

Effect of *Zymomonas mobilis* degraded cassava sift on blood profile, carcass characteristics and sensory properties of Broiler chickens

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Abstract

The perennial scarcity and high market price of wheat offal have led to an urgent call for a suitable replacement. The fibrous and low nutrient nature of cassava sift limit its utilization in poultry nutrition. *Zymomonas mobilis* extracted from fresh palm wine is proposed to ferment cassava sift to improve its nutritive values. Therefore, in this study, 375, one day-old chicks were used for a 56-day feeding trial to evaluate the effect of *Zymomonas mobilis* degraded cassava sift (CSZ) on haematology, serum metabolites, carcass characteristics and sensory properties in meat from broiler chickens. Five experimental diets were formulated such that the cassava sift (CSZ) was included to replace wheat offal at 0, 50 and 100% levels. A total of 75 chicks were randomly allotted to each diet at 15 chicks per replicate in a completely randomized design. At the starting phase, the birds fed 100% CSZ had the highest ($p < 0.05$) haemoglobin (Hb) and packed cell volume (PCV) values, whereas at finishing phase the white blood cells, mean corpuscular haemoglobin, mean corpuscular volume and heterophil of birds fed 100% CSZ were highest ($p < 0.05$). Birds fed 50% CSZ had the lowest ($p < 0.05$) value for white blood cells. The birds fed 50% CSZ and 100% CSZ had the highest ($p < 0.05$) values for breasts while the least value was recorded in 50% CS. Broiler chickens fed 100% CS had the highest ($p < 0.05$) values for kidneys, gizzard and whole gastrointestinal tract while 100% CSZ had lowest values for heart, lungs, gizzard. It is therefore concluded that 50% *Zymomonas mobilis* degraded cassava sift can replace wheat offal in broiler chickens' diets.

Keywords: Blood profile; cassava sift; sensory properties; *Zymomonas mobilis*

Effet de la farine de manioc dégradée par *Zymomonas mobilis* sur le profil sanguin, les caractéristiques de la carcasse et les propriétés sensorielles des poulets à griller



Résumé

La rareté perpétuelle et le prix élevé sur le marché des sous-produits de blé ont conduit à un besoin urgent de remplacement approprié. La nature fibreuse et pauvre en nutriments de la farine de manioc limite son utilisation en nutrition aviaire. *Zymomonas mobilis*, extrait du vin de palme frais, est proposé pour fermenter la farine de manioc afin d'améliorer sa valeur nutritive. Dans cette étude, 375 poussins d'un jour ont été utilisés pour un essai de 56 jours afin d'évaluer l'effet de la farine de manioc dégradée

par *Zymomonas mobilis* (CSZ) sur l'hématologie, les métabolites sériques, les caractéristiques de la carcasse et les propriétés sensorielles de la viande des poules de chair. Cinq régimes expérimentaux ont été formulés, de sorte que la farine de manioc (CSZ) remplace les sous-produits de blé à 0, 50 et 100 %. Un total de 75 poussins a été réparti de manière aléatoire dans chaque régime, avec 15 poussins par réplique dans un design complètement aléatoire. À la phase de départ, les oiseaux nourris avec 100 % de CSZ avaient les valeurs les plus élevées ($p < 0,05$) d'hémoglobine (Hb) et de volume globulaire (PCV), tandis qu'à la phase de finition, les globules blancs, l'hémoglobine corpusculaire moyenne, le volume corpusculaire moyen et les hétérophiles des oiseaux nourris avec 100 % de CSZ étaient les plus élevés ($p < 0,05$). Les oiseaux nourris avec 50 % de CSZ avaient les valeurs les plus faibles ($p < 0,05$) de globules blancs. Les oiseaux nourris avec 50 % et 100 % de CSZ avaient les valeurs les plus élevées ($p < 0,05$) pour les poitrines, tandis que la valeur la plus basse a été enregistrée avec 50 % CS. Les poulets à griller nourris avec 100 % CS avaient les valeurs les plus élevées ($p < 0,05$) pour les reins, le gésier et l'ensemble du tractus gastro-intestinal, tandis que 100 % CSZ avaient les valeurs les plus basses pour le cœur, les poumons et le gésier. Il est donc conclu que 50 % de farine de manioc dégradée par *Zymomonas mobilis* peut remplacer les sous-produits de blé dans les régimes des poulets à griller.

Mots-clés : Profil sanguin ; farine de manioc ; propriétés sensorielles ; *Zymomonas mobilis*

Running title: *Zymomonas mobilis* degraded cassava sift on blood parameters

Introduction

Agro-industrial by-products (AIBPs) are the wastes derived during the processing of the main products. These include brewers spent grains, shells, cakes, peels, wheat and maize offals and molasses etc. These by-products are often burnt or improperly disposed and resulting in environmental pollution (Onyeonagu and Njoku, 2010). The utilization of these by-products as animal feed ingredients thus could solve the risk of environmental pollution arising from indiscriminate disposal, leading to cheaper feed stuffs, reduced cost of poultry products and increased profit. Cassava sift emanates from the processing of cassava flour, this waste constitutes nuisance as they are not directly useful to humans. Studies (Ewane, 1996; Aro *et al.* 2010; Odunsi, 2017) have shown that cassava peels and cassava waste derived from the processing of cassava roots could be utilized to a great extent in the feeding of poultry and pigs. However, efficient use of cassava and its products for poultry feeding would require application of different biotechnological techniques to improve its preservation, nutritional value, and its utilization (Aro *et al.* 2010) due to its toxicity and fibrous nature.

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different biotechnological techniques. These procedures will improve its preservation, nutritional value, and its utilization within the poultry feed industry (Aro *et al.* 2010).

Zymomonas mobilis is a bacterium belonging to the genus *Zymomonas* that is known for its bio-ethanol production efficiency, with activities that surpass yeast in some aspects (Gunasekaran and Chandra, 1999). *Zymomonas mobilis* is generally found in African palm wine and Mexican pulque (Anigbogu *et al.*, 2011). *Zymomonas mobilis* is a rod-shaped gram-negative bacterium which is 2-6 μ m long and 1-1.4 μ m wide but varied significantly. Its ability to efficiently ferment carbohydrates makes it a beautiful option as live-enzyme in animal feed (Seo *et al.*, 2005; Yanase *et al.*, 2005; Cazetta *et al.*, 2007; Onyejekwe, 2010). The treatment of cassava sift with *Zymomonas mobilis* microbes is reported to breakdown the polysaccharide and lignin contents into simpler carbohydrates (Alade *et al.* 2019). Earlier study by Alade *et al.* 2019 reported chemical composition of *Zymomonas mobilis* degraded cassava sift to contain 5.36% crude protein, 13.0% crude fibre, and gross energy of 15.45 MJ/Kg. However, the present study was carried out to determine the effects of *Zymomonas mobilis* degraded cassava sift on blood profile,

carcass characteristics and sensory properties of broiler chickens.

Materials and methods

Research station and test ingredient

The research was carried out at the Poultry Unit, Directorate of University Farms (DUFARMS), and Animal Nutrition Laboratory, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria located at 7°10'N and 3°2'E, 76 m above sea level. Abeokuta lies within the South-Western part of Nigeria with a prevailing tropical climate, mean annual rainfall of 1238 mm and an average temperature of 27.1 °C (Climate-data.org Nigeria Ogun, 2020).

Cassava sift (CS) is the by-product derived from the production of high quality cassava flour. CS is accounted for 10% to 15% while flour is made of 85% or 90% (Odunsi, 2017). It was collected from Thai Farm International Limited, Ososa near Ijebu-Ode, Ogun State, Nigeria.

Pure strains of *Zymomonas mobilis* used in this study were extracted from fresh palm wine and it was obtained from the Food Science Laboratory of the Michael Okpara University of Agriculture, Makurdi, Nigeria. It was used to inoculate the cassava sift to obtain cassava sift starter inoculum for the study.

This was prepared in the traditional setting under laboratory conditions as stated by Anigbogu *et al.* (2009) using a 3.5L fermentation vat containing 500g cassava sift was used as substrate, 100mL of *Zymomonas mobilis* suspended in a cultured media and two litres of water was poured. The mixture was stirred to obtain a homogeneous mixture at room temperature (23.1°C to 24.6 °C) and left in an anaerobic condition for 20 days and turned 24 hourly using a plastic rod. The resulting fermented dough was used as a starter inoculum for the study.

The live enzyme was prepared as described in Anigbogu *et al.* (2009) using 25 kg cassava sift placed in the fermentation a 100L vat with 50L of water added to 2.5 kg fermented dough (starter inoculum). The sample was homogeneously mixed and kept to ferment for

20 days. The fermented product was sun-dried, analyzed and stored as live-enzyme cassava sift.

Management of broiler chickens and experimental diets

A total of 375 unsexed 1-day old Marshal broiler chicks obtained from Obasanjo Farms Nigeria Limited, Lanlate, Nigeria were used for this study. The birds were weighed individually and allotted on a weight equalization basis to five dietary treatments with 75 broiler chicks per treatment and were replicated 5 times with 15 birds per replicate. The diets were formulated to include undegraded and *Zymomonas mobilis* degraded cassava sift at varying levels of 0, 50 and 100% replacing wheat offal weight for weight. Diets were formulated based on Nutrient requirement of broiler chickens (NRC, 1994). The chicks were brooded for two weeks and raised on deep litter for eight weeks (0 – 4 weeks; starter phase and 5-8 weeks; finisher phase). Feed and water were given *ad libitum*.

The birds were vaccinated against Infectious bursal and Newcastle diseases while other appropriate medications were given during the experiment.

The ingredients and chemical composition of the experimental diets are shown in Table 1.

Table 2: Proximate composition of undegraded and degraded cassava sift* (CS) (DM-basis) Alade *et al.* 2019

Data collection

Blood collection and analysis

At days 28 and 56, blood samples were collected at 07:30 am from 75 broiler chickens (15 birds per treatment) via the jugular vein puncture using sterilized needles and syringes. About 2.5mL of blood sample was collected with sterilized needles and syringes from each bird's jugular veins into vials containing ethylene diamine tetra-acetic acid (EDTA) as an anticoagulant for the determination of haematological parameters (red blood cells, white blood cells, packed cell volume and haemoglobin). However, another set of blood was collected into plain tubes for serum biochemistry measurement (glucose,

cholesterol, total protein, albumin, globulin, uric acid, creatinine, aspartate aminotransferase and alanine aminotransferase). The serum was isolated by centrifugation of 2000rpm for 10 minutes and then stored at -70°C until analysis. Haemoglobin concentration was estimated using the cyanmethaemoglobin method (Cannan, 1958), packed cell volume (PCV), red blood cells (RBC) and white blood cell (WBC) count of the blood samples were determined in the Wintrobe haematocrit tube according to the method of Schalm *et al.* (1975).

Carcass characteristics

At the 56th day of the feeding trial, 75 broiler chickens, 15 birds per treatment, whose weights were close to the average weight of the chickens in each treatment were selected and starved for about 18 hours to empty their crops. They were slaughtered, allowed to bleed, scalded in hot water and de-feathered. The dressed weight and weights of the cut parts and organs were measured with an electronic scale. The weights of the cut-up parts and organs were expressed as a percentage of live weight according to the “Modified Kosher” method as described by Abe *et al.* (1996).

Sensory Evaluation

Cooked minced breast meat samples per treatment was administered to twenty trained panelists from the Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria. Parameters evaluated include colour, juiciness, flavour, tenderness and overall acceptability. Each meat sample was coded and presented one after the opposite to each member of the panel. Each member rinsed his or her mouth with water after assessing each meat sample to avoid the carry-over effect. The panelists awarded scores employing a nine (9) point hedonic scale of (i) Dislike extremely (ii) Dislike very much (iii) Dislike moderately (iv) Dislike slightly (v) Intermediate (vi) Like slightly (vii) Like moderately (viii) Like very much (ix) Like extremely (Ogunwole *et al.*, 2013) and colour charts to measure the colour of the meat.

Table 1: The Ingredients and Chemical Composition of Experimental Diets (starter 0-4 weeks, finisher 5-8 weeks)

Ingredients	Starter diets					Finisher diets				
	0%	50% CSZ	100% CSZ	50% CS	100% CS	0%	50% CSZ	100% CSZ	50% CS	100% CS
Maize	53.60	53.60	53.60	53.60	53.60	54.60	54.60	54.60	54.60	54.60
Soyabean meal	29.50	29.50	29.50	29.50	29.50	23.50	23.50	23.50	23.50	23.50
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Groundnut cake	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Wheat offal	5.00	2.50	0.00	2.50	0.00	10.00	5.00	0.00	5.00	0.00
Cassava sift	0.00	2.50	5.00	2.50	5.00	0.00	5.00	10.00	5.00	10.00
Bone meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Broiler premix ^{ab}	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Methionine ^c	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Toxin binder	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition:										
Metabolizable energy (MJ/Kg)	12.00	12.11	12.22	12.08	12.15	11.92	12.14	12.36	12.08	12.23
Crude Protein (%)	23.38	23.03	22.68	23.09	22.80	21.68	20.98	20.28	21.10	20.52
Crude Fibre (%)	3.62	3.81	3.99	3.73	3.84	3.67	4.05	4.42	3.90	4.12
Ether Extract (%)	3.83	3.89	3.95	3.79	3.75	3.83	3.96	4.08	3.76	3.68
Ash (%)	2.60	2.63	2.65	2.63	2.65	2.26	2.30	2.35	2.31	2.63
Nitrogen Free Extract (%)	50.57	50.64	50.73	50.73	50.96	52.56	52.71	52.87	50.93	53.05
Calcium (%)	1.48	1.51	1.53	1.48	1.49	1.47	1.52	1.57	1.47	1.48
Phosphorus (%)	0.57	0.60	0.63	0.58	0.60	0.54	0.60	0.65	0.56	0.59

^aStarter Vitamin-Mineral Premix: (Rotinol) based on 2.5 kg/ton (Thiamine, 2000 mg, niacin, 30,000 mg, pyridoxine, 5000 mg, cyanocobalamine, 1700 mg, riboflavin, 7000 mg, D-panthotenate, 10,000 mg, Retinyl acetate, 12,000 iu., folic acid, 800 mg, biotin, 2000 mg, cholecalciferol, 2,400,000 iu., tocopherol acetate, 35,000 iu., menadione, 4,000 mg, ascorbic acid, 60,000 mg, iron, 70,200 mg, cobalt, 200 mg, iodine, 400 mg, selenium, 80 mg, choline chloride, 500,000 mg.

^bFinisher Vitamin-Mineral Premix: (Rotinol) based on 2.5 kg/ton (Riboflavin, 6000 mg, pyridoxine, 5000 mg, thiamine, 1000 mg, cyanocobalamine, 25 mg, niacin, 60,000 mg., D-panthotenate, 20,000 mg, folic acid, 200 mg, D-biotin, 8 mg, tocopherol acetate, 40,000 mg., Retinyl acetate, 40 mg, cholecalciferol, 500mg, menadione, 800 mg, ascorbic acid, 60,000 mg, , iron, 80,000 mg, cobalt, 80 mg, iodine, 400 mg, selenium, 40 mg, choline chloride, 80,000 mg

^cMethionine Hydroxyl Analog (MHA): (Novus International Inc.St. Charles, MO), feed supplement providing 84% Methionine activity

Table 2: Proximate composition of undegraded and degraded cassava sift* (CS) (DM-basis) Alade *et al.* 2019

Components (%)	Undegraded Cassava Sift (CS)	<i>Z. mobilis</i> Degraded Cassava Sift (CSZ)	t-test (P-value)
Dry matter	87.00 ^b	87.50 ^a	-3.60 (0.0227)
Moisture	13.00 ^a	12.50 ^b	3.60 (0.0227)
Crude protein	2.97 ^b	5.36 ^a	-17.22 (0.0001)
Crude fibre	16.00 ^a	13.00 ^b	21.61 (0.0001)
Ether extract	2.00 ^b	6.00 ^a	-28.82 (0.0001)
Nitrogen free extract	65.03 ^a	62.24 ^b	20.10 (0.0001)
Ash	1.00	0.90	0.72 (0.5111)
Neutral detergent fibre	50.00 ^a	47.00 ^b	21.61 (0.0001)
Acid detergent fibre	18.00 ^a	11.00 ^b	-50.43 (0.0001)
Acid detergent lignin	2.00	2.00	0.000 (1.0000)
Calcium (g/Kg DM)	0.20 ^b	1.12 ^a	-6.63 (0.0027)
Phosphorus (g/Kg DM)	0.63 ^b	1.27 ^a	-4.61 (0.0099)
Gross energy (MJ/Kg)	15.12	15.45	-2.38 (0.0762)
**Metabolizable energy	10.84 ^b	12.16 ^a	-9.51 (0.0007)

(MJ/Kg)

Means on the same row having different superscripts are significantly different (P<0.05)

* = Average of three determinations

**Metabolizable energy values were calculated using the method

37x %CP + 81x % EE + 35.5 x % NFE for poultry birds (Fisher and Boorman, 1986)

Experimental design and statistical analysis

The experimental design used for this study was a completely randomized design (CRD). All data collected were subjected to a one-way analysis of variance (ANOVA) as outlined by Daniel (1995) with SAS (2001) and the significant means were separated using Duncan's multiple range test at a 5% level of significance (Steel and Torrie, 1980).

Results and discussion

The haematological and serum metabolites of starting broiler chickens fed cassava sift-based diets are shown in Table 3. The birds fed 100% *Zymomonas mobilis* degraded cassava sift (CSZ) had the highest (p<0.05) values for packed cell volume (26.0%) and haemoglobin (8.70 g/dL) which were similar to the values obtained from 50% CS, 100% CS and Control diets while the least values obtained in birds fed 50% CSZ were similar to the values obtained in 50% CS, 100% CS and Control diet. The values observed in white blood cells were similar (p>0.05) in birds fed the control diet (12.50 x10⁹/L), 100% CS (13.60 x10⁹/L) and 100% CSZ (13.30 x10⁹/L) while similar lowest values were recorded in 50% CSZ and 50% CS. Similar value was observed for lymphocytes in 50% CSZ (70.0%) and 100% CSZ (70.0%) was similar (p>0.05) to the values

recorded in 50% CS (68.0%) and 100% CS (66.0%) with least value obtained from control diet (61.0%), similar (p>0.05) to the value recorded in 100% CS (66.0%).

However, the cholesterol value recorded at 50% CSZ (75.0 mg/dL) was similar (p>0.05) to that of 100% CS (79.0 mg/dL). The aspartate amino-transferase value observed in 100% CSZ (56.0 U/L) was similar (p>0.05) to the value in 50% CS (52.0 U/L). The haematological values obtained from the dietary treatments fell within the values reported by (Bounous *et al.* 2000; Isaac *et al.* 2013) as reflected on the physiological state of the birds. Thus, replacing undegraded and degraded cassava sift have no deleterious effect on the blood parameters studied.

The haematological parameters and serum metabolites at finishing phase is shown in Table 4. Birds fed 100% undegraded cassava sift (CS) had the highest red blood cells similar (p>0.05) to the values obtained for control diet and 50% CS, similar with values in 100% CSZ, control diet, 50% CS and 50% CSZ. The birds fed 100% CSZ had highest (p<0.05) white blood cells (14.50 x10⁹/L) and mean corpuscular volume (MCV) (217.0 fl). The lowest value of MCV (135.0 fl) was obtained in 100% CS and the lowest value of heterophil (19.0%) was recorded in the Control diet.

The serum metabolites at finishing phase showed that the dietary treatments had influence on values obtained. The broiler birds on 50% CSZ (132.0 mg/dL), 50% CS (125.0 mg/dL) and Control diet (120.0 mg/dL) had similar glucose values but the least value recorded in 100% CSZ (110.0 mg/dL) has similar value with 100% CS (115.0 mg/dL) and Control diet (120.0 mg/dL).

The birds fed Cassava sift based diets had similar cholesterol values (79.0 - 90.0 mg/dL) except in control diet which has the least value (63.0 mg/dL). The birds fed 50% CSZ had the highest ($p < 0.05$) uric acid value while least values were obtained in the control diet, 100% CS and 100% CSZ. The Alanine aminotransferase (ALT) value obtained in 100% CS was similar ($p > 0.05$) to the control group, 50% CSZ and 100% CSZ values. The PCV fell within the traditional range by Jain (1993) this implies that dietary treatments did not affect the measure of blood cells. As observed in this study, the PCV and haemoglobin are correlated with the nutritional status of the livestock which directly relates to the nutritional balance of the diet fed to the animals. These values were in agreement with previous studies (Benerjee, 2004; Alade *et al.*, 2020a, b).

However, the birds fed 50% CSZ and 100% CSZ had the lowest similar values of red blood cells with the control diet and 50% CS but were below the normal range of red blood cells (RBC) by Jain (1986). Ugwuene (2011) stated that a reduced red blood cells count implied a reduction in the level of oxygen that would be carried to the tissues as well as the level of carbon dioxide returned to the lungs. The values of mean corpuscular haemoglobin (MCH) which is the average amount of haemoglobin in each red blood cells measured, followed the identical trend to mean corpuscular volume (MCV).

Table 3: Haematological parameters and serum metabolites of starting broiler chickens (0 – 4 weeks) fed diets containing *Zymomonasmobilis* degraded and undegraded cassava sift.

Parameters	Dietary treatments					SEM
	1 Control diet	2 50% CSZ	3 100% CSZ	4 50% CS	5 100% CS	
Haematological parameters:						
Packed cell volume (%)	24.00 ^{ab}	22.00 ^b	26.00 ^a	24.00 ^{ab}	23.00 ^{ab}	0.51
Haemoglobin (g/dL)	8.10 ^{ab}	7.30 ^b	8.70 ^a	8.00 ^{ab}	7.70 ^{ab}	0.18
Red blood cell (x10 ¹² /L)	2.40	2.00	3.00	2.00	2.00	0.17
Mean corpuscular haemoglobin (<i>pg</i>)	34.00 ^{bc}	37.00 ^{ab}	29.00 ^c	40.00 ^a	39.00 ^{ab}	1.23
MCHC(g/dL)	33.80	33.20	33.50	33.30	33.50	0.42
Mean corpuscular volume (<i>fl</i>)	100.00	110.00	87.00	120.00	115.00	6.47
White blood cell (x10 ⁹ /L)	12.50 ^a	10.50 ^b	13.30 ^a	10.70 ^b	13.60 ^a	0.40
Heterophil (%)	37.00 ^a	28.00 ^{ab}	25.00 ^b	29.00 ^{ab}	31.00 ^{ab}	1.56
Lymphocytes (%)	61.00 ^b	70.00 ^a	70.00 ^a	68.00 ^a	66.00 ^{ab}	1.08
Eosinophil (%)	0.00 ^b	1.00 ^a	1.00 ^a	0.00 ^b	0.00 ^b	0.14
Monocytes (%)	1.00 ^c	1.00 ^c	3.00 ^a	2.00 ^b	2.00 ^b	0.21
Basophils (%)	1.00 ^a	0.00 ^b	1.00 ^a	1.00 ^a	1.00 ^a	0.14
Serum metabolites:						
Total protein (g/dL)	4.00	3.70	3.90	3.00	4.20	0.20
Albumin (g/dL)	2.10 ^{ab}	2.00 ^b	2.50 ^a	2.20 ^{ab}	2.40 ^{ab}	0.07
Globulin (g/dL)	1.90 ^a	1.70 ^a	1.40 ^a	0.80 ^b	1.80 ^a	0.12
Glucose (mg/dL)	122.00 ^b	136.00 ^a	108.00 ^c	100.00 ^d	124.00 ^b	3.46
Cholesterol (mg/dL)	85.00 ^a	75.00 ^b	87.00 ^a	87.00 ^a	79.00 ^{ab}	1.64
Uric acid (mg/dL)	5.20	5.00	3.80	5.70	3.60	0.32
Creatinine (mg/dL)	0.80 ^{ab}	1.00 ^a	0.30 ^c	0.40 ^{bc}	0.20 ^c	0.10
Aspartate amino-transferase (U/L)	49.00 ^b	51.00 ^b	56.00 ^a	52.00 ^{ab}	40.00 ^c	1.50
Alanine amino-transferase (U/L)	31.00 ^a	12.00 ^d	21.00 ^{bc}	18.00 ^c	23.00 ^b	1.74

Means on the same row having different superscripts are significantly different (P<0.05); SEM: Standard Error of Mean; n = 5

MCHC = Mean corpuscular haemoglobin concentration

Table 4: Haematological parameters and serum metabolites of finishing broiler chickens (5– 8weeks) fed diets containing *Zymomonas mobilis* degraded and undegraded cassava sift.

Parameters	Dietary treatments					SEM
	1 Control diet	2 50% CSZ	3 100% CSZ	4 50% CS	5 100% CS	
Haematological parameters:						
Packed cell volume (%)	28.00	25.00	26.00	28.00	27.00	0.74
Haemoglobin (g/dL)	9.20	8.30	8.70	9.30	8.50	0.34
Red blood cell ($\times 10^{12}/L$)	1.50 ^{ab}	1.30 ^b	1.20 ^b	1.80 ^{ab}	2.00 ^a	0.11
Mean corpuscular haemoglobin (pg)	61.00 ^{ab}	64.00 ^{ab}	73.00 ^a	52.00 ^{bc}	43.00 ^c	3.28
MCHC (g/dL)	32.90	33.20	33.50	33.20	31.50	0.46
Mean corpuscular volume (fl)	187.00 ^b	192.00 ^b	217.00 ^a	156.00 ^c	135.00 ^d	7.83
White blood cell ($\times 10^9/L$)	12.40 ^b	10.90 ^b	14.50 ^a	12.60 ^b	12.40 ^b	0.38
Heterophil (%)	19.00 ^d	27.00 ^c	40.00 ^a	34.00 ^b	37.00 ^{ab}	2.12
Lymphocytes (%)	80.00 ^a	72.00 ^{ab}	58.00 ^c	65.00 ^{bc}	59.00 ^c	2.55
Eosinophil (%)	0.00 ^b	1.00 ^a	1.00 ^a	0.00 ^b	1.00 ^a	0.17
Monocytes (%)	1.00 ^b	0.00 ^c	1.00 ^b	1.00 ^b	2.00 ^a	0.19
Basophils (%)	1.00 ^a	0.00 ^b	0.00 ^b	0.00 ^b	1.00 ^a	0.14
Serum metabolites:						
Total protein (g/dL)	4.70 ^a	3.50 ^b	3.00 ^b	3.00 ^b	4.70 ^a	0.22
Albumin (g/dL)	2.80 ^a	2.40 ^b	1.50 ^d	1.80 ^c	2.50 ^b	0.13
Globulin (g/dL)	2.10 ^a	1.10 ^b	1.50 ^{ab}	1.20 ^b	2.20 ^a	0.15
Glucose (mg/dL)	120.00 ^{abc}	132.00 ^a	110.00 ^c	125.00 ^{ab}	115.00 ^{bc}	2.61
Cholesterol (mg/dL)	63.00 ^b	79.00 ^a	90.00 ^a	83.00 ^a	85.00 ^a	2.76
Uric acid (mg/dL)	2.10 ^c	5.20 ^a	2.50 ^{bc}	3.50 ^b	3.20 ^{bc}	0.32
Creatinine (mg/dL)	0.60 ^{ab}	0.50 ^{ab}	0.80 ^a	0.20 ^b	0.20 ^b	0.08
Aspartate amino-transferase (U/L)	46.00 ^{ab}	35.00 ^c	54.00 ^a	50.00 ^{ab}	44.00 ^b	1.97
Alanine amino-transferase (U/L)	23.00 ^{ab}	24.00 ^a	22.00 ^{ab}	15.00 ^b	27.00 ^a	1.46

Means on the same row having different superscripts are significantly different ($P < 0.05$); SEM: Standard Error of Mean

n = 5 MCHC = Mean corpuscular haemoglobin in concentration

The statistical differences noticed in MCH and MCV might be attributed to the inclusion of undegraded and degraded cassava sift in the experimental diets. Birds fed 50% CS and 100% CS had MCH values that fell within the traditional range and birds fed 100% CS had MCV values within 16 to 53pg as earlier reported by Anon (1980). All the birds on the control and other diets have the highest values for MCH and MCV which were above the normal range (33.00 – 47.00pg) and (90.00 – 140.00fl) for healthy broiler chickens. This observation was not in agreement with the reports of Muhammad *et al.* (2015) and Tuleun *et al.* (2007) on broilers chickens. White blood cells are involved in protecting the animals from infection and contain lymphocytes, monocytes, neutrophils, eosinophils and basophils. They kill virus-infected cells, promote the assembly of antibodies and destroy foreign materials (antigens) that enter the body.

Therefore, a higher presence within the blood would connote a threat to normal health and the body builds up its defence against the threat (Olugbemi *et al.*, 2010). Champe *et al.* (2008) stated that neutrophils and monocytes are components of white blood cells that are responsible for both oxygen-independent and oxygen-dependent mechanisms for fighting the virus and engulfing and killing bacteria. The values of lymphocytes (58.00 to 80.00%) implied that all the broiler chickens within the treatments had adequate immune response status. Thus, the inclusion of undegraded and degraded cassava sift did not predispose broiler chickens to infection, as a higher count than normal implies that the system of the birds may be combating some kind of infection (Adeyemo and Longe, 2007). In addition, the authors reported that eosinophil phagocytize particles are formed when antibodies and antigens react, which may be a strategy for fighting disease infection by chickens. The dietary treatments influenced the serum metabolites of the finishing broiler chickens. The values of total protein and albumin observed during this study were within the normal range for healthy chickens by Anon (1980) and Mitruka and Rawnsley (1977). However, the values of globulin observed during this experiment are low compared with the normal range. Globulin is liable for **immunoglobulin** which is the main site of the antibodies (Peters *et al.*, 1982). Melluzzi *et al.* (1991) observed that alteration in nutritional protein status is best shown in the albumin than in the globulin content of the blood. The values of uric acid obtained in the study are low compared with the normal uric acid in the

blood of broiler chickens (Am. Met. Laboratory, 2001). Oyebimpe (2012) observed that a higher value of uric acid may indicate poor utilization of protein or the kidneys are not functioning properly. Also, low levels might be due to low protein intake or severe liver failure. The serum urea comes from the diet and tissue deamination of proteins. It indicates the great quality of dietary protein (Ewulola and Egbunike, 2008). The values of creatinine obtained during this study are within the reference values reported by Mitruka and Rawnsley (1977) for chickens. Higher values of creatinine than normal values indicate kidney malfunction (Champe *et al.*, 2008). Oke (1978) reported that a prime level of creatinine is sometimes observed in kidney diseases due to the kidney's role in removing creatinine, muscle degeneration and exposure to toxic substances which impair kidney functions. The lower value might indicate that the inclusion of the fibrous feedstuff did not cause muscular wastage due to anti-nutritional factors. The values of cholesterol (63.00 – 90.00mg/dL) obtained within the study are within the normal range (52 – 148mg/dL) reported by Mitruka and Rawnsley (1977) and comparable with the values of (84 – 94mg/dL) for broiler chickens fed maggot meal by Akpodiete and Okagbare (2002). The value of AST (35 - 54U/L) was within the normal range while the values obtained in the control group and other dietary treatments were lower than the values (52 – 270U/L) reported by Coles (2007). However, the values of ALT (15 – 27U/L) were within the traditional range for most birds (6.5 – 263U/L) reported by Coles (2007). The same author also observed that the values of AST and ALT can considerably vary according to age, animal species, sex and environment. This observation was contrary to the reports of Khempaka *et al.* (2014), they reported no significant difference in higher values of AST (300.72 – 358.60U/L) and lower values of ALT (12.25 – 18.80U/L) when broiler chickens were fed cassava pulp feedstuff fermented with *Aspergillus oryzae* based diet. Other authors have reported high values of AST in broiler chickens with different results arising from the dietary energy density, amino acid content and age under the normal state of health (Corduk *et al.*, 2007; Emadi *et al.*, 2010 and Azadmanesh and Jahanian, 2012).

The carcass characteristics of broiler chickens fed cassava sift-based diet are shown in Table 5. The birds fed 50% *Zymomonas mobilis* degraded cassava sift (CSZ) had the highest ($p<0.05$) values for live weight,

Table 5: Carcass characteristics of broiler chickens fed diets containing *Zymomonas mobilis* degraded and undegraded cassava sift.

Parameters	Dietary treatments					SEM
	1(Control)	CSZ 2 (50%)	CSZ (100%)	3 CS 50%4	CS 5 100%	
	Diet					
Live weight (g)	1600.00 ^b	1800.00 ^a	1600.00 ^b	1700.00 ^{ab}	1600.00 ^b	25.77
Dressed weight (g)	1500.00 ^{bc}	1660.00 ^a	1520.00 ^{bc}	1620.00 ^{ab}	1440.00 ^c	25.98
Eviscerated weight (g)	1180.00 ^d	1460.00 ^a	1240.00 ^c	1380.00 ^b	1180.00 ^d	30.16
Dressing percentage (%)	73.75 ^c	81.11 ^a	77.50 ^b	81.18 ^a	73.75 ^c	0.90
Cut-up parts						
(% of LW)						
Head (%)	1.90 ^b	3.33 ^a	3.28 ^a	3.53 ^a	3.75 ^a	0.23
Breast (%)	17.14 ^c	18.89 ^a	18.59 ^{ab}	15.29 ^d	17.50 ^{bc}	0.37
Thigh (%)	8.57 ^c	12.22 ^a	10.94 ^b	12.94 ^a	10.00 ^b	0.44
Drumstick (%)	9.52 ^b	11.11 ^a	12.03 ^a	11.76 ^a	11.25 ^a	0.28
Wing (%)	7.62 ^b	10.00 ^a	7.66 ^b	9.41 ^a	7.50 ^b	0.32
Back (%)	18.10 ^a	16.67 ^b	16.41 ^b	17.65 ^{ab}	13.75 ^c	0.43
Neck (%)	2.86 ^c	3.33 ^c	4.38 ^{ab}	4.71 ^a	2.50 ^c	0.27
Shank (%)	2.86 ^c	4.44 ^b	4.38 ^b	5.88 ^a	6.25 ^a	0.36
Internal organs						
(% of LW)						
Heart (%)	0.95 ^{ab}	0.56 ^b	0.55 ^b	1.18 ^a	1.25 ^a	0.10
Spleen (%)	0.07	0.11	0.08	0.18	0.21	0.02
Lungs (%)	0.76 ^a	0.67 ^{ab}	0.55 ^b	0.76 ^a	0.81 ^a	0.03
Liver (%)	1.90 ^b	2.22 ^b	2.19 ^b	3.53 ^a	3.13 ^{ab}	0.22
Kidneys (%)	0.45 ^b	0.56 ^b	0.60 ^b	0.59 ^b	0.94 ^a	0.05
Proventriculus (%)	0.95 ^b	1.11 ^{ab}	1.09 ^{ab}	1.18 ^a	1.25 ^a	0.03
Gizzard (%)	2.86 ^d	3.33 ^c	2.19 ^e	3.53 ^b	3.75 ^a	0.15
Empty gizzard (%)	0.95 ^c	2.22 ^b	1.09 ^c	2.35 ^{ab}	2.50 ^a	0.18
Abdominal fat (%)	0.95 ^b	1.11 ^{ab}	1.09 ^{ab}	0.59 ^c	1.25 ^a	0.06
Whole GIT (%)	14.29 ^d	12.22 ^e	20.23 ^b	17.65 ^c	25.00 ^a	1.20

Means on the same row having different superscripts are significantly different ($P < 0.05$), LW:

Live weight; GIT: Gastro-intestinal tract; SEM: Standard Error of Mean

n = 5

dressed weight and eviscerated weight. Similar ($p>0.05$) values were obtained in the control diet, 100% CS and 100% CSZ for live weight and dressed weight and eviscerated weight. The similar dressing percentage was observed in 50% CS and 50% CSZ. As observed, the cut-up parts were influenced ($p<0.05$) by the replacement of wheat offal by cassava sift. The breast values were higher in birds fed 50% CSZ and 100% CSZ. The back value in the control diet was similar ($p>0.05$) to the value in 50% CS while the lowest value was obtained in 100% CS. Higher values were recorded for heart, lungs, kidneys, proventriculus, gizzard, empty gizzard, abdominal fat and whole gastro-intestinal tract in bird fed 100% CS. However, birds on 100% CSZ had the lowest organs weights and abdominal fat. The positive influence of dietary treatment on the carcass yields as reflected by the dressing percentage are comparable to the findings of other authors (Esonu *et al.* 2008; Lamidi *et al.* 2008) who reported 74.82 - 77.39% and 69.49 - 73.98% respectively. However, the reduction in dressing percentage in 100% CS may be due to the gastro-intestinal tract weight which was twice the value obtained in 50% CSZ. Moreover, authors (González-Alvarado *et al.* 2007 and Jiménez-Moreno *et al.* 2009) had reported that inclusion of additional fibre increased the relative weight of the various segments of the gastro-intestinal tract in birds. However, Muhammad *et al.* (2015) reported no significant differences within the values for cut-up parts expressed as a percentage of slaughter weight.

The differences in organ weights observed were contrary to the report of Noman *et al.* (2015), they reported no differences in weight of liver, gizzard, heart, spleen or pancreas. A higher bird weight with lower

organ weight indicates good performance as reported by Plumber and Kiepper (2011).

The higher values in gizzard observed in 50% CS and 100% CS could be due to the fibrous nature of the undegraded cassava sift. Hetland *et al.* (2005) reported that retention of coarse insoluble fibre resulted in increased gizzard activities.

The handling of bulky feeds due to increased fibre content of ration affects the weight of gastro-intestinal tracts and gizzards positively (Adeyemo and Longe, 2007). Rose (2001) also noted that increased development of the gizzards will enhance their grinding role. Aderemi (2003) reported that anti-nutritional factors might be associated with the enlargement of organs such as the liver and pancreas because of their higher detoxification activity.

The sensory evaluation of breast meat from the broiler chickens fed cassava sift-based diets are shown in Table 6. The replacement of wheat offal with undegraded and degraded cassava sift influenced the taste, colour, flavour, juiciness and tenderness of breast meat. The highest value of colour obtained in the control diet was similar ($p>0.05$) to the values recorded in diets 50% CSZ and 100% CSZ but the least value was observed in 50% CS. The meats from birds fed 50% CSZ recorded highest values for juiciness, flavour, tenderness and overall acceptability, while the lowest values for colour, tenderness and overall acceptability were recorded in 50% CS. The sensory attributes were higher for the CSZ than CS and could be due to improvement in meat quality as a result of CSZ in the diets. This agreed with the study of Omojola and Adesehinwa (2007) that flavour, juiciness and tenderness were among the eating qualities that were significantly improved by the exogenous enzyme inclusion in broiler chickens diet.

Table 6: Sensory evaluation of meat from broiler chickens fed diets containing *Zymomonas mobilis* degraded and undegraded cassav

Parameters	Dietary treatments					SEM
	1	2	3	4	5	
	Control diet	50% CSZ	100% CSZ	50% CS	100% CS	
Colour	5.95 ^a	4.85 ^c	5.25 ^b	5.85 ^a	5.75 ^a	0.12
Juiciness	5.40 ^b	4.95 ^c	4.40 ^d	6.35 ^a	4.95 ^c	0.18
Flavour	5.05 ^b	4.95 ^b	4.50 ^b	6.00 ^a	5.05 ^b	0.16
Tenderness	5.80 ^b	5.05 ^d	5.55 ^c	6.20 ^a	5.70 ^{bc}	0.10
Overall acceptability	5.90 ^b	5.45 ^c	5.10 ^d	6.55 ^a	5.75 ^b	0.13

^{abc}Means on the same row having different superscripts are significantly different ($P<0.05$) SEM: Standard Error of Mean

n = 5

Conclusion

Haematology, serum metabolites, dressing percentage and cut-up parts were positively improved by the cassava sift-based diets with no deleterious influence on the organs of the broiler chickens. The 50% CSZ

Acknowledgement

The authors expressed their appreciation to Professor Anigbogu, N. M. for the technical support and provision of pure *Zymomonas mobilis* suspension for the production of *Zymomonas mobilis* degraded cassava sift.

The authors are grateful for the research support with Reference number PG020054 received from the World Bank Africa Centre of Excellence in Agricultural Development and Sustainable Environment, Federal University of Agriculture, Abeokuta, Nigeria.

Moreover, this work was financially supported by Mrs. Felicia Omolara Alade of the ASUU-UNAAB Cooperative Multipurpose Society Limited, Federal University of Agriculture, Abeokuta, Nigeria.

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- increased the carcass characteristics of the experimental birds. Therefore, 50% *Zymomonas mobilis* degraded cassava sift can be used to replace wheat offal in broiler chickens' diets without compromising the health status of the broiler chickens.
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Date received: 13th December, 2022

Date accepted: 10th September, 2024