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Performance of Palm Kernel Shell as Nitrification Media for Aquaculture Wastewater at Varying Drying Time

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Keywords: *biofilter media, nitrification, ammonia removal, palm kernel shell, polypropylene.*

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I. Introduction

Recirculating aquaculture system (RAS) technology for high-density fish culture is one such technology that is becoming very popular throughout the world and has attracted considerable attention over the years due to its greatly reduced land and water requirements, a high degree of environmental control and high production rates (Bovendeur *et al.,* 1987). All recirculating aquaculture systems utilize processes to remove solid wastes, oxidize ammonia and nitrite-nitrogen, aerate and/or oxygenate the water (Ebeling et al., 1993).

Recently, many commercial biofilter media and operating systems have been developed and utilized on commercial scales. Sand, polypropylene bioblock, Polystyrene microbeads, and Kaldnes beads are commonly used as biofilter media. These media have their own advantages and disadvantages. Sand has high specific surface area (SSA) because the sand particles are small. However, because of the specific gravity of sand (i.e., 2.65), it is much heavier than water (Summerfelt, 2006), and thus a sand filter needs a strong pump to fluidize it (Wheaton et al., 1994). Polystyrene microbeads, on the other hand, are light, with a specific gravity of only 0.16 (Timmons et al., 2006). Due to its small size, the SSA of polystyrene microbeads is relatively higher than those of other biofilter materials (Malone and Pfeiffer, 2006). However, this lightness has also been found to result in loss of beads from the biofilter vessel in some operations due to hydraulic flushing from the biofilter vessel (Timmons et al., 2006). Kaldnes beads are also light, with specific gravity of 0.95 (Rusten et al., 2006). According to Rusten et al. (2006), one important advantage of this medium is the characteristic shape of the beads, which allows biomass to grow primarily on the protected surface. In Nigeria, commercial RAS facilities are essentially packaged units from Europe, and this constitute a loss in foreign exchange earnings for the country and also places expansion of RAS technology in the hand of foreigners (Akinwole, 2005). The needs to develop indigenous location specific RAS components have led to research into various local materials that can be used as different components of RAS.

This study investigated the performance of palm kernel shell, a locally available agricultural waste material as biofilter media in comparison with the commonly used synthetic injection-moulded polypropylene bioblock.

II. Materials and Methods

a) Biofilter media

i. Palm kernel shell

Palm kernel shell is the hard endocarp of palm kernel fruit which is the seed of oil palm tree *(Elaeis guineensis)* (Abiola, 2006). Palm kernel shells are obtained as crushed pieces after threshing or crushing to remove the palm seed for the production of palm kernel oil. Palm kernel shell has been estimated to constitute 34.5% of a single ripe fresh fruit (Aragbaiye,

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2007). Palm kernel shells are generated in large quantities and widely available in southern Nigeria. It is a natural material (Plate 1a) with specific surface area (SSA) of 166.53m^2/m^3, Bulk density of 800kg/m^3 void ratio of 28% and volume used as single biofilter unit (600mm heights of the housing) is 0.00977m^3.

ii. *Polypropylene bioblock*

The polypropylene bioblock is a synthetic material (Plate 1b) of injection-moulded type, it has SSA of 166.67m^2/m^3, bulk density of 400kg/m^3, void volume of 92% and the volume used as single biofilter unit (600mm heights of the housing) is 0.00924m3.

b) Description of Biofilter Units

The filter housing was prepared in line with the nitrification column described by Dauda et al., (2014). Six biofilters were used, both media have three replicates each.

c) Aquaculture Wastewater

Aquaculture effluent was obtained from the University of Ibadan fish farm earthen pond being used for integrated aquaculture of fish, rice and pig. The operating condition of culture system during the period of the wastewater sampling is shown in table 1

Table 1: Operating condition of the integrated fish culture system used for wastewater sampling

Parameters	Integrated system
Organisms cultured	*Clarias gariepinus*,
Rice and Pigs	
Age of the fish (Weeks)	14
Age of the Pigs (Weeks)	28
Age of the Rice (Weeks)	17
Feed type	Sinking pellet
Feeding frequency/day	Twice
% Crude Protein in Feed	28
Type of water holding facilities	Earthen
Water Source	Seepage
Water exchange rate	less frequently
No of Fish stocked	1,120
No of Pigs	10
Flushing of pig waste into pond	Once in a week
No of rice cultivated (strands)	857
Volume of water in the holding structure (m^3)	150.84

A: Palm kernel shell (PK)

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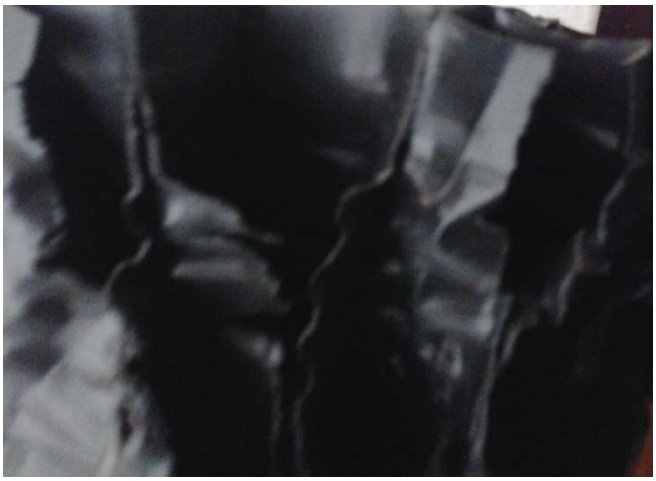

B: Polypropylene bioblock (PP)

Plate 1 : The two biofilter media evaluated in the experiment

d) Experimental Procedure

The filter housings were pre filled with gravel of 40mm diameter up to 150mm height, this was done for all the filter housings to ensure uniformity following the procedure of Akinwole (2005). This is primarily essential for the PK to prevent the strands of the shell from going out with the filtrate. PP block was cut and inserted into the housing in line with Dauda et al. (2014), the palm kernel shell was sieved to remove sand particles and later put in basket in batches, thoroughly washed with water and soaked in water for three days in order to remove impurities. The PK was later sundried for two days and kept in water proof sacks before loading into the filter housing up to 600mm height to fill up to 750mm height of the housing unit.

The biofilter media was inoculated with aquaculture wastewater and left for 24 hours before commencement of the experiment. Five litres of the wastewater was run through the column and the filtrate was collected in the receiving container. The filtrate was collected as described by Dauda et al., (2014) for determination of residence time and rate of biofiltration. Sixty centiliters (60cl) of the well drained filtrate was collected for the selected water quality parameters analysis and the whole experiment was repeated for 24 hours, 72 hours and 144 hours drying times. Change in the selected water quality parameters was used to assess the performance of the biofilter. The experiment was done in triplicates.

e) Water Quality Analysis

Dissolved oxygen (DO), Total Ammonia Nitrogen (TAN), pH, Temperature, Nitrate-nitrogen and Nitrite-nitrogen were determined for both the influents and the filtrates and all the analysis were done as described by Dauda et al., (2014).

f) Performance Assessment of the Biofilter Media

Performance of the media was evaluated using the degree of change in the selected water quality parameters while the nitrification efficiency of the biofilters was determined using the Percentage total ammonia-nitrogen removed (PTR) and Volumetric total ammonia-nitrogen conversion rate (VTR) as suggested by Colt et al., (2006).

$$PTR = \frac{TAN_{in} - TAN_{out} \times 100}{TAN_{in}}$$

$$VTR\ (mg\ TAN/m^3d) = \frac{86{,}400Q\ (TAN_{in} - TAN_{out})}{V}$$

TAN_{in} is the concentration (mg/L) of total ammonia nitrogen of the aquaculture effluent,

TAN_{out} is the concentration (mg/L) of total ammonia nitrogen of the filtrate,

V is the volume (m^3) of the media,

Q is the biofilter flow (m^3/day),

8,640 is a conversion factor from seconds to day (60x60x24).

g) Statistical / Data Analysis

Simple descriptive statistics was used to determine the mean and standard deviation of the selected water quality parameters, change in water quality parameters, residence time and biofiltration rate. The mean of the TAN was used to evaluate the Volumetric TAN conversion rate (VTR) and Percentage TAN removed (PTR) in the column. T-test was used to determine if the difference in the selected water quality parameters, change in selected water quality parameters, residence time , biofilter flow, PTR and VTR was significant between the two media for all the drying time at $P < 0.05$. ANOVA and Duncan multiple range test were used to determine if there was significant difference in biofilter flow, PTR and VNR among the three drying time in each biofilter media and to determine the exact pairs that were significant respectively. IBM SPSS version 20 was used for all the statistical analysis.

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h) Biofilter Media Economics

The biofilter media economics was done by evaluating the cost of components and operation of a unit of the biofilter assembly. Comparison was made between the cost of the two biofilter media and the cost involved in the operation of the two media. The biofilter unit consists of wooden frame, the PVC columns, the funnels, filtrate collectors, polythene bag and the biofilter media (PP and PK). Therefore the unit cost was determined by evaluating the cost of all the materials used in making a biofilter unit.

III. Results and Discussion

a) Water quality amendment

Temperature is an important water quality parameter in fish culture according to Le Morvan and Deschaed, (1995), it controls the rate of reaction in organisms, sudden and extreme change in temperature would cause a shock to the fish and could lead to stress. The temperature reported in the filtrates during the study were 28.33±0.58^{0}c, 27.83±0.29^{0}c and 27.17±0.29^{0}c for the three drying time of 24, 72 and 144 hours in the PP filtrate while 27.67±0.29^{0}c, 27.00±0.50^{0}c and 26.33±0.58^{0}c were recorded for the three drying time 24, 72 and 144 hrs respectively in the PK filtrates (table 2). All the temperature recorded were suitable for warm water fish culture (Ajani et al., 2011), and safe for discharge (< 40^{0}c) into the environment (FEPA, 1988). The temperature in PP filtrates was higher than that of PK at all the drying time. T-test showed significant difference in temperature between the two media at 72 and 144 hrs. The change in temperature between the influent and the effluent for the PP filtrate were -0.33±0.58^{0}c (-1.18%), -0.83±0.29^{0}c (-3.07%), and -0.17±0.290c (-0.63%) for 24, 72 and 144 hrs drying time respectively while for PK 0.33±0.29^{0}c (1.18%), 0.00±0.50^{0}c (0.00%) and 0.67±0.58^{0}c (2.48%) where recorded for the 24, 72 and 144 hrs drying time respectively (table 3). PP had negative value for all the drying time while PK had positive values at 24 and 144 hrs, this indicated higher temperature in the filtrates and can be attributed to the metabolic activities of the nitrifying bacteria. The change in temperature between the media for all the drying times were very close with highest difference of 2.48% recorded in 144 hrs for PK. T-test did not show any significant difference between the two media except at 144 hrs. The low percentage change at all the drying time indicated a relatively stable system and hence the cultured organisms would be saved.

Table 2 : Mean values of Selected water quality parameters for the nitrification columns

Parameter	Influent	PP	PK
24 HRS			
Temperature (^{o}c)	28.00±0.00	28.33±0.58^a	27.67±0.29^a
Dissolved Oxygen (mg/L)	3.00±0.00	3.47±0.12^a	4.77±0.31^b
pH	7.60±0.00	7.23±0.12^a	7.50±0.10^b
NH_4-N(mg/L)	0.80±0.00	0.53±0.23^a	0.47±0.12^a
NO_2-N (mg/L)	0.15±0.00	0.15±0.00^a	0.01±0.00^b
NO_3-N(mg/L)	0.00±0.00	40.00±17.32^a	5.00±5.00^b
72 HRS			
Temperature (^{o}c)	27.00±0.00	27.83±0.29^a	27.00±0.50^b
Dissolved Oxygen (mg/L)	4.00±0.00	4.00±0.17^a	5.33±0.58^b
pH	7.80±0.00	7.30±0.10^a	7.33±0.06^a
NH_4-N(mg/L)	0.80±0.00	0.53±0.23^a	0.40±0.00^a
NO_2-N (mg/L)	0.01±0.00	0.07±0.07^a	0.01±0.01^a
NO_3-N(mg/L)	0.00±0.00	3.33±2.89^a	5.00±0.00^a
144HRS			
Temperature (^{o}c)	27.00±0.00	27.17±0.29^a	26.33±0.58^b
Dissolved Oxygen (mg/L)	4.00±0.00	4.80±0.20^a	5.60±0.17^b
pH	7.40±0.00	7.37±0.12^a	7.27±0.06^a
NH_4-N(mg/L)	0.80±0.00	0.53±0.12^a	0.47±0.12^a
NO_2-N (mg/L)	0.02±0.00	0.03±0.00^a	0.01±0.00^b
NO_3-N(mg/L)	0.00±0.00	6.67±2.89^a	1.67±2.89^b

Values (mean±SD of the three replicates) in the same row with different letters as superscripts are significantly different at P < 0.05

Oxygen is necessary for respiration in all organisms except for anaerobic organisms. In culture water it is present in dissolved form and the amount present is very important for fish survival (Gehrke, 1991). The DO oxygen of the PP filtrates were 3.47±0.12mg/L, 4.00±0.17mg/L and 4.80±0.20mg/L while PK had 4.77±0.31mg/L, 5.33±0.58mg/L and 5.60±0.17mg/L for 24, 72 and 144 hrs respectively (table 2). The dissolved oxygen in the filtrates were within the recommended level for fish culture (Ajani et al., 2011) and also safe for discharge into the environment (FEPA 1988). The DO (>2mg/L)can support the metabolic

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activities of the nitrifying bacteria (1995), The difference in DO between the two media was significant at all the drying time. The change in DO between the influent and the effluent were -0.47±0.12 mg/L (-15.67%), 0.00±0.17 mg/L (0.00%) and -0.80±0.20 mg/L (-20.00%) for the PP filtrate and -1.77±0.31 mg/L (-59.00%), -1.33±0.58 mg/L (-33.25%) and -1.60±.17 mg/L (-10.00%) across the 24, 72 and 144 hrs drying time respectively (table 3). The negative values recorded in most of the treatment indicated that the filtrates DO were higher than that of the influents and this is contrary to observation of Akinwole (2005). This may be due to the higher void ratio of PP and PK compared to that of sand used as biofilter media by Akinwole (2005), the cascading movement of the wastewater in the media may account for the increase. Change in DO was only significant between the two media at 144hrs.

Table 3 : Change in selected water quality parameters for the nitrification columns

Parameter	PP (%)	PK (%)
24 HRS		
Temperature (^{0}c)	-0 .33±0.58^a (-1.18)	0.33±0.29^a (1.18)
Dissolved oxygen (mg/L)	-0.47±0.12^a (-15.67)	-1.77±0.31^a (-59.00)
pH	0.37±0.12^a (4.87)	0.10±0.10^a (1.32)
NH_4-N (mg/L)	0.27±0.23^a (33.75)	0.33±0.12^a (41.25)
NO_2-N (mg/L)	0.00±0.00^a (0.00)	0.14±0.00^a (93.35)
NO_3-N (mg/L)	-40.00±17.32^a (NA)	-5.00±5.00^a (NA)
72 HRS		
Temperature (^{0}c)	-0.83±0.29^a (-3.07)	0.00±0.50^a (0.00)
Dissolved oxygen (mg/L)	0.00±0.17^a (0.00)	-1.33±0.58^a (-33.25)
pH	0.50±0.10^a (6.41)	0.47±0.06^b(6.03)
NH_4-N (mg/L)	0.27±0.23^a (33.75)	0.40±0.00^a (50.00)
NO_2-N (mg/L)	-0.06±0.07^a (-600.00)	0.00±0.01^a (0.00)
NO_3-N(mg/L)	-3.33±2.89^a (NA)	-5.00 ±0.00^b (NA)
144 HRS		
Temperature (^{0}c)	-0.17±0.29^a (-0.63)	0.67±0.58^b (2.48)
Dissolved oxygen (mg/L)	-0.80±0.20^a (-20.00)	-1.60±.17^b (-10.00)
pH	-0.03±0.12^a (0.41)	0.13±.03^b (1.76)
NH_4-N (mg/L)	0.27±0.12^a (33.75)	0.33±0.12^a (41.25)
NO_2-N (mg/L)	-0.01±0.00^a(-50.00)	0.01±0.00^b (50.00)
NO_3-N (mg/L)	-6.67±2.89^a (NA)	-1.67±2.89^b (NA)

Values (mean ±SD of the three replicates) in the same row with different letters as superscripts are significantly different at P < 0.05
NA means not applicable

PH is an important water quality parameter in recirculating systems because various processes such as nitrification and optimum health of the fish are related to the optimum pH in the water (Al-Hafedh et al., 2003). The pH recorded for the PP filtrates were 7.23±0.12, 7.30±0.10 and 7.37±0.12 while 7.50±0.10, 7.33±0.06 and 7.27±0.06 were recorded for PK filtrate across 24, 72 and 144 hrs drying time respectively (table 2). The difference in pH was only significant at 24 hrs. All the pH values were within the recommended range by Ajani et al., (2011) for warm water fish culture and for discharge to the aquatic environment (FEPA, 1988) as well as fell within optimum range for nitrifying bacteria, as stated by Michael et al. (1995), below a pH of 6.8 bacteria are inhibited and do not remove the toxic nitrogenous waste. The change in pH, 0.37±0.12 (4.87%), 0.50±0.10 (6.41%) and -0.03±0.12 (0.41%) were observed in the PP filtrates while, 0.10±0.10 (1.32%), 0.47±0.06 (6.03%) and 0.13±.03 (1.76%) were observed in the PK for 24, 72 and 144 hrs drying time respectively (table 3). The percentage change was low for all the drying time, this indicated that the system is stable. The differences between the change in pH was significant for 72 and 144 hrs drying time.

Total ammonia nitrogen (TAN) is the most critical water quality parameter in intensive recirculating systems (Al-Hafedh et al., 2003). It consists of two fractions, un-ionized ammonia (NH3) and ionized ammonia, of which the former is extremely toxic to fish, Ajani et al., (2011) noted fish continuously exposed to more than 0.2mg/L of the un-ionized form of ammonia may exhibit reduced growth and increased susceptibility to disease. The TAN recorded for PP filtrates during the study period were 0.53±0.23mg/L, 0.53±0.23mg/L and 0.53±0.12mg/L for the 24, 72 and 144 hrs drying time respectively and 0.47±0.12mg/L, 0.40±0.00mg/L and 0.47±0.12mg/L for the 24, 72 and 144hrs drying time respectively for the PK filtrates (table 2). All the TAN reported were still within the recommended level (< 8.8 mg/L) for warm water fish culture (Akinwole, 2005). Though there was no significant difference between the two media for all the three drying time, the PK performed

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better at all the drying time. Although the TAN was higher than that of 0.02mg/L reported by Ridha and Cruz, (2001), but it is lower than 0.92mg/L) reported by Al-Hafedh et al., (2003). The change in TAN for the PP filtrates were 0.27±0.23 mg/L (33.75%), 0.27±0.23 mg/L (33.75%) and 0.27±0.12 mg/L (33.75%) and 0.33±0.12 mg/L (41.25%), 0.40±0.00 mg/L (50.00%) and 0.33±0.12 mg/L (41.25%) for the PK filtrates across the 24, 72 and 144 hrs respectively (table 3).

NO_2-N is a product of ammonia oxidation and is toxic to fish above 0.5mg/L (Ebeling et al., 1993). The NO_2-N in the PP filtrates were 0.15±0.00mg/L, 0.07±0.07mg/L and 0.03±0.00mg/L while 0.01± 0. 00 mg/L, 0.01±0.01mg/L and 0.01±0.00mg/L were recorded for the PK filtrates at the 24, 72 and 144 hrs drying time respectively (table 2). All the nitrite-nitrogen values were within the recommended level for warm water fish culture (Ajani et al., 2011). The difference in NO_2-N between the two media was significant at 24 and 144hrs drying time. The PP filtrate had higher NO_2-N than the PK filtrate at all the drying time, this suggested that PK is slightly better in terms of NO_2-N. This could be attributed to higher biofiltration rate in PP than PK, Abeysinghe et al., (1996) also noted that increase in biofilter flow will result in NO_2-N accumulation. The change in NO2-N for the PP filtrates were 0.00±0.00mg/L (0.00%), -0.06±0.07mg/L (-600.00%) and -0.01±0.00mg/L (-50.00%) for the 24, 72 and 144 hrs drying time respectively and 0.14±0.00mg/L (93.35%), 0.00±0.01mg/L (0.00%) and 0.01±0.00mg/L (50.00%) for the PK at the 24, 72 and 144 hrs drying time respectively. The change in NO_2-N is only significant at 144hrs drying time.

NO_3-N is one of the products of ammonia oxidation, though it is not generally considered to be of serious concern to fish culture (Ebeling et al., 1993) except at very high concentration of above 200mg/L but it can constitute nuisance to the environment even as low as 20mg/L. The NO_3-N recorded during the study period were 40.00±17.32mg/L, 3.33±2.89mg/L and 6.67±2.89 mg/L for the PP filtrates and 5.00±5.00mg/L, 5.00±0.00mg/L and 1.67±2.89mg/L for the PK filtrates for 24, 72 and 144 hrs drying time respectively (table 2).The difference in NO_3-N between the two media was significant at 24 and 144 hrs drying time. The change in the NO_3-N between the influents and the filtrates were -40.00±17.32mg/L (NA), -3.33±2.89mg/L (NA) and -6.67±2.89mg/L (NA) for the PP filtrates and -5.00±5.00 mg/L (NA), -5.00 ±0.00 mg/L (NA) and -1.67±2.89 mg/L (NA) for the PK for the 24, 72 and 144 hrs drying time respectively (table3). The negative values indicated that the filtrate had higher NO_3-N than the influent wastewater for all the drying time in the two media and hence there is nitrification. Change in NO_3-N between the two media was significant at 72 and 144hrs and PK seems to do better as the nitrate-nitrogen in the filtrates fell within the safe limit for the environment therefore the use of PK may save the environment from excessive enrichment with nutrient.

Table 4 : Effluent residence time and biofilter flow in the nitrification columns

Drying time (Hrs)	PP	PK
Residence time (s)		
24hrs	77.67±2.30^{a1}	96.00±5.00^{b1}
72hrs	63.67±3.06^{a2}	91.33±4.16^{b2}
144hrs	74.33±1.15^{a1}	76.67±5.03^{a3}
Biofilter flow (x10^{-5}m^3/s)		
24 Hrs	5.80±0.18^{a1}	4.70±0.24^{b1}
72 Hrs	7.80±0.33^{a2}	4.93±0.22^{b2}
144Hrs	6.05±0.00^{a1}	5.89±0.38^{a3}

Values (mean ±SD of the three replicates) in the same row with different letters as superscripts are significantly different at $P < 0.05$

Values (mean ±SD of the three replicates) in the same column with different figures as superscripts are significantly different at $P < 0.05$

b) Residence time and biofilter flow

Water residence time is the period the sample spent in the column, this is naturally dependent on the void ratio of the media among other factors such as loading height and size of the container opening. The PP had residence time of 77.67±2.30s, 63.67±3.06s and 74.33±1.15s respectively for the 24, 72 and 144 hrs drying time while for the PK 96.00±5.00s, 91.33±4.16s and 76.67±5.03s were recorded for the three drying time respectively (table 4). The PK had higher residence time for all the drying time and this can be attributed to its lower void ratio compared to PP. The difference in residence time between the two media was significant at 24 and 72 hrs drying time. ANOVA showed significant difference between 24hrs and 72hrs and between 72hrs and 144 hrs drying time for the PP in both while for PK the significant difference was among the three drying time.

Biofilter flow is dependent on the residence time and void volume of the media. The biofilter flow for the the PP were 5.80±0.18 x10-5m3/s , 7.80±0.33 x10-5m3/s and 6.05±0.00 x10-5m3/s while PK had

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4.70±0.24 x10-5m3/s, 4.93±0.22 x10-5m3/s and 5.89±0.38 x10-5m3/s for the 24, 72 and 144 hrs drying time respectively (table 4). The biofilter flow is generally higher in PP for all the drying time, the difference in biofilter flow between the two media was significant at 24 and 72 hrs drying time, this can be attributed to high void volume of PP compared to PK. ANOVA showed significant differences between 24hrs and 72hrs as well as between72hrs and 144 hrs drying time in the PP while in the PK ANOVA showed significant differences among all the drying time.

Table 5 : Nitrification efficiency of the two biofilter media

Parameter	PP	PK
	Percentage total ammonia removed (PTR)	
24 Hrs	33.75±28.88[a1]	41.25±14.43[a1]
72Hrs	33.75±28.88[a1]	50.00±0.00[a1]
144 Hrs	33.75±14.43[a1]	41.25±14.43[a1]
	Volumetric Total ammonia conversion rate (VTR) in mg TAN/m^3d	
24 Hrs	142.04±123.01[a1]	145.95±51.54 [a1]
72Hrs	120.39±104.42 [a1]	264.76±12.53[b2]
144 Hrs	150.63±63.91[a1]	182.66±64.19[a12]

Values (mean ±SD of the three replicates) in the same row with different letters as superscripts are significantly different at P < 0.05

Values (mean ±SD of the three replicates) in the same column with different figures as superscripts are significantly different at P < 0.05

c) Nitrification efficiency of the biofilter media

Nitrification efficiency is based on TAN concentration reduction (Al-Hafedh *et al.,* 2003), and in line with Colt et al. (2006), it can be measured using Percentage TAN removed (PTR) and Volumetric TAN conversion rate VTR in mg TAN/m^3d. The PTR in the PP filtrates were 33.33±28.88%, 33.33±28.88% and 33.33±14.43% while in PK filtrates the PTR were 41.67±14.43%, 50.00±0.00% and 41.67±14.43% for 24, 72 and 144 hrs drying time respectively (table 5). T-test did not show any significant difference between the two media for all the drying. ANOVA did not show any significant difference among the three drying time for the PP and PK. The PTR can be regarded to be generally low when compared with Akinwole, (2005) that recorded as high as 93% modification, but this is better than that of Al-Hafedh (2003), who reported 25.49%, 21.02% and 21.19% for Plastic rolls, plastic scrub pads and PVC pipes respectively. The PK did better at all the drying time. The PP had VTR of 142.04±123.01mgTAN/m3d, 120.39±104.42mgTAN/m3d and 150.63±63.91mgTAN/m3d for 24, 72 and 144hrs drying time respectively while the PK had VTR of 145.95±51.54mgTAN/m3d, 264.76±12.53mgTAN/m^3d and 182.66±64.19mgTAN/m3d for the three drying time respectively (table 5). The difference in the VTR between the two media was shown to be significant at 72 hrs while among the drying time there was no significant difference in PP but PK had significant differences between 24hrs and 72hrs. The performance of the system was also varied with drying time, this is establishing that drying time have effect on the performance of the media, especially in PK where the difference in VTR have significant difference between 24 and 72 hrs drying time. All the drying time showed good biofiltration performance, this indicated that farmers can run there biofilter for just 24 hours before loading it with cultured fish especially in RAS being used for fingerlings or juvenile culture where ammonia load is not excepted to be very high but for a system where high ammonia load is expected such as a system for culture of grow out fish, 72 hours drying time is better because the system give the maximum performance at 72 hours drying time.

d) Filter media economics

The unit biofilter comprised biofilter columns, filtrate collectors, funnels, solid end plug PVC, polythene bags, wooden frame and the two biofilter media evaluated (PP and PK). The cost involved is common to the two media evaluated except the cost of the biofilter media themselves and cost of water for backwashing (cleaning). The total cost of the biofilter assembly excluding the cost of the media is ₦3,770 and this cost is common to the two biofilter media under evaluation. Therefore comparison was only made using the items that are varied between the two media. The PP used in a biofilter unit is evaluated to be ₦231 while the PK is evaluated to be ₦58.62, the PP was backwashed with 5 litres of water evaluated to be ₦5 while for the PK 25 litres of water was used in backwashing at a cost of ₦25 (table 6). The cost of biofilter media and backwashing in PP is ₦236 while in PK it is ₦83.62. The PK had a surplus value of ₦152.38 when compared with PP. The economic analysis showed that the cost of installation and operation is higher in PP than PK.

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Table 6 : Components and operation cost of a biofilter unit for the two media

Components (units)	Unit cost (₦)	Quantity used	Cost for the PP (₦)	Cost for the PK (₦)
Fixed costs				
PVC housing (m)	500	1.2	600	600
Wooden frame	5,000	½	2,500	2,500
Funnel	100	1	100	100
Filtrate collector	170	1	170	170
PVC Solid end plug	400	1	400	400
Subtotal (₦)			3,770	3,770
Operating cost				
Polypropylene bioblock (m^3)	25,000	0.00924	231	NA
Palm kernel shell (m^3)	6,000	0.00977	NA	58.62
Water for backwashing (litre)	1	5	5	NA
Water for backwashing (litre)	1	25	NA	25
Subtotal for the media and operation (₦)			236	83.62
Grand total (₦)			4,006	3,853.62

*All costing were done using the prevailing price at the 'time of study (2013)' in Nigeria

IV. Conclusion

Findings in the study established that Palm kernel shell is a good biofilter media. It was able to produce change in the selected water quality parameters that are within the limit for discharge into the environment and also safe for reuse in fish culture. The media can perform well at 24 hours, 72 hours and 144 hours drying time though 72 hours showed best performance and this is therefore encouraged. It can be establish that PK (a local material) is better than PP (a synthetic and imported material) as a biofilter media and it is also available at a cheaper price. Further research on the performance of the media is therefore recommended under continuous loading conditions as would be expected in a commercial aquaculture water reuse systems.

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