CHEMICAL COMPOSITION OF PALM OIL MILL SLUDGE-BIODEGRADED SWEET ORANGE PEEL MEAL MIXTURE AND ITS EFFECT AS DIETARY ENERGY SOURCE ON NUTRIENT DIGESTIBILITY BY BROILER CHICKENS

AUTHORS CONTRIBUTIONS

This work was collaborative among all authors. KBO and OIAO designed the research, field work done by KBO, supervised by OIAO and KTO. KBO did data curation and statistical analysis, OIAO wrote the manuscript and all authors approved of it.

ABSTRACT

A feeding trial, which lasted for seventy days, was conducted in which palm oil mill sludge and biodegraded sweet orange peel mixture was fed to substitute maize in broiler chicken diet at 0%, 5%, 10%, 15%, 20% and 25%. Sweet orange (*Citrus sinensis*) fruit peel was fermented by soaking for 48 h in retted cassava waste water (CWW) and sundried, to obtain biodegraded sweet orange peel (BSOP). Palm oil mill effluent was filtered with a 0.30 mm pore plastic mesh sieve, poured into a 0.75 µm pore fine cheesecloth bag and allowed to stand for five hours to produce a paste of palm oil mill sludge (POMS). The POMS was mixed with BSOP in ratio 1:1, sundried, milled to produce a POMS-BSOP mixture. One hundred and eighty day-old Cobb 700 broilers divided into six equal parts, and three replicates of 10 birds each were used. Each part was assigned to one of 6 diets compounded with 0% (T1), 5% (T2), 10% (T3), 15% (T4), 20% (T5) and 25% (T6) of POMS-BSOP mixture. The microbial composition of retted CWW, chemical composition of the POMS-BSOP mixture, and the digestibility of nutrients by the broiler chickens were determined. Isolated from CWW were; *Staphylococcus aureus*, *Streptococcus* spp., *Salmonella* spp., *Escherichia coli* (bacteria), *Aspergillus* spp. (fungus) and *Candidia* spp. (yeast). POMS-BSOP was high in energy (4415.69 kcalME/kg), ether extract (41.50%), crude fibre (25.63%) and dry matter (92.28%), moderate in crude protein (6.83%), low in indigestible lignin (4.90% ADL), alkaloid (0.01%), tannin (0.02%), saponin (0.03%), phytate (0.05%), oxalate (0.15%) and flavonoid (0.17%). Dietary treatments significantly ($P<0.05$) affected digestibility of ether extract and metabolisable energy and crude protein digestibility by broiler chickens. Dietary maize can be replaced at up to 25% with a POMS-BSOP mixture to improve energy digestibility by broiler chickens.

***Key words*:** Antinutritional factors, cell wall constituents, proximate composition, nutrient digestibility

1. INTRODUCTION

The animal sub-sector of the agricultural industry in most developing nations is pivotal to many socio-economic activities and development. Its positive impact touches 600 million subsistence farmers in the developing world [1]. Animal-source foods are nutritional requirements in the design of dietary models for healthy living, but a wide margin of intake, ranging from less than 4 to 100 kg per person exists within and between countries ([2]. In Nigeria, the livestock industry contributed not less than 5% and 15% of the nation's total gross domestic product (GDP) and agricultural GDP, respectively [3]. As in many developing countries, it is fraught with dependence majorly on conventional feed stuffs which are often expensive and prohibitive, thus putting constraints on their use especially for non-ruminant animal production. It has been reported [4] that the reason for low livestock production in Nigeria is the scarcity of conventional feedstuffs for monogastric animal feeding which results in a cost estimate of more than 70% of the overall cost in an intensive system of farm animal production.

Most of the conventional feed stuffs used in the formulation and compounding of farm animal diets are utilised as food by man, and as raw materials in agro-allied industries. The livestock industry in Nigeria is diminutive, growing at a slow pace compared to a fast growing population of over 206 million [5], thereby making the intake animal protein by majority of the populace low [6].
Several possible solutions have been suggested to boost significantly animal source foods availability. Both [7] and [8] have an suggested increase in poultry production as a possible way out to redress the problem of meat scarcity in Nigeria and sub-Saharan Africa. Poultry and its meat enjoy wide acceptability, with practically no cultural restriction to its consumption unlike the case of pork forbidden by the Islamic faith [9]. Broiler chicken has a relatively short production period and can supply the highly needed protein for man in terms of quality and quantity [10]. It is a heavy eater and to ensure steady availability of broiler feed, it is essential to explore the use of alternative feed ingredients that are cheaper, useable, locally available and of low human preference in ration formulation to provide cheap and affordable products. Some agro-industrial by-products such as sweet orange peel meal [11], palm oil sludge [12] composite mango fruit reject meal [13] are used to substitute energy cereal grains in broiler chicken and rabbit diets. Sweet orange peel even though contains appreciable energy content, high in metabolisable energy, has a high fibre level thereby limiting its feed value in raising broiler chickens. Cassava (*Manihot esculenta*) waste water is another agro-allied by-product. It contains an array of microorganisms with potential for the production of amylase and cellulase [14, 15], which have direct industrial applications and can possibly be used for the biodegradation of sweet orange peel to improve its nutritional quality. Palm oil sludge is the material that remains after decantation of palm oil [16] and its irrational handling can cause problems to the entire surrounding ecosystem [17]. The utilization of the mixture of palm oil mill sludge and biodegraded sweet orange fruit peel as a source of energy feed stuff for broiler production will help to reduce environmental problems emanating from their irrational disposals and, also minimize the cost of feed and ensure the production of cheap and affordable animal protein. Thus, this study was conducted to determine the effect of utilization of palm oil mill sludge-biodegraded *Citrus sinensis* fruit peel mixture in place of dietary maize, a conventional energy feed stuff on nutrient digestibility of table meat chickens.

2 MATERIALS AND METHODS

2.1 Experimental site

The study was conducted in Okuku, Cross River State in Nigeria which houses the Medical Campus of the Cross River State University of Technology. Okuku is a low grassland town located between latitude 6^{o} 7´1´´ N - 6^{o} 7´18´´ N and longitude 8^{o} 7´85´´ E - 8^{o}7´80´´E [18]. Temperature average ranges between 20 ^{o}C - 40 ^{o}C, relative humidity is between 42% - 95% and annual rainfall is between 250 mm - 750 mm [19].

2.2 Collection and Preparation of Test Ingredients

The palm oil mill sludge was collected from a local processing mill in the University town of Okuku. A plastic sieve of 0.30 mm pore size was used to filter the palm oil mill sludge to reduce the residual fibre, and thereafter poured into a fine cheesecloth bag of 0.75 µm pore size to reduce the moisture content and allowed to stand for five hours to produce a paste of the palm oil mill sludge (POMS). Fermented cassava waste water (CWW) was also collected in Okuku, from small agro-allied cassava processing units with polyvinyl chloride (PVC) plastic containers and thereafter, filtered with a plastic sieve of 0.30 mm pore size to remove residues. Fermented CWW sample was taken to the Microbiology Laboratory of the College of Veterinary Medicine, Federal University of Agriculture, Makurdi for microbial analysis using the procedure of [20]. Sweet orange (*Citrus sinensis*) fruit peels obtained in Okuku from retailers marketing peeled fruit were then submerged in the fermented CWW in ratio 1 kg : 2 L, covered and allowed 48 h biodegradation. Thereafter the biodegraded peels were sun-dried to about 10% moisture on a polythene sheet and milled. The palm oil mill sludge (POMS) paste was mixed with the biodegraded sweet orange fruit peel (BSOP) in the ratio of 1:1 and the mixture was sun-dried to about 10% moisture on a polythene sheet and milled.

Analyses of a sample of the composite mixture of palm oil mill sludge-biodegraded peel meal for proximate constituents in Table 1 [21], cell wall fractions in Table 2 [22] and anti-nutritional factors in Table 3 [21] prior to feed compounding. Hemicellulose was calculated as Hemicellulose = NDF – ADF, and cellulose was calculated as Cellulose = ADF - ADL.

Table 1: Nutrient Content of POMS-BSOP and BSOP (%DM)

Nutrients	POMS-BSOP	BSOP
Dry matter	92.28	87.58
Crude protein (CP)	6.83	8.11
Crude fibre (CF)	25.63	19.37
Ether extract (EE)	41.50	3.31
Ash	3.58	5.82
Nitrogen free extract (NFE)	22.46	63.39
Energy (kcalME/kg)	4415.69	2818. 86

ME=Metabolizable energy = 37 x %CP + 81.1 x %EE + 35.5 x %NFE ------ [23].
POMS-BSOP= Palm oil mill sludge-biodegraded sweet orange fruit peel meal mixture
BSOP = Biodegraded sweet orange fruit peel meal fermented with cassava wastewater for 48 hours

Table 2: Cell wall Constituents of Palm Oil Mill Sludge-Biodegraded Sweet Orange Fruit Peel Meal Mixture and Biodegraded Sweet Orange Peel Meal

Nutrients (%)	POMS-BSOP	BSOP
Cellulose	33.00	29.30
Hemicellulose	20.10	9.70
Neutral detergent fibre	58.00	40.20
Acid detergent fibre	37.90	30.50
Acid detergent lignin	4.90	1.20

POMS-BSOP = Palm oil mill sludge-biodegraded sweet orang fruit peel meal mixture.
BSOP = Biodegraded sweet orange fruit peel meal fermented with cassava wastewater for 48 hours

Table 3: Anti-Nutritional Factors in Palm Oil Mill Sludge-Biodegraded Sweet Orange Fruit Peel meal Mixture

Anti-nutrient	POMS-BSOP
Alkaloid (%)	0.01
Saponin (%)	0.03
Phytate (%)	0.05
Oxalate (%)	0.15
Tannin (%)	0.02
Flavonoid (%)	0.17

POMS-BSOP = Palm oil mill sludge-biodegraded sweet orange fruit peel mixture

2.3 Experimental Treatments, Animals and Management

The palm oil mill sludge-biodegraded sweet orange peel meal mixture incorporated in both starter broiler (Table 4) and finisher broiler diets (Table 5), substituted maize at levels of 0% (T1), 5% (T2), 10% (T3), 15% (T4), 20% (T5) and 25% (T6). The other feed ingredients used in the formulation and compounding of the experimental diets were, groundnut cake, maize offal, blood meal, lysine, methionine, limestone, bone ash, mineral /vitamin premix and common salt. One hundred and eighty (180) day old Cobb 700 broilers from Zartech Farms, Ibadan, Nigeria were grouped into six (6) on an equal number and similar live weight basis. Each of the groups was randomly assigned to one of the six (6) experimental dietary treatments and the birds were raised in deep litter. Dietary treatments were replicated three times, and replicates had 10 birds each, vaccinated against Newcastle disease at day old, infectious bursal disease at ten days and Newcastle disease (Lasota) at 21 days. Anti-stress supplement (vitalyte) was administered at day old, a day pre- and post-vaccination, and to prevent stress associated with management routines. Anticoccidiostat, antibiotics were administered orally as prophylactic. The birds were served the experimental diets and drinking water *ad-libitum* for seventy days.

A metabolic study was done in the tenth week of feeding to determine dietary nutrient utilization by broiler chickens. One bird per replicate was selected from each dietary treatment, moved into metabolic cages and allowed an adjustment period of two days. Thereafter, the birds were served daily weighed ration for five days, and left over feed was collected and weighed to determine feed intake by difference. Fresh faecal droppings were collected daily per replicate, weighed and oven-dried at 105^{o}C for 24 hours. Faecal collections per replicate were bulked, milled and homogeneous sample of each, and the experimental diets were analyzed for nutrient composition ([21] and metabolizable energy content calculated [23]. Quantity of nutrients in diets and faeces were determined by multiplying nutrient percentage in diets and faeces by dry matter in diets and faeces, respectively. Nutrient retained was then determined as nutrient intake minus nutrient voided in faeces. Apparent digestibility coefficient was calculated (Table 6) using the formula;

$$D = \frac{1-F}{I} \times 100$$

Where D = digestibility coefficient, I = nutrient intake and F = nutrient voided in faeces

Data Analysis

Digestibility coefficient data collected were subjected to one-way analysis of variance using [24]. Indices with significantly different (P<0.05) means were separated using the Duncan multiple range test in the SPSS.

3 RESULTS

The microbial assay of fermented CWW showed that it contained four different types of bacteria: *Staphylococcus aureus*, *Streptococcus* spp, *Salmonella* spp. and *Escherichia coli*. One type each of fungi *Aspergillus* spp. and yeast *Candida* spp. The proximate composition of palm oil mill sludge-biodegraded sweet orange fruit peel meal mixture (POMS-BSOP) showed it contained 92.28% dry matter (DM), 6.83% crude protein (CP), 25.63% crude fibre (CF), 41.50% ether extract (EE), 3.58% ash, 22.46% nitrogen free extract (NFE) and energy content of 4415.69 kcal ME/kg (Table 1). The cell wall constituents of the POMS-BSOP mixture contained 33.00% cellulose, 20.10% hemicellulose, 58.00% NDF, 37.90% ADF and 4.90% ADL (Table 2).

Table 4: Ingredient Composition (%) of Experimental Diets for Broiler Starter

Ingredients	T1 (0%)	T2 (5%)	T3 10%)	T4 (15%)	T5 (20%)	T6 (25%)
Yellow maize	57.00	54.15	51.30	48.45	45.60	42.75
POMS-BSOP	0	2.85	5.70	8.55	11.40	14.25
Groundnut cake	34.00	34.00	34.00	34.00	34.00	34.00
Blood meal	4.00	4.00	4.00	4.00	4.00	4.00
Lysine	0.35	0.35	0.35	0.35	0.35	0.35
Methionine	0.30	0.30	0.30	0.30	0.30	0.30
Bone ash	3.00	3.00	3.00	3.00	3.00	3.00
Limestone	0.80	0.80	0.80	0.80	0.80	0.80
Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Common salt	0.30	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient						
ME (Kcal/kg)	2915.84	2942.85	2969.86	2996.86	3023.88	3050.89
Crude protein (%)	23.46	23.40	23.35	23.28	23.23	23.16
Ether extract (%)	5.41	6.48	7.55	8.62	9.68	10.75
Crude fibre (%)	2.90	3.55	4.21	4.68	5.51	6.16
Calcium (%)	1.45	1.47	1.50	1.51	1.54	1.56
Avail.P (%)	0.77	0.78	0.79	0.79	0.78	0.79
Lysine (%)	1.30	1.30	1.30	1.31	1.31	1.31
Methionine (%)	0.61	0.64	0.61	0.61	0.61	0.66

POMS-BSOP = Palm oil mill Sludge-Biodegraded sweet orange fruit peel, ME = Metabolizable energy, Avail .P = Available phosphorus,*Premix Containing: Vitamin premix per kg; vit. A 12000 IU, vit.D3 3000 IU, vit.E 30mg,vit.K3 2.5mg, Folic Acid 1mg, Niacin 40mg, Calpan 10mg, vit. B2 5mg, vit.B12 0.2Mg, vit.B1 2mg, vit.B6 3.5mg, Biotin 0.08mg, Antioxidant 125mg. Mineral Premix per kg; Co 0.25mg, Se 0.25mg, I 1.2mg, Fe 40mg, Mn 40mg, Co 8 mg, Zn 60mg, Choline Chloride 200mg.

T1=0% maize replacement with POMS-BSOP (Control diet)
T2=5% maize replacement with POMS-BSOP
T3=10% maize replacement with POMS-BSOP
T4=15% maize replacement with POMS-BSOP
T5=20% maize replacement with POMS-BSOP
T6=25% maize replacement with POMS-BSOP

Table 5: Ingredients Composition (%) of Experimental Diets for Broiler Finisher (5-8 Weeks)

Ingredients	T1 (0%)	T2 (5%)	T3 (10%)	T4 (15%)	T5 (20%)	T6 (25%)
Yellow maize	64.00	60.80	57.60	54.40	51.20	48.00
POMS-BSOP	0	3.20	6.40	9.60	12.80	16.00
Groundnut cake	28.00	28.00	28.00	28.00	28.00	28.00
Blood meal	3.00	3.00	3.00	3.00	3.00	3.00
Lysine	0.40	0.40	0.40	0.40	0.40	0.40
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Bone ash	3.55	3.55	3.55	3.55	3.55	3.55
Limestone	0.30	0.30	0.30	0.30	0.30	0.30
Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Common salt	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
Calculated nutrient						
ME (Kcal/kg)	2979.43	3009.76	3039.97	3069.80	3100.51	3130.79
Crude protein (%)	20.61	20.32	20.54	20.48	20.42	20.35
Ether extract (%)	5.10	6.31	7.53	8.85	10.09	11.34
Crude fibre (%)	2.91	3.65	4.57	5.31	6.05	6.78
Calcium (%)	1.47	1.57	1.57	1.58	1.59	1.60
Avail.P (%)	0.95	0.95	0.96	0.96	0.96	0.97
Lysine (%)	1.28	1.28	1.31	1.31	1.31	1.38
Methionine (%)	0.52	0.53	0.52	0.52	0.52	0.52

POMS-BSOP = Palm oil mill Sludge-Biodegraded sweet orange fruit peel, ME = Metabolizable energy, Avail .P = Available phosphorus, *Premix containing: Vitamin premix per kg; vit. A 12000 IU, vit.D3 3000 IU, vit.E 30mg,vit.K3 2.5mg, Folic Acid 1mg, Niacin 40mg, Calpan 10mg, vit. B2 5mg, vit.B12 0.2Mg, vit.B1 2mg, vit.B6 3.5mg, Biotin 0.08mg, Antioxidant 125mg. Mineral Premix per kg; Co 0.25mg, Se 0.25mg, I 1.2mg, Fe 40mg, Mn 70mg, Cu 8 mg, Zn 60mg, Choline Chloride 200mg.

T1 = 0% maize replacement with POMS-BSOP (Control diet)
T2 = 5% maize replacement with POMS-BSOP
T3 = 10% maize replacement with POMS-BSOP
T4 = 15% maize replacement with POMS-BSOP
T5 = 20% maize replacement with POMS-BSOP
T6 = 25% maize replacement with POMS-BSOP

The quantitative values of the anti-nutritional factors present in the palm oil mill sludge - biodegraded sweet orange peel meal mixture were alkaloid 0.01%, saponin 0.03%, phytate 0.05%, oxalate 0.15%, tannin 0.02% and flavonoid 0.17% (Table 3).

The apparent digestibility of the nutrients in the experimental diets by finisher chickens is shown in Table 6. Significant (P<0.05) variation in crude protein, ether extract, and metabolisable energy occurred among the groups. Protein digestibility was highest in T1 the control diet (85.67%), but was not significantly (P>0.05) different from T2, T3 and T4. Lower apparent values were given by birds in T5 (68.26%) and T6 (70.14%). Significantly (P<0.05) high ether extract digestibility was recorded in T1 (96.16%) which was not significantly (P>0.05) different from T2, T4, T5 and T6. The least apparent digestibility of ether extract was in T3 (86.45%).

Table 6: Digestibility of Nutrient by Finisher Chickens fed Palm Oil Mill Sludge-Biodegraded Sweet Orange Fruit Peel Meal Mixture Diets

Nutrients (%)	T1	T2	T3	T4	T5	T6	SEM
Dry matter	87.78	82.95	83.76	87.06	81.51	81.47	1.02^{ns}
Crude protein	85.67^{a}	76.65^{abc}	75.60^{abc}	84.15^{ab}	68.26^{c}	70.14^{bc}	4.13*
Ether extract	96.16^{a}	89.93^{ab}	86.45^{b}	94.51^{a}	94.21^{a}	93.57^{a}	2.51*
NFE	93.76	88.48	92.93	91.60	90.11	88.72	1.02^{ns}
Crude fibre	71.80	67.98	66.98	78.31	65.38	73.98	2.58^{ns}
Metabolisable Energy	84.58^{ab}	87.57^{ab}	92.37^{a}	90.64^{ab}	83.54^{b}	87.46^{ab}	0.98*

^{a,b,c}Means with different superscripts in the same row are significantly (p<0.05) different, *(p<0.05), ^{ns}Not significantly (p>0.05) different, SEM = Standard error of mean, ME = Metabolisable energy, NFE = Nitrogen Free Extract

T1 = 0% maize replacement with POMS-BSOP (Control diet)
T2 = 5% maize replacement with POMS-BSOP
T3 = 10% maize replacement with POMS-BSOP
T4 = 15% maize replacement with POMS-BSOP
T5 = 20% maize replacement with POMS-BSOP
T6 = 25% maize replacement with POMS-BSOP

The apparent metabolisable energy digestibility was highest (P<0.05) in T3 (92.37%). It was however, not significantly (P>0.05) different from T1, T2, T4 and T6. The coefficient of digestibility of crude protein and ether extract by the broiler chickens in the maize based control dietary group was comparatively better than by the chickens in the POMS-BSOP based diets, while for the metabolisable energy the sequence tended to be the opposite.

4 DISCUSSION

The liquid (waste water) squeezed out of cassava tubers during processing contains heavy loads of microorganisms, lactic acid, lysine (from *L. coryneformis*), amylase (from *L. delbruckii*) capable of hydrolyzing the glycosides [25]. Many researchers have reported success in the use of microorganisms to improve the nutritive value of low quality feedstuff [26, 27]. All the B vitamins are reported to be synthesized by bacteria such as *Clostridium* spp. and *Streptococcus* spp. and vitamin K synthesized by *Escherichia coli* ([28]. Applied bio-technologies fermentation has been reported to increase digestibility of ration based on non-conventional wastes [27, 29]. Utilization of microbial inoculants in feed processing through the fermentation process for the degradation of fibrous agro-allied by-products and feed residues is one of the technologies that can be further developed to improve feedstuff quality [30].

The proximate composition of POMS-BSOP mixture showed it had a higher percentage of dry matter of 92.28%, in comparison to 87.60% reported by [31] for biodegraded sweet orange peel (BSOP) fermented with rumen content for 48 hrs. The high dry matter in POMS-BSOP as against BSOP obtained in the current study can be attributed to the contributory effect caused by the mixing of palm oil mill sludge with the biodegraded sweet orange peel. There was also the possibility of microbial flora action on the POMS-BSOP during processing, breaking down of soluble nutrients in the mixture thereby increasing its dry matter content. Crude protein of 6.83% was lower in the POMS-BSOP mixture compared to a range of 7.71% - 9.26% for BSOP [32] possibly for reasons of the diluting effect of the POMS mixed with BSOP and also the conductivity of its water molecules could have possibly carried away some water soluble nutrients like protein present in the mixture. Also, bacterial proliferation that could have increased the crude protein in the mixture may have been weakened due to the increase in acidity of the palm oil mill sludge [33]. The crude fibre value of 25.63% was higher in POMS-BSOP mixture compared to a range of 13.88% -

15.82% reported for BSOP [32]. This could be due to the degrading activities of microbes on some of the nutrients during feed ingredient processing, leaving behind less soluble matter having high fibre content in the mixture. Also, there was the possibility that organic acids in the palm oil mill sludge dissolved some nutrients in the mixture that were removed during drying, and left the less soluble matter with the concomitant higher fibre level. Ether extract of 41.50% in POMS-BSOP mixture was high compared to 2.33% - 3.41% in BSOP [32]. This may be attributed to the presence of high concentration of fatty acids like lauric, myristic, palmitic, stearic, oleic, linoleic, arachidic [34] present in the palm oil mill sludge. The ash content of 3.58% in the POMS-BSOP mixture was lower than 5.82% in BSOP. The presence of some acids in the palm oil mill sludge can cause chelation of minerals in the sweet orange peel, coupled with additional loss of some minerals present during sun drying process alluded to in an earlier study [35]. Microbes present in the mixture could have utilized much of the soluble carbohydrates for their growth and development, leaving a feed material with less soluble carbohydrates. Metabolisable energy was high in the mixture possibly due to the energy yield from various very short chain fatty acids and other fatty acids including contained in the palm oil sludge [36].

The result of the cell wall of POMS-BSOP constituents determined showed that it had higher NDF (58.00%) and hemicellulose (20.10%) when compared to 40.20% and 9.70% for BSOP respectively. ADF (37.90%) and cellulose (33.00%) were also higher in the mixture compared to 30.50% and 29.30% respectively in BSOP. The acid detergent lignin 4.90% was also higher in comparison to that in BSOP (1.20%) in BSOP. These differences in the cell wall constituents could be a result of residual fibre left during the processing of palm oil mill sludge. The anti-nutrient assay of the palm oil mill sludge-biodegraded sweet orange fruit peel meal mixture revealed the presence of alkaloid, saponin, flavonoid, phytate, oxalate and tannin at low concentrations. This agrees with some earlier studies that fat has the ability to mitigate the effect of dietary anti-nutritional factors [37, 38]. The lower the concentrations of anti-nutritional factors in animal feeds, the safer such feeds are for farm animal use [39], especially non-ruminant animals in which most nutrient absorption occurs in the small intestine before caeca where there could be some degree of microbial activities.

There was an insignificant improvement for the T2, T3, T4 and T5 treatments in the metabolisable energy values, and a significant decrease in the ether extract digestibility in T3 and the protein digestibility in T5and T6 only, compared to the control. Broiler chickens on POMS-BSOP based diets however did not show a definite pattern in nutrient digestibility. It was apparent that utilisation of POMS-BSOP in preparation of broiler chicken diets depressed crude protein digestibility at high levels (20% and 25%) only. It is reported by [40] that fibre in the diet of non-ruminant animals impairs the utilization of other nutrients especially when it is above the recommended level. The non-significant variation and similar nutrient digestibility of nitrogen free extract suggested that replacement of maize by POMS-BSOP in broiler chicken diets did not reduce the readily available carbohydrates. This showed that the experimental chickens had high quality carbohydrates to be transformed to chemical energy for growth and biosynthetic processes in the body. Metabolisable energy digestibility in this study showed that, POMS-BSOP based diets can provide sufficient metabolisable energy needed for growth of the broiler chickens. Dry matter digestibility of 81.47% - 87.78% in this study was high and it was inferred that the crude fibre levels in the experimental diets varied from 2.91% in diet T1 (0% POMS-BSOP) to 6.78% in diet T6 (25% POMS-BSOP) did not have an adverse effect on dry matter. Hence, the POMS-BSOP fibre had minimal effect on dry matter digestibility in spite of its contribution to the increase in dietary fibre across the treatment groups. This is an indication of the nutritional potential of

POMS-BSOP as an acceptable feed material for utilisation in compounding broiler chicken diet.

5 CONCLUSION

The study has shown the prospect of fermented cassava waste water for biodegradation of the peel of *Citrus sinensis* fruit to boost the potential of its nutrients in broiler chicken nutrition, and the utilisation of palm oil mill sludge-biodegraded sweet orange peel mixture as a substitute for up to 25% maize, to enhance dietary metabolisable energy digestibility by finisher broiler chicken.

DATA AVAILABILITY STATEMENT

All relevant data to this report have been provided.

COMPETING INTEREST

There are no conflicting interests.

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