Trop. Anim. Prod. Invest. 22 (1): 01-09 (2019)
ISSN: 1115-2540
http://animalsci.agric.ui.edu.ng/TAPI/index.php/tapijournal/index

ORIGINAL RESEARCH ARTICLE

Dietary Influence of Charcoal Supplementation on Theobromine Remediation in Cocoa Bean Shell Fed to Broiler Chickens

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ABSTRACT

Cocoa bean shell (CBS) is one of the by-products generated by cocoa producing and processing countries that have potential as livestock feed resource. However, its use has been limited largely due to theobromine toxicity. In this study, a feeding trial was conducted to determine whether the adsorbing capacity of charcoal would suppress theobromine toxicity and support growth performance, carcass characteristics and haematology of broiler chickens fed CBS based diets. Five diets were formulated with a standard diet 1 (as control). Diets 2 and 3 contained 5% and 10% CBS respectively, while diets 4 and 5 contained 5% and 10% CBC with 25gkg^{-1} charcoal supplementation arranged in 2x2 factorial lay-out plus the control. Growth performance was examined at the starter (2-4 weeks), finisher (5-8 weeks) and combined starter/finisher phases (2-8weeks). Overall performance showed that broilers on control had a higher (P <0.05) weight gain and better feed conversion ratio than the other diets. At 10% inclusion level of CBS, a significant (P<0.05) reduction in weight gain was observed, which did not improve with supplemental charcoal. Broilers fed CBS diets consumed more (P<0.05) feed than the birds fed control diet. Carcass yield was significantly lower (P<0.05) in broilers fed CBS with supplemental charcoal, while haematological parameters exhibited no significant (P>0.05) variations across treatments. It could be concluded that growth performance was consistently low at 10% level of CBS compared to 5% CBS and 0% CBC (control diet). Moreover, supplemental charcoal at 25g/kg^{-1}d in this study could not suppress the negative impact of theobromine contained in either 5 or 10% CBC. Caution should also be exercised in the use of charcoal as feed supplement because of their adsorbing property capable of compromising micronutrients availability in vivo.

Keywords: Broiler, cocoa bean shell, charcoal, theobromine, performance

INTRODUCTION

Africa contributes over 70% of the total world production of cocoa bean while Nigeria remains the third largest producer in Africa behind Cote D'ivoire and Ghana (FAO 2017). Large quantities of cocoa by-products including discarded cocoa beans, cake, shells and husks produced annually by farmers and associated processing industries constitute a disposal problem in these cocoa bean producing countries (Odunsi and Longe, 1998; Balentic e*t al*. 2018). Given the acute shortage in livestock production in many countries in Africa, attributable largely to the exorbitant cost of animal feed, the utilization of this discarded cocoa waste products as affordable accessory animal feed would be of tremendous benefit to stakeholders in the feed industry (Alemawor *et al.*, 2009; Ogunlade *et al.*, 2010; Hamzat and Adeola 2011, Adamafio , 2013). Most of the by-products from cocoa bean have been investigated in animal feeding systems (Ayinde *et al.*, 2010; Emiola *et al.*, 2011; Ogunsipe *et al.* 2017). Processed by-products of cocoa harvesting industries have also been reported as a suitable replacement for some conventional feedstuffs in monogastric production (Eghosa *et al*., 2010 and Ogunsipe *et al*., 2017). Indeed, by-products of cocoa bean processing has huge potential as a tropical feed resource capable of reducing environmental pollution, storage problems, and cost of feeding farm animals. The proximate composition of cocoa bean shell showed that it is comparable to other agro- allied by-products such as maize bran and wheat offal. It has an intermediate buffer value between the protein and cereal sources of feed (Carolien, 2001). The chemical composition and feeding values have been reported (Olubamiwa *et al.*, 2000; Oluponna *et al.*, 2003; Emiola *et al.*, 2011) Olubamiwa *et al.* (2000) suggested 10% dietary inclusion as a replacement for maize in layer diets while the values of 5-7.5%; 10% and 10-15% were considered as being adequate for broilers, cockerel chicks and finishers respectively (Hamzat and Babatunde 2006; Hamzat *et al.*, 2006). Similar studies had indicated that the inclusion of up to 30% cocoa pod husk in the diet of growing-finishing pigs does not cause any detrimental effects (Oddoye *et al*., 2010) whereas spontaneous abortions in pregnant pigs were reported by Rhule *et al.* (2005). The presence of theobromine has been implicated a**s** a factor limiting the feeding value of cocoa shell meal (Alexander *et al*., 2008; Adamafio 2013). Cocoa husk meal, cocoa bean shell and cocoa bean meal have been reported to contain 1.5- 4.0, 8.0-16.9 and 20-33 g theobromine per kg material respectively. Adeyeye *et al*. (2016) also stated that cocoa bean shell is high in fibre and also contain antinutritional factors such as theobromine (2.64%), caffeine (1.14%) and tannin (0.92%). However, several methods have been adopted in the treatment and processing of cocoa by-products for the purpose of animal feed formulation. Many of these methods are expensive and cumbersome for adoption by local farmers. Hence, the need for cost effective and simpler method for effective utilisation of cocoa by-products

Activated charcoal has been suggested by Kutlu *et al.* (2000) as a potential sequestering agent for certain toxins and antinutritional metabolites which are detrimental to animals. Charcoal is also widely employed in adsorption therapy as a non-digestible carrier which might prevent formation of ingested toxicants in the gastrointestinal tract (Kutlu *et al.*, 2000). Addition of charcoal to animal's diets has also been indicated to improve live weight gain. Several mechanisms for its beneficial effects have been suggested to include toxin binding, improve digestion and retention of nitrogen (Prasai *et al*., 2016). The present study was therefore conceived to study the response of broiler chickens to cocoa bean shell based diets supplemented with charcoal. Growth performance, carcass evaluation and haematological indices were used as measures of response.

MATERIALS AND METHODS

Experimental diets and their compositions

Charcoal was obtained from a local market and ground through a mill to pass a 1 mm sieve and on analysis contained 946 g DM/kg, 154g ash/kg, 97.5g-crude fibre/kg 10.8g ether extract/kg; 19.6g crude protein/kg and 664.1g nitrogen free extracts/kg. Cocoa bean shell (CBS) was obtained from Cocoa Research Institute of Nigeria (CRIN) Ibadan and also contained - 915.0g DM/Kg. 128g crude protein/kg, 135.2g crude fibre/kg; 171.4g ether extract/kg; 69.5g ash/kg and 450.9g nitrogen free extracts/kg and 2.7mg/g theobromine - on analysis. Five diets each were formulated during the starter (1-4 weeks) and finisher (5-8 weeks) phases. Diet 1 served as the control diet without CBS or charcoal. Diets 2 and 3 contained 5 and 10% levels of CBS without charcoal respectively. Diets 4 and 5 contained 5 and 10% levels of CBS respectively each supplemented with 2.5% charcoal. The diet compositions for the two phases are shown in Tables 1 and 2.

Experimental birds and Management

A total of 180, unsexed Anak 2000 strain of broiler chicks were procured from Farm Support Services, Ibadan and fed a commercial broiler starters mash (24%CP / 2900 ME kcal/kg) for 7 days. They were subsequently weighed and randomly allotted to the five dietary treatments in triplicate of 12 chicks each arranged in 2x2 factorial layout. The five (5) experimental starter and finisher diets were provided to the birds during the starter and finisher phases respectively. The birds were kept on a floor-littered poultry house. Feed and water were provided *ad* *libitum*. Other routine management practices were strictly observed.

Table 1: Composition of experimental diets at starter's phase (kg/100kg diet)

Ingredients	T_1	T_2	T_3	T_4	T_5
	Control	**5%**	**10%**	**5% +**	**10%+**
Maize	52.7	48.3	43.9	45.3	40.9
Groundnut cake	30.6	30.0	29.4	30.5	29.9
*Cocoa bean shell	-	5.0	10.0	5.0	10.0
Fixed Ingredients	16.7	16.7	16.7	16.7	16.7
Wood charcoal	-	-	-	2.50	2.50
Calculated values					
Dry matter	91.3	91.8	91.7	91.8	91.8
Crude protein	22.9	22.9	22.9	22.9	22.9
Ether extract	8.79	8.15	8.17	9.09	9.44
Crude fiber	3.46	3.96	4.48	4.0	4.60
Crude ash	3.47	3.40	3.34	3.59	3.72
N. F. E	53.2	53.2	52.9	53.2	51.1

*Cocoa bean shell contains (%): Dry matter, 91.5; Crude protein, 12.8; crude fibre, 13.52; ether extract, 17.14; ash, 6.95; nitrogen free extract, 45.09.
Fixed ingredients consists (%): fish meal, 5.0; wheat bran, 8.0; bone meal, 2.0; Oyster shell, 1.0; salt, 0.25; methionine, 0.2; premix, 0.25 +Charcoal supplementation, 25/kg diet

Table 2: Composition of experimental diets at finisher's phase (kg/100kg diet)

Ingredients	T_1	T_2	T_3	T_4	T_5
	Control	**5%**	**10%**	**5% +**	**10%+**
Maize	58.4	53.0	48.5	50.0	45.5
Groundnut cake	25.4	25.8	25.3	26.3	25.8
Cocoa bean shell	-	5.00	10.0	5.00	10.0
Fixed Ingredients	16.2	16.2	16.2	16.2	16.2
Charcoal	-	-	-	2.50	2.50
Calculated analyses					
Dry matter	90.4	91.2	91.0	90.6	91.5
Crude protein	20.5	20.49	20.3	20.7	20.8
Ether extract	6.41	6.02	6.14	7.01	7.31
Crude fibre	4.04	4.61	4.81	4.78	5.02
Crude ash	3.34	3.43	3.52	3.63	3.71
N. F. E	56.1	56.7	56.2	54.6	54.6

Fixed ingredients contains (%): Fish meal, 2.5; wheat offal, 10.0; bone meal, 2.0; Oyster shell, 1.0; salt, 0.25; methionine, 0.20 and Premix, 0.25

Data collection

Initial body weights of the birds were taken on replicate basis at the start of the study and thereafter on weekly basis. Weekly feed intake was also recorded. The mean daily weight gain, daily feed intake and feed to gain ratio were thus calculated from the data obtained during the starter, finisher and combined starter/finisher phases.

On day 56, two birds of mean weight close to the average group weight were randomly selected from each replicate and starved of feed for 12 hours to empty their crops. The birds were exsanguinated, defeathered, eviscerated and dressed. Each bird's carcass, cut-up parts and organs were separately weighed and expressed as percentage of dressed weight. Blood samples were collected in bottles containing ethylene tetra- acetic acid as anticoagulant for haematological analyses that included packed cell volume, erythrocyte (red blood cell), leucocytes (white blood cells) and haemoglobin. The mean cell volume, Mean cell haemoglobin and mean cell haemoglobin concentration were calculated. The haematological parameters were determined according to method described by Davis and Lewis (1991).

The proximate composition of cocoa bean shell, wood charcoal, and experimental diets were determined according to AOAC (2000) methods. Data obtained were analysed using SAS (2006) software package and significant means were separated by the Duncan option of the same computer package

RESULTS

The growth performance data of broiler chickens fed CBS based diets with or without supplemental charcoal during the starter, finisher and combined starter/finisher periods are presented in Tables 3 and 4. At the starter phase, body weight gain were similar between starter chicks fed control and 5% CBS diets irrespective of charcoal supplementation while those on 10% CBS+C had reduced ($P<0.05$) weight gain. At 5% and 10% CBS inclusion levels, charcoal supplementation reduced the body weight gain by 8.89% and 25.63% respectively. Similar pattern was observed for feed conversion ratio. At the finisher phase, higher feed intake was observed in CBS diets which did not translate to higher body weight with charcoal supplementation (Tables 4a and 4b). Higher level of CBS (10%) significantly ($P<0.05$) depressed body weight gain (Table 4). The overall feeding period revealed that birds on control had a higher body weight gain (35.31 g/bird) and better-feed conversion ratio (2.52) than those on the other diets. Increase in CBS from 5 to 10% resulted in a significant decrease ($P<0.05$) in weight gain and feed conversion ratio.

The carcass yield, cut-up parts and organ weights of broilers fed experimental diets are presented in Table 5. Carcass yield and abdominal fat were reduced ($P<0.05$) in diets supplemented with charcoal. Charcoal supplementation at 5% and 10% significantly reduced the abdominal fat of the broilers by 8.60% and 16.91% respectively, while cut-up parts and organ weights did not show any major variations ($P>0.05$) among dietary treatments. The haematological indices (Table 6) were not significantly influenced ($P>0.05$) by addition of charcoal

Table 3: Performance of broilers fed CBS diet with or without charcoal supplementation

		Without charcoal		With charcoal			(P Value)		
	0%	5%	10%	5%	10%				
Parameters	T_1	T_2	T_3	T_4	T_5	SEM	L	C	L x C
Day 7-28									
BWG (g/b/d)	20.5	21.4	19.9	19.50	14.8	1.23	0.04	0.002	0.175
DFI (g/b)	48.6	48.41	51.90	54.30	52.91	1.21	0.33	0.21	0.389
FCR	2.37	2.26	2.61	2.70	3.58	0.24	0.05	0.02	0.383
Days 29-56									
BWG (g/b/d)	50.31	45.20	39.10	44.81	36.8	2.80	0.003	0.050	0.146
DFI (g/b)	122.2	126.1	125.0	126.1	125.1	2.13	0.32	0.150	0.146
FCR	2.43	2.79	3.20	2.81	3.34	0.52	0.07	0.18	0.075
Days 7-56									
BWG (g/b/d)	35.31	33.31	30.25	31.7	30.06	1.91	0.25	0.37	0.12
DFI (g/b)	88.80	90.21	89.51	91.22	94.00	1.21	0.37	0.14	0.35
FCR	2.52	2.71	2.96	2.87	3.12	1.93	0.04	0.05	0.06

Table 4: Single Effect of levels of CBS inclusion and charcoal supplementation in diets of broilers at starter, finisher and starter /finisher combined phases

	Table 4a: CBM inclusion				Table 4b: Charcoal supplementation			
Parameters	**Control**	**5%CBC**	**10%CBC**	**SEM**	**Control**	**- charcoal**	**+ charcoal**	**SEM**
Days 7-28								
BWG (g/b/d)	20.5[a]	20.45[a]	17.35[b]	1.23	20.50[a]	20.65[a]	17.15[b]	1.23
DFI (g/b)	48.6	51.36	52.41	2.21	48.6[b]	50.16[ab]	53.61[a]	2.21
FCR	2.37[b]	2.48[b]	3.10[a]	0.24	2.37[b]	2.44[b]	3.14[a]	0.24
Days 29-56								
BWG (g/b/d)	50.31[a]	45.01[a]	37.95[b]	2.8	50.31[a]	42.15[b]	40.81[b]	2.8
DFI (g/b)	122.2[b]	126.1[a]	125.1[a]	4.13	122.2	125.55	125.6	4.13
FCR	2.43[b]	2.80[ab]	3.27[a]	0.52	2.43[a]	3.00[b]	3.08[b]	0.52
Days 7-56								
BWG (g/b/d)	35.31[a]	32.505[ab]	30.16[b]	1.91	35.31	31.78	30.88	1.91
DFI (g/b)	88.8	90.715	91.76	3.21	88.8	89.86	92.61	3.21
FCR	2.52[b]	2.79[ab]	3.04[a]	1.93	2.52[b]	2.84[ab]	3.00[a]	1.93

Table 5: Carcass and organ measurements of broiler chickens fed CBS with or without supplemental charcoal based diet

	Without charcoal			**With charcoal**		**(P Value)**			
	0%	**5%**	**10%**	**5%**	**10%**				
Parameters, %	T_1	T_2	T_3	T_4	T_5	SEM	L	C	L x C
Carcass weight (kg/b)	1.35	1.29	1.06	1.20	0.99	0.03	0.12	0.20	0.175
Carcass yield (%BW)	73.1	71.4	70.1	69.7	67.9	4.24	0.33	0.21	0.389
Abdominal fat	0.95	0.93	0.91	0.85	0.77	0.08	0.07	0.05	0.383
Wing	12.7	12.0	14.4	13.6	14.2	1.08	0.12	0.20	0.24
Thigh	19.2	18.9	17.0	15.9	16.2	2.56	0.35	0.05	0.146
Drumstick	14.6	16.3	16.2	14.8	14.7	2.21	0.32	0.15	0.146
Breast	25.3	23.6	21.7	25.9	22.8	3.24	0.07	0.18	0.075
Back	18.1	20.0	19.2	20.0	19.6	2.40	0.53	0.42	0.54
Neck	7.00	7.30	7.80	7.00	8.50	1.42	0.25	0.37	0.12
Organs (% of CW)									
Liver	2.17	2.42	2.43	2.35	2.71	0.32	0.04	0.05	0.06
Kidney	0.51	0.96	0.97	0.93	0.86	0.04	0.17	0.14	0.25
Lung	0.54	0.60	0.83	0.82	0.89	0.09	0.11	0.06	0.06
Heart	0.61	0.53	0.53	0.58	0.60	0.08	0.07	0.07	0.06
Spleen	0.12	0.10	0.10	0.11	0.13	0.01	0.11	0.06	0.06
Gizzard	2.72	3.01	3.11	2.82	3.21	0.12	0.17	0.10	0.13

Table 6: Haematology of broiler chickens fed CBS with or without supplemental charcoal based diets

		Without charcoal		With charcoal		(P Value)			
	0%	5%	10%	5%	10%				
Parameters.%	T_1	T_2	T_3	T_4	T_5	SEM	L	C	L x C
Pack cell volume	29.0	25.5	24.5	24.5	20.2	0.53	0.20	0.15	0.30
Haemoglobin	9.67	7.95	8.15	7.65	6.65	0.36	0.11	0.21	0.22
White BC $x10^6$/L	4.83	3.98	4.08	4.05	3.33	0.18	0.12	0.20	0.24
Mean Cell Volume, fl	59.9	60.4	60.1	60.5	60.1	0.07	2.10	0.32	0.40
Mean Cell Hb., pg	3.33	3.32	3.33	3.14	3.33	0.04	0.30	0.23	0.40
Mean Cell Hb Conc.	200	210	200	190	200	0.51	0.93	0.75	0.72

DISCUSSION

Theobromine concentration of 2.70mg/g in CBS was within the value reported in literature. The differences in values from different authors are largely attributed to method of extraction used (Arlorio *et al*., 2001; Becket, 2009; Hernández-Hernández *et al*., 2018 and Barbosa-Pereira *et al*., 2018). The growth depression observed in broilers fed cocoa bean shell was probably due to the increase in crude fibre content and presence of the anti-nutritional factor theobromine at toxic level in the diets. This result was corroborated by the findings of Balentic *et al*. (2018) who also observed damaging effects on growth when the level of cocoa pod husk incorporated in the diet of broiler chickens exceeded 10%. This result is also in agreement with the earlier findings of Adeyemo *et al*. (2015) who reported that dietary inclusion of CBS beyond 10% lowered weight gain of broiler chickens. Fibrous diets have been implicated to decrease digestible protein ultimately affecting tissue lay down. Reduced growth performance could be ascribed to presence of antinutritional factors in the diets which affect efficient utilization of minerals and protein by the animals (Muzaffe *et al* 2003) while some amino acids have been implicated in detoxification process. With reduced availability of these nutrients, birds consuming diets with this anti-metabolic factor may not be able to meet their nutrient requirements for tissue accretion hence the reduced growth rates of birds fed CBS diets. Again, it was indicated by Adeyemo *et al*. (2015) that theobromine has the capacity to bind essential nutrients. Consequently affect their bioavailability to birds, thereby reduces the growth of birds.

General higher feed intake in CBS diets was not in conformity with the earlier findings of Emiola *et al* (2011) who reported that increased level of sun dried CBS resulted in linear decrease in feed intake. The reduction was largely attributed to high fibre and theobromine content in cocoa bean shell. Although, feed intake was slightly higher, the adsorbing property of charcoal could not mitigate the conceivable effect of theobromine in the feed. Generally, high fibre increases feed intake because of the dilution of the calory content of the feed by fibre sources. A number of studies have shown that the inclusion of up to 30% cocoa pod husk in the diet of growing-finishing pigs does not cause any detrimental effects (Oddoye *et al.*, 2010). Although, earlier studies had found that feeding of cocoa pod husk led to spontaneous abortions in pregnant pigs (Rhule *et al.*, 2005).

A higher value of feed/gain ratio with CBS indicates a reduced utilization of feed with dietary inclusion of charcoal. This indicates that while feed intake were not negatively affected by CBS, their conversion were less. It could also be that while charcoal adsorbs antinutritional component of the feed, some nutrients or growth promoting factors were equally adsorbed as earlier observed by Akande *et al*. (2006). This finding conforms to works of Ortiz *et al.*, (1994) who reported adverse effect of antinutritional factor on feed conversion ratio and impairment of growth and feed utilization when diets containing fibrous ingredients are fed to chickens. Also, the decrease in growth and increase in FCR may be ascribed to the fibrous nature of the test ingredient (CBS). This observation was in line with earlier findings of Alemawor *et al*. (2009) who indicated that high fibre content depressed feed utilization in monogastric animals.

The reduction in carcass yield of broiler chickens fed diets with CBS with or without charcoal was a reflection of the reduced live weight, weight gain and poor FCR. The observed reduction in carcass yield is contrary to the report of Olubamiwa *et al*. (2016) who reported minor differences in various carcass characteristics when broilers were fed CBS-based diets. The carcass proportions to internal organ measurements did not show any significant change which revealed that CBS did not cause disproportionate growth of the organs. The values are similar to those reported by Murawska and Bochno (2007). The reduction in abdominal fat is a reflection of the previous observations recorded (Odunsi *et al.*, 2007) that was related to the effect of charcoal supplementation. Tewe and Egbunike (1992) also reported a consistent decline in body fat of the birds with increase in dietary fibre. The effects of both the CBS and the wood charcoal were clearly shown on abdominal fat. The result indicated that both CBS and charcoal have the tendency to reduce the abdominal fat deposition in broiler chickens. This may be accrued to their high fibre content as earlier stated by Tewe and Egbunike (1992). The non-significant variations in haematological indices of broiler chickens reflected little or no changes in the blood profile of birds fed CBS and/or charcoal in this study. Earlier report showed that broiler chickens fed 15% untreated cocoa bean meal exhibited negative effects including an increase in creatinine and haemoglobin levels. These adverse effects were absent in chickens fed a similar amount of cocoa bean meal which had been treated with alkali or hot water to reduce theobromine content.

In a previous study, Ayanwale *et al.* (2006) concluded that there is no beneficial effect of feeding activated sheabutter charcoal supplemented diets to pullet chicks and growers up to 15 weeks of age. However, they reported beneficial effect at the laying stage in terms of improved egg weight and reduced proportion of cracked eggs.

CONCLUSION

Findings from this study showed that birds on 5% CBS had no serious deviations from control group while 10% CBS did not support optimum performance of broiler chicken. At finisher’s phase, the birds appeared to show some level of tolerance to the intake of theobromine. Furthermore, the inherent shortcomings in the use of cocoa bean shell were not appreciably ameliorated by the inclusion of 2.5% charcoal in this study. Although, the ability of charcoal as an absorbing agent is well-known, its chelating effect on micro nutrients calls for caution in its use. Further studies on activating charcoal as potential toxin sequestering agent should be carried out on the numerous under-utilized tropical feedstuffs.

CONFLICT OF INTEREST:

There is no conflict of interest for this manuscript

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