Applied Tropical Agriculture
Volume 25, No.2, 28 - 37, 2020

EFFECTS OF SUBSTITUTING FERMENTED SWEET ORANGE (*Citrus sinensis*) PEEL MEAL FOR MAIZE ON GROWTH, FEED UTILIZATION AND BODY COMPOSITION OF *Clariasgariepinus* FINGERLINGS

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Abstract
*An eight-week experiment was conducted to assess the effects of dietary incorporation of Fermented Orange (Citrus sinensis)Peel Meal (FOPM) at seven inclusion levels[0% (as control), 10%, 20%, 30%, 40%, 50% and 60% coded as Diet 1, Diet 2, Diet 3, Diet 4, Diet 5, Diet 6 and Diet 7 respectively] on the growth, feed utilization and survival of 280 Clarias gariepinus fingerlings. The fish were fed twice daily at 5% of their body weight. Proximate composition of fermented orange peel meal-supplemented diets and fish carcass was determined using standard procedures. Mean Weight Gain (MWG), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR) and Fish Survival were determined. Data were analyzed using descriptive statistics and analysis of variance at p=0.05.Crude protein significantly (p < 0.05)increased from 58.30% in the initial pre-treatment fish to values ranging between 60.40% in fish fed Diet 6 and 62.40% in fish fed Diet 5. Fish fed Diet 2 (10% FOPM-supplemented diet) had significantly (p < 0.05) superior values of MWG (23.65 g), SGR (3.08%/day) and FCR (0.46) compared to fish fed Diet 1 and Diets 3 to 7 in which growth indices gradually reduced (MWG: 16.08–6.25 g; SGR: 2.53–1.42%/day and FCR: 0.57–1.08). Percentage survival was highest (82.50%) in fish fed Diet 2and lowest (67.50%)in fish fed Diet 7. The study clearly demonstrated that fermented sweet orange peel meal could effectively replace yellow maize meal up to 10% substitution level in C. gariepinus fingerlings' diets without noticeable deleterious effects on growth, **feed utilization** and survival.*

Key *words:Unconventional feedstuffs* *Clariasgariepinus, Feed Processing, Protein Intake, Fish Nutrition*

Introduction

Aquaculture sector has been described as the most rapidly expanding human food production industry globally and about 50% of all fish consumed by humans emanates from it(Thorarinsdottir*et al.*, 2011).In spite of the significant growth of intensive aquaculture enterprises in Nigeria, the escalating cost and shortage of preferred feeds have constituted serious constraints against its successful operations due to feed supply which has been identified as the most expensive factor in the overall aquaculture production process. The costly nature of most conventional feedstuffs constitutes a major challenge facing many local fish farmers (Abowei and Ekubo, 2011). Rapidly increasing demand for conventional feedstuffs by humans and livestock has increased competition for those ingredients (Ogunlade, 2007) which has led to increase in the search for alternative feedstuffs more especially those of plant origin. In the current approach intended to minimize feed production cost without compromising feed quality (Houlihan*et al.,* 2001), unusual feedstuffs, agriculturalby-products, crop residues, agro-industrial and agro-allied by-products are considered as cost-effective alternatives for expensive conventional feedstuffs in fish feed preparation. Maize is one of the major sources of metabolizable energy in most formulated catfish diets that is readily digestible by fish (Olurin *et al*., 2006). However, maize has been widely used for human consumption in Nigeria and its insufficient production, increasing cost and scarcity have necessitated the need to exploit other previously under-utilized energy-rich alternatives (FAO, 2005). Previous studies on substitution of maize by unconventional alternative energy ingredients in fish diets included the use of coffee pulp (Moreau *et al*., 2003), rice husk (Aderolu and Oyedokun, 2009), sweet potato peels (Nwanna *et al*., 2009), cocoyam tuber (Aderolu and Sogbesan, 2010), banana peels (Lawal *et al*., 2011), cassava peel meal (Ojukannaiye *et al*., 2014), *Chrysophyllumalbidum seed meal(Jimohet al., 2014) and* melon seed peel (Iheanacho *et al., 2018).*

Sweet orange peel has been identified as an agricultural by-product with high dietary potential as an energy source which can be used to replace maize. In Nigeria, sweet orange peels are obtained from orange fruits and area bundantly available throughout the year, although high production of the fruit spans from October to March. Large quantities of peels can be freely collected from orange fruit vendors who use sharp knives or razors to remove the outermost epicarp and then sell the peeled fruits to consumers for direct consumption of the juice. The peels have not been put into any specific productive use but are usually haphazardly discarded and piled up in heaps in large quantities after each day's sales on streets, roadsides, drainage channels and refuse dumps, causing serious environmental pollution. They are easily processed by sun-drying and crushed into meal when crispy.

Sweet orange peels have been reported to contain 9.30 - 10.96% crude protein, 2.33 - 2.90% crude lipid, 13.66 - 14.94% crude fibre, 5.07 - 5.56% ash and 65.30 - 67.95% nitrogen-free extract (Oluremi *et al*., 2007a). The orange peel is closely comparable to maize in its compositional values of protein and metabolisable energy (Agu *et al*., 2010). Its crude protein and metabolisable energy contents are 10.73% CP and 3988.7 kcal ME/kg respectively compared to 9.00% CP and 3432 kcal ME/kg for maize (Agu *et al*., 2010). These closely similar proximate components highlight the potential of sweet orange fruit peels as a feed ingredient capable of replacing maize in fish nutrition. A few studies conducted on the nutritional relevance of orange fruit peels and by-products included the following: citrus by-products and ruminants' growth and lactation (Bampidis and Robinson, 2006), citrus fruit peel meal and livestock's growth (Oluremi *et al*., 2007a), orange pulp meal and rabbits' growth (Hon *et al*., 2009; Effiong *et al*., 2016), water-soaked orange peel meal and broiler chicks' growth (Orayaga, 2010; Agu *et al*., 2010) and orange peel meal and goats' blood indices (Oloche *et al*., 2015). Currently, there is a dearth of literature reports on the utilization of sweet orange peel as a potential dietary energy ingredient in formulating practical diets for *C. gariepinus*, a highly-valued cultivable omnivorous catfish that can effectively utilize energy-rich ingredients from plant origin. Therefore, this study was conducted to appraise the effects of substituting fermented sweet orange peel meal for maize on growth, feed utilization and body composition of C. *gariepinus* fingerlings

Materials and Methods

Processing of Sweet Orange Peels and Preparation of Experimental Diets

Three (3) kilograms of fresh sweet orange peels were collected from orange vendors at various locations within Okitipupa, Ondo State, washed and fermented in a bowl of clean water for 48 hours. The fermented peels were spread on concrete floor and allowed to sundry until they became crispy after which they were milled to obtain Fermented Orange Peel Meal (FOPM). Seven iso-nitrogenous (40% crude protein) diets were formulated for *C. gariepinus* fingerlings in which FOPM was substituted for yellow maize at graded levels of 0% (0.00 g = Diet 1), 10% (2.29 g = Diet 2), 20% (4.59 g = Diet 3), 30% 6.88 g = Diet 4), 40% (9.17 g = Diet 5), 40% (11.47 g = Diet 6) and 60% (13.76 g = Diet 7) and were designated as Diets 1, 2, 3, 4, 5, 6 and 7 respectively as shown in Table 1. Each diet was prepared by thoroughly mixing the dry ingredients using a mixer (Pars Electric Company, Tehran, Iran) after which palm oil and hot water were added to homogenize the dry mixture into a uniform paste. Each diet mixture was steam-pelleted through 2-mm apertures of Hobart pelleting machine (A-2007 Model, UK), sundried for three days on clean concrete slabs, cooled to room temperature and carefully packaged in a separate airtight container prior to use.

Table 1: Ingredient Composition of Experimental Diets (g/100 G Dry Matter)containing Graded Levels of Fermented Orange Peel Meal Replacing Yellow Maize

Feed ingredients	Diet1 0% FOPM(Control)	Diet 2 10% FOPM	Diet 3 20% FOPM	Diet 4 30% FOPM	Diet 5 40% FOPM	Diet 6 50% FOPM	Diet 7 60% FOPM
Fishmeal	25.75	25.75	25.75	25.75	25.75	25.75	25.75
Groundnut cake	25.75	25.75	25.75	25.75	25.75	25.75	25.75
Soybean meal	25.75	25.75	25.75	25.75	25.75	25.75	25.75
Fermented orange peel meal		2.29	4.59	6.88	9.17	11.47	13.76
Yellow maize	13.76	11.47	9.17	6.88	4.59	2.29	
Bone meal	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin premix	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Palm oil	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Salt	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Starch	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total(g)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

FOPM=Fermented orangepeelmeal

**Each kilogram* of vitamin/mineral premix *contained the following:*
Vit. A: 1,000,000 IU; Vit. B_1: 250 mg; Vit. B_2: 1750 mg; Vit. B_6: 875 mg; Vit. B_{12}: 2500 mg; Vit. C: 12,500 mg; Vit. D_3: 600,000 IU; Vit. E: 12,000 IU; Vit. K_3: 15 mg; Calcium D-pantothenate: 5000 mg; Nicotinic acid: 3750 mg; Folic acid: 250 mg; Cobalt: 24,999 mg; Copper: 1999 mg; Iron: 11,249 mg; Selenium ($Na_2SeO_3 \cdot 5H_2O$): 75 mg; Iodine (Potassium iodide): 106 mg; Anti-oxidant: 250 mg.

Source of production: *DSM Nutritional Products Europe Limited, Basle, Switzerland.*

Experimental Design and Fish Feeding Trial
Three hundred and twenty (320) *C. gariepinus* fingerlings (mean weight: 5.12 ± 0.31g; mean length: 8.64 ± 0.31 cm)were purchased from Ibukunoluwa Fish Farm, Okitipupa, Ondo State and transported in a 50-litre open gallon filled with water to the Fish Nutrition Laboratory of the Department of Fisheries and Aquaculture Technology, Olusegun Agagu University of Science and Technology, Okitipupa. The fish were acclimatized in a plastic tank (2 x 2 x 1 m) and fed with 2-mm Coppens feed for one week after which two hundred and eighty (280) of them were randomly sorted, batch-weighed using a high-precision electric top-loading balance (Mettler Zurich, model CP8201, Sweden) and distributed into fourteen plastic tanks (50 x 40 x 40 cm) at twenty fish per tank containing 20 litres of water each. Each of the seven treatment groups was replicated twice to constitute fourteen treatment units. Fish were manually fed twice daily at 5% of their body weight administered in two equal portions at 07:00 and 17:00 hours. Water temperature, dissolved oxygen and pH in the experimental tanks were monitored and measured weekly using mercury-in-glass thermometer, YSI oxygen meter (model 550A, YSI Inc., Yellow Springs, USA) and pH meter (Combo pH and EC meter, Hanna Instruments, Arizona, USA) respectively. Eight (8) catfish from the initial pre-treatment fish pool and four (4) catfish from each post-treatment group were sacrificed at the commencement and end of the feeding trial respectively and analyzed for their carcass composition according to the methods of AOAC (AOAC, 2011).

Biological Evaluation of Experimental Fish
Growth and feed utilization indices were determined using the following formulae: *Mean weight gain (MWG) = (W1-W2)g* (Iheanacho *et al*., 2017).
where; Wi= initial mean weight (g); W2= final mean weight (g)

percentage weight gain, PWG (%) =

$$\frac{Mean\ weight\ gain\ (g) \times 100}{Initial\ mean\ weight\ (g)}$$

(Adesina and Ikuyeju, 2019)

Feed intake (g) *= Summation of the quantities of feed supplied to fish in each treatment throughout the experimental period* (Adesina and Ikuyeju, 2019).

Feed conversion ratio (FCR)=

$$\frac{Mean\ feed\ intake\ (g)}{Mean\ weight\ gain\ (g)}$$ ***Adesina and Ikuyeju. 2019***

***Specific growth rate, SGR* (%/day)=**

$$\frac{(Ln\ Wf - Ln\ Wi) \times 100}{t\ (days)}$$ **Adesina and Ikuyeju. 2019**

where:Ln W_f = natural logarithm of fish final weight; Ln W_i= natural logarithm of fish initial weight; t= experimental duration in days.

Protein intake (g of protein in 100g diet/fish)=

$$\frac{feed\ intake \times \%\ crude\ protein\ in\ diet}{100}$$

(Adesina and Ikuyeju. 2019)

Protein efficiency ratio (PER) =

$$\frac{Mean\ weight\ gain}{Mean\ protein\ intake\ (g\ of\ protein\ in\ 100g\ of\ diet/fish)}$$

(Adesina and Ikuyeju. 2019)

Nitrigen Metabolism (NM)=

$$\frac{0.549 \times (Wi+Wf)t}{2}$$ **(Nwanna, 2003)**

where:W_i= initial mean weight of fish; W_f= final mean weight of fish; t= experimental period in days; 0.549 = metabolism factor.

Percentage survival, PS (%)=

$$\frac{Final\ number\ of\ fish\ harvested \times 100}{Initial\ number\ of\ fish\ stocked}$$

(Adesina and Ikuyeju. 2019)

Cost-benefit analysis of substituting fermented orange peel meal for yellow maize meal in the diets of *C. gariepinus* fingerlings

Economic evaluation of the study was done by determining incidence of cost and profit index as follows:

Cost of incidence (CI)=

$$\frac{Cost\ of\ feed\ used\ in\ production\ (₦/kg)}{Total\ weight\ of\ fish\ produced\ (kg)}$$

Profit Index (PI) =

$$\frac{Value\ of\ fish\ produced\ (₦/kg)}{Cost\ of\ feed\ used\ in\ production\ (₦/kg)}$$

The calculated values of CI and PI were based on the following assumptions:

1. The cost of formulated diets was based on

market prices at the feed stores at the time of this study.

2. The cost of producing fermented orange peel meal was based on the cost of processing.
3. The value of fish produced was based on the selling price of fresh *C. gariepinus* per kg (i.e. ₦700/kg) in fish markets within Okitipupa as at the end of this study.

The total weight of fish produced was calculated from the weight of fish recovered alive at the end of the feeding trial.

Data Analysis

The effects of substituting fermented orange peel meal for yellow maize meal on growth, feed utilization and body composition of *C. gariepinus* were subjected to analysis of variance (ANOVA) using Statistica 6.0 (Stat-Soft Inc., USA). Values generated were presented as mean ± standard deviation. Significant differences among treatment means were compared and separated using Tukey's multiple range test (Zar, 1996). Differences were considered to be significant at probability levels below 0.05 (i.e. $p < 0.05$).

Results and Discussion

Proximate Composition of Experimental Diets Containing Fermented Orange Peel Meal

Table 2 shows the proximate composition of the experimental diets and indicates that the values of parameters significantly ($p < 0.05$) varied irregularly across the diets and did not correspond to the various inclusion levels of fermented sweet orange peel meal. Crude protein was nearly uniform ($p > 0.05$). These values satisfied the protein requirements of *C. gariepinus* fingerlings and corroborated the assertion of Adegbesan *et al*. (2018) that the ideal growth rate and feed conversion efficiency in *C. gariepinus* could be achieved within 38 - 42% dietary protein. The present values were similar to 43.97 – 44.28% reported by Iheanacho *et al*. (2018) for melon peel meal-based diets but superseded 16.92 – 17.00% and 22.88 – 23.76% documented for sundried orange peel meal-based diets (Oloche *et al*., 2015) and water-soaked orange peel meal-based diets (Guluwa *et al*., 2016) respectively. Crude lipid ranged between 5.06% in Diet 6 and 10.10% in Diet 5. These values agreed with 7.95 – 10.15% reported for sundried orange peel meal-based diets (Oloche *et al*., 2015) but exceeded 3.47 – 3.79% and 4.15 – 4.37% reported for soaked orange peel meal-based diets (Guluwa *et al*., 2016) and melon peel meal-based diets (Iheanacho *et al*., 2018) respectively. Crude fibre progressively ($p < 0.05$) increased from 4.23% in Diet 1 to 4.67% in Diet 7 with increase in the substitution of orange peel meal and almost doubled 2.57 – 2.71% found in melon peel meal-based diets (Iheanacho *et al*., 2018). Similar increasing patterns (4.36 – 9.43% and 15.27 – 15.42%) were observed for soaked orange peel meal-based diets (Guluwa *et al*., 2016) and sundried orange peel meal-based diets (Oloche *et al*., 2015) respectively. Ash content also gradually increased from 11.17% in Diet 1 to 12.06% in Diet 7 and was comparable to 10.73 – 11.35% found in melon peel meal-based diets (Iheanacho *et al*., 2018). Moisture content varied irregularly ($p < 0.05$) from 8.28% in Diet 6 to 12.38% in Diet 1 and markedly exceeded 5.37 – 6.08% recorded for melon peel meal-based diets (Iheanacho *et al*., 2018). NFE was highest (27.39%) in Diet 7, followed by 26.69% in Diet 2 and least (22.79%) in Diet 4. These fairly high values somewhat confirmed the dietary potential of orange peel meal as a dietary energy unconventional ingredient. However, these values was below 57.50 – 59.78% recorded for sundried orange peel meal-based diets (Oloche *et al*., 2015) and 31.56 – 32.86% for melon peel meal-based diets (Iheanacho *et al*., 2018).

Table 2: Proximate Composition of Experimental Diets Containing Fermented Orange Peel Meal

Proximate parameters	Diet 1 0% FOPM (Control)	Diet 2 10% FOPM	Diet 3 20% FOPM	Diet 4 30% FOPM	Diet 5 40% FOPM	Diet 6 50% FOPM	Diet 7 60% FOPM
Crude protein	40.42±0.13[a]	41.40±0.07[a]	41.18±0.05[a]	41.32±0.12[a]	40.65±0.03[a]	41.08±0.07[a]	40.28±0.14[a]
Crude lipid	5.17±0.23[d]	6.25±0.06[c]	8.98±0.01[b]	9.85±0.51[a]	10.10±0.46[a]	5.06.±0.32[d]	6.84±0.61[c]
Crude fibre	4.23±0.06[b]	4.27±0.01[b]	4.32±0.34[b]	4.39±0.51[b]	4.62±0.05[a]	4.65±0.27[a]	4.67.±0.45[a]
Ash	11.17±0.35[b]	11.21±0.06[b]	11.23±0.45[b]	11.30±0.67[b]	11.38±0.42[b]	11.47±0.37[b]	12.06±0.61[a]
Moisture	12.38±0.32[a]	10.18±0.61[b]	10.56±0.37[b]	10.35±0.45[b]	8.81±0.52[c]	8.28±0.23[c]	8.76±0.41[c]
Nitrogen-free	26.63±0.55[ab]	26.69±0.31[ab]	23.73±0.26[c]	22.79±1.27[d]	24.44±0.31[c]	26.18±0.35[b]	27.39±0.47[a]

Means with different superscripts along the same row were significantly different at $p < 0.05$.
FOPM: Fermented orange peel meal

Carcass Proximate Composition of *C. gariepinus* Fingerlings Fed Fermented Orange Peel Meal-based Diets

Table 3 shows the carcass proximate indices of *C. gariepinus* fingerlings fed fermented orange peel meal-baseddiets which revealed significant ($p < 0.05$) variations, followed an irregular pattern and suggested that the varied levels of orange peel meal in the diets affected fish body composition. The crude protein (60.40 – 62.40%) of the post-treatment fish significantly ($p < 0.05$) exceeded the pre-treatment value (58.30%). This result specified that there was enhanced synthesis of tissue protein in the experimental fish (Tiamiyu *et al*., 2015) as reflected in fish growth and weight gain (Fountoulaki *et al*., 2003). Crude lipid significantly ($p < 0.05$) increased from 3.20% to final values ranging from

4.50% in Diet 2 to 5.34% in Diet 1. *Moreover, t*he moderately high level of carcass lipid content suggested improved lipid synthesis in the fish (Fountoulaki *et al*., 2003) which could be linked with increase in the dietary crude lipid content.Final ash content (11.03 – 11.27%) progressively increased from Diets 1 to 7 and significantly ($p < 0.05$) exceeded the initial value (10.50%). These values markedly superseded 3.95 – 4.11% reported by *Jimohet al*. (2014) for*C. gariepinus* fingerlings fed *Chrysophyll umalbidum*seed meal-based diets but were lower than 16.90 – 18.32% found in *C. gariepinus* fingerlings fed *Acacia auriculiformis leaf meal*-supplemented diets (Afe and Omosowone, 2019).Moisture content wasinitially 7.50% while the final values ranged between 7.12 and 8.44% which slightly surpassed6.24 – 6.49% found in *C. gariepinus* fingerlings fed *A.auriculiformisleaf meal*-supplemented diets (Afe and Omosowone, 2019).Nitrogen-free extract significantly ($p < 0.05$) decreased from 20.50% to final values ranging between 14.01 and 15.04% which, however, noticeably exceeded 1.81 – 4.50% documented for*C. gariepinus* fingerlings fed *A.auriculiformisleaf meal*-supplemented diets (Afe and Omosowone, 2019).

Table 3: Carcass proximate composition of *C. gariepinus*fingerlings fed fermented orange peel meal-baseddiets

Proximate parameters	Initial carcass values	Diet 1 0% FOPM (Control)	Diet 2 10% FOPM	Diet 3 20% FOPM	Diet 4 30% FOPM	Diet 5 40% FOPM	Diet 6 50% FOPM	Diet 7 60% FOPM
Crude protein	58.30±0.01[d]	61.40±0.62[b]	62.20±0.57[a]	62.22±0.41[a]	62.24±0.71[a]	62.40±0.26[a]	60.40±0.35[c]	61.20±0.50[b]
Crude lipid	3.20±0.01[c]	5.34±0.52[a]	4.50±0.36[b]	5.15±0.01[a]	5.16±0.25[a]	5.01±0.16[a]	5.22±0.54[a]	5.12±0.18[a]
Ash	10.50±0.33[b]	11.03±0.26[a]	11.14±0.17[a]	11.20±0.01[a]	11.22±0.53[a]	11.24±0.13[a]	11.24±0.51[a]	11.27±0.31[a]
Moisture	7.50±0.01[b]	8.19±0.15[a]	7.12±0.31[b]	7.23±0.50[b]	7.16±0.25[b]	7.30±0.41[b]	8.44±0.29[a]	8.40±0.36[a]
Nitrogen-free extract	20.50±0.17[a]	14.04±0.36[b]	15.04±0.19[b]	14.20±0.18[b]	14.22±0.24[b]	14.10±0.75[b]	14.70±0.13[b]	14.01±0.11[b]

Means with different superscripts along the same row were significantly different at $p < 0.05$. FOPM = fermented orange peel meal

Growth Response and Feed Utilization of *C. gariepinus* Fingerlings Fed Fermented Orange Peel Meal-based Diets

Table 4 shows that growth and feed utilization indices of *C. gariepinus* fingerlings fed fermented orange peel meal-based diets significantly ($p < 0.05$) varied, reflected appreciable increase in their weight and suggested that addition of fermented orange peel meal as a protein source has enhanced fish growth. Mean weight gain (MWG) significantly ($p < 0.05$) increased from12.19 g in fish fed Diet 1 (control) to the highest value (23.65 g) in fish fed Diet 2 and afterward progressively significantly ($p < 0.05$) declinedfrom16.08 g in fish fed Diet 3 to 6.25 g in fish fed Diet 7. Comparably higher weight gain (9.10 – 23.97 g) was reported by Iheanacho *et al*. (2018) for *Oreochromis niloticus juveniles* fed melon peel meal-based diets. However, these higher MWG values reflected better growth compared to1.95 – 8.00 g and7.90 – 13.63 g reported for*C. gariepinus* fingerlings fed *C. albidum* seed meal-based diets *(Jimohet al*., 2014) and *A. auriculiformisleaf meal*-supplemented diets (Afe and Omosowone, 2019) respectively as well as 7.67 – 10.46 g recorded for *O. niloticus* fingerlings fed cassava peel-based diets (Ojukannaiye*et al*., 2014). Similarly, specific growth rate (SGR) increased from 2.17 %/day in fish fed Diet 1 to 3.08 %/day) in fish fed Diet 2. The highest SGR of the fish fed with Diet 2 suggested that they were better able to convert the nutrients to flesh compared to fish fed with the other diets. These values agreed with1.83 – 3.31%/day reported for*C. gariepinus* fingerlings *(Jimohet al*., 2014) andreflected better growth compared to 0.82 – 1.09 %/day and 1.13 – 1.24 %/day respectively obtained for *C. gariepinus* fingerlings (Afe and Omosowone, 2019) and *O. niloticus* fingerlings (Ojukannaiye *et al*., 2014). The gradual decline in growth with higher orange peel meal substitution above 10% level could have resulted from reduced digestion and utilization of experimental diets at higher levels which could be associated with residual anti-nutrients in the diets as reported by Adewolu (2008). Similarly, Gatlin (2010) stressed that increasing fibre content beyond a threshold level could reduce fish growth due to poor digestion of cellulose while Fakunle *et al.* (2013) stated that toxic components or anti-nutrients in most agricultural by-products may irritate the digestive tract and cause reduced feed intake and growth. Aderolu *et al.* (2011) stated that high dietary fibre content reduces the rate of nutrient absorption causing growth depression as observed in*C. gariepinus which* Oyelere *et al.* (2016) had reported to manifest poor handling of high fibre in its diets. Hence, this situation probably accounted for the progressively reduced growth response of fish fed orange peel meal substitution above 10% level. Furthermore, Nwanna *et al.* (2009) stated that very high substitution levels of unconventional dietary carbohydrate sources have often resulted in poor fish growth. Therefore, the declining trend of fish growth and feed utilization with increase in the substitution levels of orange peel meal suggested that it has the potential of replacing yellow maize provided it is incorporated at low levels of substitution in the diet of *C. gariepinus and thereby reduce* the cost of fish feed.

Feed conversion ratio (FCR) of fish fed Diet 2 (0.46) was significantly ($p < 0.05$) lower compared to 0.57 - 1.08 of those fed Diets 1 and 3 to 7 which indicated that fish fed diet 2 optimally utilized orange peel meal at 10% substitution level and efficiently converted feed to flesh. Besides, the present low FCR values (0.46 - 1.08) implied superior feed utilization compared to 1.16 – 1.50 and 3.70 – 4.31 reported for *C. gariepinus* fingerlings fed *C. albidum* seed meal-based diets*(Jimohet al*., 2014) and *A. auriculiformis leaf meal*-supplemented diets (Afe and Omosowone, 2019) respectively as well as 1.75 – 2.04 recorded for *O. niloticus* fingerlings fed cassava peel-based diets (Ojukannaiye *et al*., 2014).Protein intake increased from 3.30 g/100g diet/fish in fish fed Diet 1 to the highest value (4.51 g/100g diet/fish) in fish fed Diet 2after which it assumed a declining trend ($p < 0.05$) from 3.74 g/100g diet/fish in fish fed Diet 3 to 2.71 g/100g diet/fish in those fed Diet 7. This observation suggested optimal assimilation of dietary protein by fish fed diet 2.The present PI values (2.71 – 4.51 g/100g diet/fish) reflected better dietary protein utilization when compared with 0.84 – 1.33 g/100g diet/fish found in *C. gariepinus* fingerlings fed pawpaw leaf meal-based diets (Adesina and Ikuyeju, 2019) but were lower than 5.33 – 6.51 g/100g diet/fish in *O. niloticus* fingerlings fed cassava peel-based diets (Ojukannaiye*et al*., 2014).Likewise, protein efficiency ratio (PER) improved from 3.70 in fish fed Diet 1 to the maximum value (5.24) in fish fed Diet 2andsubsequently ($p < 0.05$) dropped from 4.30 in fish fed Diet 3 to 2.31 in those fed Diet 7. The present higher PER values (2.31 – 5.24) suggested superior dietary protein utilization compared with 0.20 - 0.34 and 1.66 – 2.15 found in *C. gariepinus* fingerlings fed *A. auriculiformis leaf meal*-supplemented diets (Afe and Omosowone, 2019) and *C. albidum* seed meal-based diets *(Jimoh et al*., 2014) respectively. Besides, lower PER values (0.27 – 0.54) had been reported by Iheanacho *et al*. (2018) for *O. niloticus juveniles* fed melon peel meal-based diets while Ojukannaiye *et al*. (2014) observed 1.42 – 1.73) in *O. niloticus* fingerlings fed cassava peel-based diets. Nitrogen metabolism (NM) increased from 345.10 in fish fed Diet 1 to the highest value (520.96) in fish fed Diet 2, followed by 404.90in those fed Diet 3 and there after significantly ($p < 0.05$) reduced to 253.48 in those fed Diet 7.These values (253.48 – 520.96) reflected superior nitrogen utilizationas they doubled 209.06 – 256.25 reported for *C. gariepinus* fingerlings fed pawpaw leaf meal**-based diets**(Adesina and Ikuyeju, 2019).Percentage survival was highest (82.50%) in fish fed Diet 2, closely followed ($p > 0.05$) by 80.00% in those fed Diet 3butsignificantly ($p < 0.05$) declined from 77.50% in those fed Diets 4 and 5 to the least 67.50% in those fed Diet 7.The non-significant difference in the survival of fish fed with Diet 3 compared to those fed with Diet 2 implied that substitution of fermented orange peel meal up to 20% in the diets could effectively support fish growth and survival. Fish survival observed in this study was similar to 75.55–91.10% documented for *C. gariepinus* fingerlings fed *C. albidum* seed meal-based diets *(Jimohet al*., 2014) and signified superior survival compared to 48.00 - 86.00% recorded by Anyanwu *et al*. (2015) for *C. gariepinus* fingerlings fed *Azadirachtaindica* leaf meal-based diets. The high survival recorded in this study reflected considerable acceptability of diets by fish coupled with suitability of fermented orange peel meal substitution in the diets, appropriate feed processing, proper handling and adequate water quality management. Besides, fish survival has been linked with tolerance level of the fish species as well as the nature and amount of anti-nutrients in a particular feedstuff (Oyelere*et al*., 2016). The acceptance of the fermented orange peel meal-based diets in this study as revealed by the considerable growth, feed utilization and survival indices has confirmed the flexibility of *C. gariepinus* fingerlings to efficiently utilize a wide range of unconventional feed ingredients.

Table 4: Growth Response and Feed Utilization Indices of *C. gariepinus* fingerlings fed Fermented Orange Peel Meal-based Diets

Growth parameters	Diet1 0% FOPM (control)	Diet 2 10% FOPM	Diet 3 20% FOPM	Diet 4 30% FOPM	Diet 5 40% FOPM	Diet 6 50% FOPM	Diet7 60%FOPM
Initial mean weight(g)	5.13±0.21^{a}	5.12±0.01^{a}	5.13±0.05^{a}	5.12±0.12^{a}	5.12±0.03^{a}	5.12±0.04^{a}	5.12±0.04^{a}
Final m ean weight (g)	17.32±0.21^{c}	28.77±0.13^{a}	21.21±0.14^{b}	17.77±0.04^{c}	17.41±0.24^{c}	14.29±0.14^{d}	11.37±0.59^{e}
Mean weight gain(g)	12.19±0.20^{c}	23.65±0.02^{a}	16.08±0.11^{b}	12.65±0.14^{c}	12.29±0.24^{c}	9.17±0.05^{d}	6.25±0.65^{e}
Percentage weight gain (%)	237.62±0.25^{c}	461.91±1.24^{a}	313.45±0.14^{b}	247.07±1.31^{c}	240.04±0.52^{c}	179.10±0.59^{d}	122.07±0.95^{e}
Specific growth rate (%/day)	2.17±0.02^{c}	3.08±0.02^{a}	2.53±0.01^{b}	2.22±0.03^{c}	2.19±0.01^{c}	1.83±0.03^{d}	1.42±0.02^{e}
Total feed intake(g)	326.27±0.31^{c}	436.19±0.22^{a}	363.63±0.32^{b}	330.59±0.04^{c}	327.14±0.32^{c}	297.18±0.25^{d}	269.15±0.85^{e}
Mean feed intake (g)	8.16±0.02^{c}	10.90±0.12^{a}	9.09±0.21^{b}	8.26±0.12^{c}	8.18±0.03^{c}	7.43±0.11^{d}	6.73±0.27^{e}
Feed conversion ratio	0.67±0.10^{c}	0.46±0.03^{e}	0.57±0.13^{d}	0.65±0.27^{c}	0.67±0.04^{c}	0.81±0.13^{b}	1.08±0.05^{a}
Protein intake	3.30±0.03^{c}	4.51±0.13^{a}	3.74±0.04^{b}	3.41±0.02^{c}	3.33±0.21^{c}	3.05±0.14^{d}	2.71±0.18^{d}
Protein efficiency ratio	3.70±0.62^{c}	5.24±0.07^{a}	4.30±0.11^{b}	3.71±0.51^{c}	3.70±0.02^{c}	3.00±0.06^{c}	2.31±0.47^{d}
Nitrogen metabolism	345.10±0.23^{c}	520.96±0.15^{a}	404.90±0.35^{b}	351.87±0.20^{c}	346.33±1.32^{c}	298.37±1.13^{d}	253.48±0.87^{e}
Percentage Survival (%)	75.00±0.31^{b}	82.50±0.24^{a}	80.00±0.41^{a}	77.50±1.23^{b}	77.50±0.25^{b}	70.00±1.03^{c}	67.50±0.05^{d}

Means with different superscripts along the same row were significantly different at $p < 0.05$.
FOPM= Fermented orange peel meal

Cost-benefit Implications of Substituting Fermented Orange Peel Meal For Yellow Maize in the Diets For *C. Gariepinus* Fingerlings

Table 5 presents a cost analysis of dietary ingredients used in this study and reveals that substituting fermented orange peel meal for yellow maize has reduced the total cost of ingredients. The cost of producing fermented orange peel meal was based on the cost of processing. Cost of feeds gradually reduced from ₦37.33/100 g to ₦35.27/100 g with increase in the substitution of orange peel meal from diets 1 to 7. Table 6 shows the cost implications of substituting fermented orange peel meal for yellow maize and reveals that the total cost of feed was highest (₦373.30/kg) in diet 1 and lowest (₦352.70/kg) in diet 7. Fish fed diet 2 performed best in terms of feed intake, growth and bio-economics. Values of fish produced (in ₦/kg) by diets 2 and 3 were significantly higher ($p < 0.05$) than the values produced by the rest of the diets while diet 7 produced the least value of fish. Cost incidence was highest (0.941) in diet 7, least (0.261) in diet 2 and varied significantly ($p < 0.05$) among the substitution levels. Profit index was highest (4.477) in diet 2 and least (1.240) in diet 7. The highest profit index and least cost incidence in diet 2 evidently signified that more profit was generated from the fish produced from diet 2. Similarly, the lower cost incidence (0.380) and higher profit index (3.072) recorded for diet 3 compared to 0.510 and 2.286 respectively of the control diet suggested that utilization of diet 3 (20% FOPM) was more cost-effective than the control diet. The highest values of feed intake and weight gain recorded for fish fed with diet 2 implied that fermented orange peel meal was best utilized by fish placed on diet 2 and this consequently led to the highest value of fish produced which would correspondingly accrue more profit to the fish farmer as observed by Nwanna (2003).

5: Cost analysis of ingredients and fermented orange peel meal-based diets fed to *C. gariepinus* fingerlings

Feed ingredients	Cost of feed Ingredients (₦/kg)	Diet 1 0%FOPM (Control)	Diet 2 10%FOPM	Diet 3 20%FOPM	Diet 4 30%FOPM	Diet 5 40%FOPM	Diet 6 50%FOPM	Diet 7 60%FOPM
Fishmeal	850.00	21.89 (25.75)	21.89 (25.75)	21.89 (25.75)	21.89 (25.75)	21.89 (25.75)	21.89 (25.75)	21.89 (25.75)
Groundnut cake	185.00	4.76 (25.75)	4.76 (25.75)	4.76 (25.75)	4.76 (25.75)	4.76 (25.75)	4.76 (25.75)	4.76 (25.75)
Soybean meal	200.00	5.15 (25.75)	5.15 (25.75)	5.15 (25.75)	5.15 (25.75)	5.15 (25.75)	5.15 (25.75)	5.15 (25.75)
Fermented orange peel meal	50.00	______	0.11 (2.29)	0.23 (4.59)	0.34 (6.88)	0.46 (9.17)	0.57 (11.47)	0.69 (13.76)
Yellow maize	200.00	2.75 (13.76)	2.29 (11.47)	1.83 (9.17)	1.38 (6.88)	0.92 (4.59)	0.46 (2.29)	______
Bone meal	50.00	0.05 (1.00)	0.05 (1.00)	0.05 (1.00)	0.05 (1.00)	0.05 (1.00)	0.05 (1.00)	0.05 (1.00)
Vitamin premix	650.00	0.98 (1.50)	0.98 (1.50)	0.98 (1.50)	0.98 (1.50)	0.98 (1.50)	0.98 (1.50)	0.98 (1.50)
Palm oil	400.00	0.60 (1.50)	0.60 (1.50)	0.60 (1.50)	0.60 (1.50)	0.60 (1.50)	0.60 (1.50)	0.60 (1.50)
Salt	200.00	0.40 (2.00)	0.4 0 (2.00)	0.40 (2.00)	0.40 (2.00)	0.40 (2.00)	0.40 (2.00)	0.40 (2.00)
Starch	250.00	0.75 (3.00)	0.75 (3.00)	0.75 (3.00)	0.75 (3.00)	0.75 (3.00)	0.75 (3.00)	0.75 (3.00)
Total cost of ingredients per diet (₦/100 g)		₦37.33	₦36.98	₦36.64	₦36.30	₦35.96	₦35.61	₦35.27

Values of gross ingredient composition were indicated in parentheses.

Table 6: Cost Implications of Substituting Fermented Orange Peel Meal for Yellow Maize in the Diets for *C. gariepinus* Fingerlings

Cost evaluation indices	Diet1 0%FOPM (Control)	Diet 2 10%FOPM	Diet 3 20%FOPM	Diet 4 30%FOPM	Diet 5 40%FOPM	Diet 6 50%FOPM	Diet 7 60%FOPM
Mean feed intake (g)	8.16 ± 0.02^{c}	10.90 ± 0.12^{a}	9.09 ± 0.21^{b}	8.26 ± 0.12^{c}	8.18 ± 0.03^{c}	7.43 ± 0.11^{d}	6.73 ± 0.27^{e}
Mean weight gain (g)	12.19 ± 0.20^{c}	23.65 ± 0.02^{a}	16.08 ± 0.11^{b}	12.65 ± 0.14^{c}	12.29 ± 0.24^{c}	9.17 ± 0.05^{d}	6.25 ± 0.65^{e}
Cost of feed (₦/kg)	373.30 ± 1.04^{a}	369.80 ± 0.31^{b}	366.40 ± 0.22^{c}	363.00 ± 0.03^{c}	359.60 ± 0.16^{cd}	356.10 ± 0.41^{cd}	352.70 ± 0.31^{d}
Value of fish produced (₦/kg)	853.30 ± 0.34^{d}	1655.50 ± 0.13^{a}	1125.60 ± 0.04^{b}	885.50 ± 0.32^{c}	860.30 ± 0.15^{d}	641.90 ± 0.06^{e}	437.50 ± 0.31^{f}
Cost Incidence	0.510 ± 0.02^{c}	0.261 ± 0.01^{e}	0.380 ± 0.01^{d}	0.478 ± 0.05^{c}	0.488 ± 0.04^{c}	0.647 ± 0.02^{b}	0.941 ± 0.01^{a}
Profit index	2.286 ± 0.12^{c}	4.477 ± 0.23^{a}	3.072 ± 0.14^{b}	2.439 ± 0.01^{c}	2.392 ± 0.06^{c}	1.803 ± 0.15^{d}	1.240 ± 0.06^{e}

Means with different superscripts along the same row weresignificantly differentat $p < 0.05$.

Conclusion

The study has revealed that sweet orange peel meal has the potential to partly replace yellow maize in the diet, reduce the cost of feeding and thereby contribute significantly to the growth of the African catfish. In view of the highest values of growth, feed utilization, survival and profit index recorded for fish fed with Diet 2, followed by those fed with Diet 3 above those of fish fed with the control diet, the results of this study have clearly demonstrated that fermented sweet orange peel meal could effectively replace yellow maize meal up to 20% inclusion level (that is, 4.59 g per 100 g of diet) in the formulated diet of *C. gariepinus* without causing negative effects on its growth. Therefore, the study indicated that it is advisable to incorporate sweet orange peel meal at a moderate quantity, such as 4.59 g per 100 g of diet, in an attempt to achieve efficient feed utilization and optimal growth response of *C. gariepinus*.

Recommendation

In view of the fact that sweet orange peels are abundant in the tropics, are locally available throughout the year and their collection attracts little or no cost, it is therefore cost-effective to partly include sweet orange peel meal in the diet of *C. gariepinus*. In addition, considering the nutritional potential of fermented sweet orange peel meal as an unconventional feedstuff and as a possible substitute for yellow maize in the diets of *C. gariepinus*, further studies are recommended on more effective processing techniques in a bid to increase awareness on the usefulness of orange peel meal and thereby expand its scope of utilization in fish feed production.

Acknowledgement

The authors gratefully thank the staff members of Works and Maintenance Unit of the University for their technical assistance and the anonymous reviewers for the valuable time and efforts they invested into the review of this manuscript and for their several helpful comments and suggestions.

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