Original Paper

Health-Related Response of Weaned Pigs to Cassava Tuber Meal's Cyanide with Activated Charcoal Supplementation

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Article Details: Received: 2025-05-12 | Accepted: 2025-06-19 | Available online: 2026-03-31

https://doi.org/10.15414/afz.2026.29.01.19-31

The health-related response of weaned pigs to cassava tuber meal's cyanide with activated charcoal supplementation was evaluated. Large White x Landrace (n = 64, age = 8 weeks, $\bar{x}$ = 9.45 ±0.30 kg, treatment = 8; 8 pigs per replicate), each pig was a replicate in a 2 × 4 arrangement of a completely randomized design. Two sets of four diets each were compounded to contain processed cassava tuber meal (CTM) at 0, 25, 50 and 75% replacement levels for maize while a group was supplemented with activated charcoal (AC) at 40 g/kg diet. Data were collected on blood parameters, organ weights and carcass indices after eight weeks. Weaner pigs fed 25% CTM had significantly (P < 0.05) higher values of 43.93%, 17.81 × 10^3/mm^3 and 13.44 g/dl for PCV, WBC and Hb, respectively. However, CTM and ACS interaction showed significantly (P < 0.05) higher PCV (44.88%) and WBC (18.28 × 10^3 /mm^3) at 25%. Diets with ACS significantly (P < 0.05) depressed the values of albumin, globulin, total protein, and ALP whereas supplementation with AC significantly increased (P < 0.05) AST, cholesterol and triglyceride values as CTM increased. Pigs fed 25% CTM with ACS had higher values (P < 0.05) for belly, ham, and loin. Increasing levels of CTM with and without ACS indicated (P < 0.05) resulted in higher values for organ weights except lungs. In conclusion, ACS in CTM diets at 25% is recommended to safeguard the health of weaned pigs especially for increased PCV, Hb, WBC, and reduced AST, ALT and ALP and liver.

Keywords: carcass cut, haematology, organs, pig, serum biochemistry

1 Introduction

Blood parameters, among others, are often employed as indices in the appraisal of the nutritional, physiological, pathological and health status of animals. Blood constituents primarily influenced by diet includes red blood cell (RBC), paccked cell volume and plasma proteins (Ewuola et al., 2004). Available information also indicates that the number of RBC and white blood cell (WBC) of animals in good health varies among species, individuals, and in the same individual according to its condition and health (Jean, 1993) and are influenced by many factors, including nutrition, infection, toxin, etc (Talebi et al., 2005).

Moreover, hydrogen cyanide (HCN) has been reported to react with haemoglobin to form the non-toxic cyanohaemoglobin. Cyanohaemoglobin, although not itself toxic, is not an oxygen carrier. The blood cannot function in respiration if a significant percentage of its cells is in the form of cyanohaemoglobin (Clarke & Myra, 1975), leading to cytotoxic hypoxia (Cardoso et al., 2005). The combination of HCN and hemoglobin may obstruct the active site for O_2 binding, resulting in reduced digestibility, nutrient absorption (Lukuyu et al., 2014)., and growth (Onyimonyi and Okeke, 2008) in affected animals.

Furthermore, activated charcoal has shown higher affinities for toxins, poisonous plants, and drugs than other adsorbing agents (Poage et al., 2000, Kutlu et al. 2002). Hatch et al. (1982) noted that animals that consumed AC 8 hours after aflatoxin exposure had no visible liver lesions and had a lower percentage of hepatic damage (3%) compared to ones that received no antidote in induced acute aflatoxicosis (25%). Olayeni et al. (2023 and 2024a, b) demonstrated that AC lowers

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the bioavailability of cyanide in the gastrointestinal tract of layers and pigs. Thus, the purpose of this study was to ascertain how the haematological and serum biochemistry, as well as the carcass parameters of weaner pigs, were affected by cassava tuber meal's hydrogen cyanide supplemented with or without AC.

2 Materials and Methods

2.1 *Experiment Location*

The investigation took place within the Piggery Section of the Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeria, a derived savanna region with a mean yearly precipitation of 1,247 mm, 85% relative humidity, 26.2 °C temperature, and 500 m altitude (Ojediran et al., 2020).

2.2 *Collection of Test Ingredients (Cassava Roots and Activated Charcoal)*

Fresh cassava of sweet variety (TMS 3052) was obtained from Aarada Central Market, located in the Ogbomoso South Local Government Area of Oyo State. The market is a popular converging point for several agricultural produce from farmers within and outside the local government area, with cassava being the major among other roots/tubers. The cassava tubers were processed as described by Olayeni et al. (2023), and AC was procured locally.

2.3 *Experimental Animals and Management*

Large White x Landrace (n = 64, age = 8 weeks, $\bar{x}$ = 9.45 ±0.30 kg) were weight equalised to eight groups of eight pigs per treatment, with each pig being a replicate. Each pig was housed in a 0.46 × 0.9 m concrete pen equipped with feeding and drinking troughs. They were acclimatized for a week on the control diet and water supplied *ad libitum*, during which they were dewormed using Ivomec® against endo and exo-parasites.

They were offered feed 4% of body weight daily at 8:00 and 16:00 hr and left-over feed was collected daily to monitor daily consumption. They were weighed weekly from the commencement of the experiment to 8 weeks. The CTM contained 89.44% dry matter, 2.71% crude protein, 4.23% crude fibre, 1.16% ether extract, 82.75% carbohydrates, 3.94% ash and 3.60% hydrogen cyanide. The hydrogen cyanide intake on average was 0.00, 6.49, 12.79 and 19.71 mg/kg for CTM: 0, 25, 50 and 75% respectively. The method of Bradbury et al. (1999) was used to determine the HCN in the CTM.

2.4 *Experimental Design*

In a fully randomized design, a 2 × 4 factorial setup was employed such that there were two factors (with or without ACS) and 4 levels (CTM: 0, 25, 50 and 75%).

2.5 *Data Collection*

2.5.1 *Collection of Blood Samples*

Using separate sets of syringes and needles, two sets of blood specimens were taken from the ear veins of each animal. Blood samples intended for serum biochemical indices were obtained in plain plastic tubes devoid of the anticoagulant, EDTA. While blood samples intended for haematological analysis were collected in EDTA bottles. To preserve the freshness of the blood samples, they were kept in ice-cold packs and later sent to the laboratory for analysis.

Table 1 Gross composition of experimental diets for weaner pigs

Ingredients (%)	1 (0%)	2 (25%)	3 (50%)	4 (75%)	1 (0%)	2 (25%)	3 (50%)	4 (75%)
Maize	55.00	41.25	27.50	13.75	55.00	41.25	27.50	13.75
Cassava tuber meal	0.00	13.75	27.50	41.25	0.00	13.75	27.50	41.25
Bone meal	3.25	4.25	5.25	6.25	3.25	4.25	5.25	6.25
Wheat offal	10.00	9.00	8.00	7.00	10.00	9.00	8.00	7.00
Fixed ingredients	31.75	31.75	31.75	31.75	31.75	31.75	31.75	31.75
Activated charcoal	+	+	+	+	-	-	-	-
Calculated nutrients								
Crude protein	18.04	18.22	17.79	17.34	18.04	18.22	17.79	17.34
ME(MJ/kg)	11.49	11.38	11.25	11.13	11.49	11.38	11.25	11.13
Crude fibre	3.94	4.09	4.12	4.24	3.94	4.09	4.12	4.24

fixed ingredients – 24.00% soybean meal, 2.00% fishmeal, 3.00% bone meal, 1.50% oyster shell, 0.50% salt, 0.50% premix, 0.25% methionine; ME – metabolisable energy, MJ – megajoule; * each kg feed contained (vitamin-mineral premix): Vit. A, 1500 IU; Vit. 2,500 IU, Vit. E, 1101 U; Vit B3, 40mg; Vit. B6, 20 mg; chlorine chloride, 400 mg; Mn 120 mg, Fe, 70 mg; Cu, 100 m; I l; 2.2 m; Se, 0.2 mg; Zn, 45 m; Co, 0.02 m

2.5.2 Determination of Haematological Parameters

Using the micro-haematocrit method outlined by Dacie and Lewis (1991), packed cell volume (PCV) was calculated. The cyanomethaemoglobin-colometry approach was used to identify the hemoglobin concentration (Kelly, 1979). The enhanced Neubauer hemocytometer method, as outlined by Jain (1986), was used to determine the counts of red blood cells and white blood cells. Wright's stain was used to create differential smears, which allowed for the measurement of the differential white blood cell counts (Dacie and Lewis, 1991).

2.5.3 Determination of Serum Biochemistry

Serum was isolated from blood samples intended for serum chemistry by centrifuging them for 10 minutes at 1000 rpm. Using diagnostic reagent kits (Rend Dia gnusztikal Reagents, Keszlet, Hungary), serum constituents were analyzed: total protein (Weehelbaun, 1984), albumin and globulin (Doumas and Briggs, 1972), and cholesterol (Roshian et al., 1974). Using the methods of Reitman and Frankel (1957), the colorimetric activities of alkaline phosphatase (ALP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) were measured.

2.5.4 Dissection of Carcass (Carcass and Organ Evaluation)

Thirty-two (32) animals were slaughtered at the end of eight weeks, having been fasted overnight. They were stunned and immediately bled by severing the jugular vein.

The carcasses were opened up from the neck to the pelvic region, breaking through the pubic symphyses, and the following organs: liver, heart, spleen, and kidney were quickly removed, blotted free of blood and all adhering connective tissues, and weighed.

The carcasses were scalded, dressed, and split into two symmetric halves along the vertebral column. The left side was carefully dissected into primal cuts (ham, loin, belly, boston butt and picnic shoulder) from the carcasses. The relative weights were calculated as percentage of live weight of the animals.

2.6 Statistical Analysis

All data were analysed using GLM of SAS (2000) and means were compared using DMRT. The model used was:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where: Y_{ij} – represents the response variable being measured; μ – denotes the overall mean effect; α_i – represents the effect of the i^{th} treatment; β_j – represents the effect of the j^{th} inclusion; $(\alpha\beta)_{ij}$ – represents the interaction effect of the ij^{th} inclusion; ε_{ijk} – represents the error term for the ij^{th} observation

3 Results and Discussion

3.1 Haematological Characteristics of Weaned Pigs

The dietary effects of CTM's cyanide on the haematological traits of weaner pigs are shown in Table 2. Packed cell volume, WBC, haemoglobin concentration (Hb), RBC, neutrophils and lymphocytes differed remarkably ($P < 0.05$) by CTM level in the diets. Weaner pigs fed 25% CTM had notably increased ($P < 0.05$) values of 43.93%, 17.81 × 10^3/mm^3, and 13.44 g/dl for PCV, WBC, and Hb, respectively.

The main effects of ACS on the haematological traits of weaner pig are shown in Table 3. ACS significantly ($P < 0.05$) affected PCV, WBC, Hb, RBC, neutrophils and lymphocyte counts. Weaner pigs with ACS had significantly ($P < 0.05$) higher values of 41.42%, 13.39g/dl and 54.58% for PCV, Hb, and lymphocyte counts, respectively. ACS significantly ($P < 0.05$) lowered WBC, RBC and neutrophil count: 16.98 × 10^3/mm^3 vs 14.91 × 10^3/mm^3, 4.63 × 10^6/mm^3 vs 4.08 × 10^6/mm^3, 51.31%

Table 2 Treatment effects of CTM on haematological traits of weaner pigs

Parameters (%)	% CTM				
	0	25	50	75	SEM
Packed cell volume (%)	37.62^d	43.93^a	42.91^b	40.00^c	0.13
White blood cell count (×10^3/mm^3)	15.06^c	17.81^a	16.17^b	14.74^d	0.02
Haemoglobin concentration (g/dl)	12.91^c	13.44^a	13.28^b	12.60^d	0.02
Red blood cell count (× 10^6/mm^3)	4.72^a	4.41^b	4.02^c	4.26^b	0.06
Neutrophil (%)	44.48^d	46.92^b	45.42^c	50.97^a	0.09
Lymphocyte (%)	54.08^a	50.33^c	52.64^b	48.48^d	0.07

a, b, c, d – significant variations ($P < 0.05$) exist between values within a single row having distinct superscripts and, 42.58% respectively, for the non- supplemented vs the supplemented group.

The interaction effects of feeding CTM and ACS on the haematological traits of weaner pigs are shown in Table 4. The interaction between CTM and ACS had a substantial ($P < 0.05$) impact on PCV, Hb, RBC, WBC, neutrophil, and lymphocyte counts. For every haematological feature examined, there were significant differences ($P < 0.05$) between the weaner pigs fed 0, 25, 50, and 75% CTM with and without ACS. Packed cell volume values were substantially ($P < 0.05$) lower for pigs on 75% CTM with and without ACS but were considerably ($P < 0.05$) greater for weaner pigs fed 25–50% with or without ACS. The same trend was observed for Hb except for pigs on diet 50% CTM where non-significant ($P > 0.05$) interaction was observed for PCV and Hb. Red blood cell count for supplemented groups differed significantly ($P < 0.05$) and pigs fed 50% CTM had the highest value. For the non-supplemented group, pigs fed 50% CTM had the lowest value while those fed 0% CTM had the highest value. Neutrophil significantly ($P < 0.05$) increased with CTM inclusion for charcoal supplementation, while the reverse was the case for the non-supplementation.

This study revealed that PCV, WBC, and Hb were significantly higher in pigs fed 25% CTM, while RBC and lymphocytes values were higher in the control diet.

Table 3 Supplementation effects of AC on the haematological traits of weaner pigs

Parameters (%)	Activated charcoal		
	-	+	SEM
Packed cell volume (%)	40.80^{b}	41.42^{a}	0.69
White blood cell count (×10^{3}/mm^{3})	16.98^{a}	14.91^{b}	0.46
Haemoglobin concentration (g/dl)	12.73^{b}	13.39^{a}	0.18
Red blood cell count (×10^{6}/mm^{3})	4.63^{a}	4.08^{b}	0.09
Neutrophil (%)	51.31^{a}	42.58^{b}	1.47
Lymphocyte (%)	48.19^{b}	54.58^{a}	1.47

a, b – significant variations ($P < 0.05$) exist between values within a single row having distinct superscripts; + charcoal supplementation; - non-charcoal supplementation

Table 4 Interaction effect of CTM and ACS on the haemotological traits of weaner pigs

Parameter	% CTM					
	charcoal supplementation	0	25	50	75	SEM
Packed cell volume (%)	-	36.26^{cy}	42.98^{ay}	42.95^{a}	41.03^{bx}	0.07
	+	38.98^{cx}	44.88^{ax}	42.88^{b}	38.97^{cy}	0.20
	SEM	0.10	0.08	0.18	0.19	
Haemogolobin concentration (g/dl)	-	11.56^{cy}	13.30^{ay}	13.30^{a}	12.75^{bx}	0.01
	+	14.25^{ax}	13.59^{bx}	13.25^{c}	12.46^{dy}	0.03
	SEM	0.02	0.01	0.03	0.02	
Red blood cell count (×10^{6}/mm^{3})	-	5.46^{ax}	4.82^{bx}	3.87^{dy}	4.39^{cx}	0.13
	+	4.01^{cy}	4.00^{cy}	4.18^{ax}	4.11^{by}	0.01
	SEM	0.01	0.13	0.01	0.01	
White blood cell count (×10^{3}/mm^{3})	-	16.79^{cx}	17.34^{by}	15.75^{dy}	17.94^{ax}	0.01
	+	13.33^{cy}	18.28^{ax}	16.59^{bx}	11.45^{dy}	0.04
	SEM	0.01	0.01	0.01	0.03	
Neutrophil (%)	-	56.63^{ax}	49.50^{cx}	51.50^{by}	47.63^{dy}	0.17
	+	32.34^{dy}	44.34^{by}	39.34^{cy}	54.32^{ax}	0.01
	SEM	0.04	0.10	0.10	0.07	
Lymphocyte (%)	-	42.50^{cy}	49.00^{by}	48.63^{by}	52.63^{ax}	0.12
	+	65.06^{ax}	51.66^{cx}	56.66^{bx}	44.34^{dy}	0.00
	SEM	0.10	0.01	0.07	0.07	

a, b, c, d – significant variations ($P < 0.05$) exist between values within a single row having distinct superscripts; x, y – values within the same column with varying superscripts differ notably ($P < 0.05$)

However, the values of these parameters were within the reference range values established by Mitruka and Rawnsley (1977), Ross et al. (1978), and Merck Manual (2022a). Despite this observation, it could be observed that the majority of these parameters were depressed at 75% CTM, attributable to the residual cyanide in CTM. This agrees with the work of Oke (1969), who postulated that hydrogen cyanide has a high affinity for metal ions such as copper and iron, which could have prevented the absorption of these important erythropoietic metals. It also supports Brown and Clime (1991) and Ojediran et al. (2024a), who observed diminishing haematological values linked with low protein quality and elevated HCN in pig. A normal lymphocyte count was observed in this study because an increase in lymphocytes may be caused by all conditions that have associated neutropenia and lymphocytic leukaemia, during the recovery stages of certain infections, and sometimes following vaccination (Mitruka & Rawnsley, 1977). The values obtained, being within normal range, demonstrated that erythropoietic function was not impaired, as also demonstrated by PCV higher than 30% (Perri et al., 2016).

Supplementation of CTM-based diets with AC showed a reducing effect on the WBC, RBC, and neutrophil values. This is an indication that AC cannot satisfactorily counter the negative effect of HCN. The adsorbing capacity of AC was not fully enhanced to reduce the effect of HCN to bind with metals in blood. Neutrophil is identified as a very effective defensive agent/machine (Oyebola, 2002) and is the body's first line of defence against bacteria. However, values obtained were within the literature values of Mitruka and Rawnsley (1977) and Merck Manual (2022a).

The interaction effects of CTM and ACS revealed that majority of the haematological indices were not significantly favoured by the AC at 75% CTM level. Generally, the pattern was not definite.

3.2 Serum Indices of Weaner Pigs

Effects of cassava tuber meal (CTM) on serum traits are shown in Table 5. Pigs given 25% and 50% CTM had greater serum albumin levels ($P < 0.05$), while globulin and total protein levels were considerably higher ($P < 0.05$) in 50% CTM than in other diets. The same trend was observed for ALT and AST. These parameters increased ($P < 0.05$) in weaner pigs offered 50% and 75% CTM, although AST value was higher in 50% CTM than 75% CTM, while the ALT value was higher in 75% CTM than in other diets. Alkaline phosphatase was affected ($P < 0.05$) by the levels of CTM. Weaner pigs fed 50% and 75% CTM showed similar values (34.50 and 34.63 iu/l, respectively), which were remarkably ($P < 0.05$) greater than others. Cholesterol levels were similar for 0%, 25%, and 50% CTM but were notably ($P < 0.05$) reduced compared to 75% CTM. Triglycerides for 25% considerably higher ($P < 0.05$) than those 0% and 50% CTM, while those offered 75% were comparable.

Effects of ACS on the serum traits of weaner pigs are presented in Table 6. All traits differ considerably ($P < 0.05$). Diets with ACS notably ($P < 0.05$) depressed the values of albumin, globulin, total protein, and ALP whereas supplementation with AC had significantly higher ($P < 0.05$) value of AST (35.72 iu/l). Also, cholesterol and triglyceride values significantly ($P < 0.05$) increased (from 3.00 to 3.27g/dl) and (from 1. 20 to 1.50mg/dl) respectively.

The effects of interaction between feeding cassava tuber meal and ACS on the serum traits of weaner pigs are presented in Table 7. Weaner pigs fed 0, 25, 50 and 75% CTM without ACS exhibited considerable ($P < 0.05$) disparities in the value of albumin, with pigs fed 25 and 50% CTM showing no influence ($P > 0.05$).

A similar trend was noticed for charcoal supplementation. ACS at different CTM levels essentially ($P < 0.05$) affected

Table 5 Treatment effect of CTM on Serum traits of weaner pigs

Parameters	% CTM				
	0	25	50	75	SEM
Albumin (g/dl)	2.50^{c}	2.70^{a}	2.70^{a}	2.60^{b}	0.03
Globulin (g/dl)	2.39^{d}	2.58^{c}	2.72^{a}	2.70^{b}	0.01
Total protein (g/dl)	4.89^{c}	5.28^{b}	5.42^{a}	5.30^{b}	0.01
AST (iu/l)	34.00^{c}	33.38^{d}	37.50^{a}	35.19^{b}	0.14
ALT (iu/l)	24.56^{d}	26.67^{c}	33.54^{b}	35.06^{a}	0.24
ALP (iu/l)	30.13^{b}	29.63^{c}	34.50^{a}	34.63^{a}	0.11
Cholesterol (g/dl)	2.85^{b}	3.02^{b}	2.98^{b}	3.68^{a}	0.60
Triglyceride (mg/dl)	1.26^{b}	1.50^{a}	1.26^{b}	1.37^{ab}	0.50

a, b, c, d – significant variations ($P < 0.05$) exist between values within a single row having distinct; AST – aspartate aminotransferase; ALT – alanine aminotransaminase; ALP – alkaline phosphatase

Table 6 Supplementation effect of AC on the serum parameters of weaner pigs

Parameters	Activated charcoal		
	-	+	SEM
Albumin (g/dl)	3.17[a]	2.08[b]	0.03
Globulin (g/dl)	2.98[a]	2.21[b]	0.04
Total protein (g/dl)	6.15[a]	4.29[b]	0.06
AST (iu/l)	34.31[b]	35.72[a]	1.04
ALT (iu/l)	30.34	29.57	1.39
ALP (iu/l)	34.94[a]	29.50[b]	1.07
Cholesterol (mg/dl)	3.00[b]	3.27[a]	0.5
Triglyceride (mg/dl)	1.20[b]	1.50[a]	0.1

a, b – significant variations (*P* < 0.05) exist between values within a single row having distinct; + charcoal supplementation; - non-charcoal supplementation

Table 7 Interaction effect of CTM and ACS on serum traits of weaner pigs

Parameters		Treatment				
	charcoal supplementation	0	25	50	75	SEM
Albumin (g/dl)	-	2.93[cx]	3.28[ax]	3.30[ax]	3.10[bx]	0.02
	+	2.08[aby]	2.11[ay]	2.09[ay]	2.04[by]	0.01
	SEM	0.03	0.02	0.01	0.01	
Globulin (g/dl)	-	2.85[dx]	3.10[ax]	3.03[bx]	2.96[cx]	0.01
	+	1.92[cy]	2.07[by]	2.43[ay]	2.43[ay]	0.00
	SEM	0.00	0.01	0.02	0.01	
Total Protein (g/dl)	-	5.78[cx]	6.38[ax]	6.33[ax]	6.13[bx]	0.02
	+	4.00[dy]	4.18[cy]	4.52[ay]	4.47[by]	0.02
	SEM	0.03	0.02	0.02	0.01	
AST (iu/l)	-	29.00[dy]	32.25[cy]	35.88[by]	40.13[ax]	0.17
	+	39.00[ax]	34.50[bx]	39.13[ax]	30.25[cy]	0.14
	SEM	0.00	0.27	0.13	0.23	
ALT (iu/l)	-	24.25[d]	28.50[cx]	29.50[by]	39.13[ax]	0.20
	+	24.88[c]	24.84[cy]	37.58[ax]	31.00[by]	0.27
	SEM	0.20	0.15	0.54	0.07	
ALP (iu/l)	-	30.25[d]	35.25[bx]	41.00[ax]	33.25[cy]	0.19
	+	30.00[b]	24.00[dy]	28.00[cy]	36.00[ax]	0.00
	SEM	0.13	0.13	0.00	0.13	
Cholesterol (mg/dl)	-	2.89[b]	2.79[by]	2.76[b]	3.56[ay]	0.12
	+	2.81[c]	3.26[bx]	3.20[b]	3.79[ax]	0.02
	SEM	0.06	0.03	0.15	0.04	
Triglycerides (mg/dl)	-	1.47[ax]	1.19[aby]	1.21[ab]	0.90[by]	0.10
	+	1.05[dy]	1.81[bx]	1.31[c]	1.83[ax]	0.00
	SEM	0.08	0.01	0.07	0.04	

a, b, c, d – significant variations (*P* < 0.05) exist between values within a single row having distinct; x, y – values within the same column with varying superscripts differ notably (*P* < 0.05) albumin. Supplementation depressed (*P* < 0.05) the values at all levels of CTM inclusion (2.08, 2.11, 2.09, and 2.04 g/dl for 0, 25, 50, and 75%, respectively). Serum globulin and total protein for weaner pigs at different levels of CTM without ACS were influenced (*P* < 0.05) differently. Similarly, the values at different levels of CTM with charcoal supplementation showed noticeable differences (*P* < 0.05). Both globulin and total protein values for the ACS were saliently higher (*P* < 0.05) compared to non-supplemented ones.

The AST and ALT for weaner pigs fed 0–75% CTM with and without ACS differ remarkably (*P* < 0.05). Moreover, AST at 75% CTM was elevated (*P* < 0.05) when compared with other CTM levels without charcoal supplementation, but lowest in 75% CTM with ACS. At all levels of CTM, AST was increased (*P* < 0.05) by charcoal supplementation, except at 75% CTM level where a significant (*P* < 0.05) reduction was observed. The trend was different for ALT except in the control diet (0% CTM), which showed similarity (*P* > 0.05) and higher value at the 50% CTM level with ACS. Outstanding (*P* < 0.05) difference was also observed for alkaline phosphatase, with the highest values at 50% CTM level for non-supplemented diet and 75% CTM level for supplemented diets. Similarity was observed with supplemented and non-supplemented levels (*P* > 0.05) at 0% CTM level (30.00 and 30.25), while at other CTM levels, relevant (*P* < 0.05) differences were manifested. Cholesterol values remarkably (*P* < 0.05) rose as CTM levels increased for supplemented and except for non-supplemented ones at 25 and 50%. Similarly, at 50 and 75% CTM levels, higher values (*P* < 0.05) were observed for charcoal. However, values of 2.89 and 2.81 at 0% CTM and 3.20 at 50% CTM for non-supplemented and supplemented AC were comparable (*P* > 0.05), respectively. Triglyceride considerably (*P* < 0.05) decreased to 0.90 mg/dl at 75% CTM level for non-supplemented diets, while it was reversed with charcoal supplementation. Weaner pigs fed diets 2, 3, and 4 with charcoal supplementation had considerably (*P* < 0.05) greater triglyceride values than the control diet. However, at 50% CTM level, those fed supplemented and non-supplemented diets had similar (*P* > 0.05) values.

Albumin, globulin, and total protein are reflectors of the adequacy of protein quality and quantity in the diets. Their values were significantly better at 50% CTM level. The same trend is observed in AST and ALP. This could reflect this level of CTM as the best for this study with charcoal supplementation. Total serum protein has been identified as an indication of the protein retained in the animal body (Esonu et al. 2001; Ojediran et al., 2024a). Reasonably, the values were comparable for all parameters, even at 75% CTM level. This shows that the cyanide content was able to cause some excitement, but not below or above literature values. The responses of animals to protein, both quantitatively and qualitatively, are dependent on the antigenic stimuli. Since these animals are not exposed to any infection, even accidentally, it means the quality of the diets is adequate and the nutrients were well utilized. The marginal increase in serum proteins conformed to the finding of Ozung et al. (2011), when rabbits were fed cassava peel meal based diets, but contradicts the findings of Omole and Onwudike (1982) when palm oil was added. The ALT and AST values in this study for the test diets were generally higher. This observation corroborated Ojediran et al. (2021, 2024a), contrary to the report of Alagbe (2024), who fed Doum palm meal and partial maize to pigs at up to 20%. These serum enzymes are liable to toxic agents in diets (Nyirenda, 2021). The enzymes also increase in the blood due to tissue damage in vital organs like the liver and kidney (Fevrier-Paul et al., 2018).

Supplementation with AC did not significantly increase albumin, globulin, total protein, ALT, and ALP in this study. Malnutrition and liver dysfunction are part of the causes of decreased serum protein.

3.3 Carcass Cut/Characteristics

The carcass cut /characteristics of weaner pigs given varying levels of cassava tuber meal are presented in Table 8. Carcass weight and dressing percentage were similar for the four diets (*P* > 0.05). Picnic shoulder remarkably (*P* < 0.05) increased as the level of CTM increased.

However, inconsistent variations (*P* < 0.05) were noticed among the diets for belly, loin and boston butt. Weaner pigs fed diet 2 had the highest values of 9.74, 8.60 and 1.93% for belly, loin and boston butt respectively.

The effect of ACS on carcass characteristics/cuts of weaner pigs fed cassava tuber-based diets is presented in Table 9. Supplementation with AC had a non-significant (*P* > 0.05) effect on carcass weight and dressing percentage of weaner pigs. Weaner pigs fed CTM based diets without ACS showed higher values (*P* < 0.05) for picnic shoulder and boston butt while saliently higher (*P* < 0.05) values were observed for belly, ham and loin of pigs given feeds supplemented with AC.

Table 10 shows the interaction effect of CTM levels and ACS on carcass/cut characteristics of weaner pigs. Only the carcass weight was not noticeably (*P* > 0.05) affected by the interaction effects. The dressing percentage was similar across the dietary treatments for CTM diets with ACS as well as for CTM diets without supplementation except for the control diets. However, weaner pigs offered gradient levels of CTM without charcoal supplementation indicated remarkably ($P < 0.05$) higher values of dressing %. Picnic shoulder values of weaner pigs fed 0–75% CTM diets without ACS were 3.86, 4.24, 4.58 and 4.59%, respectively, with pigs fed 50 and 75% CTM levels having similar values but noticeably ($P < 0.05$) higher than others. Activated charcoal supplemented groups also had innegligibly ($P < 0.05$) different values, with 75% CTM having a considerably ($P < 0.05$) highest value compared with other diets. The supplementation effect was recorded for the value with pigs fed diets without supplementation showing noticeably ($P < 0.05$) higher values for all the diets. Various levels of CTM and charcoal supplementation significantly affected ($P < 0.05$) belly, ham, loin and boston butt. Pigs fed CTM with charcoal supplementation had higher values ($P < 0.05$) for belly, ham, loin and boston butt.

It was observed from this study that the carcass weight and dressing percentage of the weaner pigs were comparable across the treatments, indicating that the replacement of maize with cassava tuber meal did not affect these parameters. The same observation was made by Ojediran et al. (2024a) that the highest level of cassava diets produced leaner carcasses. Ojediran et al. (2024b, c) attributed the leanness to dietary fibre. Ozung et al. (2011) reported that replacing of maize with cassava peel meal in the diets of rabbits had no effect on the carcass and dressing percentage. Cut characteristics did not present a trend; however, at 25% CTM level, relative weights of the belly, ham, loin and boston butt were higher when compared to other inclusion levels.

The supplementation effect of AC did not affect the carcass weight and dressing percentage. Adesehinwa et al. (2011) reported no significant effect of cassava based diets supplemented with Farmazyme (R) 300 proenx on the carcass and dressing percentage of pigs. Johri (2004) and Torres et al. (2003) made a similar observation on broilers. Charcoal supplementation favoured belly, ham, and loin development in this study.

Table 8 Treatment effect of cassava tuber meal on the carcass cut of weaner pigs

Parameters	% CTM				
	0	25	50	75	SEM
Carcass weight (kg)	19.21	17.73	18.33	18.30	0.84
Dressing percentage (%)	69.25	65.49	66.01	68.25	2.00
Picnic shoulder (%)	3.24^{c}	3.32^{c}	3.94^{b}	4.11^{a}	0.04
Belly (%)	9.36^{c}	9.74^{a}	9.38^{bc}	9.43^{b}	0.02
Ham (%)	12.57^{a}	12.63^{a}	12.38^{b}	12.27^{c}	0.60
Loin (%)	8.23^{b}	8.60^{a}	7.34^{d}	7.86^{c}	0.02
Boston butt (%)	1.13^{c}	1.93^{a}	1.45^{b}	1.07^{c}	0.01

a, b, c, d – significant variations ($P < 0.05$) exist between values within a single row having distinct

Table 9 Supplementation effect of AC on the carcass/ cut characteristics of weaner pigs fed CTM diets (expressed as percentage of final live weight)

Parameters	Activated charcoal		
	-	+	SEM
Carcass weight (kg)	18.09	18.70	0.50
Dressing percentage (%)	68.46	66.04	1.32
Picnic shoulder (%)	4.31^{a}	3.00^{b}	0.11
Belly (%)	8.23^{b}	10.72^{a}	0.10
Ham (%)	9.67^{b}	15.07^{a}	0.10
Loin (%)	5.32^{b}	10.69^{a}	0.13
Boston butt (%)	1.81^{a}	1.50^{b}	0.01

a, b, c, d – significant variations ($P < 0.05$) exist between values within a single row having distinct; + charcoal supplementation; - non-charcoal supplementation

Table 10 Interaction effect of CTM and ACS on the carcass/ cuts characteristics of weaner pigs (expressed as percentage of final live weight)

Parameter		% CTM				
	charcoal supplementation	0	25	50	75	SEM
Carcass weight (kg)	-	18.84	17.27	18.48	17.76	1.33
	+	19.58	18.19	18.17	18.85	0.36
	SEM	0.59	0.95	0.92	0.93	
Dressing percentage	-	71.15x	66.55	68.51	67.62	3.39
	+	67.36y	64.43	63.51	68.89	1.55
	SEM	2.06	2.54	1.61	3.77	
Picnic shoulder (%)	-	3.86cx	4.24bx	4.58ax	4.59ax	0.06
	+	2.63cy	2.41dy	3.30by	3.63ay	0.00
	SEM	0.06	0.00	0.05	0.01	
Belly (%)	-	7.17cy	8.30by	8.29by	8.62ay	0.04
	+	11.01bx	11.17ax	10.47cx	10.24dx	0.01
	SEM	0.04	0.01	0.02	0.02	
Ham (%)	-	9.49by	10.39ay	9.65by	9.11cy	0.05
	+	14.87cx	14.88cx	15.11bx	15.43ax	0.00
	SEM	0.03	0.01	0.04	0.03	
Loin (%)	-	5.42by	5.63ay	5.07dy	5.18cy	0.02
	+	11.30bx	11.57ax	9.61dx	10.54cx	0.01
	SEM	0.02	0.02	0.02	0.01	
Boston butt (%)	-	1.63dy	1.99ay	1.85by	1.77cy	0.02
	+	8.63bx	7.87dx	9.05ax	8.37cx	0.02
	SEM	0.02	0.00	0.03	0.01	

a, b, c, d – significant variations (*P* < 0.05) exist between values within a single row having distinct; x, y – values within the same column with varying superscripts differ notably (*P* < 0.05)

3.4 Relative Organ Weights

The effects of varying levels of CTM on the relative organ weights (Table 11) revealed that weaner pigs given 75% CTM had remarkably (*P* < 0.05) high values for lung, liver, heart, kidney, and spleen than other treatments. However, comparable values of heart were obtained for pigs on 0% and 75% CTM diets.

The Supplementation effect of AC on the relative organ weights of weaner pigs is presented in Table 12. Pigs fed charcoal-supplemented diets had considerably higher (*P* < 0.05) values for lung, liver, and heart, while those on non-supplemented diets had noticeable (*P* < 0.05) increased values for kidney and spleen.

Table 13 shows the interaction effect of charcoal supplementation and varying levels of CTM on the relative organ weights of weaner pigs. The interaction effects significantly (*P* < 0.05) affected the lung, liver, heart, kidney and spleen. Varying levels of CTM with and without supplementation indicated significantly (*P* < 0.05) higher values for all organs presented in the table, except for the value of the heart, which showed improved values for 75% CTM with charcoal supplementation. Weaner pigs fed CTM with charcoal supplementation showed significantly better lung values for the four diets than the non-supplemented ones.

The addition of CTM to weaner pig diets significantly accounted for higher values or hypertrophy of the lung, liver, heart, kidney, and spleen, especially at 75% CTM level. Attempt to cope with the level of the HCN might have accounted for these values. This shows that he liver being the organ of detoxification is overworked (Nyirenda, 2021). Also, the filtering role played by the kidney (Dybiec et al., 2022) increased, as metabolic activities of other organs such as lungs, heart and spleen (Adesheinwa et al., 2011) due to the increased cyanide. This is contrary to the report of Ozung et al. (2011) where no differences were observed in the weight of these organs in broilers when cassava peel meal was fed at 75% level. This is similar to the report of Ojediran et al. (2024b).

Table 11 Treatment effect of CTM level on the relative organ weights of weaner pigs (expressed as a percentage of live weight)

Parameters	% CTM				
	0	25	50	75	SEM
Lung	2.36^{b}	2.02^{c}	1.85^{d}	2.50^{a}	0.02
Liver	4.06^{c}	3.73^{d}	4.44^{b}	4.67^{a}	0.01
Heart	0.93^{a}	0.80^{c}	0.85^{b}	0.94^{a}	0.01
Kidney	0.68^{b}	0.63^{d}	0.66^{c}	0.84^{a}	0.01
Spleen	0.32^{b}	0.2^{c}	0.31^{b}	0.35^{a}	0.01

a, b, c, d – significant variations (*P* < 0.05) exist between values within a single row having distinct

Table 12 Supplementation effect of AC on the relative organ weights of weaner pigs (expressed as percentage of live weight)

Parameters	Activated charcoal		
	-	+	SEM
Lung	1.95^{b}	2.41^{a}	0.07
Liver	4.06^{b}	4.38^{a}	0.01
Heart	0.84^{b}	0.92^{a}	0.06
Kidney	0.73^{a}	0.68^{b}	0.02
Spleen	0.34^{a}	0.28^{b}	0.01

abcd – significant variations (*P* < 0.05) exist between values within a single row having distinct; + charcoal supplementation; - non – charcoal supplementation

Table 13 Interaction effect of cassava tuber meal and ACS on the relative organ weights of weaner pigs (expressed as percentage of live weight)

Parameters		% CTM				
	charcoal supplementation	0	25	50	75	SEM
Lung	-	2.06^{a}y	1.76^{b}y	1.59^{c}y	1.69^{b}y	0.02
	+	2.65^{ax}	2.28^{bx}	2.11^{cx}	2.60^{ax}	0.04
	SEM	0.01	0.00	0.08	0.03	
Liver	-	4.07^{b}	3.64^{c}y	4.25^{a}y	4.29^{a}y	0.01
	+	4.06^{c}	3.82^{dx}	4.63^{bx}	5.40^{ax}	0.01
	SEM	0.00	0.00	0.02	0.01	
Heart	-	0.87^{b}y	0.71^{d}y	0.83^{c}y	0.97^{ax}	0.01
	+	0.99^{ax}	0.89^{cx}	0.88^{cx}	0.92y^{b}	0.00
	SEM	0.01	0.01	0.01	0.01	
Kidney	-	0.68^{c}	0.59^{d}y	0.71^{bx}	0.94^{ax}	0.01
	+	0.68^{b}	0.68^{bx}	0.62^{c}y	075^{a}y	0.00
	SEM	0.01	0.00	0.01	0.00	
Spleen	-	0.37^{ax}	0.29^{c}	0.32^{b}	0.39^{ax}	0.01
	+	0.26^{c}y	0.27^{b}	0.31^{a}	0.31^{a}y	0.00
	SEM	0.01	0.00	0.01	0.01	

abcd – Significant variations (*P* < 0.05) exist between values within a single row having distinct; x,y – values within the same column with varying superscripts differ notably (*P* < 0.05)

Supplementation with AC caused enlargement of the lung, liver, and heart due to overwork, while non-supplementation accounted for an increase in size of the kidney and spleen. Hesham et al. (2004) showed that the relative weight of the liver was significantly increased in chicks consuming aflatoxin compared to those fed activated charcoal. It should be noted that aflatoxin is a metabolite of fungi, as against the natural toxin in cassava (cyanide). Also, it has been established that the principal target organ for aflatoxicosis is the liver (Dalvi & Ademoyero, 1984). According to Bone (1979), anomalies in the weights of the liver and kidney would be seen if the diet contained any hazardous substances or toxic components. Activated charcoal was able to bind reasonably to the HCN and reduce the weight of the kidney and spleen. However, enlargement of the liver, heart, and lungs could be attributed to the inability of the charcoal to prevent the action of anti-nutritional factor (HCN) on the organs at higher inclusion level of CTM. According to Ani et al. (2008), the liver and kidneys are crucial for the body's detoxification and removal of the majority of harmful substances. Also, infiltration of fluid into the cells of the organs may also cause enlargement (Iyayi & Taiwo, 2003).

4 Conclusions

It can be concluded that despite the variations in the blood parameters of weaner pigs fed CTM diets with or without AC supplementation, the values were within the normal literature value, indicating the safety of the test ingredients. Albumin, globulin and total protein increased as CTM level increased up to 50% but were significantly reduced by ACS. However, 25% CTM with ACS improved the PCV, Hb and WBC, lowered ALP, AST and ALP. Thus, the animals were not anaemic, has good immnity and organ integrity. ACS supplementation effect significantly favoured belly, ham, loin and boston butt cuts but higher values are observable at 25% CTM level and ACS for belly and loin. Liver, kidney, and spleen weights increased in weaner pigs fed 75% CTM with or without ACS. However, 25% CTM had lower values for liver among the pigs fed CTM. The use of ACS in CTM diets at up to 25% is recommended to safeguard the health of weaned pigs especially with blood (increased PCV, Hb, WBC, and reduced AST, ALT and ALP) and liver.

Conflict of Interest

The author declares that they have no conflict of interest.

Author Contributions

Tunji B. Olayeni: conceptualization, designed the experiment, performed the experiment, analyzed the data, and corrected the draft. Taiwo K. Ojediran: performed the experiment, interpreted the data, and wrote the first draft and corrected the draft.

AI and AI-Assisted Technologies Use Declaration

No generative AI tools/AI-assisted technologies were used during the preparation of the manuscript.

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