; as a result, cholesterol levels in CCP-supplemented diets were significantly reduced.

The use of phytogenic supplements as antioxidants to reduce the effects of oxidative stress is on the rise (37). Antioxidants that prevent oxidation include catalase, glutathione peroxidase, and superoxide dismutase (38). The observed increase in serum catalase, glutathione peroxidase, and superoxide dismutase activities in birds fed CCP supplemented diets demonstrated CCP's antioxidant properties and potential to improve the antioxidant status of the experimental birds. The results are consistent with the findings of (39), who found increased antioxidant activity in non-ruminant animals fed phytogenic supplemented diets. Because oxidative stress has been identified as a significant factor preventing tropical domestic animals from reaching their full growth potential, the improved oxidative status seen in this study's birds fed the CCP supplemented diets may also be connected to the improved performance noted in the same set of birds (40).

The reduced meat cholesterol level found in broiler chickens fed CCP supplemented diets in this study has health benefits because consumers are concerned about the quality of the products they consume. Meat with low cholesterol is beneficial to health, especially for those with cardiac issues (39). The results clearly demonstrated the hypocholesterolemic effect of the CCP supplements. The observed hypocholesterolemic effect could be attributed to the activities of phytosterols in CCP, which inhibit cholesterol absorption in the intestine due to their similar structure (41). This finding correlates with the findings of (42), who reported a significant decrease in cholesterol levels in broiler chickens fed a CCP diet. Similarly, the lower lipid peroxidation levels in the meat of birds fed CCP supplemented diets compared to controls could be attributed to the higher levels of antioxidant enzymes found in the broiler chickens' muscle for the present study. Lipid peroxidation is the leading non-microbial cause of quality deterioration in muscle food, resulting in off-flavors and oxidized compounds that are harmful to consumer health (42). Studies have shown that phytogenic feed additives can reduce lipid peroxidation in muscle food due to their inherent bioactive components and antioxidant activity (43).

Conclusion

Cinnamon ceylon powder is rich in bioactive compounds that has a potent antioxidant capacity to scavenge free radical and other reactive species. Additionally, this study shows that the inclusion of CCP at 0.2, 0.4 and 0.6% enhanced body weight gain of the broiler chickens and reduced meat cholesterol level and meat lipid peroxidation of the broiler chickens. It could be recommended that dietary inclusion of CCP up to 0.6% to enhance the weight gain, maintain the health status and improved the meat quality of the broiler chickens.

References

Comment [P7]: Put Doi at the end of each referance

Alagawany, M., Elnesr, S.S., Farag, M.R; Abd El- Hack, Khafaga, A.F., Taha, A.E., Dhama, K. (2019). Use of licorice (Glycyrrhiza glabra) herb as a feed additive in poultry: Current knowledge and prospects. Animals 9: 536.

Reda, F.M., Alagawany, M., Mahmoud, H.K., Mahgoub, S.A., Elnesr, S.S. (2019). Use of red pepper oil in quail diets and its effect on performance, carcass measurements, intestinal microbiota, antioxidant indices, immunity and blood constituents. Animal,1-9.

Abd El-Hack, M.E., Mahgoub, S.A., Hussein, M.M., Saadeldin, I.M (2018). Improving growth performance and health status of meat-type quail by supplementing the diet with black cumin cold-pressed oil as a natural alternative for antibiotics. *Environmental Science Pollution Resources*, 25 : 1157-1167.

Osman, N., Talat, G., Mehmet, C., Bestami, D., Simsek, G. (2005).The effect of an essential oil mix derived from oregano, clove and aniseed on broiler performance. *International Journal Poultry Science* 4: 879-884.

Han, T., Zhang,Q., Liu, N., Wang, j., Li, Y., Huang, X., Liu, J., Wang,J., Qu, Z., Qi, K. (2020). Changes in antibiotic resistance of Escherichia coli during the broiler feeding cycle. *Poultry Science*, 99: 6983-6989.

Schokker, D., Jansman, A., Veninga, G., De Bruin, N., Vastenhouw, S.A., De Bree, F.M., Bossrs, A., Rebel, J.M.J., Smits, M.A (2017). Perturbation of microbiota in one –day old broiler chickens with antibiotics for 24 hours negatively affects intestinal immune development. BMC. Genom. 18, 1-14.

Pandey, A.K., Kumar, P., Saxena, M.J (2019). Feed additives in Animal Health. In Nutraceuticals
in Veterinary Medicine, Springe: Berlin, Germany, pp.345-362.

Abdel-Wareth, A.A.A., Kehraus, S., Sudekum, K,H., Peppermint and its respective active component in diets of broiler chickens (2019). Growth performance, viability, economics, meat physicochemical properties and carcass characteristics.*Poultry Science* 98: 3850-3859.

Vangalapati, M., Satya, S., Prakash, S., Avanigadda, S. (2012). A review on pharmacological activities and clinical effects of cinnamon species. Res. Journal of Pharmaceutical, Biology and Chemical ssScience 3: 653-663.

Rao, P.V., Gan, S.H (2014). Cinnamon : A multifaceted medical plant. Evid Based Complement. Alternative medicine,1-12.

Fauvelle, C., Lambotin, M., Heydmann, L.,Prakash, E., Bhaskaran, S., Vishwaraman, M., Moog, C., Baumert , T.F. (2017). A cinnamon –derived procyanidin type A compound inhibits hepatitis C virus cell entry. *Hepatology International*. 11: 440-445.

Noshirvani, N., Ghanbarzadeh, B., Gardrat, C.,Rezaei,M.R., Hashemi, M., Le Coz, C.,Coma, V. (2017). Cinnamon and ginger essential oils to improve antifungal, physical and mechanical properties of chitosan- carboxymethyl cellulose films. *Food Hydrocoll*. 70:36-45.

Sharma, U.K., Sharma, A.K., Pandey, A.K. (2016). Medicinal attributes of major phenylpropanoids present in cinnamon. BMC complement. Alternative Medicine 16: 1-11

Sun,Q., Yang, H., Tang, P.,Liu, J., Wang, W., Li, H. (2016). Interactions of *Cinnamaldehyde* and its metabolite cinnamic acid with human serum albumin and interference of other food additives. *Food Chemistry* 243: 74-81.

Benoit, J., Oerting, H., Schroeder, K., Goemann, C., Diaz, E. (2016). Fragrance Composition. U.S
patent 20,160,032,217,4 .

Kumar,M., Kumar, V., Roy, D., Kushwaha, R., Vaswani, S. (2014). Application of herbal feed additives in animal nutrition: A Review International. *Journal Livestock Res.* 4:1.

Bohm, B.A and Kocipai-Abyazan, C. (1994). Flavonoids and condensed tannin from leaves of Hawaiian *Vaccinium Vaticulatum* and *V. calycinium*. *Pacific Science* 48: 458-463.

Ignat, I., Volf, I. and Popa, V.I (2013). Analytical methods of phenolic compounds. In: Ramawat,
K., Merillon JM, editors. Natural products. Springer, Berlin, Heidelberg.

Brunner, J.H (1984). Direct spectrophotometer determination of saponin. *Analytical Chemistry 3*4:1324-1326.

Sofowora A. (1993). Medicinal plants and traditional medicine in Africa, Ibadan, Nigeria. Spectrum Books Ltd., Ibadan.

Pulido, R., Bravo L. and Saura-Calixto, F. (2002). Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/ antioxidant power assay. 48: 3396-3402.

Gyamfi, M.A., Yonamine, M. and Aaniya, Y. (1999). Free radical scavenging action of medicinal

Comment [P8]: Need corrdination

herbs from Ghana: Thonningia sanguine on experimentally induced liver injuries. Gem. *Pharmacology* 32: 661-667.

Rotruck, J.T., Pope, A.L., Ganther, H.E.,Hafeman, D.G and Hoekstra, W.G (1973). Selenium: Biochemical role as a component of glutathione peroxidase. *Science* 179:588-590.

Aebi, H. (1974). Catalase estimation. In H.V Bergmeyer (Ed.), Methods of enzymatic analysis. Newyork, NY: Verlag Chemic, New York Academic Press.

Allain, C.C., Poon, L.S., Chan, C.S.G, Richmond, W. and Fu, P.C (1974). Enzymatic determination of total serum cholesterol. *Clinical Chemistry* 20 (Suppl 4): 470-475.

Botsoglou, N.A ., Fletouris, D.J., Papageorgiou, G.E., Vassilopoulos, V.N., Mantis, A.J and Trakatellis, A. (1994). Rapid, sensitive and specific thiobarbituric and method for measuring lipid peroxidation in animal tissue, food and feedstuff samples. *Journal Agriculture and Food Chemistry* 42: 1931-1937.

Lillehoj, H., Liu, Y., Calsamiglia, S., Miyakawa, M.E.F., Chi, F., Cravens, R.L., Oh, S. and Gay, C.G. (2018). Phytochemicals as antibiotic alternatives to promote growth and enhance host health. *Veterinary Resource* 49: 76. doi:10.1186/s13567-018-0562-6.

Sharma, M.K., Dinh, T. and Adhikari, P.A (2020). Production performance, egg quality and small intestine histomorphology of the laying hens supplemented with phytogenic feed additive. *Journal of Applied Poultry Resources.*https://doi.org/10.1016/j.japr.2019.12.001.

Kohen, R. and Gati, I. (2000). Skin low molecular weight antioxidants and their role in aging and in oxidative stress. *Toxicology* 148: 149-157.

Longhi, J.G., Perez, E., Jose de Lima, J. and Candido, L.M.B. (2011). In vitro evaluation of Mucuna Pruriens(L.) DC. Antioxidant activity. *Brazilian Journal Pharmaceutical Science* 47 (3). http://dx.doi.org/10.1590/S1984-82502011000300011.

Siddhuraju, P. and Becker, K (2003). Studies on antioxidant activities of mucuna seed (Mucuna pruriens var utilis) extract and various non-protein amino/imino acids through in vitro models. *Journal of Science, Food and Agriculture* 83 (14) : 1517-1520. https: //doi.org/10.1002/jsfa.1587.

Kamel, C. (2001). Tracing methods of action and roles of plant extract in non-ruminants. In: Res.Adv. Animal Nutrition (eds). Garnos Worty , P.C and J.Wiseman, Nottingham University Press. Nottingham, UK.

Shirzadegan, K., Gharavysi, S. and Irani M. (2012). Investigation on the effect of Iranian green tea powder in diet on performance and blood metabolites of broiler chicks. M.Sc thesis. Islamic Azad University, Qaemshahr, Iran.

Koochacsaraie, R.,Irani, M. and Gharavysi S. (2011). The effect of cinnamon powder feeding on blood metabolites in broiler chicks. *Journal of British Poultry Science* 13:197-201.

Oloruntola, O.D., Ayodele, S.O., Adeyeye, S.A., Jimoh, A.O., Oloruntola, D.A and Omoniyi, S.I (2020). Pawpaw leaf and seed meals composite mix dietary supplementation: effects on broiler chicken's performance, caecum microflora and blood analysis. *Agroforestry system.* 94: 555-564.

Jiwuba, P.C andOnunwa, E.C (2018). Dietary effect of velvet bean (Mucuna utilis) leaf meal on haematology and serum biochemistry of broiler finisher birds. Sustain. *Food Prod.*2:1-5.

Comment [P9]: Need corrdination

Comment [P10]: Need corrdination

Gupta, C., Garg, A.P., Uniyal , R.C., Kumari, A. (2008). Comparative analysis of the antimicrobial activity of cinnamon oil and cinnamon extract on some food-borne microbes. *African Journal Microbiology Resource.* 2: 247-251.

Afolabi A.B and Oloyede O.I (2014). Antioxidant properties of the extracts of *Talinum triangulare* and its effects on antioxidant enzymes in tissue homogenate of Swiss albino rat. *Toxicology International* 21(3): 307-313.

Oloruntola, O.D., Agbede, J.O., Ayodele, S.O., Adeyeye, S.A and Agbede, J.O (2018). Performance, haemato-biochemical indices and antioxidant status of growing rabbits fed on diets supplemented with Mucuna pruriens leaf meal. *World Rabbit Science*. 26: 277-285.

Jimoh, O.A., Ayedun, E.A., Oyelade, W.B., Oloruntola, O.D., Daramola,O.T., Ayodele, S.O and Omoniyi I.S (2018). Protective effect of soursop (Annona muricata linn) juice on oxidative stress in heat-stressed rabbits. *Journal of Animal Science Technology*. 60:28.

Plat, J. and Mensink , R.P (2002). Increased intestinal ABCAI expression contributes to the decrease in chosterol absorption after plant stanol consumption, The *Fed. American Society*. *Exp.Biology Journal* 16 (10): 1248-1253.

Falowo, A.B., Fayemi, P.O and Muchenje, V. (2014). Natural antioxidants against lipid-protein oxidative deterioration in meat and meat products: A review. Food Resource International 64: 171-181. Doi:10. 1016/j.foodres.06.022.

Valenzuela-Grijalva, N.V., Pinelli- Saavedra, A., Muhlia-Almazan, A., Dominguez-Diaz, D., and Gonzalez-Rios, H. (2017). Dietary inclusion effects of phytochemicals as growth promoters in animal production. Journal of Animal Science and Technology, 59: 8. Doi:http://doi.org/10.1186/s40781-071-0133-9.