The effects from diet substitution by *Zymomonas mobilis* degraded soybean hull in broiler chickens on haematology, blood chemistry, carcass traits and sensory evaluation

A.A. Alade[1,*], A.M. Bamgbose[2], S.A. Olanloye[3], A.O. Fafiolu[1], A.O. Oso[2], B.A. Adewumi[1], N.M. Anigbogu[4], L.N. Agwunobi[5], O.O. Oluwatosin[1] and O.E. Oke[6]

[1] Africa Centre of Excellence in Agricultural Development and Sustainable Environment, Federal University of Agriculture, Abeokuta 111101, Nigeria
[2] Department of Animal Nutrition, Federal University of Agriculture, Abeokuta 111101, Nigeria
[3] Department of Animal Production, Olabisi Onabanjo University, Ago-Iwoye 120107, Nigeria
[4] Coordinator Life-Enzyme and Fine Chemical Research, Department of Animal Nutrition and Forage Science, Michael Okpara University of Agriculture, Umudike 440101, Nigeria
[5] Department of Animal Science, University of Calabar, Calabar 540271, Nigeria
[6] Department of Animal Physiology, Federal University of Agriculture, Abeokuta 111101, Nigeria
* Corresponding author: saintaustin01@yahoo.com
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ABSTRACT

The fibrous nature of agro-industrial by-products limited their utilization in poultry production. A study was conducted for 56 days to evaluate the response of Marshal broiler chicks fed diets containing *Zymomonas mobilis* degraded soybean hull (SHZ). Three hundred and seventy-five a day-old unsexed broiler chicks were randomly allotted to 5 treatments of 5 replicates with 15 birds each in a 2 × 2 factorial design. Five diets containing undegraded soybean hull (SH) and SHZ were formulated to replace wheat offal at 0, 50, and 100% at starting and finishing phases. The dietary treatments did not ($P > 0.05$) influence the red blood cells (RBC), white blood cells (WBC), and monocytes of the starting broiler chickens. At the finishing phase, the birds fed 50% SH had the highest values ($P < 0.05$) for packed cell volume (PCV), hemoglobin (Hb), and red blood cell (RBC). There was no influence ($P > 0.05$) on uric acid at starting and finishing phases. The birds fed 50% SH and 50% SHZ had higher ($P < 0.05$) values for the liver, while birds fed 100% SHZ had least value for the liver. However, the birds fed 50% SHZ had the highest values of breast and the same least values ($P > 0.05$) for kidneys and gizzards with birds fed 100% SH. Moreover the color of the meat was increased ($P < 0.05$) by the soybean hull based diets while 100% SH had highest value for flavor. The carcass traits were improved ($P < 0.05$) by 100% SH, 50% and 100% SHZ. Replacing wheat offal with SH-based diets promoted the development of the carcass trails of the birds. Therefore, 100% SH, 50% and 100% SHZ can replace wheat offal on a weight-to-weight basis without compromising their health status.

Keywords: Blood biochemistry, carcass traits, hematology, sensory evaluation, soybean hull, *Zymomonas mobilis*

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INTRODUCTION

In the past, agro-industrial by-products such as brewers' spent grains, wheat and maize offals, and molasses were either being burnt or improperly disposed of on land or in the water bodies, which led to environmental pollution (Onyeonagu and Njoku, 2010). It is necessary to alleviate the negative impact of indiscriminate disposal of these organic materials in the environment by converting them for livestock feeding, bio-fertilizer production, and bioenergy generation (Kivaisi *et al*., 2010). Soybean hull is a by-product derived from dehulled soybean seeds before being processed into soya milk or soybean meal. Soybean hulls, due to their high fiber contents, are known to be poorly digested by monogastric animals but usually well digested by ruminant animals (Chee *et al*., 2005). Esonu (1998) reported that soybean hull has an estimated feeding value of 74–80% of that of maize when included in moderate to high quality maize-based broiler finishers' diets. Some researchers have utilized the soybean hull meal with or without enzyme supplementation in broiler chicken diets. Kurul *et al*. (2020) observed that up to 60 g/kg of dietary soybean hull improved apparent ileal digestibility and had no negative effect on the growth performance of broilers. However, Esonu *et al*. (2006) reported that 20% dietary inclusion of soybean hull with 10% Safztme® (exogenous cellulolytic enzyme) could not improve the nutritive value of soybean hulls for finishing broiler chickens. The antinutritional factors present in the raw and processed soybean are protease inhibitors 45–60 and 4–8 mg/g CP, lectins 50–200 mg/g, glycinin 150–200 and 40–70 mg/g, β-conglycin 50–100 and 10–40 mg/g, saponins 0.5% and 0.6%, oligosaccharides 14% and 15%, and phytic acid 0.6% and 0.6%, respectively (Van Eys *et al*., 2004).

Zymomonas mobilis is a bacterium belonging to the genus *Zymomonas* which is generally found in African palm wine and Mexican pulque. It is a rod-shaped gram-negative bacterium. It is 2–6 µm long and 1–1.4 µm wide but can vary significantly (Cazetta *et al*., 2007). Its ability to efficiently ferment carbohydrates using the Entner-Doudoroff pathway makes it an attractive option for life-enzyme for animal feed (Onyejekwe, 2010). The treatment of fibrous feedstuffs with *Zymomonas mobilis* microbes is proposed to break down the polysaccharide and lignin contents into simpler carbohydrates, which the poultry birds can utilize for better productivity. Also, the utilization of degraded fibrous feedstuffs for farm animals will reduce the cost of production, encourage the production of cheap animal protein for Africans, increase foreign reserves, and greatly reduce environmental hazards/pollution (Anigbogu and Anosike, 2010). Therefore, little information is available on the effect of feeding *Zymomonas mobilis* fermented fibrous feedstuffs on blood parameters and carcass yield of broiler chickens.

The aim of studying blood composition is to differentiate the normal state of animal health and ill health. Plasma or serum metabolite values are useful in the assessment of the nutritional and efficient performance of animals (Olajide and Akinsoyinu, 2015). Therefore, this study was carried out to determine the effects of undegraded and degraded soybean hull on hematology, serum biochemistry, carcass traits, and sensory evaluation of the meat of broiler chickens.

MATERIALS AND METHODS

Research Station and Test Ingredient

The study was carried out at the Poultry Unit, Directorate of University Farms, Federal University of Agriculture, Abeokuta, Nigeria, located at 7°10′N and 3°2′E, 76 m above sea level. It lies within the South-Western part of Nigeria with a prevailing tropical climate, mean annual rainfall of 1,238 mm, and an average temperature of 27.1 °C (Climate-Data.org, 2020).

The soybean hull was collected from Nestle Plc., Agbara Estate, Ogun State, Nigeria. Pure isolates of *Zymomonas mobilis* extracted from palm wine were obtained from the Food Science Laboratory of Michael Okpara University of Agriculture, Makurdi, Nigeria. The sundried

soybean hull was milled using a grinding machine because of its slippery nature and stored on pallets. The soybean hull was biologically degraded in the traditional setting (anaerobic condition) as in Anigbogu *et al*. (2009). Inoculum fermentation was done using 200 mL of pure isolates of *Zymomonas mobilis*, 1 kg of milled soybean hull, and 4 L of water in a sealed fermentation vat which was kept from sunlight. The life enzyme was prepared using a 50 kg milled soybean hull placed in a fermentation vat (volume = 200 L) with 100 L of water added to 5 kg previously *Zymomonas mobilis* degraded soybean hull as starter inoculums. The sample was homogeneously mixed and kept fermenting for 20 days at a room temperature of between 23.1 and 24.6 °C. After this, the fermented product was sun-dried, analyzed, and stored as a life enzyme (soybean hull degraded *Zymomonas mobilis* microbes) for the experimental study.

Management of Birds and Experimental Diets

Three hundred and seventy-five 1-day old unsexed marshal broiler chicks were obtained from Obasanjo Farms Nigeria Limited, Lanlate, Nigeria. They were weighed individually and allotted on a weight equalization basis into replicate pens. The average initial weight was 34 ± 0.26 g. A total of 75 broiler chicks were used per treatment and were replicated 5 times with 15 birds each. The chicks were brooded for 2 weeks. The broiler chicks were vaccinated against Gumboro disease on the 7th and 18th days while the Newcastle disease vaccine was administered on the 12th day of life. Coccidiostat was also administered to the birds during the experiments. Feed and water were supplied to the broiler chickens *ad libitum*. The birds were raised for 8 weeks (0–4 weeks for the starter phase and 5–8 weeks for the finisher phase) in deep litter pens with floors covered with wood shavings. The test diets were formulated to include undegraded soybean hull and *Zymomonas mobilis* treated soybean hull at varying levels of 0, 50, and 100% replacing wheat offal weight for weight basis. The ingredients and chemical composition of the experimental broiler chicken diet are shown in Table 1.

Chemical Analysis

The proximate composition of crude protein, crude fiber, ether extract, and ash of the milled samples of undegraded soybean hull and *Zymomonas mobilis* degraded soybean hull was determined according to the standard procedures of AOAC (2015). The fiber fraction, such as neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) was determined by the method of Van Soest *et al*. (1991). The calcium and phosphorus of the test ingredients were determined by the methods of Grueling (1966). The gross energy of the ground samples was determined using a Gallenkamp Ballistic bomb calorimeter (Cam Metric Ltd., Cambridge, UK).

Data Collection

Blood collection and analysis

Blood samples were collected individually from 75 broiler chickens (15 birds per treatment) via the wing veins using a sterilized syringes at the end of the starting and finishing phases of the feeding trials. About 2.5 mL of blood sample was collected from each bird into vial containing ethylene diamine tetra-acetic acid (EDTA) as an anticoagulant for the determination of hematological parameters. However, another set of blood samples were collected into plain tubes for serum biochemistry measurement. Hemoglobin concentration was estimated using the cyanmethemoglobin method (Cannan, 1958), packed cell volume (PCV), red blood cell (RBC), and white blood cell (WBC) count of the blood samples were determined in the Wintrobe hematocrit tube according to the method of Schalm *et al*. (1975).

Table 1 Ingredients and chemical composition of experimental broiler chicken diets (%DM-basis)

Composition	Starter diets					Finisher diets				
	0%	50% SH	100% SH	50% SHZ	100% SHZ	0%	50% SH	100% SH	50% SHZ	100% SHZ
Ingredient										
Maize	53.60	53.60	53.60	53.60	53.60	54.60	54.60	54.60	54.60	54.60
Soybean 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
Soybean hull	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
L-lysine HCL	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
DL-Methionine[c]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Toxin binder[d]	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
Calculated ME (MJ/kg)	13.09	13.05	13.01	13.09	13.07	13.10	13.04	13.07	13.10	13.05

Table 1 Cont.

Composition	Starter diets					Finisher diets				
	0%	50% SH	100% SH	50% SHZ	100% SHZ	0%	50% SH	100% SH	50% SHZ	100% SHZ
Determined chemical composition										
Crude protein (%)	22.70	22.68	22.75	22.93	22.75	20.60	20.59	20.64	20.73	20.96
Crude fiber (%)	4.81	5.15	5.49	4.96	5.10	4.84	5.52	5.20	5.13	5.41
Ether extract (%)	3.67	3.73	3.83	3.79	3.88	3.72	3.93	3.94	3.98	3.99
Ash (%)	2.55	2.59	2.63	2.60	2.65	2.43	2.45	2.57	2.48	2.58
Nitrogen-free extract (%)	55.77	55.35	54.80	55.22	55.12	57.91	57.01	57.15	57.18	56.56
Calcium (%)	1.29	1.30	1.32	1.31	1.32	1.26	1.28	1.31	1.29	1.33
Phosphorus (%)	0.51	0.54	0.57	0.55	0.58	0.52	0.56	0.59	0.57	0.59

Note: [a] Starter vitamin-mineral premix: retinol based on 2.5 kg/t (thiamine 2,000 mg, riboflavin 7,000 mg, pyridoxine 5,000 mg, cyanocobalamine 1,700 mg, niacin 30,000 mg, D-pantothenate 10,000 mg, folic acid 800 mg, biotin 2,000 mg, retinyl acetate 12,000 IU, cholecalciferol 2,400,000 IU, tocopherol acetate 35,000 IU, menadione 4,000 mg, ascorbic acid 60,000 mg, manganese, nil, and iron 70,200 mg, zinc, nil, copper, nil, and cobalt 200 mg, iodine 400 mg, selenium 80 mg, choline chloride 500,000 mg).

[b] Finisher vitamin-mineral premix: retinol based on 2.5 kg/t (thiamine 1,000 mg, riboflavin 6,000 mg, pyridoxine 5,000 mg, cyanocobalamine 25 mg, niacin 60,000 mg, D-pantothenate 20,000 mg, folic acid 200 mg, D-biotin 8 mg, retinyl acetate 40 mg, cholecalciferol 500 mg, tocopherol acetate 40,000 mg, menadione 800 mg, ascorbic acid 60,000 mg, manganese, nill, and iron, 80,000 mg, zinc, nill, copper, nil, and cobalt 80 mg, iodine 400 mg, selenium 40 mg, choline chloride 80,000 mg).

[c] Methionine Hydroxyl Analog (Novus International Inc., St. Charles, MO), feed supplement providing 84% methionine activity[d] Toxin binder (Jubaili Agrotec Ltd, Spain). SH = diets containing undegraded soybean hull, SHZ = diets containing *Zymomonas mobilis* degraded soybean hull, ME = metabolizable energy.

Carcass traits and internal organ weight determination

At the end of 8 weeks, 75 broiler chickens (15 birds per treatment) were selected at random and starved for about 18 hours to empty their crops for each experiment. They were slaughtered by cervical dislocation, allowed to bleed, scalded in warm water, and de-feathered. They were thereafter taken to the laboratory, where other measurements like the dressed weight, the weight of the cut parts, and internal organs were taken with a sensitive electronic scale. The weight of the cut-up parts and internal organs was expressed as a percentage of live weight according to the Modified Kosher method as described by Abe *et al*. (1996), while the dressing percentage was calculated as follows:

$$\text{Dressing (\%)} = \frac{\text{Eviscerated weight}}{\text{Live weight}} \times 100$$

Sensory evaluation of breast meat

The sensory evaluation of cooked samples of broiler chicken breast minced meat from 15 birds per treatment was carried out by 20 panelists. The parameters that were evaluated by the panelists include color, juiciness, flavor, tenderness, and overall acceptability. Each meat sample was coded and presented one after the other 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 using a nine (9) point hedonic scale: (1) dislike extremely, (2) dislike very much, (3) dislike moderately, (4) dislike slightly, (5) intermediate, (6) like slightly, (7) like moderately, (8) like very much, and (9) like extremely (Ogunwole *et al*., 2013).

Compliance with Ethical Standards

All protocols for farm animals and human experimentation were under ethical standards (Institutional and National Standards). The experiment was approved by the Institutional Animal Care and Use Committee Ethical of the College of Animal Science and Livestock Production, the Federal University of Agriculture, Abeokuta, Nigeria with Reference number PG020054.

Experimental Design and Statistical Analysis

The experimental design used for this study was a 2 × 2 factorial design. All data collected were subjected to analysis of variance (ANOVA) using a statistical package SPSS (version 22), and the significant means were separated by Duncan's multiple range test at a 5% level of significance (Steel and Torrie, 1993). The sensory evaluation data were subjected to Kruskal-Wallis H test.

RESULTS AND DISCUSSION

The result of the proximate composition of the undegraded soybean hull and degraded soybean hull is shown in Table 2. The fermentation of soybean hull with *Zymomonas mobilis* increased ($P < 0.05$) the value of crude protein, nitrogen-free extract, and ash. The crude fiber, neutral detergent fiber, acid detergent fiber, and acid detergent lignin had 78.2, 62.18, 105.11, and 88.10% reductions, respectively after biodegradation. There was a reduction ($P < 0.05$) in gross energy while the metabolizable energy increased ($P < 0.05$) by 34.62%. The biodegradation of soybean hull has considerably increased its crude protein content and reduced fiber content. Egounlety and Aworh (2000) observed that fermentation brings about numerous biochemical and nutritional changes in the raw materials, besides the breakdown of certain constituents, reduction of antinutritional factors, and the synthesis of B vitamins.

Table 2 Proximate analysis of undegraded and degraded soybean hull (DM-basis)

Components (%)	Undegraded soybean hull (SH)	Degraded soybean hull (SHZ)	t-test (P-value)
Dry matter	87.94[b]	89.00[a]	-7.64 (0.0020)
Moisture	12.06[a]	11.00[b]	7.64 (0.0020)
Crude protein	17.06[b]	19.68[a]	-18.88 (0.0001)
Crude fiber	35.64[a]	20.00[b]	112.68 (0.0001)
Ether extract	9.90	10.00	-0.72 (0.5100)
Nitrogen free extract	31.38[b]	35.32[a]	-28.39 (0.0001)
Ash	2.87[b]	4.00[a]	-8.14 (0.0012)
Neutral detergent fiber	81.09[a]	50.00[b]	223.98 (0.0001)
Acid detergent fiber	57.43[a]	28.00[b]	212.03 (0.0001)
Acid detergent lignin	18.81[a]	10.00[b]	63.47 (0.0001)
Calcium (g/kg DM)	1.00[b]	1.39[a]	-2.81 (0.0483)
Phosphorus (g/kg DM)	2.27	2.16	0.79 (0.4724)
Gross energy (MJ/kg)	16.10[a]	15.31[b]	5.69 (0.0047)
Metabolizable energy* (MJ/kg)	7.67[b]	11.73[a]	-29.25 (0.0001)

Note: Means on the same row having different superscripts are significantly different ($P < 0.05$). Results are average of three determinations (n = 3). *Metabolizable energy (ME) values were calculated using the method of Fisher and Boorman (1986): ME = (37 × %CP) + (81 × %EE) + (35.5 × %NFE) for poultry birds.

The hematological parameters and serum metabolites of starting broiler chickens fed diets containing undegraded and degraded soybean hull are shown in Table 3. The dietary treatments significantly ($P < 0.05$) affected all the hematological parameters with the exception of the red blood cells, white blood cells and monocytes. The starting broiler chickens fed the control diet had statistically ($P > 0.05$) similar values with birds fed diets 100% SH, 50% SHZ, and 100% SHZ for PCV and Hb. There were no significant ($P > 0.05$) differences observed in RBC, WBC, and monocytes. The results obtained for PCV and Hb of the birds suggested the nutritional adequacy of the soybean hull-based diets. Furthermore, MCH followed the same pattern as mean corpuscular volume (MCV) across the dietary treatments. Although MCH indicates the blood-carrying ability of the red blood cells, this could suggest that the broiler chickens fed the diets are more efficient in performing respiratory function, as observed by Abdulazeez *et al*. (2016). The control group had the least value of WBC since white blood cells are known to fight against diseases. The result of this study indicated that birds on soybean hull-based diets had similar immunity status, which is superior to those of the control group. Furthermore, livestock with low white blood cell count is exposed to a high risk of disease infection, while those with high counts are capable of producing antibodies in the process of phagocytosis and have a higher degree of resistance to diseases (Soetan *et al*., 2013). Moreover the soybean hull based diets influenced ($P < 0.05$) the serum metabolites with the exception of uric acid. At 28 days of age, the broiler chickens had higher total protein values than the control group. This observation indicates that the birds had low protein demand for tissues. The birds fed 100% SHZ had higher creatinine which might be due to the life enzyme incorporated in their diets. This might be directly related to increased muscle activity and volume (Café *et al*., 2012).

Table 3 Hematological parameters and serum metabolites of starting broiler chickens (0–4 weeks) fed diets containing undegraded (SH) and degraded soybean hull (SHZ)

Parameters	Control	Undegraded		Degraded		SEM	P-values		
		50% SH	100% SH	50% SHZ	100% SHZ		Treatment	Levels	Interaction
Hematological parameters									
Packed cell volume (%)	30.50^{ab}	25.00^{c}	31.00^{ab}	29.00^{b}	32.50^{a}	0.91	0.1370	0.0024	0.0007
Hemoglobin (g/dL)	10.10^{ab}	8.30^{c}	9.65^{b}	9.30^{b}	10.60^{a}	0.28	0.0796	0.0092	0.0048
Red blood cell (×10$^{12/L}$)	2.37	2.10	2.50	2.40	2.75	0.10	0.1598	0.0433	0.0893
MCH (pg)	40.43^{a}	39.54^{a}	39.64^{a}	38.77^{b}	38.49^{b}	0.07	0.0267	0.0039	0.0001
MCH in concentration (g/dL)	33.12^{a}	33.28^{a}	31.15^{b}	32.11^{b}	32.57^{b}	0.24	0.7761	0.0684	0.0001
Mean corpuscular volume (fL)	122.18^{b}	118.92^{c}	128.00^{a}	121.09^{b}	118.19^{c}	1.16	0.1037	0.2001	0.0001
White blood cell (×10$^{9/L}$)	11.85	22.90	23.00	19.25	21.30	0.53	0.0042	0.3347	0.0090
Heterophil (%)	34.50^{a}	30.50^{b}	29.00^{b}	34.00^{a}	30.50^{b}	0.64	0.0444	0.0444	0.0091
Lymphocytes (%)	64.50^{b}	68.00^{a}	68.00^{a}	64.50^{b}	68.00^{a}	0.51	0.0836	0.0836	0.0030
Eosinophil (%)	0.00^{b}	0.00^{b}	0.50^{a}	0.50^{a}	0.00^{b}	0.09	1.0000	1.0000	0.0202
Monocytes (%)	0.50^{b}	1.00^{ac}	1.00^{ab}	1.00^{ab}	1.50^{a}	0.14	0.3951	0.3951	0.5523
Basophils (%)	0.50^{b}	0.50^{b}	1.50^{b}	0.00^{b}	0.00^{b}	0.19	0.0031	0.2138	0.0002
Serum metabolites									
Total protein (g/dL)	2.45^{d}	3.75^{a}	3.15^{b}	2.95^{bc}	2.75^{c}	0.11	0.0034	0.0877	0.0001
Albumin (g/dL)	1.40^{c}	1.80^{b}	2.10^{a}	1.45^{c}	1.75^{b}	0.08	0.0148	0.0463	0.0033
Globulin (g/dL)	2.05^{a}	1.95^{a}	1.05^{c}	1.50^{b}	1.00^{c}	0.13	0.3675	0.0018	0.0057
Glucose (mg/dL)	97.00^{d}	106.00^{c}	129.50^{b}	77.00^{e}	134.00^{a}	6.84	0.3962	0.0001	0.0001
Cholesterol (mg/dL)	77.00^{d}	82.00^{c}	91.00^{b}	100.00^{a}	89.50^{b}	1.95	0.0260	0.8582	0.0001
Uric acid (mg/dL)	5.20	5.20	3.15	4.60	4.00	0.26	0.8237	0.0038	0.0068
Creatinine (mg/dL)	0.70^{b}	0.45^{c}	0.35^{c}	0.20^{a}	0.90^{a}	0.08	0.3756	0.4750	0.0001
Aspartate aminotransferase (U/L)	58.50^{a}	55.50^{a}	57.50^{a}	48.50^{b}	60.00^{a}	1.42	0.5081	0.0131	0.0035
Alanine aminotransferase (U/L)	28.50^{b}	21.50^{d}	30.50^{a}	24.00^{c}	22.00^{d}	1.12	0.1929	0.1220	0.0001

Note: Means on the same row having different superscripts are significantly different ($P < 0.05$). SEM = standard error of the mean, MCH = mean corpuscular hemoglobin.

The hematological and serum metabolites of finishing broiler chickens (5–8 weeks) fed undegraded and degraded soybean hull are shown in Table 4. The dietary treatments influenced the hematological parameters of the finishing Marshal broiler chickens fed diets containing soybean hull-based diets. The birds fed 50% SH had significantly the highest values for packed cell volume, hemoglobin and red blood cells while others were significantly similar but in RBC, the least value was obtained in the control diet. The hemoglobin values were greater than the normal range (7.0–13.0 g/dL) cited by Bounous *et al.* (2000). This further indicated that all the broiler chickens had a higher tendency to resist respiratory stress because hemoglobin is the oxygen-carrying pigment which is carried on the red blood cells (Muhammad and Oloyede, 2009). The birds fed 50% SH had the lowest value for MCH in concentration while others are statistically similar across the treatment groups. The values obtained in this study were within the normal range for broiler chickens (Feldman *et al*., 2000).

White blood cell fight against diseases, the result of this study indicated that broiler chickens on undegraded and degraded soybean hull-based diets have similar immunity status which is superior to those of the control group. Therefore, farm animals with low white blood cell counts are exposed to a high risk of disease infection, however, livestock with high WBC counts are capable of producing antibodies in the process of phagocytosis and have a higher degree of resistance to diseases (Soetan *et al*., 2013). Moreover, the fed 100% SH had the highest value ($P < 0.05$) of lymphocytes and least value of heterophil. High lymphocyte values would be recorded in bacterial and viral infections such as coccidiosis and high monocyte values would be recorded in case of injury to body tissues. Eosinophil, monocyte and basophil suggest the resistance of the broiler chickens in disease conditions. It can be inferred from the results that the replacement of wheat offal with undegraded and degraded soybean hull did not adversely influence the broiler chicken's physiological status.

The serum metabolites of the finishing broiler chickens were statistically ($P < 0.05$) influenced by the soybean hull-based diets but did not affect uric acid. The values of total protein were comparable with the values (3–5 g/dL) reported by Obikaonu *et al*. (2012). It implied an efficient utilization of the dietary protein by the finishing broiler chickens. The decrease in total protein concentration in the control group may be an indication of a reduction in protein synthesis. The uric acid values were lower than the normal range (7–21 mg/dL) reported by American Medical Laboratories (2001). However, Oyebimpe (2012) observed that high urea concentration may be toxic to the liver and kidneys of broiler chickens. Also, Kwiecien *et al*. (2015) reported that an increased concentration of uric acid in plasma may be due to oxidative stress and it can be a result of the body's adaptation to increased production of reactive oxygen species. The values of creatinine for the control diet, 100% SH, 50% SHZ, and 100% SHZ were greater than the values (0.46 ± 0.05 mg/dL) reported by Silva *et al*. (2007) for 42-day-old broiler chickens, while the lowest value obtained in 50% SH was lower than the values reported by the same authors. The alanine aminotransferase (ALT) values were comparable with the values (19–32 U/L) by Opoola *et al*. (2017). It implied that the livers were not adversely affected by the replacement of wheat offal with soybean hull-based diets. Broiler chickens fed 100% SHZ had the lowest value of ALT which is an indication that *Zymomonas mobilis* degraded soybean hull has decreased antinutritional factors thereby maintaining the integrity of the liver.

The carcass traits of Marshal broiler chickens fed diets containing undegraded and degraded soybean hull are shown in Table 5. The dietary treatments significantly ($P < 0.05$) influenced the eviscerated weight, dressing percentage, carcass characteristics, and internal organ weight.

Table 4 Hematological parameters and serum metabolites of finishing broiler chickens (5–8 weeks) fed diets containing undegraded (SH) and degraded soybean hull (SHZ)

Parameters	Control	Undegraded		Degraded		SEM	P-values		
		50% SH	100% SH	50% SHZ	100% SHZ		Treatment	Levels	Interaction
Hematological parameters									
Packed cell volume (%)	38.00^{b}	47.00^{a}	37.00^{b}	36.00^{b}	39.00^{b}	1.43	0.1194	0.2382	0.0019
Hemoglobin (g/dL)	12.20^{b}	14.80^{a}	12.00^{b}	11.70^{b}	12.80^{b}	0.07	0.1893	0.1893	0.0001
Red blood cell (×10$^{12/L}$)	2.90^{d}	3.80^{a}	3.20^{c}	3.20^{c}	3.40^{b}	0.42	0.1790	0.3313	0.0069
MCH (pg)	42.07^{a}	38.95^{ab}	37.51^{b}	36.55^{b}	37.67^{ab}	0.26	0.0208	0.7725	0.0001
MCH in concentration (g/dL)	32.12^{a}	31.57^{b}	32.50^{a}	32.48^{a}	32.93^{a}	0.15	0.0164	0.0124	0.0001
Mean corpuscular volume (fL)	131.10^{a}	123.66^{ab}	115.62^{b}	112.46^{b}	114.67^{b}	1.28	0.0086	0.2731	0.0001
White blood cell (×10$^{9/L}$)	14.70^{d}	20.80^{b}	16.90^{c}	24.60^{a}	18.00^{c}	0.92	0.1932	0.0003	0.0001
Heterophil (%)	33.00^{a}	36.00^{a}	27.00^{b}	34.00^{a}	37.00^{a}	1.31	0.1326	0.2723	0.0032
Lymphocytes (%)	65.00^{b}	62.00^{bc}	69.00^{a}	65.00^{b}	61.00^{c}	1.05	0.2531	0.5025	0.0040
Eosinophil (%)	1.00^{a}	0.00^{b}	1.00^{a}	0.00^{b}	1.00^{a}	0.17	1.0000	0.0003	0.0086
Monocytes (%)	1.00^{ab}	2.00^{a}	2.00^{a}	0.00^{b}	1.00^{ab}	0.29	0.0031	1.0000	0.0110
Basophils (%)	0.00^{b}	0.00^{b}	1.00^{a}	1.00^{a}	0.00^{b}	0.17	1.0000	0.4178	0.0086
Serum metabolites									
Total protein (g/dL)	3.30^{ab}	2.60^{c}	3.60^{a}	3.00^{bc}	3.50^{ab}	0.14	0.6075	0.009	0.0046
Albumin (g/dL)	2.10^{b}	1.50^{d}	1.90^{c}	2.40^{a}	1.80^{c}	0.10	0.0378	0.6399	0.0001
Globulin (g/dL)	1.20^{b}	1.10^{b}	1.70^{a}	0.60^{c}	1.70^{a}	0.14	0.3975	0.0001	0.0001
Glucose (mg/dL)	100.00^{b}	126.00^{a}	131.00^{a}	127.00^{a}	124.00^{a}	0.83	0.0689	0.5744	0.0012
Cholesterol (mg/dL)	100.00^{a}	72.00^{c}	98.00^{b}	97.00^{a}	91.00^{b}	3.17	0.1649	0.1179	0.0001
Uric acid (mg/dL)	3.50^{ab}	3.00^{b}	4.20^{a}	3.30^{ab}	3.40^{ab}	0.20	0.5643	0.1128	0.1880
Creatinine (mg/dL)	0.50^{b}	0.20^{c}	0.60^{ab}	0.60^{ab}	0.80^{a}	0.07	0.0204	0.0204	0.0002
Aspartate aminotransferase (U/L)	47.00^{c}	46.00^{c}	52.00^{b}	56.00^{a}	50.00^{b}	1.13	0.0754	1.0000	0.0001
Alanine aminotransferase (U/L)	20.00^{bc}	26.00^{a}	21.00^{abc}	25.00^{ab}	17.00^{c}	1.18	0.3094	0.0007	0.0017

Note: Means on the same row having different superscripts are significantly different ($P < 0.05$). SEM = standard error of the mean, MCH = mean corpuscular hemoglobin.

Table 5 Carcass traits of broiler chickens fed diets containing undegraded (SH) and degraded soybean hull (SHZ)

Parameters	Control	Undegraded		Degraded		SEM	P-values		
		50% SH	100% SH	50% SHZ	100% SHZ		Treatment	Levels	Interaction
Live weight (kg)	2.10	2.10	2.25	2.30	2.10	0.04	0.7767	0.7767	0.1915
Dressed weight (kg)	2.02	2.04	2.04	2.04	1.92	0.02	0.2170	0.2170	0.1749
Eviscerated weight (kg)	1.48^{ab}	1.42^{b}	1.54^{ab}	1.58^{a}	1.50^{ab}	0.02	0.1131	0.6183	0.0002
Dressing percentage (%)	70.60^{a}	67.63^{b}	68.89^{b}	68.85^{b}	71.43^{a}	0.42	0.0151	0.0123	0.0001
Carcass characteristics (% live weight)									
Head (%)	3.81^{a}	2.86^{c}	2.67^{d}	3.48^{b}	2.86^{c}	0.09	0.0192	0.0192	0.0001
Breast (%)	20.00^{b}	21.90^{b}	22.22^{b}	25.22^{a}	21.90^{b}	0.44	0.0870	0.0870	0.0001
Two thighs (%)	8.57^{c}	9.52^{b}	9.78^{a}	7.83^{d}	9.52^{b}	0.23	0.0294	0.0294	0.0001
Two drumsticks (%)	11.43^{a}	9.52^{c}	10.67^{b}	8.70^{d}	10.48^{b}	0.26	0.3517	0.0004	0.0011
Two wings (%)	8.57^{b}	8.57^{b}	8.89^{a}	7.83^{c}	8.57^{b}	0.12	0.0184	0.0184	0.0001
Back (%)	17.14^{a}	16.19^{c}	16.89^{b}	15.65^{d}	14.29^{e}	0.29	0.0010	0.5906	0.0001
Neck (%)	4.76^{a}	2.86^{e}	3.56^{d}	4.35^{b}	3.81^{c}	0.16	0.0013	0.8177	0.0001
Two shanks (%)	4.76^{a}	4.76^{a}	3.56^{b}	3.81^{b}	3.81^{b}	0.16	0.2848	0.0475	0.0048
Internal organ weight (% live weight)									
Heart (%)	0.77^{a}	0.49^{c}	0.54^{b}	0.56^{b}	0.50^{c}	0.01	0.4732	0.8133	0.0066
Spleen (%)	0.11^{ab}	0.14^{a}	0.07^{b}	0.11^{ab}	0.13^{a}	0.01	0.4622	0.2080	0.0162
Liver (%)	1.67^{bc}	1.90^{a}	1.56^{c}	1.74^{ab}	1.10^{d}	0.09	0.0985	0.0023	0.0001
Two kidneys (%)	0.29^{a}	0.29^{a}	0.18^{b}	0.17^{b}	0.29^{a}	0.25	0.3900	0.3900	0.0001
Gizzard (%)	2.86^{a}	2.86^{a}	2.67^{b}	2.61^{b}	2.86^{a}	0.04	0.7045	0.7045	0.0016
Gastro-intestinal tract (%)	18.10^{a}	10.48^{d}	11.56^{c}	13.04^{b}	12.38^{bc}	0.31	0.0014	0.7554	0.0014

Note: Means on the same row having different superscripts are significantly different ($P < 0.05$). SEM = standard error of the mean.

The higher values of livers of finishing broiler chickens fed soybean hull-based diets agreed with the reports of Scapini *et al*. (2018) that broiler chickens fed SH-based diets without enzyme supplementation had higher liver weight at 21 and 42 days of age. This implies that liver activities are related to the dietary fiber level. The highest values for the drumstick and back of the Marshal broiler chickens were recorded in the control group while the least values were obtained in 50% SHZ for the drumstick and 100% SHZ for the back. The birds fed 50% SH had higher ($P < 0.05$) values for the spleen and liver while birds fed 100% SH and 100% SHZ had the least values for the spleen and liver, respectively. However, the birds fed 50% SHZ has the highest value ($P < 0.05$) of breast and least values for kidneys and gizzard. The values of dressing percentage were within the values (67.6–82.07%) of the dressing percentage reported by Zanu *et al*. (2017). The birds fed 50% SHZ had the highest ($P < 0.05$) value of breast meat compared to other treatment groups. It indicates that SHZ promoted the deposition of muscle. Chicken breast is lean and has the most protein by weight, making it ideal for human health (Sanwo *et al*., 2019). The SHZ did not elevate the values of the organs compared with the control group and other dietary treatments. This may indicate that there were no abnormalities or pathological lesions in these organs.

The sensory evaluation of meat from broiler chickens fed diets containing undegraded and degraded soybean hull is shown in Table 6. The dietary treatments significantly ($P < 0.05$) increased the color and flavor but did not influence ($P > 0.05$) juiciness, tenderness, and overall acceptability. The strong influence of SHZ on the color of the meat might be due to the improved color of the SH by the *Zymomonas mobilis*. There were no differences in the juiciness and tenderness of the meat of the broiler chickens used in the study. This agreed with the findings of Ponte *et al*. (2008) who reported that subterranean clover pasture had no impact on the juiciness and tenderness of broiler meat. Although, they observed that differences in tenderness may be due to the fast growth of broiler chickens. Moreover, Seabra *et al*. (2001) observed that tenderness is usually thought to be the essential organoleptic attribute of meat. The replacement of wheat offal with undegraded and degraded soybean hull may result in different flavors which led to different sensory attributes (Gordon and Charles, 2002). The replacement of wheat offal with soybean hull-based diets has a positive impact on sensory attributes and does not exert any adverse effect on the quality or acceptability of meat.

Table 6 Sensory evaluation of meat from broiler chickens fed diets containing undegraded (SH) and degraded soybean hull (SHZ)

Parameters	Control	Undegraded		Degraded		Chi-square	P-value
		50% SH	100% SH	50% SHZ	100% SHZ		
Color	2.00^{c}	5.67^{b}	9.00^{ab}	10.83^{a}	12.50^{a}	10.7039	0.0301
Juiciness	5.00	10.83	7.67	8.83	7.67	2.7208	0.6056
Flavor	11.00^{b}	6.67^{bc}	14.00^{a}	4.00^{c}	4.33^{bc}	11.5990	0.0206
Tenderness	10.66	10.33	9.33	4.67	5.00	5.2038	0.2670
Overall acceptability	7.67	12.50	10.17	5.83	3.83	7.1432	0.1285

Note: Values on the same row having different superscripts are significantly different ($P < 0.05$). The values on the table are not mean.

Zymomonas mobilis derivable from fresh palm sap can be effectively and efficiently used in the bio-remediation of milled soybean hull to promote quality fibrous feedstuff for broiler chickens without compromising their health status. The incorporation of degraded soybean hull in the diet of broiler chickens will also reduce the level of environmental pollution as a result of indiscriminate disposal of the by-product of soybean processing factories.

CONCLUSION

The replacement of wheat offal with SH and SHZ increased the PCV, hemoglobin, red blood cell, total protein, and glucose of the broiler chickens. The carcass characteristics were improved by 100% SH, 50% SHZ, and 100% SHZ in their diets with the healthy development of the organs of the birds. Moreover, the sensory attributes such as color and flavor of the meat were improved by the 50% SHZ-based diet. Therefore, 100% undegraded, 50% and 100% *Zymomonas mobilis* degraded soybean hull can be incorporated into the broiler chicken diets to replace wheat offal on a weight-to-weight basis without compromising their health status.

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