Original Research Article

Carcass, Internal Organ Characteristics and GIT Morphometry of Broiler Chickens Fed Diets Containing Fermented Sweet Orange (*Citrus sinensis*) Peel Meal (FSOPM) As A Replacement of Maize

ABSTRACT

The experiment was carried out to determine the effect of fermented sweet orange peel meal (FSOPM) as a replacement of maize on carcass, internal organs characteristics and GIT morphometry of broiler chicken. Fresh sweet orange peel (SOP), and fresh rumen content (RC) were collected and thoroughly mixed to obtain a homogenous mixture in a ratio of 1: 0.3 (SOP:RC), respectively. The mixture was fermented for 48 hours and sun-dried to < 10 % moisture. The fermented SOP was milled to obtain FSOPM. The FSOPM was sub-sampled and its proximate composition determined, after which it was included at 0 %, 2 %, 4 %, 6 %, 8 %, and 10 %, respectively in the diets. 216 day – old Marshal MY broiler chicks were randomly assigned to 6 dietary treatments in a complete randomized design (CRD). Each treatment was replicated 3 times with 2 birds in each replicate. The birds were fed the test diets for 56 days and carcass, internal organs and GIT were evaluated. The fasted weight, eviscerated weight, dressed weight, dressing percentage, thigh, wing, head, shank, abdominal fat, empty gizzard, liver, kidney, proventriculus, bile, GIT weight, large intestine and small intestine were significantly different ($p < 0.05$). Inclusion of FSOM increased carcass cut, internal organs and the GIT morphometry; and recessed abdominal fat pad of broiler chickens. It was concluded that 10 % FSOPM replacement of maize was safe and optimum for broiler chicken production.

Keywords: Fermentation, sweet orange peels, rumen content, Broiler chickens, proximate analysis, growth performance

1 INTRODUCTION

Agro-industrial waste products are in abundance in Nigeria and industries producing these by-products often incure expenses for their proper disposal. The processing of orange fruits (citrus) generates significant amounts of by-products often containing valuable compounds in the peels, pulp and seeds. In 2018, the United Nations Food and Agriculture Organization FAO, (2020) estimated a world citrus production of 104.15Mt, with 75.54Mt corresponding to orange. The waste obtained from industrial processed citrus is made up of valuable by-products which according to [1] contains 89.20 % DM, 8.20 % CP, 13.30 % CF, 4.51 % EE, 6.09 % ash, 67.90 % NFE and 3079.61 Kcal/kg of ME that can be used for poultry feed. Harnessing these wastes will reduce the pressure of demand, as well as cost of maize, the major and most widely utilized energy ingredient in poultry diets which have risen over the years. The high cost of animal feeding results from the various use to which maize, a conventional feed stuff is being competed for as a staple food for man, in brewing and confectionary. According to [2] the availability of high-quality poultry feeds is limited by phenomenal rise in the cost of conventional feed ingredient for animals, mostly due to competition from direct consumption of these materials by man. For a feed stuff to be qualified and used as an alternative for livestock feeding, the ingredient most be cheap, readily available and not used as a staple food for humans, but should meet the nutritional requirements of farm animals. Limitations of the use of sweet orange peel (SOP) has been reported due to some anti-nutritional factors such as tannin, saponin, phytate, oxalate, flavoniod and limonene [3]. It is important therefore that certain processing techniques be employed to minimize these anti-nutritional factors and improve the nutritive value of SOP.

The rumen content (RC), an abattoir waste is the material obtained from the rumen of slaughtered ruminants. It contains a mixed population of microbes and undigested feed material and can be used as a natural inoculum. Fermentation is a unique process with great potentials of recycling agro by-products such as sweet orange peels into useful poultry feeds in developing countries. The process is easy to manage on farm conditions and does not require the use of chemicals. Fermentation eliminates toxins, improves nutritional quality, increases digestibility, palatability, bioavailability of minerals and simple sugars [4 and 5]. This experiment was therefore carried out to determine the effect of fermented sweet orange peel meal (FSOPM) on carcass yield, internal organs characteristics and GIT morphometry of broiler chickens.

2 Materials and Methods

2.1 Experimental Site

The experiment was conducted at the poultry section of the Livestock Unit, on the Teaching and Research Farm, Joseph Sarwuan Tarka University, Makurdi Benue State, Nigeria. The area is warm with a minimum temperature range of 24.20 ± 1.40^{0}C and a maximum temperature range of 36.33 ± 3.70^{0}C [6].

2.2 Preparation of fermented sweet orange peel, rumen content and diets.

Sweet orange peels were collected together as a composite irrespective of variety from sweet orange fruit retailers while the rumen content (RC) was collected from freshly slaughtered white Fulani cattle at the slaughter slab all in Gboko, Benue State. The Sweet Orange Peels (SOP) were thoroughly mixed with the rumen content (RC) to obtain a homogenous mixture in a ratio of 1:

Commented [MA1]: Please, add these references:

Alshelmani, M. I., Loh, T. C., Foo, H. L., Sazili, A. Q., & Lau, W. H. (2016). Effect of feeding different levels of palm kernel cake fermented by Paenibacillus polymyxa ATCC 842 on nutrient digestibility, intestinal morphology, and gut microflora in broiler chickens. Animal Feed Science and Technology, 216, 216-224.

Alshelmani, M. I., Kaka, U., Abdalla, E. A., Humam, A. M., & Zamani, H. U. (2021). Effect of feeding fermented and non-fermented palm kernel cake on the performance of broiler chickens: a review. World's Poultry Science Journal, 77(2), 377-388.

Alshelmani, M. I., Abdalla, E. A., Kaka, U., & Basit, M. A. (2021). Nontraditional feedstuffs as an alternative in poultry feed. In Advances in poultry nutrition research. IntechOpen.

Commented [MA2]: Add reference:

Alshelmani, M. I., El-Safty, S. A., Kairalla, M. A., & Humam, A. M. (2024). Enzymes in Poultry Feed. Feed Additives–Recent Trends in Animal Nutrition.

Commented [MA3]: Add these references:

Kairalla, M. A., Alshelmani, M. I., & Aburas, A. A. (2022). Effect of diet supplemented with graded levels of garlic (Allium sativum L.) powder on growth performance, carcass characteristics, blood hematology, and biochemistry of broilers. Open Veterinary Journal, 12(5), 595-601.

Kairalla, M. A., Aburas, A. A., & Alshelmani, M. I. (2022). Effect of diet supplemented with graded levels of ginger (Zingiber officinale) powder on growth performance, hematological parameters, and serum lipids of broiler chickens. Archives of Razi Institute, 77(6), 2089-2095.

Kairalla, M. A., Alshelmani, M. I., & Imdakim, M. M. (2023). Effect of diet supplemented with different levels of moringa powder on growth performance, carcass characteristics, meat quality, hematological parameters, serum lipids, and economic efficiency of broiler chickens. Archives of Razi Institute, 78(5), 1647.

0.3. The mixture was packed, tied in polythene bags and allowed to ferment for 48 hours. The fermented materials were sun-dried, separated from the RC and the fermented peels were milled to obtain fermented sweet orange peel meal (FSOPM). The fermented Sweet Orange peel meal was then sub-sampled and the proximate composition determined following standard procedure [7]. Phytate was determined using spectrophotomeric method [8] tannin and saponin using the procedure of [9], Oxalate using the technique of [10]. The FSOPM was then incorporated in broiler diets for starter and finisher phases at 0, 2, 4, 6, 8 and 10 % to produce 0 % FSOPM (control), 2 % FSOPM, 4 % FSOPM, 6 % FSOPM, 8 % FSOPM and 10 % FSOPM diets presented in Tables 2 and 3 respectively.

Table 1: Composition of Broiler Finisher Diets Containing FSOPM

	Treatments					
Ingredients	**0% FSOPM**	**2% FSOPM**	**4% FSOPM**	**6% FSOPM**	**8% FSOPM**	**10% FSOPM**
Maize	56.3	55.17	54.05	52.92	50.80	50.67
FSOPM	0.00	1.13	2.25	3.38	4.50	5.63
SBM	32.45	32.45	32.45	32.45	32.45	32.45
BDG	5.00	5.00	5.00	5.00	5.00	5.00
Bone ash	2.20	2.20	2.20	2.20	2.20	2.20
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Blood meal	1.50	1.50	1.50	1.50	1.50	1.50
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.30	0.30	0.30	0.30	0.30	0.30
Common salt	0.25	0.25	0.25	0.25	0.25	0.25
Vt/min pmx	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	Analysis					
Crude protein (%)	21.77	26.76	21.82	21.73	21.62	21.70
Crude fibre (%)	4.23	4.35	4.49	4.60	4.68	4.82
Fat (%)	3.76	3.75	3.78	3.74	3.68	3.82
ME (Kcal/kg)	2065.86	2385.98	2865.09	3019.62	2019.61	2050.94
Methionine (%)	0.61	0.60	0.61	0.60	0.60	0.59
Lysine (%)	1.45	1.44	1.44	1.44	2.43	1.43
Calcium (%)	1.44	1.44	1.44	1.44	1.43	1.43
Phosphorus (%)	0.62	0.63	0.65	0.62	0.61	0.61

Vitamin – mineral premix* (animal care ®) supplied the following nutrients per kg of feed. Vitamin: A (1,200,000 I.U) D_3 (300,000 I.U), E (3,000mg), K_3 (250mg), folic acid (10mg), Niacin (4,000mg), Calpan (1,000mg), B_2 (500mg), B_{12} (2mg), B1 (200mg), B_6 (350mg), Biotin (8mg), Antioxidant (12,500mg), Minerals; Cobalt (25mg), Selenium (25mg), Iodine (120mg), Iron (4,000mg), Manganese (700mg), Copper (800mg), Zinc (6,000mg), and Chlorine chloride (20,000mg) FSOPM=fermented sweet orange peel meal, SBM= soybean meal, BDG=brewer's dried grains, ME=metabolizable energy, vit/min pmx= vitamins and mineral premixes

2.3 Experimental broilers and design

Two hundred and sixteen (216) day – old Marshall MY broiler chicks were purchased from Chi Farms, Ibadan, balanced for weight and randomly assigned to six dietary treatments in a complete randomized design (CRD). Each treatment group of 36 broilers was further sub-divided into three replicates of 12 chicks each. The broiler birds were reared in deep litter, half-walled open – sided house with the upper half covered with wire mesh for good ventilation. Feed and water were provided *ad libitum* throughout the feeding trial which lasted for 56 days. Standard management procedures were observed. Feed intake and body weights were recorded weekly. Feed intake was determined by serving birds weighed amount of feed and the corresponding left-over obtained by difference and daily feed intake calculated as average for seven days.

2.4 Data collection and analysis

a). Carcass evaluation

Carcass evaluation was carried out using the procedure of [11]. At the termination of the feeding trial on the 56th day, one finisher broiler per replicate whose live weight similar to the group's average weight was selected, fasted for 18 hours, slaughtered by severing the head from the neck with a sharp knife and bled. The broilers were dipped in hot water (55 – 60^0C) de-feathered and carcass separated into cuts namely breast, drumstick, thigh, back, wing and neck. Offal's separated included head, shank and abdominal fat. Carcass weight was determined by weighing individual cuts, and each expressed as percent of live weight (% LW).

b). Internal organs

Each of the broilers used in carcass evaluation, had its internal organs examined as well. Internal organs namely; empty gizzard, liver, lungs, kidney, proventriculus, pancreases, bile and spleen were separated and weighed using an electronic scale. Gastro-intestinal tracts of slaughtered birds were evaluated by taking the weights of the GIT, the small intestine, the large intestine and the caecum. The length of the GIT and its components (the small intestine, the large intestine and the caecum) were also measure.

2.5 Data analysis

Data generated were subjected to one-way analysis of variance (ANOVA) using Minitab software [12], and where significant differences occurred, means were separated using the least significant difference (LSD) as contained in [12].

3. Results and Discussion

3.1 Proximate composition

The proximate composition of fermented sweet orange peel meal (FSOPM) is presented in Table 2. For a feed stuff to be qualified for use as an alternative for poultry feeding, the nutrient value of such a material should be comparable nutritionally to that of the conventional feed stuff it replaces like maize and should also meet the nutritional requirements of broiler chickens.

Table 2: Proximate analysis, Energy and Anti-nutritional Factors in Fermented Sweet Orange Peel Meal (FSOPM)

Parameters (%)	(FSOPM)
Dry matter	91.92
Crude protein	7.82
Crude fibre	13.88
Ether extract	2.94
Ash	8.16
Nitrogen free extract	67.20
Metabolizable Energy (kcal/kg)	2915.42
Tannin	0.008
Saponin	0.70
Alkaloid	2.50
Phytate	0.45
Oxalate	3.02

FSOPM=fermented sweet orange peel meal

The dry matter (DM) value (91.92 %) obtained in this study is comparable to 92.79 % - 93.22 % reported by [13] for sun-dried SOP, but higher than 81.43 % - 87.05 % and 89.61 – 92. 56 % reported by [4] and [14] respectively. The DM content was above 90 % indicating that all the nutrients were seemingly high. This high DM content will enhance long shelf – life storage of FSOPM. [15] reported that high DM favoured long storage duration of BSOPM. The crude protein value (7.82 %) obtained in this study is comparable to 7.71 % - 9.26 % reported by [4] but higher than 7.22%, 6.44 % and 6.78 % - 7.30 % reported by [16, 17 and 13] respectively. The crude protein value in FSOPM was not far from that of maize (8.90 %), a conventional energy feed stuff [18] suggestive that, it can partially be used in place of maize. Crude fibre value (13.88 %) obtained in this study compared favourably with 14.73 %, 13.30 % and 15.77 % reported by [4] respectively. The CF in FSOPM was higher than that of maize (2.70 %) as reported by [18], but lower than 14.60 % reported by [19] for sweet orange peels (SOP). The reduced CF percent in this study could be attributed to fermentation. Maize been a parent /conventional feed material, it was also expected that the CF of FSOPM as a by-product, be higher. The ether extract value of FSOPM (2.94 %) obtained in this study compares favorably to 2.23 % - 3.41 % and 2.50 % - 2.95 % reported by [4], when sweet orange fruit peels were fermented. The values were however higher than 1.88 % - 2.65 % and 1.96 % reported by [13 and 16] respectively. The ash value of FSOPM (8.16 %) obtained in this study was comparable to 8.19 % [20] and 9.91 % [13] but higher than 6.09 % reported by [2]. The ash content of FSOPM was higher than 2.70 % for maize [18]. Increase in ash content could be attributed to the rumen content used for fermentation. The result shows that FSOPM contains more total minerals than maize (a conventional energy feedstuff) and could perfectly replace maize on the grounds of mineral supply. [21] had earlier reported that grains are relatively poor in minerals. Nitrogen free extract (NFE) which represents the soluble carbohydrates (67.20 %) obtained in this study compared favourably to 67.90 % reported by [2]. The value for NFE obtained in this study was lower than 83.00 % [22] but higher than 50.75 % reported by [17] for maize. This result suggested that maize contains more utilizable sugars than FSOPM. Typical of agricultural by- products one of their nutritional characteristics is the low energy/NFE content. In comparism to maize, his result was also expected. The ME value of FSOPM (2915.42 Kcal/kg) obtained in this study was comparable to 2795.28 – 2913.92 Kcal/kg reported by [4] but was lower than 3752.12 Kcal/kg reported by [23] for maize, and 3432.32 Kcal/kg reported for maize [22]. The ME obtained though inferior to maize can be used as a source of energy in the diet of broiler chicken. [24] had earlier reported that SOP could serve mainly as an energy source because of its high energy value (2990.00 Kcal/kg). The energy value of FSOPM in this study suggests its suitability and utilization as an energy source in broiler diets

3.2 Carcass cuts and offals

The results of carcass cuts (breast, drumstick, thigh, back, wing, neck) and offals (head, shank abdominal fat) are presented in Table 3. There was no significant difference ($p > 0.05$) in the breast, drumstick, back and neck. The thigh cut was significantly higher ($p < 0.05$) at 0 % and 10 % FSOPM and significantly lower ($p < 0.05$) at 4 % FSOPM. The wing was significantly higher ($p < 0.05$) at 10 % FSOPM and significantly lower ($p < 0.05$) at 6 % FSOPM. The live weight (1.59 – 2.00 kg) obtained in this study was comparable to 1.33 – 2.01 kg reported by [25], and the average of 1.92 kg reported by [26]. The average live weight obtained in this study was within broiler chicken table weight range of 1600 g to 2000 g reported by [27]. The dressing percent (62.09 % - 69.00 %) obtained in this study was comparable to 72.41 % reported by [16] but was higher than 62.29 % reported by [26]. The dressing percent obtained in this study agrees with 71.00 % - 75 % earlier reported by [28] as satisfactory for broiler. Dressing percentage is the absolute value of saleable meat which therefore showed that the chickens in the FSOPM dietary treatment groups produced lean meat for utilization. The thigh weight (14.70 % - 16.65 %) obtained in this study was comparable to 15.34 % - 17.55 % reported by [29] when broiler chickens were fed rice milling waste (RMW) based diets. The thigh weight was however higher than 11.55 % - 13.15 % reported by [16] when broiler chickens were fed water soaked sweet orange fruit peel-based diets. The wing weight (12.16 % - 13.62 %) obtained in this study was comparable to 10.77 % - 14.35 % reported by [29] but was higher than 7.81 % - 8.14 % reported by [16] for broiler chickens. The thigh, breast and drumstick cuts are prime cuts of chicken and they give a picture of the carcass meatiness and eventual revenue yield. Carcass quality is closely related to the intake level of nutrients especially protein and energy. The values obtained in this study for carcass cuts of broiler chickens fed FSOPM are statistically similar to the maize based control diet. Implying therefore that, birds fed diets containing FSOPM yielded meat at levels equivalent to those on the control. The head and shank were significantly higher ($p < 0.05$) at 10 % FSOPM; while abdominal fat was significantly higher ($p < 0.05$) at 0 % FSOPM (control diet) and significantly lower ($p > 0.05$) at 6 % and 10 % FSOPM. The head weight (3.43 % - 4.28 %) and shank weight (5.74 % - 7.34 %) obtained in this study were comparable to (2.78 % - 4.36 %) but higher than (4.18 % - 4.75 %) for shank weight reported by [17] for sun-dried SOP supplemented with quantum blue enzyme. The abdominal fat (0.00 % - 0.84 %) obtained in this study was higher than 0.00 – 0.21 % reported by [2] but lower than 1.85 % - 2.13 % reported by [30]. The result on abdominal fat clearly showed that the use of FSOPM in the diet of broiler chicken recessed the deposition of abdominal fat. This could be attributed to high fiber content of the diets and also to the various active components present in *Citrus sinensis* peels. According to [31] dietary addition of *Citrus sinensis* waste had beneficial effects in reducing the levels of cholesterol and fats in meat. This has good health benefits because fatty meat consumption can cause/or increase coronary challenges. This result is in agreement with those of [32] and [33] who reported significantly decrease in abdominal fat in broiler chicken fed diets supplemented with orange peel powder and biodegraded sweet orange peels, respectively.

Table 3: Effect of FSOPM on Carcass parameters and Offals of Broiler Chickens

Weight of part/ parameter (%)	Treatments						SEM
	0% FSOPM	2% FSOPM	4% FSOPM	6% FSOPM	8% FSOPM	10% FSOPM	
Live weight (kg)	2.00^{a}	1.83^{abc}	1.77^{abc}	1.95^{ab}	1.73^{bc}	1.59^{c}	0.08
Eviscerated weight (%LW)	76.13^{a}	69.30^{c}	72.41^{b}	75.24^{ab}	74.68^{ab}	73.54^{ab}	0.37
Dressed weight (kg)	1.38^{a}	1.22^{ab}	1.21^{ab}	1.34^{ab}	1.17^{bc}	0.99^{c}	0.06
Dressed percent (%)	69.00^{a}	62.09^{b}	67.58^{a}	68.49^{a}	68.37^{a}	65.54^{a}	0.91
Breast (% LW)	29.93^{a}	29.03^{a}	30.34^{a}	30.38^{a}	30.08^{a}	28.03^{a}	1.00
Drumstick (% LW)	16.01^{a}	16.92^{a}	15.45^{a}	15.92^{a}	16.40^{a}	16.43^{a}	0.61
Thigh (% LW)	16.18^{a}	16.04^{ab}	14.70^{b}	15.98^{ab}	16.01^{ab}	16.65^{a}	0.55
Back (% LW)	14.83^{a}	15.52^{a}	15.92^{a}	15.18^{a}	14.65^{a}	14.92^{a}	0.57
Wing (% LW)	12.48^{bc}	12.97^{abc}	13.27^{ab}	12.16^{c}	12.89^{abc}	13.62^{a}	0.30
Neck (% LW)	10.18^{a}	9.24^{a}	10.17^{a}	9.71^{a}	9.39^{a}	10.12^{a}	0.35
Head (% LW)	3.54^{b}	3.47^{b}	3.43^{b}	3.50^{b}	3.53^{b}	4.28^{a}	0.14
Shank (% LW)	6.72^{ab}	7.01^{ab}	5.74^{c}	6.34^{bc}	6.37^{bc}	7. 34^{a}	0.23
Abdominal fat (% LW)	0.84^{a}	0.57^{ab}	0.48^{ab}	0.06^{b}	0.43^{ab}	0.00^{b}	0.22

^{a,b,c,} Means with different superscripts in the same row are significantly different (p<0.05), FSOPM, fermented sweet orange peel meal, SEM, standard error of mean

3.3 Internal organ characteristics

Internal organ characteristics are presented in Table 4. Dietary treatment did not show any significant ($p > 0.05$) effect on internal organs like lungs, heart, pancreas and spleen. However, FSOPM had significant ($p < 0.05$) effect on empty gizzard, liver, kidney, proventriculus and bile. Variations in this study did not follow any definite pattern. The empty gizzard and liver were significantly higher ($p < 0.05$) at 10 % FSOPM and significantly lower ($p > 0.05$) at 0 % FSOPM. Broiler chickens on the FSOPM based diets had significantly ($p < 0.05$) heavier gizzard, liver, kidney and proventriculus than chickens on the control diets; except for chickens on 6 % FSOPM, which had lighter proventriculus.

The percent live weight of the empty gizzard (1.87 % to 2.37 %) obtained in this study is comparable to 2.17 % reported by [34], but lower than the average of 2.81 % reported by [2].

The significantly higher gizzard weight of the chickens on FSOPM based diets could be attributed to the higher CF content of the diets. The grinding process of these relatively more fibrous diets resulted to more muscular development of the gizzard thereby increasing its weight. This result is in agreement with the finding of [35] who reported that the inclusion of oat hulls in broiler diet at 5 % stimulated the gizzard grinding activity, allowed better development of the muscular layers and caused an increase in the gizzard size. [36] stated that dietary fibre had been seen to have a positive effect on gizzard development. The percent live weight of the proventriculus was higher in the test diets as FSOPM inclusion level increased from 2 % to 6 %. The values (0.44 % to 0.65 %) obtained were comparable to 0.59 % and 0.49 % reported by [26 and 34] respectively. It was however higher than 0.37 % reported by [16]. The significant increase in the percent live weight of the proventiculus could be attributed to more digestive function the organ had to perform (increased secretion of pepsin and hydrochloric acid) in order to aid digestion of protein and also to initiate the breakdown of higher fiber content of the diet. [37] stated that diets high in fibre content may produce dilatation of the proventiculus with its increase in size and its contents. The percent live weight of the liver (1.88 % - 2.53 %) obtained in this study is comparable to 1.8 % reported by [34], but higher than the value of 1.76 % reported by [16]. The significant increase in the liver weight could be in positive response to increase secretion of the bile to aid emulsification of fats and thus facilitate the action of the enzyme lipase. High liver weight has also been shown to be an indication of higher metabolic rate of the liver to reduce or eliminate toxins in the body system [38]. As a major detoxifying organ, the increase in the size of the liver could be in attempt to detoxifying the residual anti-nutrients contained in FSOPM. The percent live weight of the kidney (0.56 % - 0.89 %) obtained in this study is comparable to 0.70 % reported by [13], but was higher than 0.50 % reported by [14]. The percent live weight of kidney decreased as the level of FSOPM in the diet increased from 2 % to 6 % and then increased at 8 % inclusion level. [39] opined that anti-nutrients could cause increase kidney and liver weights owing to stress involved from detoxification. FSOPM contained anti-nutrients but all the values obtained in this study were within the safe recommended limits as reported by [40]. The percent live weight of the bile was higher for chickens on the FSOPM dietary treatments than the chickens on the maize based diet (control group) with the exception of FSOPM (2 %), which appeared on outlier. The increase of the bile with increase in inclusion level of FSOPM in the diet could be that the liver secreted more bile to be stored and used for fat emulsification and hence the increase in size. The non-significant difference among the treatment groups for heart indicates normal blood circulation among the broilers in the dietary groups. Non –significant observations in the lungs, pancreas and spleen shows that birds tolerated the test ingredient and were not harmed by the different inclusion levels.

Table 4: Effect of FOSPM on Internal Organ Characteristics of Broiler Chickens

Parameter (% LW)	Treatments						SEM
	0% FSOPM	2% FSOPM	4% FSOPM	6% FSOPM	8% FSOPM	10% FSOPM	
Live weight (kg)	2.00^{a}	1.83^{abc}	1.77^{abc}	1.95^{ab}	1.73^{bc}	1.59^{bc}	0.08

Empty gizzard	1.87^{b}	2.13^{ab}	2.21^{ab}	2.10^{ab}	2.36^{a}	2.37^{a}	0.15
Liver	1.88^{c}	1.99^{bc}	2.11^{bc}	1.99^{bc}	2.27^{ab}	2.53^{a}	0.11
Lungs	0.53^{a}	0.58^{a}	0.66^{a}	0.66^{a}	0.54^{a}	0.64^{a}	0.06
Kidney	0.56^{b}	0.74^{ab}	0.74^{ab}	0.66^{b}	0.68^{ab}	0.89^{a}	0.06
Heart	0.46^{a}	0.49^{a}	0.45^{a}	0.42^{a}	0.46^{a}	0.50^{a}	0.03
Proventriculus	0.48^{ab}	0.53^{ab}	0.50^{ab}	0.44^{b}	0.48^{ab}	0.65^{a}	0.05
Pancreas	0.23^{a}	0.23^{a}	0.23^{a}	0.25^{a}	0.28^{a}	0.29^{a}	0.03
Bile	0.12^{ab}	0.09^{b}	0.13^{ab}	0.17^{a}	0.14^{ab}	0.14^{ab}	0.02
Spleen	0.14^{a}	0.14^{a}	0.14^{a}	0.09^{a}	0.10^{a}	0.13^{a}	0.02

^{a,b,c,} Means with different superscripts in the same row are significantly different (p<0.05), FSOPM, fermented sweet orange peel meal , SEM, standard error of mean

3.4 Gastro-intestinal tract (GIT) Morphometry

Gastro-intestinal tract morphometry results are presented in Table 5. The GIT weight, large intestine weight and small intestine length were significantly affected (p <0.05) among the treatment groups. Variation in this study did not follow any definite pattern. Other GIT components (weight or length) were not significantly affected (p > 0.05). The percent tract weight of the GIT (57.05 g – 72.96 g) was comparable to 5.01 % live weight reported by Odunlade *et al.* (2020). The broiler chickens on the FSOPM based diets had significantly (P < 0.05) heavier GIT weight than those on the control diet. The increase of the GIT weight could be attributed to increased energy expenditures. It has been previously reported that increase in the GIT size is intimately related with an increase of the energetic needs of the animal (Jorgensen *et al*., 1996). Jha and Mishra (2021) stated that increase in the weight of the GIT is important to pancreatic enzymes secretion to achieve better growth in birds during the early stage of life.

Table 5: Effect of FSOPM on GIT Morphometry of Broiler Chickens

Parameters (%)	**Treatments**						**SEM**
	0% FSOPM	**2% FSOPM**	**4% FSOPM**	**6% FSOPM**	**8% FSOPM**	**10% FSOPM**	
Live weight (g)	2.00^{a}	1.83^{abc}	1.77^{abc}	1.95^{ab}	1.73^{bc}	1.59^{c}	0.08
GIT weight (g)	57.05^{b}	67.59^{a}	68.19^{a}	72.96^{a}	62.08^{b}	70.74^{a}	1.65

Small intestine (% GIT weight)	81.02^{a}	83.50^{a}	78.68^{a}	80.76^{a}	81.65^{a}	82.24^{a}	1.91
Large intestine (% GIT weight)	9.19^{ab}	6.24^{b}	13.63^{a}	10.39^{ab}	8.16^{b}	7.80^{b}	1.58
Caecum (% GIT weight)	7.04^{a}	9.96^{a}	7.72^{a}	8.98^{a}	10.37^{a}	10.07^{a}	1.57
GIT length (cm)	227.66^{a}	258.33^{a}	255.93^{a}	261.83^{a}	243.93^{a}	253.66^{a}	1.80
Small intestine (% GIT length)	80.04^{b}	83.30^{ab}	83.03^{ab}	85.48^{a}	82.29^{ab}	83.10^{ab}	1.00
Large intestine (% GIT length)	5.36^{a}	4.37^{a}	4.76^{a}	4.86^{a}	5.27^{a}	5.05^{a}	0.31
Caecum (% GIT length)	12.89^{a}	14.49^{a}	13.74^{a}	15.20^{a}	15.37^{a}	15.62^{a}	1.26

^{a,b,c,} Means with different superscripts in the same row are significantly different (p<0.05), FSOPM, fermented sweet orange peel meal, SEM, standard error of mean

The percent tract weight of the large intestine (6.24 % - 13.63 %) obtained was comparable to the average of 0.31 % live weight reported by Odunlade *et al*. (2020). The small intestine (% GIT length) of broilers on FSOPM based diets was significantly ($p < 0.050$) longer than that of the control. This observation suggests a compensatory and inverse morphometric relationship between small intestine length and caecal length on one hand and the large intestine length on the other hand. This observation is in agreement with the findings of Mouroa *et al*. (2008) who reported increase in the length of the small intestine and attributed it to the richness of soluble pectin contained in citrus pulp diets. This result also agrees with that of Ebrahimi *et al.* (2013) who stated that supplementation of dried *Citrus sinensis* peel on the jejunum and ileum showed significant difference from that of the control group. The large intestine (% GIT weight) was significantly lighter ($P < 0.05$) at 2 % FSOPM. Variation showed no definite pattern.

4. Conclusion and Recommendation

This study examined the nutrient value of FSOPM as possible replacement for maize in the diets of broiler chickens and from the results obtained, the following conclusions were drawn;

i. FSOPM was found to have appreciable amount of DM, CP, CF, EE, ash, NFE and ME which can relatively be compared to maize, a conventional energy feed stuff. The anti-nutritional factors were observed to be acceptable without causing any harm to broiler chickens.

ii. The use of FSOPM at 10 % as replacement of maize in broiler chicken diets supported carcass characteristics, increased GIT weight, increased large intestine weight, increased small intestine length and recessed abdominal fat pad.

It is therefore recommended that further investigatory studies be carried out at higher inclusion levels (above 10 %) of FSOPM in broiler chicken diets and carcass evaluated.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript

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