Replacing maize with cassava peels in diets of *Oreochromis niloticus*: evaluation of feed performance and meta-analysis

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Abstract. Large quantity of cassava (*Manihot esculenta*) peels are produced annually by the cassava processing industry in Nigeria with mounting pressure for their safe disposal. Alternative uses are therefore necessary. This study incorporated cassava peal meal (CPM) in lieu of maize at levels of 0%, 25%, 50%, 75% and 100% to investigate diet utilization by Nile tilapia (*Oreochromis niloticus*). Diets were prepared with a crude protein of 30% and minimum protein to energy ratio (P:E) 21 mg protein/Kj. The diets were fed to *O. niloticus* fingerlings in hapas using a completely randomised design for 56 days to determine the effect of the replacement. The final weight of the fish increased initially with addition of CPM but declined with increasing substitution and this differed significantly ($p < 0.05$). Specific growth rate also followed a similar pattern with the best feed conversion ratio (1.70) being recorded in the diet with 25% CPM (Diet 2) in lieu of maize. Protein efficiency declined with increasing levels of CPM in the diet with best performance recorded by fish fed Diet 2. Lipid content of the fish carcass was quite higher than the initial values prior to feeding but generally the trend was not regular. CPM can therefore replace maize in the diets of *O. niloticus* at a ratio of 25%:75% and P:E ratio of 21 mg protein/Kj to give favourable growth and feed utilization.

Key Words: growth, cassava peel, protein, energy.

Introduction. Food production from aquaculture has continued to expand over the last decade with percentage contribution from aquaculture to total fish production rising from about 50 million tonnes in 2007 to about 67 million tonnes in 2012 (FAO 2014). However, the rapid growth comes at the expense of sustainability hence the challenge of combating disease, increasing growth rates, producing more efficient feed, improved larval rearing and finally a food product that meets nutritional and safety standards (Coyne 2015).

Feed ingredient cost has remained a major problem in the aquaculture feed industry and by extension, aquaculture itself. Fish feed production is constrained by the cost of ingredient purchase which according to the FAO (1980) is about 80% of the production budget. Varied opinions however exist as to the percentage cost of feed as part of the variable cost in an aquaculture venture. A report (Price & Egna 2014) estimated the percentage cost of feed in aquaculture to be 80% but El-Sayed et al (2015) estimated between 75-90%. On the lower side, Emerenciano et al (2013) opined that feed costs account for about 50% of production cost with WorldFish (2009) giving a range of 50-70%. At a more practical level, Hyuha et al (2011) reported that about 85% of running cost on an aquaculture facility is spread between labour, feed and fish seed.

Alternative ingredient sources for aquaculture feeds have focused mainly on the protein ingredients such as fishmeal and soybean meal. De Silva & Anderson (1994) defined unconventional feedstuff as ingredients that are capable of replacing fishmeal in the diets of aquaculture species. This definition obscures the need for sustainability given the fact that most of the ingredients apart from fishmeal are also being used in terrestrial animal husbandry as well as in human diets (Rana et al 2009). The drive towards sustainability of aquaculture must be taken in total as against the partial drive that exists currently. Hertrampf et al (2012) pointed out the thin line between a conventional and a non-conventional feedstuff hence the classification scheme can be inappropriate. The need for cheap animal protein nutrition for people in the developing countries has been stressed (Tacon 1995). To meet this goal therefore requires a reduction in feed cost hence the need to discover alternatives.

Fishes require higher levels of protein in their diets than land animals (NRC 1993) because of their low energy requirement which stems from the fact that they utilize little energy in movement and maintaining their position in water using buoyancy (Strand et al 2005; Barboza et al 2008). The protein requirement varies between 25 and 65% crude protein depending on the species water temperature, salinity, trophic level and taxonomic phyla (Molina-Poveda 2016). Quantitative amino-acid requirements on the other hand are of great importance since they depend on age, culture environment and the physiological condition of the species (Liao & Sheen 1993). These factors are also the key determinants of energy needs of the fish (Conklin 2000). The energy component of fish diets is important because it spares protein (Shiau & Peng 1993) and therefore creates room for effective utilization of protein for body tissue build-up hence increased growth to desirable sizes. However, the digestibility of the carbohydrate ingredient as well as the end result of a fatty fish limits increased inclusion of carbohydrates and lipids in fish diets (Lin & Wu 2014).

Tilapia is a ubiquitous aquaculture candidate with production at 4.8×10^7 tonnes valued at $8.25 million in 2013 (FAO 2016). The production is expected to reach 7.3×10^7 tonnes in 2030 (Worldbank 2013). The species tolerate various environmental conditions hence their ability to thrive worldwide. Tilapia aquaculture has grown as a result of the development of new strains (Ng & Hanim 2007). The feeding habit of tilapia is also a key factor in its suitability for aquaculture (Shoko et al 2016) with food consumption being at the primary level (Welcomme 1996).

Utilization of carbohydrate by tilapia is within a range of 35-40% of the digestible portion depending on certain factors such as the size of the fish, incidence of feeding, origin of the carbohydrate and presence of other ingredients (El-Sayed 2006). Polysaccharides and complex sugars are better utilized than simple sugars hence they can spare protein in low crude protein diets (Shiau 1997). Tung & Shiau (1993) observed that size of tilapia affects their ability to utilize pure glucose with larger tilapia gaining weight than smaller tilapia but utilization of starch was equal among the two sizes. However, utilization of these complex forms of carbohydrates is limited by the feeding frequency (Tung & Shiau 1991) and supplementation with chromic oxide (Shiau & Chen 1993; Shiau & Liang 1995) or zinc (Zhao et al 2011).

Cassava (*Manihot esculenta*) is an arable crop with origins traceable to Mexico and Central America as well as the North-Eastern part of Brazil (Olsen & Schaal 1999). It is an important food crop with a total production of 278.6 million tonnes in 2013 and a forecasted production of 288.8 million tonnes for 2016 (FAO 2015). Production of cassava in Nigeria is among the top ten in the world (Phillips et al 2004). Production in Africa accounts for more than 50% of world total (FAO 2015). Utilization of cassava in Nigeria comes in many forms and every part of the plant is useful (Phillips et al 2004). The current boom in cassava production also comes with the associated increase in production of by-products hence the need for utilization as a way of waste management. One major constraint with cassava peel is the presence of two cyanogenic glycosides: linamarin and lotaustralin with the former accounting for >90% of the total cyanide content (McMahon et al 1995). These toxins are poisonous if dietary cysteine and methionine are inadequate (White et al 1998). Processing in the form of fermentation and sun drying are traditional methods used for detoxification (Padmaja & Steinkraus 1995). Cassava roots have high carbohydrate content with very low protein. However, the peels contain more protein and cyanide [Hydrogen Cyanide (HCN)] than the roots. Average crude protein content of the dry root is 2.54% compared to 4.54% for the dry peel (Heuze et al 2016) on dry matter basis. Nitrogen free extract composition of the cassava peel is about 71% on dry matter basis (Onabowale 1992). The raw unpeeled cassava tuber contains 156 ppm of HCN while the cassava peel contains 180 ppm HCN which reduces to 3 ppm and 4 ppm respectively after processing (Onabowale 1992).

The processing of cassava for human use and consumption generates waste in the form of peels that can be used as alternative feed ingredient for animals (Padmaja & Steinkraus 1995). Cassava peel has been used in diets for poultry (Salami & Odunsi 2003; Nwokoro & Ekhosuehi 2005; Ajuonuma & Uchendu 2013), pigs (Balogun & Bawa 1997; Adesehinwa et al 2008; Ekwe et al 2011; Zhao et al 2011) and sheep (Adebowale 1981). Tests using cassava peel in diets of tilapia have been reported. Ubalua & Ezeronye (2008) reported that *O. niloticus* fed cassava peel based diets performed in a similar manner as those fed soybean meal based diets. Ojukannaiye et al (2014) and Fakunmoju et al (2014) have reported the use of cassava peels in the diet of *O. niloticus* with performance at 75% and 70% respectively while economics of production was reported in favour of 75% inclusion in lieu of maize meal (Fakunmoju et al 2014). However, these researchers used a lot more ingredients hence this research sets out to use a minimal number of ingredients to determine the growth performance of *O. niloticus* fed diets containing cassava peel meal in lieu of maize meal at various levels of replacement.

Material and Method. This study took place between July 2015 and September 2015. Yellow maize, soybean, cassava peels, fishmeal and mineral/vitamin premix were selected as ingredients. Soybean was toasted at 150°C until the bean coat cracked without being burnt. Cassava peels were washed thoroughly to remove soil particles then spread on a flat platform and sundried until they became bristle. Sun drying of the cassava peel was achieved within 3 days hence some fermentation was also achieved. The toasted soybean, yellow maize and sundried cassava peel were milled using a hammer mill, packaged in polyethylene bags and stored at 4°C while fishmeal was stored at -20°C until use.

Feed formulation and compounding. Pearson's square method was used to formulate the diet to achieve 30% crude protein diet. Cassava peel inclusion was fixed at 25, 50, 75 and 100% of the maize inclusion while vitamins and mineral premix was fixed at 2% (Table 1). Carboxy-methyl cellulose was used as a binder included at 1%. The milled ingredients were mixed in dry form before addition of water at 0.5 L kg^{-1} of mixture. Water used was at a temperature of 70°C. This enabled dough formation before pelleting was carried out using a 3 mm dice.

Table 1

Composition of experimental diets

Ingredients (%)	*Diet 1 (0%)*	*Diet 2 (25%)*	*Diet 3 (50%)*	*Diet 4 (75%)*	*Diet 5 (100%)*
Cassava peel	0	13.96	27.93	41.89	55.85
Maize meal	55.85	41.89	27.93	13.95	0
Soybean meal	15.83	15.83	15.83	15.83	15.83
Fishmeal	25.32	25.32	25.32	25.32	25.32
Min/Vit. Premix	2.0	2.0	2.0	2.0	2.0
CMC	1.0	1.0	1.0	1.0	1.0
P:E ratio (mg KJ^{-1})	21.79	22.59	22.85	21.87	21.92

CMC = Carboxy-methyl cellulose; Min/Vit. premix: antioxidant - 125 g, iodine - 1.2 g, selenium - 200 mg, manganese - 80 g, zinc - 50 g, iron - 20 g, copper - 5 g, cobalt - 200 mg; vitamin A - 8,000,000 IU, vitamin D3 - 1,600,000 IU, vitamin E - 6,000 IU, vitamin K - 2,000 mg, thiamine B1 - 1,5000 mg, riboflavin B2 - 4,000 mg, pyriodoxine B6 - 1,5000 mg, niacin - 15,000 mg, vitamin B - 1210 mg, pantothenic acid - 5,000 mg, folic acid - 500 mg, biotin - 20 mg, choline chloride - 200 g.

Feeding trial. *O. niloticus* fingerlings were obtained and stocked in a large hapa (4 x 3 x 1 m) for acclimatization in an earthen pond. The acclimatization period lasted 14 days after which surviving fish were sorted out and divided into triplicate hapas measuring 1 m x 1 m x 1 m immersed in an earthen pond of dimensions 5 m x 4 m x 1 m with a free board of 0.3 m. The fish were randomly selected into the hapas. A total of twenty fish were stocked per hapa. The hapas were routinely cleaned every week to remove accumulated waste and faecal matter to avoid biofouling. Water temperature, pH and dissolved oxygen (DO) were monitored using handheld electronic water quality test device (Hanna®). Weekly pH values ranged from 6.05 to 7.40 while temperature ranged from 22.1^{o}C to 23.87^{o}C. DO in week one and two fell below 5 mg L^{-1} with values of 4.10 and 4.20 mg L^{-1} respectively. The situation was controlled by use of aeration in the pond. However DO levels fluctuated between 3.30 and 5.10 mg L^{-1} through the duration of the experiment. Vigorous aeration was employed when DO levels were low.

Fish were fed based on 5% body weight and this was adjusted weekly to accommodate growth. Sampling was done weekly to measure the weight of the fish. Weight was determined using an electronic balance Ohaus Adventurer ARC 120; Ohaus Corp. Pine Brook NJ USA; ± 0.01 g). The fish were fed manually for fifty six days. Fish were fed twice a day at 8:00 am and 5:00 pm daily.

Proximate composition of fish and diets*.* A sample of 10 fish was used to analyse for initial body protein composition. At the end of the experiment, final body composition was also determined. The diets were analysed for moisture, ash, crude protein, crude fibre and crude lipid while fish was analysed for moisture, ash, crude protein and crude lipid. Samples were analysed for moisture by drying the samples for 16 hours at 105^{o}C. Ash content was determined by incineration in a muffle furnace for 16 hours at 550^{o}C. Kjeldahl N was determined using a Foss digestor at 420^{o}C for 1 hour and distillation using Foss auto distiller followed by titration. Kjeldahl nitrogen was translated to crude protein content by multiplication with 6.25. Crude lipid was determined using Soxhlet extraction with petroleum ether (BP 40-60°C).

Growth and feed utilisation*.* The growth of the fish was determined from the initial and final weight of the fish that was determined using the wet weighing method. Parameters determined include: weight gain, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER) and apparent net protein utilisation (ANPU).

Experimental design and statistics*.* A completely randomized design was used for this experiment with five treatments (including control) and three replications for feeding trials with three replications for proximate composition. Data were subjected to statistical analysis using analysis of variance (adjusted for covariate effect of initial weight) at 5% level of with the aid of Minitab 16.

Results and Discussion. Proximate composition of experimental diets (Table 2) revealed that cassava peel inclusion affected fiber content.

Table 2

Proximate composition of experimental diets

Treatment	*Moisture (%)*	*Dry matter basis (%)*				
		Ash	*Lipid*	*Fiber*	*Protein*	*NFE**
Diet 1	5.66	9.87	5.20	9.70	31.70	43.53
Diet 2	5.56	9.38	5.31	10.16	32.94	42.21
Diet 3	4.66	10.12	4.85	10.61	32.64	41.78
Diet 4	5.05	11.12	4.78	11.02	30.69	42.39
Diet 5	5.55	11.64	4.67	11.29	30.43	41.97

* NFE = nitrogen free extract.

Protein content of fish flesh differed significantly ($p < 0.05$) among treatments with diet 2 recording the highest content (Table 3). Carcass protein content decreased with increasing cassava peel in the diet. This trend reflects in the apparent net protein utilization (Table 4). Initial carcass composition is higher than values recorded after feeding tilapia with the various diets. There is a reduction in crude protein content of the flesh after feeding. However, lipid content of flesh increased with the feeding of the various diets although the trend is not regular.

A significant difference ($p < 0.05$) in initial weight was observed. This was due to a constraint in the number of fish available for stocking. However, all parameters that involved weight gain were adjusted for the covariate effect of the initial weight. Significant differences were observed in all parameters after adjustment for covariate effect as well as in ANPU which was not adjusted. SGR, final weight, MWG, ANPU and PER were higher in fish fed diet 2 while FCR was least for fish the same diet.

Table 3

Proximate composition of carcass

Treatment	*Moisture (%)*	*Dry matter basis (%)*		
		Ash	*Lipid*	*Protein*
Initial	78.73[a]	7.19[b]	5.55[b]	87.26[a]
Diet 1	76.45[cd]	7.37[b]	10.62[a]	82.02[c]
Diet 2	77.10[b]	5.02[c]	10.44[a]	84.54[b]
Diet 3	76.50[c]	5.60[bc]	10.87[a]	83.53[b]
Diet 4	76.00[d]	9.87[a]	9.61[a]	80.52[d]
Diet 5	76.15[cd]	10.63[a]	9.54[a]	79.83[d]

Means in the same column followed by different superscripts differ significantly ($p < 0.05$).

Table 4

Growth and feed utilization parameters of *O. niloticus* fed CPM in replacement for maize meal

Diet	*Initial Wt (g)*	*Final Wt (g)*	*MWG*	*SGR (% day^{-1})*	*FCR*	*ANPU[§]*	*PER*
Diet 1	1.01[b]	5.45[c]	0.08[c]	3.02[c]	1.95[a]	1.24[b]	1.72[b]
Diet 2	1.05[b]	7.42[a]	0.11[a]	3.49[a]	1.70[b]	1.70[a]	1.89[a]
Diet 3	1.04[b]	6.46[b]	0.10[b]	3.26[b]	1.81[b]	1.55[a]	1.78[ab]
Diet 4	1.03[b]	5.11[d]	0.07[d]	2.86[d]	1.96[a]	0.74[c]	1.76[ab]
Diet 5	1.12[a]	4.51[e]	0.06[e]	2.49[e]	2.12[a]	0.50[c]	1.64[b]

Means in the same column followed by different superscripts differ significantly ($p < 0.05$); [§]Not adjusted for covariate effect of initial weight; MWG = mean weight gain; Wt = weight.

Growth of fish fed diet 2 increased steadily from initial to the final week following a typical growth curve (Figure 1). Growth in fish fed diets 3, diet 1, diet 4 and diet 5 followed in descending order.

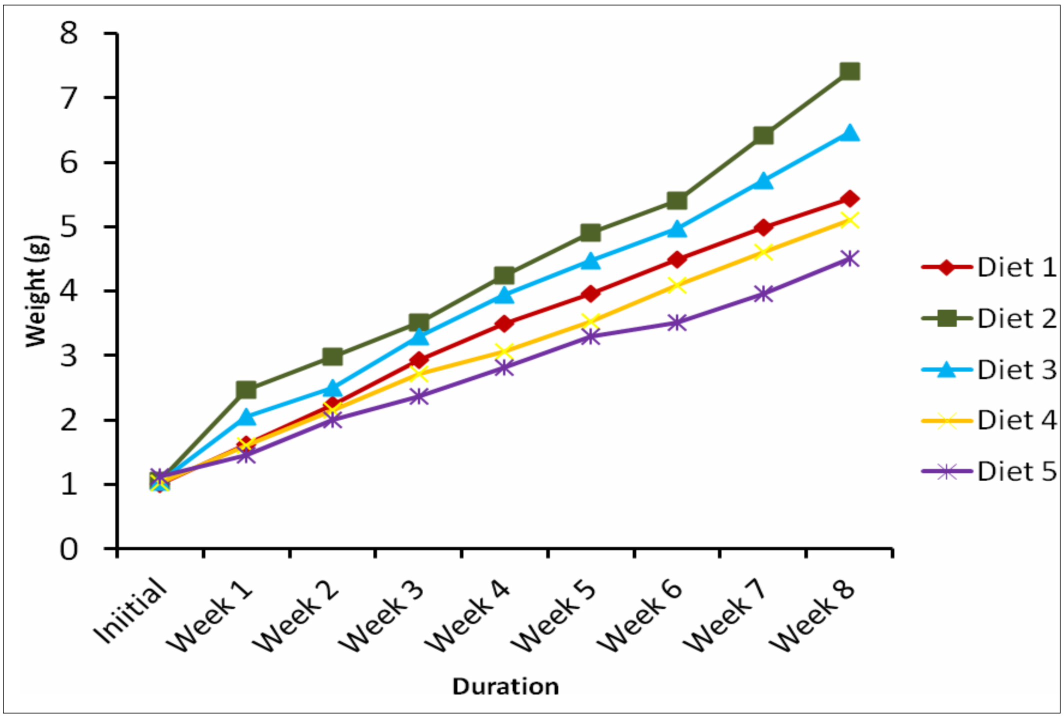

Figure 1. Growth curve of *O. niloticus* fed different CPM levels in lieu of maize meal.

Growth performance. Specific growth rate of the test fish declined with increasing inclusion of CPM however, CPM was better utilized at 25% level of substitution compared to non-inclusion. This shows there is synergy between CPM and corn meal at low levels of substitution that elicits better growth in the fish but the synergy is increasingly lost with higher levels of CPM (Omoregie et al 1991; Ubalua & Ezeronye 2008). The decline in SGR is connected with the increased FCR of the diets. Similar reports of CPM in the range of inclusion as the one in the present study that was utilized with better growth are available (Oresegun & Alegbeleye 2001; Dada et al 2015). Fish fed with diets where corn meal was totally replaced with CPM did not grow well. There is therefore a problem with utilization of CPM by tilapia in diets with total replacement of corn. It is evident that cyanide content militated against the utilization of the 100% level of CPM. Cassava peels impact heavily on cyanide content of finished products and processing involving cassava peels is not encouraged (Saka & Nyirenda 2012). In addition, sun drying is not an effective method of reducing cyanide content (Cardoso et al 2005).

Similarly, parameters such as final weight and weight gain seem to be favoured by lower inclusions of CPM. Low levels of CPM seem more digestible than higher levels. The digestibility of CPM is quite low (Sonaiya & Omole 1983) hence the effect is seen in the growth performance of the test fish. Broilers also utilize low levels of CPM compared to higher levels (Eruvbetine et al 2003). However, Solomon et al (1996) reported that CPM at a level of 30% in a diet mixed with yellow maize produced the best growth parameters in tilapia. Similar reports of higher CPM to maize percentage producing the best growth in tilapia using diets with about 35% crude protein are presented by Fakunmoju et al (2014) and Ojukannaiye et al (2014). In comparison, the few ingredients used in the present study at 30% crude protein level, produced an FCR which is less than values earlier reported by Omoregie et al (1991), Ojukannaiye et al (2014), and Dada et al (2015).

Protein was efficiently utilized by fish fed 25%, 50% and 75% levels of CPM in lieu of maize compared to 0% and 100% substitutions. Protein efficiency was higher than earlier reported by Omoregie et al (1991) and Ojukannaiye et al (2014). Since protein ingredients are quite expensive, the use of minimal number of ingredients as well as CPM in such a way that protein is well utilized seems to be a good development. Dietary protein forms the basis for development of muscles and enzymatic functions as well as tissue repair (Yang et al 2002). Therefore, diets with CPM at 100% level of substitution for maize affected protein efficiency negatively. Crude protein levels of diets have an inverse relationship with PER (Bahnasawy 2009; Oishi et al 2010). This implies that diets must have ingredients that do not interfere with protein utilization if the barest minimum of crude protein requirement is employed. An interesting discovery is the fact that 25% level inclusion of CPM boosted PER compared to diets with maximum substitution of CPM.

Protein content of carcass declined with diets administered. Initial level was higher than levels observed after feeding including the control. At 25% level of CPM inclusion, carcass protein was higher than other levels. Carcass composition has been reported to have an irregular pattern in terms of protein content (Winfree & Stickney 1981). The lipid content of carcass generally decreased with increasing CPM except in diet 3 while the ash content increased with increasing CPM in the diet. The inclusion of cassava leaf meal in the diet of tilapia was also found to affect carcass in a similar manner as we report here (Ng & Wee 1989). These similar findings show that cyanide in cassava tends to affect protein retention hence it can be concluded that high levels of cassava peel meal in tilapia diets will negatively affect protein retention in the carcass.

***Meta-analysis**.* Two reports were found with information on the substitution of cassava peel for maize with a similar design to this one reported here. Fakunmoju et al (2014) and Ojukannaiye et al (2014) reported that substitution at 75% of maize gave the best growth performance at the least feed cost. These authors used lysine and methionine as dietary additives alongside six other ingredients (Fakunmoju et al 2014) and seven ingredients (Ojukannaiye et al 2014). However, these authors did not use any binder. The total exclusion of maize at 100% replacement by CPM would imply difficulty in dough formation and subsequently pelleting leading to quick leaching. Cassava peel in fresh and dry form does not contain starch (Heuze et al 2016). Fakunmoju et al (2014) used levels of protein to energy ratios (P:E) ranging from ~32 to 37 mg protein/Kj while Ojukannaiye et al (2014) used a range from ~23 to 27 mg protein/Kj (Table 5). We used P:E ratios in the range of ~22 to 23 mg protein/Kj. Li et al (2013) re-evaluated the concept of P:E ratio in tilapia diets and they reported an optimal ratio of 21.3 mg/Kj . Our values are not far from this recommended value.

Table 5

Dietary protein:energy ratios in literature and present study (Ratio is CPM:maize)

	0%:100%	*25%:75%*	*50%:50%*	*75%:25%*	*100%:0%*
Present report	21.79	22.59	22.85	21.87	21.92
Ojukannaiye et al (2014)	27.27	25.31	23.20	24.64	22.91
Fakunmoju et al (2014)	32.21	33.10	34.49	35.45	37.20

The P:E of a diet also affects its utilization and subsequently the growth of fish fed considering protein sparing effect. While earlier reports showed that tilapia has a P:E ratio requirement of between 26 to 29 mg protein/Kj depending on size (Winfree & Stickney 1981), recent research (Li et al 2013) has demonstrated that a lower level of 21 mg protein/Kj will produce more desirable effects of weight gain and less FCR compared to higher levels with effects of protein on final weight, FCR and survival not being significant while energy had significant effect on final weight, weight gain and FCR. Furthermore, they reported that there is no interaction between protein and energy with respect to the aforementioned parameters. According to Tran-Duy et al (2008), increasing starch content of tilapia diets leads to a decrease in digestible energy intake considering blood glucose levels and oxygen uptake under satiation. Energy in the diet significantly explains the moisture, whole body energy, protein content of tilapia flesh and digestible energy retention while protein content of diets have been reported to explain flesh moisture, protein content and protein retention in tilapia (Li et al 2013). Although Winfree & Stickney (1981) reported interactions between P:E ratio and condition factor as well as feed conversion in tilapia, recent report of Li et al (2013) shows otherwise.

Conclusions. Cassava peel meal can replace maize in the diets of *O. niloticus* at a ratio of 25%:75% with favourable growth and feed utilization. We have also confirmed that the use of a P:E ratio between 21 and 22 mg protein/Kj will creates the desired protein sparing effect without affecting growth and carcass composition.

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