Research Article

Growth Promoting and Anti-Lipogenic Characteristics of Three Phytogenic Feed Additives in Broilers' Diets

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Abstract | The study compared growth-promoting and anti-lipogenic characteristics of three phytogenic feed additives (PFA) in the diet of broilers. A total of 250 day-old Cobb broiler chicks were randomly assigned to five dietary treatments with five replicates of 10 birds each in a completely randomized design. Five experimental diets at starting and finishing phases were formulated. Diet 1 was the control with no PFA, diets 2, 3, 4, 5 contained PFA (garlic, turmeric, moringa) at 20gkg^{-1} diet and blend of the three (at 1:1:1) respectively. Feed intake and body weight gained were determined on weekly basis. There were significant (P<0.05) changes in body weight gain, feed intake, and feed conversion ratio. Bodyweight gained increased by 16.3 - 22% from Tumeric to moringa. Protein digestibility increased by 5% and 3% in birds fed garlic and the blend respectively while about 4% increase in fat digestibility was observed in birds with PFAs. The PFAs exhibited varied positive influence (P<0.05) on carcass yield, but no difference (P>0.05) was observed in the organ weights of the chickens. The fat deposition was substantially reduced (P<0.05) in birds with PFAs. The blood triglycerides, cholesterol, and low-density lipoprotein (LDL) were lower (P<0.05) in groups fed with PFAs. All the PFAs significantly increased the HDL above the value obtained in control. No mortality was recorded throughout the experimentation period. It was concluded that the three PFAs and their mixture used in this study improved the performance, nutrient utilization, and carcass traits of broilers. The overall benefits accrued in birds fed with the blend of the PFAs. While garlic showed a higher anti-lipogenic tendency, moringa had a greater influence on the feed intake and growth of the experimental birds.

Keywords | Blood lipids, Broiler, Carcass yield, Ilea digestibility, Phytogenic additive

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INTRODUCTION

Production of sustainable animal protein in the absence of synthetic antibiotics in many developing world require more research effort to explore local growth-promoting feed additives of natural sources. Although scientific evidence has indicated that synthetic growth-promoting antibiotics could still be used rationally in animal feeding (Phillips et al., 2004; Cervantes, 2015) yet, the market tendencies and the constant negative publicity against it indicate that great majority of the poultry industry should embrace synthetic antibiotic-free production (Brewer and Rojas, 2008).

The use of probiotics, acidifiers, and phytogenic have been suggested by different authors to improve feed efficiency, productive performance, and immune response of farm animals. The direct-fed microbial, probiotics produced from selected beneficial microbes such as *Lactobacilli, Streptococci, and Bacillus* species have been considered as potential alternative to antibiotics and are well-known for their enzymatic role which promotes nutrient digestibility and total gut health (Chaucheyras-Durand and Durand, 2010). The adequacy of these organisms to successfully replace synthetic antibiotics in poultry feed is still a work in progress.

Phytogenic additives have combinations of many bioactive compounds that are natural and had found application in traditional medicine. These bioactive substances such as alkaloids, glycosides, phenolics (tannins), and terpenoids, etc. found in herbs, botanicals, spices, and their derivative products are often called phytogenics. Some of them have nutritional value or might even be anti-nutritional (Hashemi and Davoodi, 2011). The activity of these phytogenic compounds have been reported to stimulate feed intake in animals, stabilize microbiota in the gastrointestinal tract, enhance host mucosa immunity, and improve resistance to disease organism (Kumar et al., 2014; Madej and Bednarczyk, 2015; Asgari et al., 2016). Different plants and their extracts as feed additives or supplements have been used in poultry production with varied impacts on growth and immune response in animals (Mahanta et al., 2017; Mahfuz et al., 2018; Movahhedkhah et al., 2019). Phytogenic feed additives have gained increased interest because of the exhibited improvement traits conferred on the animal and production of residue free products. There is a volume of data on the nutritional attributes of many of these individual additives. However, there are fewer reports on the comparative nutritional characteristics of many of these natural feed additives. In this study, the growth-promoting and anti-lipogenic characteristics of three phytogenic feed additives will be assessed and compared in broilers chickens.

MATERIALS AND METHOD

Experimental site and duration

The experiment was approved by the Committee for Animal Experimentation in the Department of Animal Sciences, Obafemi Awolowo University (OAU) Ile-Ife, Nigeria. The research was conducted at the Poultry Unit, Teaching and Research Farm, OAU and the experiment lasted for eight weeks between August and October 2019.

Sample Collection and Preparation

Garlic powder was obtained by peeling off the garlic cloves from the bulb, chopped with an electric blender, and dried in an oven at 70^{0}C until the cloves can break into two. It was then ground to powder. Turmeric powder was produced by boiling the turmeric rhizomes for 45 minutes, skin peeled off, sliced, and dried in an oven at 70^{0}C for four hours, and then ground into powder. Moringa powder was obtained from the harvested leaves, which were sorted and air-dried for 5 days, before milling into powder. The milled samples were kept in plastic containers for further use.

Birds Management

Two hundred and fifty (COBB-500) one-day-old broilers chicks obtained from a reputable hatchery were fed a commercial starter feed (23% crude protein and 3175kcal/kg ME) for the first one week. Charcoal pot heating system were used during brooding. The light was provided 22 h a day throughout the first week. At the end of the first week, they were divided into five treatment groups of 5 replicates each with 10 chicks per replicate. Five experimental diets at starting and finishing phases were formulated (Table 1). Diet 1 is the control diet with no additive, diets 2, 3, 4, 5 contained garlic, turmeric, moringa leaf powder, and the blend of the three (in equal ratio) and added at 20gkg^{-1} diet respectively. The feeding trial lasted 42 days.

At the end of the 6th week, four representative birds with bodyweight close to the group average were selected and fed 200mg chromic oxide (Cr_2O_3) per kg diet for digestibility trial. A feeding period of 5 days was applied to ensure stabilized excretion in the ileum.

Data Collection and Analysis

Data on feed intake and body weight were taken weekly. Bodyweight gain and FCR were calculated. Following the sacrifice by cervical dislocation, the sampling of the ileal segment of the intestine was standardized by taking a sample 30 mm before the ileocecal junction and 30 mm after Meckel's diverticulum, to circumvent contamination in the caecum and jejunum. Contents from the ileum were collected by gentle finger-stripping directly into a labeled specimen jar per replicate. Samples were held on the ice during collection and taken to the laboratory, homogenized and oven-dried (60^0 C) for 48 hr. It was later ground (0.5mm screen) and stored at -4^{o}C in airtight labeled bags for further analysis. Samples were analyzed for proximate contents according to the methodology of AOAC (2011); gross energy was determined by bomb calorimeter. Marker retrieval in digesta was determined as the total amount of chromium excreted relative to the total amount consumed. The apparent ileal digestibility coefficients of dry matter, crude protein, ether extract, and digestible energy of different diets fed were isolated using the following calculations:

Ileal Digestible Energy (kcal/kg of diet) = GEdiet – [$GE_{digesta}$ × ($Marker_{diet}$/$Marker_{digesta}$)]

$$\text{Apparent nutrient digestibility} = \frac{\text{Nutrient in feed} - \text{Nutrient in ileum}}{\text{marker in feed} \quad \text{marker in ileum}}$$

$$\frac{\text{Nutrient in feed}}{\text{Marker in feed}}$$

Source: Scott and Boldaji 1997; Khieu et al., 2002

Table 1: Gross composition of experimental diets

Control			Additives		
Ingredient	Starter	Finisher	Starter	Finisher	
Maize	56.00	58.00	56.00	58.00	
Soybean meal	15.00	10.00	15.00	10.00	
Groundnut Cake	16.00	17.50	16.00	17.50	
Palm kernel cake	4.50	8.00	2.50	6.00	
[+]Others	8.50	6.50	8.50	6.50	
*Additive	0.00	0.00	2.00	2.00	
Calculated analysis					
ME(Kcal/Kg)	3027	2985	3012±14.2	2974±20.5	
Crude Protein (%)	23.01	20.27	23.20±0.15	20.52±0.23	
Ether extract (%)	5.30	5.45	5.30±0.74	5.45±0.35	
Crude fibre (%)	3.50	3.75	3.50±1.35	3.75±0.61	
Determined Analysis,(%) for finished diets	Control	Garlic	Moringa	Turmeric	Mixture
Dry matter	8.50	7.95	8.90	9.00	8.70
Crude Protein	21.3	21.0	21.7	20.9	21.3
Ether extract	4.53	4.25	4.5	4.78	4.51
Crude fibre	5.80	6.00	6.10	5.75	5.80
Ash	7.18	6.80	7.10	7.35	7.15
NFE	52.7	54.0	51.7	52.2	52.5

[+]Others:
6.50: Fish meal =2.0; Bone meal =2.5; Oyster shell=1.0; [++]Premix=0.2; Lysine=0.3, Methionine=0.3; Salt=0.2
8.50: Fish meal =4.0; Bone meal =2.5; Oyster shell=1.0; Premix=0.2; Lysine=0.3, Methionine=0.3; Salt=0.2
[++]Vitamin and mineral premix contain the following per kg diet. Vitamins A 10,000 IU, D3 3000 IU, E 8.0 IU, K 2.0 mg, B6 1.2 mg and B12 0.12 µg; niacin 1.0 mg; pantothenic acid 7.0 mg; folic acid 0.6 mg; choline chloride 500 mg; Minerals: Fe 60 mg,Mn 80mg, Mg100 mg, Cu 8.0 mg, Zn 50 mg, Co 0.45 µg, I 2.0 mg, Se 0.1 mg.
*Additives used include garlic, moringa, turmeric, and the blend of the three (equal ratio) at 2% each.
Note: Added additive in each diet was accounted for by reducing palm kernel cake in the diets by 2%.

Table 2: Performance traits of broiler chickens fed three phytogenic feed additives

Parameters	Diets						
	T1 Control	T2 Garlic	T3 Moringa	T4 Turmeric	T5 Mixture	SEM	P-value
Initial body weight (g)	151.4	152.5	150.3	151.8	151.5	0.27	0.099
Final body weight (g)	2478^{b}	3010^{a}	3131^{a}	2932^{a}	3054^{a}	74.61	0.014
Av. Total body weight gain (g)	2326^{b}	2858^{a}	2981^{a}	2780^{a}	2902^{a}	74.71	0.014
Av. daily feed intake (g)	104.0^{c}	117.9^{ab}	119.8^{a}	112.7^{b}	119.3^{a}	1.59	0.008
Feed conversion ratio	2.1^{a}	1.8^{c}	1.9^{bc}	2.0^{ab}	1.8^{c}	0.03	0.008
Mortality	0	0	0	0	0		

[abc] means with different superscripts across the row are significantly (P<0.05) different, SEM-standard of mean

Table 3: Ilea digestibility of broilers fed three natural feed additives

Item	Control	Garlic	Turmeric	Moringa	Mixture	SEM	P-value
Chromium, g	0.72	0.81	0.73	0.75	0.78	0.057	0.070
Dry Matter, %	66.56	69.70	70.23	68.05	68.55	4.611	0.059
Crude protein, %	75.99^{b}	80.98^{a}	77.47^{b}	78.52^{ab}	78.95^{ab}	4.709	0.024
Ether extract, %	84.07^{b}	88.04^{a}	85.95^{ab}	87.01^{a}	87.86^{a}	1.589	0.030
Ileal DE, kcal/kg	75.04	79.77	77.67	80.50	76.34	15.90	0.700

^{abc}means with different superscripts across the row are significantly (P<0.05) different, SEM; standard of mean

Table 4: Carcass and organ characteristics of broiler chicken fed diets with three phytogenic additives

	T1	T2	T3	T4	T5		
Parameters,%	**Control**	**Garlic**	**Moringa**	**Turmeric**	**Mixture**	**SEM**	**P value**
Live weight(g)	2478^{b}	3010^{a}	3131^{a}	2932^{a}	3054^{a}	74.61	0.014
Carcass weight(g)	1776^{b}	2198^{a}	2225^{a}	2067^{a}	2152^{a}	53.18	0.017
Dressing	71.70	73.00	71.97	71.47	71.50	0.289	0.054
Breast	32.24	32.10	31.98	32.68	32.80	0.5559	0.4474
Back	19.91	19.06	20.27	20.60	18.86	0.6160	0.0525
Wing	10.11	11.22	10.27	10.26	11.17	0.1890	0.1383
Thigh	14.30^{b}	15.86^{ab}	16.38^{a}	15.92^{ab}	15.63^{ab}	0.3202	0.0380
Drumstick	12.30^{b}	13.59^{a}	14.25^{a}	14.27^{a}	14.00^{a}	0.5583	0.0220
Abdominal fat	2.72^{a}	1.71^{b}	1.88^{b}	1.83^{b}	1.74^{b}	0.571	0.042
Liver	2.23	1.95	2.22	2.18	1.96	0.074	0.061
Gizzard	2.31	1.95	2.22	1.94	2.10	0.067	0.057
Heart	0.48	0.48	0.46	0.41	0.49	0.013	0.287

^{abc}means with different superscripts across the row are significantly (P<0.05) different, SEM; standard of mean

Table 5: Blood lipid of broiler fed three lesser use dietary feed supplements

Parameters (mg/dl)	T1	T2	T3	T4	T5		
	Control	**Garlic**	**Moringa**	**Turmeric**	**Mixture**	**SEM**	**P-value**
Triglyceride	39.96^{a}	35.46^{ab}	34.20^{ab}	36.72^{ab}	33.40^{b}	2.320	0.021
Cholesterol	95.22^{a}	81.72^{b}	90.36^{a}	92.16^{a}	78.78^{c}	3.010	0.030
low density lipoprotein	28.80^{a}	20.70^{b}	26.08^{a}	20.52^{b}	20.28^{b}	1.610	0.046
high density lipoprotein	37.70^{c}	46.54^{b}	57.06^{a}	48.60^{b}	52.74^{ab}	2.800	0.046

^{abc}means with different superscripts across the row are significantly (P<0.05) different, SEM; standard of mean

Birds were de-feathered using hot water and eviscerated. Weights of the carcass, prime cuts, dressing percentage, abdominal fat, liver, heart, and gizzard were recorded and calculated as the percent of carcass weight.

Lipids analysis

Blood samples of each replicate were collected in an EDTA bottle and a lipid profile test was carried out in the laboratory to analyze for triglyceride, cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL). Randox Diagnostic Kits was used. The plasma total cholesterol was measured according to the procedure described by (Richmond, 1973).

Statistical Analysis

Data were analyzed with the GLM procedure of SAS (version 9.2, SAS Institute Inc., Cary, NC), while Duncan's multiple test option of the package was used to separate the means.

RESULTS

Performance of broiler chickens fed three phytogenic feed additives

Table 2 shows the performance indices of broiler chickens fed diets containing garlic, turmeric, moringa, or their mixture). The final body weights stretched from 2477.5g in the control diet to 3131g in the birds fed diet with moringa.

The final body weights of the group of birds fed garlic, turmeric, moringa, and the blend were significantly (P<0.05) higher than those on the control diet but similar (P>0.05) within the groups fed with the additives. The body weight gain and feed intake of the birds across the treatments followed a similar pattern. There were 18.6%, 22%, 16.3%, and 19.8% increase in weight gain of birds relative to control on garlic, moringa, turmeric, and the mixture respectively. The feed conversion ratios of the birds on garlic, moringa, and the blend were superior (P<0.05) in this study with about 13.5% improvement over the control

Ilea Digestibility of broiler chicken fed three phytogenic feed additives

Chromium concentrations in the diets were 213 ± 5.8 mg per kg diet. Chromium concentration in the digesta and the respective digestibility coefficients were as indicated in Table 3. Nutrients were better digested (P<0.05) in birds fed diets with additives. There were 5% and 3% increase in protein digestibility in birds placed on garlic and the blend over the control while up to 4% increase in fat digestibility was generally observed in birds with additive. Although there was a linear increase in DM and energy digestibility of birds placed on additive enriched diets, the values were not significantly different (P>0.05) from the control.

Carcass evaluation of broilers fed three natural feed additives

The results of carcass and organ characteristics are presented in Table 4. Live and carcass weight of birds fed the different phyto-additives recorded significantly higher values (P<0.05) than the control. The dressing percentage of the birds ranged from 70.47 to 73.00% with no difference among birds in different groups. It appeared that birds on phytogenic additive have heavier (P<0.05) thighs compared to the control group. Dietary Phyto-additives also had a significant (P<0.05) positive influence on the drumsticks of the birds which had heavier weight compared with birds fed control diet. Similarly, the use of the additives in this study led to a significant (P<0.05) reduction in the abdominal fat of the birds. The organs' weights were not significantly (P>0.05) different across the treatments.

Blood lipid of broiler fed three phytogenic feed additives

Results of blood lipids are as indicated in Table 5. The triglycerides, cholesterol, and low-density lipoprotein appear to be lower (P<0.05) in groups fed with additives except for Moringa whose LDL was comparable with control. All three additives significantly increased the HDL component of the blood above the value obtained in control.

DISCUSSION

Performance of broiler chicken fed three phytogenic feed additives

Bodyweight of birds fed diets containing phyto-additives significant improved. This was positively correlated with the level of feed consumption. It appears that the additives contained appetite-stimulating factors that enhanced feed consumption. Higher feed intake was more pronounced in moringa treatment. Similarly, higher nutrient digestibility of birds on PFAs could explain the reason for the better feed conversion ratio (FCR) observed (Table 3). The higher feed intake and digestibility observed with PFA may not be unconnected with their bio-active compounds which possibly exert their effect on speeding up digestion, stimulating the enzymatic system of the birds, and improving the gut health. It may be speculated that flavonol glycosides, that is, quercetin and kaempferol, which are predominant in moringa leaf meal, as well as the alkaloid moringinine may have influenced the higher voluntary feed intake as earlier indicated by Mbikay (2012) together with the presence of antioxidant (Ogbunugafor et al., 2011). Moringa is also known as a rich source of vitamins and amino acids that reportedly boost the immune systems of animals (Olugbemi et al., 2010) and perhaps contributed to the improved body weight gained. Although turmeric also appears to positively influenced bodyweight, however, the FCR did not differ from the control group. Turmeric at the rate of 5 g kg^{-1} was reported to significantly increase the bodyweight of broiler chickens compared to the birds on the control diet (Durrani et al., 2006; Raghdad and Al-Jaleel 2012; Mondal et al., 2015). Early reports have claimed that good antioxidant activity in turmeric has the potential to stimulate the pancreatic enzymatic system of birds (Adegoke et al., 2018). The report of Wang et al. (2016) with dietary supplementation of 100-300 mg/kg of turmeric rhizome extract, however, indicated no significant effect on the bodyweight of broilers.

The FCR in birds placed on garlic was preferable to others. The allicin, a popular bioactive compound is known to inhibit the growth of pathogenic bacteria by interfering with bacterial cell metabolism (Ghosh et al., 2010; Makwana et al., 2018). Consequently, when the load of these bacteria in the intestine is low, birds tend to absorb more nutrients leading to improvement in weight gain as observed in this study. Other studies have shown mixed responses in body weight gain with garlic supplementation. While Suriya et al. (2012) opined that garlic supplementation significantly improved body weight gain of broiler chickens, conclusion of Aji et al. (2011) revealed no significant effect on both feed intake body weight gain.

Ilea Digestibility of broiler chickens fed three phytogenic feed additive and their mixture

Some herbs are known to produce appetite- and digestion-stimulating effects (Jamroz et al., 2005). The improvements in nutrient digestibility observed with birds on additive enriched diets, may be as a result of such effects. This improvement in nutrient digestibility could be linked to the improved FCR earlier indicated. Hence, improvement of the ileal digestibility of nutrients and FCR could be as a result of the digestion-stimulating effect of the PFA which conceivably improved gut activities by improvement of digestive enzymes such as trypsin and lipase and absorption surface area in the intestine.

The specific aid of curcumin in turmeric has been implicated to improve the enzymatic system of birds and resulting in better digestion, increased nutrients absorption, and increased weight gain (Durrani et al., 2006). Ramakrishna et al. (2003) in their report showed that garlic activates the digestive process through enhanced pancreatic enzyme activity which improves absorption of nutrients and ultimately the growth of the animal. It should be noted that beyond nutrient digestibility, the extent of improvement in growth performance observed may probably extend to other factors such as related to gut health (e.g. gut microflora, gut maintenance, mucus production, and host immune function) and general health that take up part of the energy and nutrients that the host would otherwise use for production purposes (Montagne et al., 2004; Koutsos and Arias, 2006).

Carcass evaluation of broilers fed three phytogenic feed supplements

The improved feed conversion on birds fed PFA-base diets is a direct reason for better carcass and some prime cuts recorded. This study is in line with the works of Durrani et al. (2006) who recorded higher dressing percentage, as well as higher breast and thigh weights in broilers, fed a diet containing 5 g/kg of a natural PFA. The degree of the reduction in the abdominal fat ranged between 31-52% with garlic achieving the highest reduction followed by the mixture and the lowest value obtained in moringa. This observation appears to be one of the high points on the benefits of these phytogenic additives because accretion of fat in the abdominal area of broilers is regarded as waste in the poultry as implied loss in value and reduced consumer acceptability. Therefore, the use of garlic, turmeric, moringa, and their blend in the broiler's diet has the potential to curtail this type of waste. The decrease in abdominal fat caused by these phytoadditives is traceable to the influence of their respective bioactive compound on adipocytes (Sugiharto et al., 2011). The reduction in abdominal fat and increased carcass percentage of birds fed phytoadditive-supplemented diet also agreed with the earlier report of Wang et al. (2016). The authors stated that at 2.5 and 5% garlic supplementation in broiler diets significantly ($P<0.05$) decreased the abdominal fat content of the birds. Rajput et al. (2013) reported that the addition of curcumin (150- 200 mg/kg of feed) significantly reduced the abdominal fat ratio, as compared with the control group. In summary, the use of these three additives or their blend in broilers' diet is capable of enhancing broiler carcass yield and producing lean meat which is consumers' preference.

Blood lipid of broiler fed three phytogenic feed additives

The findings showed that the diets supplemented with garlic, turmeric, moringa, and their mixture successfully reduced the triglyceride (TG) levels in the blood compare to the control. The degree of fat deposition in the experimental birds appears to be related to the content of TG and low-density lipoprotein (LDL) in the blood. LDL is known to be involved in modulating the transport of cholesterol from the liver to other tissues (Koolman and Roehm 2005). Consequently, a lower serum cholesterol level is expected with a lower level of LDL as observed in this study.

Previous works have shown that garlic and turmeric have hypocholesterolemic properties that reduce blood cholesterol levels (Sarker et al., 2017). Curcuminoids present in garlic and turmeric were responsible for the suppression of triglycerol synthesis. However, this comparative study has shown that moringa is more beneficial in terms of improving the HDL content in chicken. Flavonoids and saponins present in moringa have been implicated to increase the HDL levels and lower LDL levels in hypercholesterolemic rats (Mehta et al., 2003). Cholesterol reduction by these bioactive compounds is achieved probably by deterring cholesterol micellar solubility as demonstrated earlier by Chávez-Santoscoy et al. (2013) through the activities of key enzymes (Zhao et al., 2013).

Similarly, in birds, fat is mainly synthesized in the liver, and the contents of TG and cholesterol are the key indices that influence its metabolism. Xie et al. (2018) have identified quercitrin, isoquercitrin, crysin-7-glucoside, and quercitrin in moringa as the main components that exert synergistic effects to inhibit adipogenesis. Related investigations in humans and mice have also indicated that dietary supplements of moringa leaf meal could decrease obesity and regulate lipid metabolism mainly by reducing the level of TG and cholesterol in the serum or liver (Almatrafi et al., 2017). The lower total cholesterol (TC) and LDL levels in birds successfully attained with the feeding of the blend of additives further indicative of the positive synergetic effect of various bioactive compounds in the selected additives used in this study.

CONCLUSION

The study has shown that the continuous feeding of the three natural phytogenic additives at 20gkg^{-1}diet or their mixture was suitable to improved feed conversion ratio and carcass yield of the experimental birds by stimulating feed consumption and digestion. Similarly, the three additives were able to depress the cholesterol and fat deposition in broiler chickens at varying proportions thereby exerting a superior quality on the carcass of the birds than control. It was noted that while garlic showed a higher anti-lipogenic tendency, moringa displayed superior influence on feed intake, the blend of the three additives appear to have a greater overall influence on the experimental birds. Extracts from these potential natural feed additives with proper blending in feed or water of birds are recommended for further study as this could offer a closer alternative to synthetic growth-promoting antibiotics.

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CONFLICT OF INTEREST

There is no conflict of interest in this article

NOVELTY STATEMENT

The main objective of this paper is to determine comparative nutritional characteristics of the selected natural feed additives in diets of broilers. Although, many researchers were worked on the use of these additives in poultry, very few researchers have compared their nutritional benefits in chickens. In this present study, the possible synergistic benefits were established through blending of these natural additives in diets of broilers

AUTHORS CONTRIBUTION

TOA: Conceived and design the study, Wrote the paper, Finance publication. DJO: Performed the analysis, Review the manuscript. PFO: Collected the data, Performed laboratory analysis, Finance the project. EO: Collected the data, Finance the project, Performed laboratory analysis. OO: Collected the data, Finance the project.

REFERENCES

Adegoke AV, Abimbola MA, Sanwo KA, Egbeyale LT, Abiona JA, Oso AO, Iposu SO. (2018). Performance and blood biochemistry profile of broiler chickens fed dietary turmeric (*Curcuma longa*) powder and cayenne pepper (*Capsicum frutescens*) powders as antioxidants. J. Vet. Anim. Sci. 6: 95–102. https://doi.org/10.1016/j.vas.2018.07.005

Aji SB, Ignatius K, Ado YA, Nuhu JB, Abdulkarim A, Aliyu AU, Gambo MB, Ibrahim MA, Abubakar H, Bukar MM, Imam HM, Numan PT. (2011). Effects of feeding onion and garlic on some performance characteristics of broiler chickens. J. Poult. Sci. 4(2): 22-27. https://doi.org/10.3923/rjpscience.2011.22.27

Almatrafi MM, Vergara-Jiménez M, Murillo AG, Norris GH, Blesso CN, Fernández ML. (2017). Moringa leaves prevent hepatic lipid accumulation and inflammation in guinea pigs by reducing the expression of genes involved in lipid metabolism. Int. J. Molecul. Sci. 18(7): https://doi.org/10.3390/ijms18071330

AOAC (2011). Official methods of analytical chemist. 18th ed. Association of Official Analytical Chemists. Arlington, VA, USA.

Asgari F, Madjd Z, Falak R, Bahar MA, Nasrabadi MH, Raiani M, Shekarabi M (2016). Probiotic feeding affects T cell populations in blood and lymphoid organs in chickens. Beneficial Microb. p. 1–8. https://doi.org/10.3920/BM2016.0014

Brewer MS, Rojas M (2008). Consumer attitudes towards issues in food safety. J. Food Safety. 28: 1-22. https://doi.org/10.1111/j.1745-4565.2007.00091.x

Cervantes HM (2015). Antibiotic-free poultry production: is it sustainable? J. Appl. Poult. Res. 24: 91–97. https://doi.org/10.3382/japr/pfv006

Chaucheyras-Durand F, Durand H (2010. Probiotics in animal nutrition and health. Beneficial Microb. 1:3-9. https://doi.org/10.3920/BM2008.1002

Chávez-Santoscoy RA, Gutiérrez-Uribe JA, Serna-Saldívar SO (2013). Effect of flavonoids and saponins extracted from black bean (*Phaseolus vulgaris L.*) seed coats as cholesterol micelle disruptors. Plant Foods Human Nutrit. 68: 416–423 https://doi.org/10.1007/s11130-013-0384-7.

Durrani FR, Ismail M, Sultan A, Suhail SM, Chand N, Durrani Z. (2006). Effect of different levels of feed added turmeric (*Curcuma longa*) on the Performance of Broiler Chicks. J. Agric. Biol. Sci. 1:9-11.

Ghosh S, Mehla RK, Sirohi SK, Tomar SK, Roy B (2010). Performance of crossbred calves with dietary supplementation of garlic extract. Indian J. Anim. Sci. 80(7):690-692.

Hashemi SR, Davoodi H (2011). Herbal plants and their derivatives as growth and health promoters in animal nutrition. Vet. Res. Commun. 35(3): 169-80. https://doi.org/10.1007/s11259-010-9458-2

Jamroz D, Wiliczkiewicz A, Wertelecki T, Orda J, Scorupinska J (2005). Use of active substances of plant origin in chicken diets based on maize and domestic grains. British Poult. Sci. 46: 485–493. https://doi.org/10.1080/00071660500191056

Khieu B, Chhay T, Ogle RB, Preston TR (2005). Research on the use of cassava leaves for livestock feeding in Cambodia. Proceeding of the regional workshop on "The Use of Cassava Roots and Leaves for On-Farm Animal Feeding", Hue, Vietnam p. 17-19

Koolman J, Roehm KH (2005). Color atlas of biochemistry. In Lipid Metabolism, 2nd edition. Thieme Stuttgart, New York p. 312-313.

Koutsos EA, Arias VJ (2006). Intestinal ecology: interactions among the gastro-intestinal tract, nutrition and the microflora. J. Appl. Poult. Res. 15:161–173. https://doi.

org/10.1093/japr/15.1.161

Kumar M, Kumar V, Roy D, Kushwaha R, Vaiswani S (2014). Application of herbal feed additives in animal nutrition – A review: Int. J. Livest. Res. 4: 1–8. https://doi.org/10.5455/ijlr.20141205105218

Madej JP, Bednarczyk M (2015). Effect of in-ovo-delivered prebiotic and synbiotic on the morphology and specific immune cell composition in the gut-associated lymphoid tissue. Poult. Sci. 94: 1209–1219. https://doi.org/10.3382/ps/pev076

Mahanta J D, Borgohain B, Sarma M, Sapcota D, Hussain J .(2017). Effect of dietary supplementation of herbal growth promoter on performance of commercial broiler chicken. Indian J. Anim. Res. 51:1097–1100. https://doi.org/10.18805/ijar.11420

Mahfuz S, Song H, Miao Y, Liu Z (2018). Dietary inclusion of mushroom *(Flammulina velutipes*) stem waste on growth performance and immune responses in growing layer hens. J. Sci. Food Agric. 99: 703–710. https://doi.org/10.1002/jsfa.9236

Makwana RB, Parikh SS, Savaliya BD, Chauhan HD, Patil SS, Patbandha TK (2018). Growth Performance and Carcass Characteristics of Broilers Fed Garlic (*Allium sativum*) Supplemented Diets. Int. J. Pure Appl. Biosci. 6 (1): 927-932. https://doi.org/10.18782/2320-7051.5547

Mbikay M (2012).Therapeutic Potential of *Moringa oleifera* Leaves in Chronic Hyperglycemia and Dyslipidemia: A Review. Front Pharmacol. 3:24. https://doi.org/10.3389/fphar.2012.00024

Mehta LK, Balaraman R, Amin AH, Bafna PA, Gulati OD (2003). Effect of fruits of Moringa oleifera on the lipid profile of normal and hypercholesterolaemic rabbits. J. Ethnopharmacol. 86: 191–195. https://doi.org/10.1016/S0378-8741(03)00075-8

Mondal MA, Yeasmin T, Karim R, Siddiqui MN, Raihanun-Nabi SM, Sayed MA, Siddiky MNA (2015). Effect of dietary supplementation of turmeric (*Curcuma longa*) powder on the growth performance and carcass traits of broiler chicks. J. Agric. 13(1):188-199. https://doi.org/10.3329/sja.v13i1.24191

Montagne L, Piel C, Lalles JP (2004). Effect of diet on mucin kinetics and composition: nutrition and health implications. Nutrit. Rev. 62:105–114. https://doi.org/10.1111/j.1753-4887.2004.tb00031.x

Movahhedkhah S, Rasouli B, Seidavi A, Mazzei D, Laudadio V, Tufarelli V (2019). Summer savory (*Satureja hortensis L.*) extract as natural feed additive in broilers: on growth, plasma constituents, immune response, and ileal microflora. Animals (Basels). 9(3): 87. https://doi.org/10.3390/ani9030087

Ogbunugafor HA, Eeneh FU, Ozumba AN, Igwo-ezikpe MN, Okpuzor J, Igwilo IO, Adenekan SO, Onyekwelu OA (2011). Physico-chemical and antioxidant properties of Moringa oleifera seed oil. Pakistan J. Nutrit. 10.:409–414. https://doi.org/10.3923/pjn.2011.409.414

Olugbemi TS, Mutayoba SK and Lekule FP (2010). Effect of Moringa (*Moringa oleifera*) inclusion in cassava-based diets fed to broiler chickens. Int. J. Poult. Sci., 9(4): 363 – 367. https://doi.org/10.3923/ijps.2010.363.367

Phillips I, Casewell M, Cox T, De Groot B, Frits C, Jones R, Nightingle C, Preston R, Waddell J (2004). Does the use of antibiotics in food animals pose a risk to human health? A critical review of published data. J. Antimicrob. Chemotherap. 53: 28–52. https://doi.org/10.1093/jac/dkg483

Raghdad A, Al-Jaleel A (2012). Use of turmeric (Curcuma longa) on the performance and some physiological traits on the broiler diets. Iraq J. Vet. Med. 36 (1): *51-57*. htpps://www.iasj.net.iasj/download/365b3eda8b0d3afd https://doi.org/10.30539/iraqijvm.v36i1.548

Rajput N, Muhammad N, Yan R, Zhong X, Wang T (2013). Effect of dietary supplementation of curcumin on growth performance, intestinal morphology and nutrients utilization of broiler chicks. J. Poult. Sci. 50:44-52. https://doi.org/10.2141/jpsa.0120065

Ramakrishna RR, Platel K, Srinivasan K (2003). In vitro influence of species and spice active principles on digestive enzymes of rat pancreas and small intestine. Nahrung. 47**:** 408-12. https://doi.org/10.1002/food.200390091

Richmond W (1973). Preparation and properties of a cholesterol oxidase from Nocardia sp. and its application to the enzymatic assay of total cholesterol in serum. Clin. Chem. 19(12):1350-6. https://doi.org/10.1093/clinchem/19.12.1350

Sarker SK, Rana M, Khatun H, Faruque S, Sarker NR, Sharmin F, Islam N (2017). Moringa leaf meal as natural feed additives on the growth performance and meat quality of commercial broiler chicken. Asian J. Med. Biolog. Res. 3 (2): 240-244. https://doi.org/10.3329/ajmbr.v3i2.33576

Scott TA, Boldaji F (1997). Comparison of inert markers [chromic oxide or insoluble ash (Celite)] for determining apparent metabolizable energy of wheat- or barley-based broiler diets with or without enzymes. Poult. Sci. 76:594-598. https://doi.org/10.1093/ps/76.4.594

Sugiharto I, Widiastuti E, Prabowo NS (2011). Effect of turmeric extract on blood parameters, feed efficiency and abdominal fat content in broilers. J. Indonesia Trop. Anim. Agric. 36:21-26. https://doi.org/10.14710/jitaa.36.1.21-26

Suriya R, Zulkifli I, Alimon AR (2012). The effect of dietary inclusion of herbs as growth promoter in broiler chickens. J. Anim. Vet. Adv. 11(3): 346-50. https://doi.org/10.3923/javaa.2012.346.350

Wang T, Ragland D, Adeola O (2016). Investigations of marker and fiber effects on energy and nutrient utilization in growing pigs. J. Anim. Sci. 94 (Suppl 5): 473. https://doi.org/10.2527/jam2016-0986

Xie Jing, Yan Wang, Wei-Wei Jiang et al. 2018. *Moringa oleifera* Leaf Petroleum Ether Extract Inhibits Lipogenesis by Activating the AMPK Signaling Pathway. Front. Pharmacol. 18. https://doi.org/10.3389/fphar.2018.01447

Zhao LG, Zhang XH, Cao FL, Sun DF, Wang T, Wang GB (2013). Effect of dietary supplementation with fermented Ginkgo-leaves on performance, egg quality, lipid metabolism and egg-yolk fatty acids composition in laying hens. Livest. Sci. 155: 77–85. https://doi.org/10.1016/j.livsci.2013.03.024