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Full Length Research Paper

Agro-industrial wastes for fish wealth creation in Nigeria: A progressive effort

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Abstract

This paper is a review of the efforts being made to utilize various agro-industrial wastes for fish feed formulation, in Nigeria. Although potentials abound in Africa for the development of viable fish farming, one of the major hindrances to the development of aquaculture industry is the lack of locally produced, high-quality fish feed. The high demand for fresh fish has led the Federal and various state governments to embark on encouragement of fish farming and establishment of fish farm settlements, to increase the supply of fish. This revolution has created a very large market for the feed industry in Nigeria. It is no longer sustainable to rely, solely, on importation of fish feed or raw materials, especially fish meal, for producing feeds to meet the current needs. Various researches are being carried out into usage of readily available agro-industrial products/wastes, such as maggots, poultry droppings, cassava peels, indomie®, gala® wastes, various leaf meals etc, to produce quality, digestible and palatable fish feeds. The inclusion of these materials, in feed formulation on a large scale, will reduce the cost of feeds and maximize profit. This would also be a waste mop-up effort to mitigate climate change.

Key words: indomie, maggot, leaf meal, blood meal, indomie®, gala®, feed

Introduction

The present contribution of Africa to the world aquaculture production is insignificant, compared to the rest of the world (Changadeya *et al*., 2003). According to FAO (2013) the entire continent contributed only 1.4million metric tonnes (2.2%) to the total world aquaculture production in 2011 (Table 1 and Fig. 1). There is considerable potential to expand aquaculture in Africa, in order to improve food security (Engle, 1997, Jamu and Ayinla, 2003) and increase her contribution.

Table 1: World aquaculture production (million metric tonnes) of food fish* by continent in 2011

Continent	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Africa	0.4	0.5	0.5	0.6	0.6	0.8	0.8	0.9	1	1.3	1.4
Americas	1.7	1.9	1.8	2.1	2.2	2.4	2.4	2.5	2.5	2.6	2.9
Asia	30.3	32.4	34.2	36.9	39.2	41.8	44.2	47	49.5	52.4	55.5
Europe	2.1	2	2.2	2.2	2.1	2.2	2.4	2.3	2.5	2.5	2.7
Oceania	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	34.6	36.8	38.9	41.9	44.3	47.3	49.9	52.9	55.7	59	62.7
Annual Growth Rate	6.8%	6.3%	5.8%	7.7%	5.7%	6.8%	5.6%	6.0%	5.2%	5.9%	6.2%

*Food fish = fishes, crustaceans, molluscs, amphibians, reptiles (excluding crocodiles) and other aquatic animals (such as sea cucumber, sea urchin, etc.) for human consumption. (FAO, 2013)

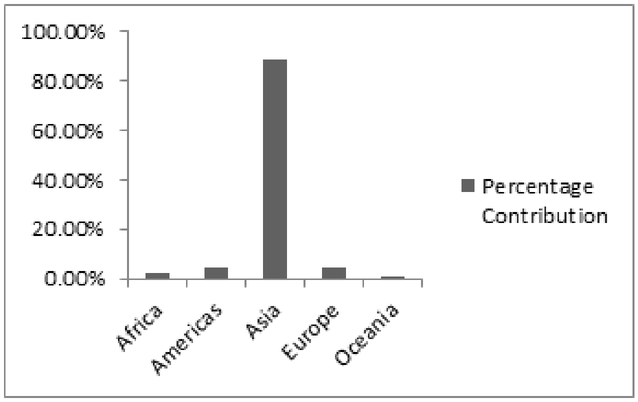


Fig. 1: The percentage contribution of Africa to the world fish food production in 2011 (FAO, 2013)

Although potentials abound in the continent for the development of viable fish farming, one of the major hindrances to the development of aquaculture industry in Africa is the lack of locally produced, high-quality fish feed. Fish requires high quality nutritionally balanced diet, for growth and attainment of market size, within the shortest possible time. Therefore, local production of fish feed is very crucial to the development and sustainability of aquaculture in Africa, especially, in the rural areas. For aquaculture to thrive and bridge the already existing wide gap between fish demand and supply, especially in the Sub-Saharan Africa, the vital role of locally produced fish feed cannot be over emphasized. These efforts, geared towards reducing production cost, will make fish farming attractive to both private and commercial investors and ultimately boost fish production.

Nigeria spends ₦125 billion (>$600 million) on fish importation annually and the current fish demand consumption in Nigeria stands at over 2.66 million tonnes yr^{-1}, while the present importation rate is over 750,000 metric tonnes. With this continuous drain of more than $600 million hard currency, thousands of jobs are exported (USAID, 2010). In order to bridge the demand-supply gap, an aquaculture transformation agenda plans to increase annual fish production from the current production of 0.78 million MT to 3.0 million tonnes, in order to achieve self-sufficiency in fish production and supply, by the year 2015 was put in place (Tijani, 2011). Some improvements have been achieved.

Aquaculture development has been identified as the only way out of this need, as the natural waters have been depleted, through overfishing. As earlier identified by Adewumi and Olaleye (2011), Adewumi *et al.* (2010), inadequate supply of quality fish seed and cost of imported feed are major bottle-necks to fish farming. Thus, progress can be achieved only through fish farming, fish seeds and feed mill development programs. Many fish farmers are out of business because of the cost of foreign feeds (Oota, 2012). Consequently, the Federal and various state governments are embarking on fish farming programmes to increase the supply of fish. This revolution has created a very large market for the feed industry in Nigeria. It is no longer sustainable to rely solely, on importation of fish feed or raw materials, especially fish meal, for producing feeds, to meet the current demands.

Review of the Use of Fish Feed in Aquaculture

Feed accounts for at least 60% of the total cost of fish production. Fish meal is the main ingredient in fish diet. It is a primary choice protein source, because it increases feed efficiency and fish growth through good feed palatability, digestion and nutrient absorption. The high quality and concentration of essential nutrients, especially of well-balanced amino acids, essential fatty acids, and energy content makes fishmeal an indispensable ingredient in diets of most aquaculture species and many land-farm animals. (Mile and Chapman, 2012). Fishmeal importation is however, no more cost effective and renders fish farming unsustainable. Due to this limitation, promising alternative plant and animal protein sources that are cheap and affordable have been tried in catfish and tilapia diets to replace the fish meal component (Solomon and Sadiku, 2005; Ingweye *et al.*, 2010; Adewumi and Olaleye, 2010). Effort have been made towards the use of locally available plant protein source but in comparison to fishmeal protein they have their limitations such as imbalance of essential amino acid (EAA), the presence of anti-nutritional factors and toxicant that have harmful effect on fish (Olukunle, 1996).

Oil seed/cake meals are also extensively used in agriculture in developing countries, especially Nigeria. These seeds include cotton seed cake, groundnut cake and soybean cake. Oil seed which is a high proteinous residue remaining from the removal of the greater part of the oil from seeds. However, researches have shown that meal can only be a supplement of fish meal at low inclusion levels in order to obtain the desired nutrient profile. This limitation is due to:

1. Toxic component such as a flatoxin (in groundnut), gossypol (in cotton seed), and anti-trypsin factors (in soybean)
2. Limiting level of essential amino acids particularly cystine, methionine and lysine
3. Low digestibility of plant protein and carbohydrates unlike fish meal that has high digestibility

Despite all these limitation of oil seed, it has been considered suitable and satisfactory for formulating feed for the African cat fish as well as other warm water species (NRC, 1993, Fagbenro, 1998). Recently discovered is a less cost and un-competitive animal protein, the maggot meal (magmeal) and it was observed that it is a good replacer for fish meal as they contain almost same nutrient as that of fish meal. In most cases however, total replacement of the fish meal component has not been achieved due to lack of some essential amino acids (Anderson *et al.*, 1995), presence of anti-nutritional factors or toxicants or poor feed digestibility (Murray *et al.*, 2010).

This therefore calls for closer look on the use of locally available agro-industrial by-products, as possible substitutes for the conventional feedstuffs which are dwindling in supply, and escalating in their cost. A wide range of materials, which are discarded as wastes, have been studied and found to possess nutrient composition which can be exploited. This include poultry wastes (maggots, feather meals, poultry droppings, poultry offals), cow blood/rumen digesta, fish and shrimp wastes, cassava peels, indomie wastes, various leaf meals, rice bran, soybean hulls and cocoa husks etc, as dietary ingredients for warm water species (Tilapia and Clarias spp). Given the euryphagic nature of Clarias, it is not surprising that it is able to efficiently utilize a wide variety of ingredients. In some quarters, it is considered as an ideal “bio-waste manager” (Sambhu, 2004).

Agricultural waste management is part of the ecological cycle in which everything is cycled and recycled such that an interdependent relationship is maintained in the eco-system (Sambu, 2004). By waste management, all the plant wastes are placed at the right place and right time for the best utilization in order to convert into useful products and pollution control. Globally, 140 billion metric tons of biomass is generated every year from agriculture (MNRE, 2009). Sherahwat and Sindu (2012) carried out a study to highlight some of the trends that could be adopted in the agricultural waste management so that the farmers become aware and take full advantage of the various possibilities of plant waste cycling, recycling and further utilization for economic purpose. Agricultural processing operations produce waste by-products. This study and that of Ubalua (2007) showed that properly managed and utilized, agricultural wastes are a natural resource that can produce economic returns.

However, some processing treatments might be required to alleviate the toxic effects of possible anti-nutritional factors in the by-products, for the achievement of optimum benefit (Murray *et al.*, 2010). It is obvious that utilization of some of these agro-industrial wastes will also reduce their menace to the environment and mitigate climate change.

Suffice to say that fish feed development in Sub-Saharan Africa has not made a significant progress in aquaculture as expected. As aquaculture becomes intensive, most farmers in Africa depend largely on imported fish feed from European countries for the productivity and sustainability of the industry. For example, in Nigeria an estimated 4,000 tons of quality fish feeds are imported into the country each year (AIFP, 2004). According to Hecht (2007), it is observed that the research on inexpensive feed ingredients has not contributed greatly to aquaculture development in Africa and suggested that more research on how best plant protein can be used as fish feed is required. Development and management of fish feed, play very vital role in aquaculture growth and expansion. Therefore this paper is a review of some of the efforts that has been made by various researchers and on-farm practicing farmers, in inculcating some agro-industrial wastes in fish feed formulation and the effect/possibility of use on commercial scale.

Review of some agro-industrial wastes used in fish feed formulation in Nigeria

Indomie®, Gala® and Biscuit Crumbs

Biscuit, Indomie® and Gala®, wastes are industrial waste products found in substantial quantities at different industrial areas in Nigeria. Agbebi *et al.* (2013) fed juveniles of *C. gariepinus* with wastes biscuit, Indomie® and Gala®, (Table 2) (collected as wastes from the industries in Ibadan), in homestead tanks. It was reported at the end of the 8weeks feeding trial that the fish fed biscuit, Indomie®and Gala® wastes respectively, had equal potentials in replacing maize, as an energy supplement, without significant deleterious effect on growth or haematological parameters (Table 3, 4). Cost analysis revealed that the use of any of these wastes in replacing maize could reduce total feed cost by at least 30% (Table 5). These workers thus concluded that these wastes have no antinutritional factor and could be a good replacement for maize and other cereals and could be economically incorporated into fish feed, by even resource poor farmers.

Table 2: The proximate analysis (g $100g^{-1}$) of the feed ingredients and cost (Kg^{-1})

Feed Ingredients	Crude Protein	Fat	Moisture	Ash	Crude Fibre	Dry Matter	Cost Kg-1 (Naira)
Maize	36.72	2.24	8.97	7.06	6.14	36.72	80
Biscuit crumbs	35.94	5.65	8.74	6.89	5.83	35.94	35
Indomie® wastes	35.62	5.78	7.66	6.86	7.68	35.62	40
Gala® wastes	39.21	3.94	8.57	6.95	5.27	39.21	40

Source: Agbebi *et al.* (2013)

Table 3: Summary of the growth response in Clarias gariepinus for 8 weeks experimental period

Parameters	Weight gain (g)	Feed intake (g)	Protein intake	PER	FCR	SGR (%day^{-1})	Survival (%)
Maize (control)	119.70±4.09	126.84±13.02	50.74±5.20	2.34±0.15	1.05±0.10	4.53±0.21	100
Biscuit	108.67±6.81	138.10±10.72	55.24±4.29	1.99±0.12	1.26±0.05	4.47±0.91	100
Indomie	107.67±6.05	114.4±12.39	45.76±4.96	2.37±0.16	1.06±0.08	4.30±0.19	100
Gala	138.71±4.34	153.89±12.26	61.56±2.50	2.28±0.17	1.11±0.04	4.63±0.15	100

Means with the same superscript in the same column are not significantly different (p>0.05), PER: Protein efficiency ratio, FCR: Feed conversion ratio and SGR: Specific growth rate. Source: Agbebi *et al.* (2013)

Table 4: Haematological parameters observed in Clarias gariepinus fed with diet for 8 weeks

Parameters	Control	Biscuit	Indomie	Gala
PCV	37.00±1.82^a	34.40±3.00^a	36.40±2.67^a	34.00±1.38^a
HB	10.22±0.29^a	9.70±0.49^a	9.40±0.46^a	9.30±0.33 ^{a}
RBC	2.26±0.17^a	2.02±0.23^a	2.18±0.13^a	2.28±0.20^a
WBC	11.76±0.47^a	10.06±1.10^a	10.80±0.64^a	11.42±0.93^a
PLAT	203.40±15.18^a	189.60±27.09^a	206.40±4.15^a	207.20±16.76^a
TP	3.04±0.18^a	2.47±0.12^a	3.40±0.32^a	3.44±0.39^a
ALBU	2.06±0.21^a	1.60±0.20^a	1.74±0.14^a	2.12±0.37^a
AST	45.80±6.85^a	49.60±4.812^a	42.60±9.212^a	52.40±4.411^a
ALT	13.80±2.31^a	17.60 2.09^a	15.20 2.56^a	15.80 1.72^a
ALP	43.20 3.94^a	45.20 3.8 ^{a}	50.00 4.58^a	46.40 4.03^a
GLOB	0.98 0.21^a	1.14 0.16^a	1.46 0.15^a	1.32 0.23 ^{a}
HCT	38.80 3.84^a	38.40 2.18^a	46.60 5.23^a	45.80 4.20^a
LYM	53.00 3.67^a	55.20 3.38^a	44.60 4.81^a	47.40 5.00 ^{a}
EOS	1.00 0.45^a	0.60 0.25^a	0.80 0.37^a	0.60 0.60^a
BAS	0	0	0	0
MON	7.20 1.86^a	5.80 2.11^a	6.00 1.34^a	5.40 1.29^a

Means with the same superscript in the same column are not significantly different (p>0.05)
Source: Agbebi *et al.* (2013)

Table 5: Cost analysis of the feed ingredients

Feed Ingredients	Cost kg^{-1} (Naira)	Cost kg^{-1} (Dollars)
Maize	80	0.53
Biscuit waste	35	0.23
Indomie waste	40	0.27
Gala waste	40	0.27

Source: Agbebi *et al.* (2013)

Maggot Meal (Magmeal)

Maggot, the larva of housefly, *Musca domestica*, grows extensively on animal dung, such as cow, goat, sheep and poultry droppings, under favourable conditions. It is also produced from wastes, which otherwise would constitute environmental nuisance. Magmeal has been reported to be a possible alternative to fish meal. Fashakin *et al.* (2003), Adewumi (2015) reported that maggot meal (magmeal) was successfully fed to *C. gariepinus* fingerlings to replace fish meal up to a level of 50% (Table 6), without any deleterious effect on growth and nutrient utilization, while Fashina-Bombata and Balogun (1997) even reported a replacement of up to 100% in their work with tilapia (*O. niloticus*).The cost of 1kg of magmeal was less than 20% of the cost of 1 kg of fishmeal. Maggot meal can be easily collected from poultry houses. It can also be grown on a mixture of cattle blood and wheat/rice bran (Aniebo *et al.*, 2009). More research is still being carried out on the magmeal, to know if it can completely be a replacer for fish meal without limitation.

Table 6: Growth performances and nutrient utilization of the fish fed maggot dietary treatments

Parameters	Diets					
	Mg0	**Mg10**	**Mg20**	**Mg30**	**Mg40**	**Mg50**
Initial weight	2.12[a]	2.08 [a]	2.34[a]	2.23	2.31[a]	2.20[a]
Final weight	15.31[a]	14.64[a]	14.92[a]	14.80[a]	14.62[a]	15.44[a]
%Weight gain	628[a]	630[a]	548[a]	573[a]	535[a]	600[a]
TFI	14.12	13.91	15.30	14.81	13.80	14.93
SGR	2.51[ab]	2.50[a]	2.46[a]	2.36[a]	2.44[a]	2.37[a]
FCR	1.17[a]	1.15[a]	1.20[a]	1.12[a]	1.11[a]	1.06[a]
PER	2.55[a]	2.60[a]	2.61[a]	2.47[a]	2.45[a]	2.62[a]
% Survival	97[a]	95[a]	97[a]	94[a]	94[a]	95[a]

TFI=Total feed intake, SGR=Specific growth rate, PER=Protein efficiency ratio. MG0=Control, MG10=10% replacement, MG20=20% replacement, MG30=30% replacement, MG40=40% replacement, MG50= 50% replacement. (Source: Adewumi, 2015)

Shrimp Waste Meal

The Nigerian shrimp fishery is predominantly an export oriented industry with annual revenues of approximately US$2.4 million. Annual production figures are estimated at 72 000 tonnes. Annual processing generates approximately 34 900 tonnes of waste (head, shell)(Table 9). Assuming a conversion ratio of 4 to 1 wet waste to dry by-product (Balogun and Akegbejo-Samsons, 1992), there is the potential to produce 8,820 tonnes of dry shrimp waste meal per annum. Shrimp head waste meal (SHWM) may be included in poultry and fish feeds. The biochemical composition of the chemically treated SHWM is shown in Table 7.

Table 7: Proximate and amino acid composition of the shrimp head silage meal

Proximate	Composition	Amino acid	composition
Parameters	**% content**	**Amino acid**	**g/100 g protein**
Crude protein	59.1	Arginine	7.5
NFE_1	0.68	Histidine	1.61
Ether extract	4.05	Isoleucine	2.64
Fibre	3.81	Leucine	4.11
Ash	28.3	Lysine	7.35
Dry matter	95.9	Methionine	2.62
$G.E(kcal/100\ g)_2$	351.1	Phenylalanine	2.35
		Threonine	2.13
		Tryptophan	0.96
		Valine	2.98
		Alanine	1.01
		Tyrosine	1.87
		Cystine	1.25
		Proline	1.36

NFE=Nitrogen Free Extract; GE= Gross energy

The method of preparing the SHWM was as reported by Nwanna *et al*., (2004). Shrimp head material was collected from International Fishing Company (ICFC) Lagos, blanched in hot water and blended into paste. Two percent each of formic and ethanoic acids of the weight of the shrimp head paste were added to aid ensilation and to prevent the growth of spoilage organisms. Ensilation was carried out (1 kg/bag) in 10 air-tight polythene bags for 14 days at pH range of 3.6-4.7. The wet silage was co-dried with 15% of hydrolysed feather meal (85: 15, w/w) as filler and oven dried at 60^{o}C for 3 days. The dried product was blended into powder form and used to replace fish meal

Primarily, SHWM is added as an attractant, and secondarily, as a protein source. However, the high cost of feed will be minimized by the inclusion of 60% SHWM in the diet of *C. gariepinus*. Available literature on replacement of fish meal with shrimp head meal contains reports on specific species of tilapia, such as (*O. niloticus* and *O. hornorum*) which suggests that shrimp head meal can successfully replace fish meal in tilapia diets. In this regard, considerable success has been achieved (Nwanna *et al*., 2004) as shrimp head meal has been successfully used as a protein source for Blue tilapia (*Oreochromus aurerus*) and Nile tilapia (*O. niloticus*) respectively. Nwanna *et al*., (2004) reported that fish meal can be replaced with up to 20% of chemically ensiled shrimp head meal in the diets of African catfish that there were no significant variations between the erythrocyte sedimentation rate (ESR) and pack cell volume (PCV) of the fishes fed fish meal based diets and the experimental diets (Table 8). Unfortunately, the high chitin content of the meal restricts its inclusion to low levels in animal feeds. The cost and availability of shrimp heads and shells in Nigeria are presented in Table 9.

Table 8: Haematological indices of *C. gariepinus* fed shrimp silage diets.

Sample	ESR (mmfall/hour)[1]	PCV (%)[2]
Initial	3.0±0.10a	29.0±0.5a
Diet 1	3.1±0.10a	31.0±0.70a
Diet 2	3.1±0.10a	31.0±1.0a
Diet 3	3.2±0.15a	31.0±1.0a
Diet 4	3.2±0.15a	31.0±0.75a
Diet 5	3.1±0.10a	29.6±1.0a
Diet 6	3.3±0.10a	29.4±0.75a

Values are means of triplicate samples Values on the column followed by the same letters are not significantly ($p>0.05$) different [1]Erythrocyte sedimentation rate; [2]Pack cell volume. (Source: Nwanna *et al.*, 2004)

Table 9: Shrimp wastes availability in Nigeria in the year 2000

Product	Quantity (tonnes)	Price (US$/tonne)	Availability
Shrimp heads	24,000	300	Adequate
Shell	10,900	180	Low

(Source: Balogun and Akegbejo, 1992)

Blood Meal

Blood meal, an animal waste product and readily available in abattoirs in Nigeria, is an alternative cheaper protein source. Aladetohun and Sogbesan (2013) reported that fish meal can be replaced completely (100%) by blood meal, in the diet of *Oreochromis niloticus*, with no adverse effect on growth, survival and feed conversion. The cow blood collected from an abattoir, was boiled, oven dried at 60°C. Fish fed with 100% blood meal replacement for fish meal had the highest final weight (69.0 g/fish) while the lowest value (36.60 g/fish) was recorded in fish fed 0% blood meal, as shown in Table 10.

Table 10: Growth and feed utilization of Tilapia (*Oreochromis niloticus)* fed with different level inclusions of blood meal

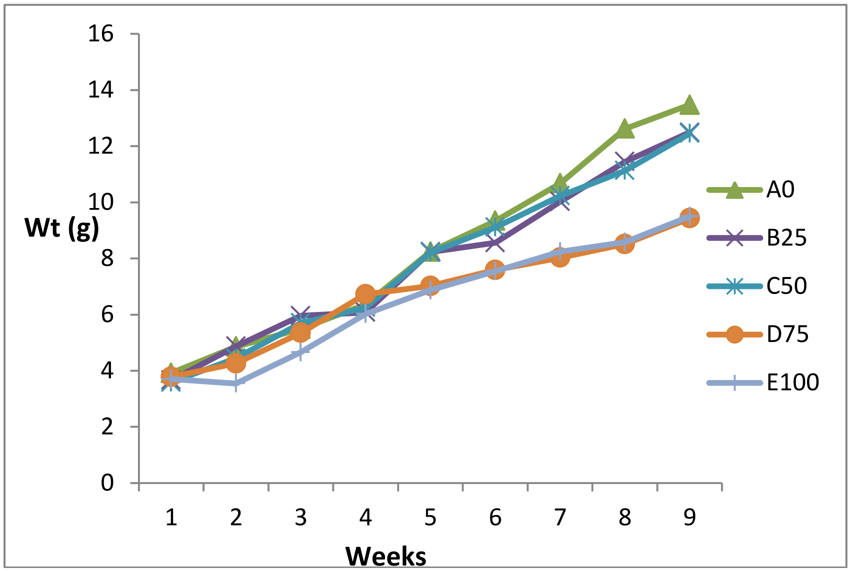
Parameter	Treatment 1	Treatment 2	Treatment 3
Experimental days	84	84	84
No of fish stored	20	20	20
Initial average weight(g)	6.20	6.26	6.15
Final average weight(g)	36.60	48.00	69.00
Average weight gain(g)	24.20	41.74	62.85
Mean weight gain/day(g)	0.29	0.50	0.75
Average weight gain/weekly	2.02	3.48	5.24
Mean weight gain/biweekly	4.40	6.96	10.47
Total (relative)weight gain(%)	390.00	666.77	1021.79
Specific growth rate	0.93	1.06	1.27
Total feed intake(g)	8.30	10.14	13.96
Feed conversion ratio	0.34	0.24	0.22
Protein intake	2.92	3.49	5.2
Protein efficiency ratio	56.76	58.38	53.40
Survival (%)	100	100	100

(Source: Aladetohun *et al.*, 2013).

Cassava Peel Meal

Cassava by-products are readily available in factories where cassava tubers are processed into starch or flour. Cassava peels derived from gari processing are normally discarded as wastes and allowed to rot in the open, thus resulting in health hazards. A number of researches have been conducted in Nigeria to include fermented cassava peels and leaf in diets for fish. In order to reduce cyanogenic and phytate content and preserve the nutritive quality of the cassava product, different processes like sun-drying, ensiling and soaking/sun-drying have been reported (Tewe, 1992; Motarjemi, 2002) to be effective in reducing cyanogenic glycosides. Ubalua and Ezeronye (2008) and Adewumi (in press) respectively observed that 50% replacement of maize with ensiled cassava peel meal (diet C50) can be tolerated by *O. niloticus* and *C. gariepinus* respectively, for good growth and nutrient utilization (Fig. 2). The cassava peel meal utilized for these trials was produced by process of fermentation.

Cassava peels (5kg), obtained from a cassava flour mill were washed and sundried for about 5 hours to wilt. This was mixed with 1kg of poultry droppings (to provide nitrogen) and 1litre of liquid drained from fermentation of cassava pulp. This mixture was kept wrapped inside black polythene bag for 21 days, at room temperature. After 21 days of fermentation, the product was sundried and milled into powdery meal. Ensilement reduced the toxicity of the ingredient drastically (Table 11), as well as jacked up the protein value of peels, otherwise regarded as agricultural wastes, and placed it among suitable basal feedstuff as maize.



A0=Control; A25, A50, A75, A100 = (25%, 50%, 75%, 100%) replacements respectively

Fig. 2: The weekly growth performances of *C. gariepinus* fed the cassava peel meal based diets

Table 11: The anti-nutritional factors in cassava peel meals

ANF	Unfermented Cassava	Fermented Cassava
Cyanide (mg kg^{-1})	45.1	23.5
Phytate (mg $100g^{-1}$)	1012	698

Udoh and Umoren (2011) conducted an experiment to evaluate the proximate composition and digestibility of the nutrients and energy in protein-rich, carbohydrate–rich and oilseed feedstuffs available in Nigeria (Table 12) and concluded that these feedstuffs could effectively substitute fish meal for *Clarias gariepinus*. Bichi and Ahmad (2010) reported an optimum level of 66.7% replacement of fishmeal by cassava leaves in the formulation of practical diets for *Clarias gariepinus*. Malomo (2014) also reported that inclusion of different portions of sweet cassava root (*Manihot palmata*) in the diet of *Oreochromis niloticus* compared favorably with the control diet containing maize in growth, haematological parameters and survivability (Table 13). It was thus concluded that *C. gariepinus* and tilapia have the digestive potentials to digest many carbohydrate based products and that fish farmers should take advantage of this ingredient (cassava peels, root and leaf) as a replacement for more expensive maize and fishmeal when formulating feed for clarias and tilapia (Udoh and Umoren, 2011, Malomo, 2014).

Table 12: Proximate composition (g kg^{-1} diet) and gross energy (MJ kg^{-1}DM) of basal diet and test ingredients used in the determination of apparent digestibility coefficient of *C. gariepinus*

Diet	DM	CP	CF	CHO	EE	Ca	P	LS	MT	GE
Basal diet	938.99	273.84	63.16	560.42	79.06	11.42	7.98	14.16	9.71	20.25
Dried fish	950.25	350.07	17.56	450.37	85.66	59.55	30.65	42.72	20.41	20.10
Duckweed meal	923.53	248.28	120.63	545.20	57.44	12.00	8.00	17.80	4.41	19.56
Blood meal	895.91	762.87	15.03	470.93	12.02	2.84	9.66	69.05	10.02	21.84
Shrimp waste meal	795.34	589.33	335.81	385.33	36.28	87.20	16.82	30.95	54.00	17.52
Rice bran	910.33	133.82	123.00	630.50	24.08	4.50	4.68	5.90	2.50	18.33
Wheat offal	880.50	190.50	105.70	714.34	45.52	1.30	18.90	7.10	5.65	16. 56
Cassava root meal	870.21	251.62	28.56	886.34	6.80	1.03	5.66	7.56	3.67	17.21
Cocoyam root meal	882.80	285.50	36.87	910.30	33.60	8.98	2.18	7.22	3.12	17.24
Groundnut oilcake	900.20	453.65	50.05	427.20	110.50	2.60	8.90	18.75	6.60	18.31
Soybean oilcake	915.00	450.35	85.80	532.92	75.90	2.83	7.55	25.90	5.78	18.55
Sesame cake	850.25	386.81	78.35	358.98	155.76	25.55	12.10	10.36	23.81	17.21
Cotton seed oilcake	886.98	265.00	224.70	420.56	68.90	2.20	15.05	20.55	12.85	18.92

DM=Dry matter; CP=Crude protein, CF=Crude fibre; CHO=Total carbohydrate; EEether extract; Ca=Calcium; P=Phosphorous; LS=Lysine; MT=Cysteine+methionine; GE=Gross energy
(Source: Udoh and Umoren, 2011)

Table 13: Growth performance and nutrient utilization *O. niloticus* fed different portions of cassava root diets

Experimental Diets

Parameters	Control	Peel	Tuber	Starch	Chaff
IW (g)	6.99±0.02^{a}	6.86±0.09^{a}	6.88±0.09^{a}	6.87±0.06^{a}	6.88±0.04^{a}
FW (g)	9.42±0.69^{a}	8.98±0.20^{a}	8.49±0.21^{a}	8.69±0.39^{a}	8.59±0.47^{a}
WG (g)	2.44±0.67^{a}	2.11±0.21^{a}	1.61±0.15^{a}	1.82±0.35^{a}	1.71±0.47^{a}
FI (g)	3.96±0.20a	3.79±0.08^{a}	3.57±0.09a	3.65±0.16a	3.61±0.15a
Survival (%)	93.33±3.85^{a}	97.7767±2.22^{a}	95.55±2.22^{a}	95.56±4.44^{a}	93.33±3.85^{a}
SGR (% day^{-1})	0.46±0.01^{d}	0.39±0.01^{c}	0.30±0.01^{a}	0.33±0.01^{ab}	0.32±0.01^{b}
FCR	1.62±0.57^{a}	1.80±0.14^{a}	2.22±0.15^{a}	1.99±0.27^{a}	2.11±0.76^{a}

Mean ± S.E with different superscript are significantly different from each other ($p<0.05$). Note: IW = Initial Weight; FW = Final Weight; WG = Weight Gain; FI = Feed Intake; SGR = Specific Growth Rate; FCR = Feed Conversion Ratio.
(Source: Malomo, 2014)

Leaf Meal

The use of leaf protein concentrate as a potential dietary feed ingredient has also been evaluated with regard to tropical and subtropical plant leaves. Just as man is seeking herbal solution to his food and health requirements, various research efforts have been made to include leaf meal in fish diets, for food and health. Anti-nutritional factors in these leaves, as well as high fibre content of the leaves, have limited the use of these leaves adequately. Adewumi and Ola-Oladimeji (2016) supplemented fish meal with fermented mulberry (*Morus alba*) leaf meal in the diet of *Clarias gariepinus* juveniles and concluded that supplementation of up to 20% level is without adverse effects on the growth and nutrient utilization (Table 14) of the fish.

To get mulberry meal, fresh mulberry (*Morus alba)* leaves (variety S54) were obtained from a Sericulture farm and soaked inside water for three days, at room temperature, after which the fermented leaves were sun/air dried and milled into fine meal.

Table 14: The growth performance and nutrient utilization of the catfish fed mulberry based diets

	Diets				
Parameters	**A(0%)**	**B(10%)**	**C(20%)**	**D(30%)**	**E(40%)**
Initial Wt.	42.40[a]	42.92[a]	43.00[a]	43.75[a]	41.05[a]
Final Wt.	126.0[a]	122.10[a]	124.03[a]	100.21[b]	89.01[c]
DWG	1.55[a]	1.46[a]	1.50[a]	1.04[b]	0.88[b]
%Wt. Gain	197[a]	184[a]	188[a]	104[b]	89[c]
Survival %	100[a]	98[a]	100[a]	100[a]	97[a]
SGR	0.86[a]	0.88[a]	1.06[a]	0.73[b]	0.81[a]
FCR	1.33[a]	1.40[a]	1.41[a]	1.62[a]	1.85[a]

[a, b, c, d] Different sup erscripts within the same raw demonstrate significant differences.
(p>0.05). A0=Control, B10=10% replacement, C20=20% replacement, D30= 30% replacement, E40= 40% replacement, (Source: Adewumi and Oladimeji, 2016)

Adeparusi and Agbede (2005) conducted a study to evaluate the suitability of cucumber leaves (CL), squash leaves (SL), and broad bean leaves (BBL) meal, as alternative protein sources to replace soybean meal protein in the Nile tilapia diet. The results showed that fish groups fed on the diet contained 25% BBL had significantly higher growth performance and feed utilization, compared with the fish fed on the diet containing 25% CL and SL meals (Table 15). The authors reported that increasing the BBL substitution levels decreased the cost of raising the fish.

Table 15: Effect of replacing soybean meal protein with some plant leaves (CL, SL and BBL) on growth performance parameters of Nile tilapia diet

Treatment	**Initial Wt (g/fish)**	**Final Wt (g/fish)**	**Av. Daily Wt Gain (g/fish/day)**	**SGR**	**Survival (%)**
Control	23.30	45.76[a] ±1.58	0.25 [a] ±0.5	0.74[a] ±0.07	100
Cucumber leaves	23.30	41.77[b] ±0.24	0.20[b] ±0	0.64[b] ±0.01	99
Squash leaves	23.30	41.13[b] ±0.45	0.19[b] ±0	0.62[b] ±0.02	98
Broadbean leaves	23.30	44.43[a] ±1.44	0.23[a] ±0	0.71[a] ±0.03	99

a, b, c, d means in the same column bearing different letters differ significantly at 0.05 level.
(Source: Adeparusi and Agbede, 2005)

Recent Farm Adaptive Trial

Several combinations of the use of the locally available ingredients have been proposed by a number of researchers, based on formulations using the Pearson's method. Some groups of farmers in Ilesha, Osun state, Nigeria, adapted the following formulation for raising the African catfish, *C. gariepinus*, and recorded impressive success (1.8-3.2kg in 4months) (Table 17).

Table 16: The local dietary formulation (100kg^{-1}) for *C. gariepinus* in Ilesha, Nigeria

After 2 months		**After 3 months**		**After 4 months**	
Ingredients	Quantity	Ingredients	Quantity	Ingredients	Quantity
Maize	25.64	Maize	16.29	Maize	28.91
Indomie wastes	25.95	Indomie wastes	16.77	Indomie wastes	14.89
Local fishmeal	10.38	PKC	11.98	PKC	8.51
Full fat soybean	12.97	Full fat soybean	16.77	Full fat soybean	12.52
Blood meal	10.38	Local fishmeal	16.77	Local fishmeal	13.14
Bone meal	5.19	Blood meal	11.98	Blood meal	8.51
Lysine	0.75	Bone meal	4.06	Bone meal	6.39
Methionine	0.75	Oyster shell	5.38	Oyster shell	6.38
Salt	0.75	Lysine	0.75	Lysine	0.75
Grower's mix	0.75	Methionine	0.75	Methionine	0.75
Tonic (Masiyed)	6.49	Grower's mix	0.75	Grower's mix	0.75
TOTAL	100 Kg		100 kg	Salt	0.75
				TOTAL	100 kg

*1.8-3.2kg attained in 4months

In making efforts to utilize bio-wastes in fish feed formulations, it is imperative to take note of the following essential information before a formula is adapted. The feed requirements of fish vary in quantity and quality, according to their feeding habits, digestive anatomy as well as their size and reproductive state. Feed requirements of fish are also affected by environmental variations such as temperature and the amount and type of natural food available. Fish eat primarily to satisfy energy requirements. If there is too much energy compared with protein, animals will stop eating before they consume enough protein for maximum growth. Too much energy from dietary fat or carbohydrate can also lead to high body fat, low dress out yield and poor shelf life of the fish. If there is too little energy, compared with protein, part of the dietary protein will be used for energy. This obviously would not be economical. Generally the ratio of energy to protein increases as the animal gets bigger. The success of fish farming invariably depends on the provision of suitable and economical fish feed. However, besides ingredient specification, ingredient digestibility, ingredient palatability and nutrient utilization are usually recognized as the most important knowledge in order to judiciously use particular ingredient in feed formulation.

Conclusion

Many agro-industrial wastes (poultry wastes, fish wastes, indomie, gala, biscuit, maggots etc) have been used successfully in fish feed rations in Nigeria. The Waste Management Agencies should work towards pooling wastes to the required centers where they are needed for research and feed production. There is need for more research on the essential nutrient composition of the available feedstuffs and in collaboration with the industry, move towards adoption and commercialization of approved feed formulae. The feed industries should be mandated to adopt feed formulae utilizing wastes. The commercialization of locally formulated feeds will solve a greater part of the challenges confronting aquaculture development in Nigeria. Some foreign exchange can be saved and the inclusion of these agro-industrial waste materials in feed formulation, on a large scale is going to be a waste mop-up effort to mitigate climate change.

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