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Partial Characterization and Use of Activated Charcoal from Different Sources in Pollution Abatement in Aquaculture

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Received: December 13, 2021 Accepted: February 20, 2022

ABSTRACT Controlling aquaculture pollution and water management is a challenge especially in water-scarce areas. A study was conducted to characterize and assess the effectiveness of activated charcoal from mango wood (MWAC, coconut shell (CSAC) and Indian bamboo wood (IBAC) in removal of pollutants from aquaculture water. One hundred and twenty (120) *Clarias gariepinus* fingerlings of initial average weight 2.3±0.1g were assigned to four treatment groups with different activated charcoal-types in a completely randomized design; each having three replicates. Treatment 1 contained MWAC; treatment 2 contained CSAC; treatment 3 contained IBAC and treatment 4 had no charcoal and served as control. The experiment lasted for 9 hours. The data collected were analyzed using SPSS® (version 20). The result obtained revealed that MWAC had the highest iodine number. MWAC and CSAC generally performed better in reduction of alkalinity, total ammonia nitrogen, phosphate, nitrites and dissolved oxygen; with MWAC having a relatively better adsorptive strength in comparison to CSAC. CSAC and IBAC were almost at par in pH regulation with IBAC having a relatively lower pH reduction in the 3rd hour than CSAC. IBAC recorded the highest conductivity value than MWAC and CSAC. The study showed that MWAC has better prospects to serve as adsorbent for use in pollutant removal from aquaculture water than CSAC and IBAC respectively. It is recommended that utilization of activated charcoal from Mango and coconut shell should be enhanced and optimized for use in pollutant removal in aquaculture, including the time needed to remove and replace activated charcoal in a tank.

KEYWORDS Activated charcoal, Aquaculture, Pollution, water quality, Wood

Introduction

Water is life and the quality and adequacy of water is an essential measure of the quality of life. Water quality is a term used to describe the chemical, physical and biological characteristics of water, usually in respect to its suitability for a particular purpose. Scientific measurements are used to define water quality. It is the quality of natural water that makes it suitable for aquatic plants and animals. Water quality is closely linked to water use and to the state of economic development (Desbureaux *et al.*, 2019).The management of water quality, or the protection of the aquatic ecosystem in a broader sense, means the control of pollution (Bhatnagar & Sillanpaa, 2017).

Water pollution is the introduction of substances by man directly or indirectly, that can cause harm to living resources, hazard to human health, hindrance to aquatic activities and impairment of water quality with respect to its use in agriculture, industrial and other economic activities (Denchak, 2018). The major sources of pollution include domestic and industrial wastewater discharges, mining, surface runoff and agrochemicals (Denchak, 2018). The contaminants associated with these sources include organic chemicals (pesticides and herbicides), inorganic chemicals (acids, alkalis, salt and metals),

nutrients (nitrogen and phosphorus), pathogens (bacteria, viruses and parasites), radioactive materials (uranium, thorium, caesium, iodine and radon), sediment (soil and silt) and solid waste (Matilainen *et al*., 2010).

There is an on-going debate on the implications of growing aquaculture production on the balance of the ecosystem. It has been shown by Boyd (2011) that aquaculture contributes to nutrient enrichment of the ecosystem (i.e. nitrogenous and phosphorus-containing compounds), salinization of freshwater, sedimentation of natural water, release of drugs, antibiotics and other chemicals to the aquatic ecosystem, etc. These are the major pollutants from aquaculture effluent discharges. Adopting measures to remove these pollutants from aquaculture water can reduce water exchange rate, thereby reducing the amount of water used and associated costs. Removal of these pollutants can help in the conservation of the ecosystem of the water bodies where effluent discharges are to be made. In this study we focus on removal of nutrients.

Activated carbon (charcoal) is an amorphous form of carbon in which a high degree of porosity has been developed during manufacturing or treatment. This high degree of porosity and associated large surface area make it an excellent adsorbent for a wide variety of heavy metals in both liquid and gaseous phases (Omeiza *et al*., 2011).The use of "carbon" dates back to ancient Egypt (1500BC) where it was employed for medicinal purposes. Later in ancient Greece, wood chars were used to treat host of ailments (Omeiza *et al*., 2011). It is also used in odor removal from wounds (Akhmetova *et al*., 2016) and as decolorizing agent for sugar (Aljohani *et al*, 2018). A wide variety of agricultural by-products and agricultural wastes comprising mostly cellulose matrix were tried by different workers for removal of heavy metals from their aqueous solutions. These include; saw dust , cotton, fibre , biomass of fungi and yeast, plantain stem, sugar refinery wastes, *Carica papaya* seed (Omeiza *et al*., 2011; Adinaveen *et al*., 2014; Bhatnagar & Sillnanpaa, 2017; Ekpete *et al*., 2017; Saleem *et al*., 2019), etc. The preparations of activated carbon from agricultural wastes is motivated by cost considerations (relatively cheaper), local generation in developing countries and effectiveness in the removal of heavy metals (Bhatnagar & Sillnanpaa, 2017).

Nwabuisi (2018) researched on the efficacy of activated charcoal in removal of ammonia from aquaculture water and found that the charcoal adsorbed ammonia but after some time, shortly after 5 hours, if it was not removed and reactivated, the ammonia would be released back into the water (Nwabuisi, 2018). The study did not specify the source of the activated charcoal employed in it nor did it report on the characteristic qualities of the charcoal utilized (i.e. the iodine number of the activated charcoal used). Mianowski *et al.* (2007) reported that the value of iodine number is an indication of the level of activation Thus, there is need to determine some characteristic qualities of the activated charcoal used in aquaculture water purification in order to make proper comparison with other studies. .There is also need to find out if the source of charcoal affects its capacity to purify aquaculture water. The aim of this study is to characterize and determine the pollutant removal strengths of activated charcoal from mango wood (MWAC), coconut shell (CSAC) and Indian bamboo (IBAC) sources in removal of some pollutants (ammonia, nitrites and phosphorus) from aquaculture water and to assess the associated variations in some other physicochemical parameters

Materials and Methods

Study Area

The research was conducted at Nnamdi Azikiwe University (NAU) Awka, Anambra State, Nigeria. It has the geo-coordinates: between Latitude 6.245° and 6.283° N and Longitude 7.115° to 7.121° E (Figure 1). The temperature in Awka is generally 27-30° C between June and December but rises to 32-34° C between January and April with the last few months of the dry season marked by the intense heat. It has an average annual temperature of 26.3° C. It has a rainfall pattern ranging from 1828 mm – 2002 mm. The climate of Awka falls within the tropic wet and dry type based on Koppen's classification (Ezenwaji *et al.*, 2013 and Chukwu *et al.*, 2020).

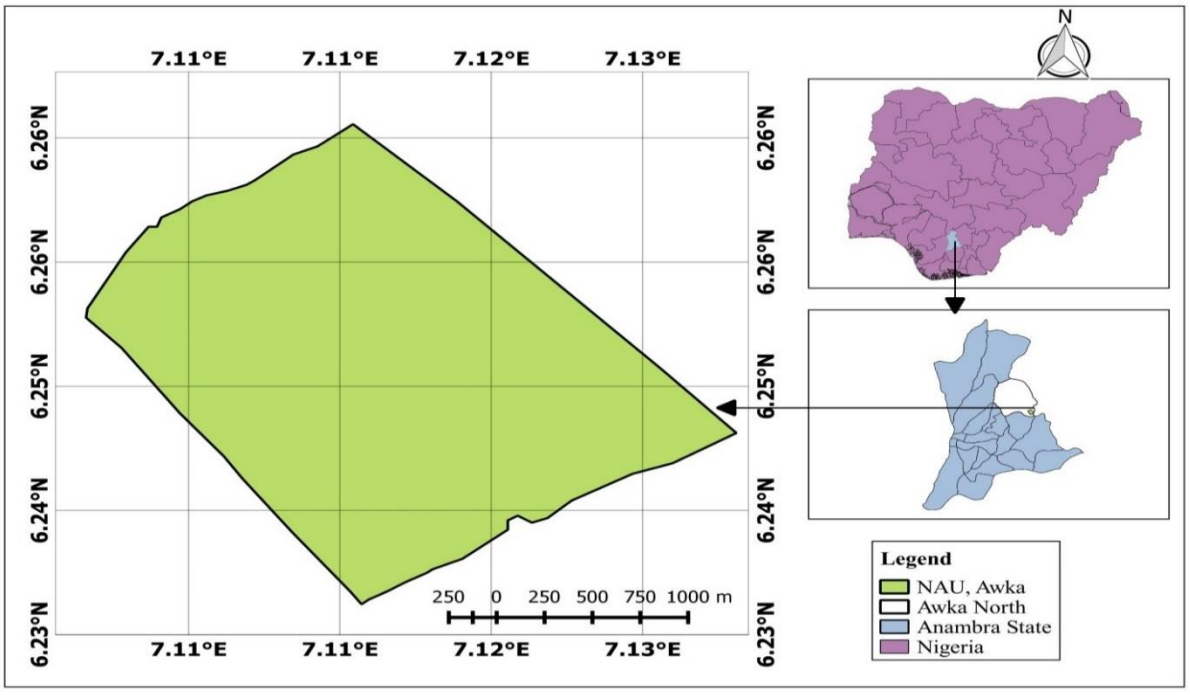

Figure 1: Map of Nnamdi Azikiwe University, Awka, Nigeria
Source: Chukwu *et al.* (2020)

Experimental Fish

One hundred and twenty (120) *Clarias gariepinus* fingerlings of initial average weight (2.3±0.1g) were sourced from the Department of Fisheries and Aquaculture Management Research Farm, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria and were acclimatized for 14 days at which time they were fed with a floating commercial fish feed (2 mm extruded pellets) at 5% body weight per day (bwd) (Agro, 2017) in two rations. During acclimatization, the culture water was renewed every three days until the 9th day and was left afterwards without change so as to ensure relatively high accumulation of pollutants.

Experimental Design

The experiment was conducted using 12 plastic bowls having the water capacity of 25 L and 10 fingerlings per tank; with each containing 20 liters of borehole water. The fish were divided into four treatment groups with each having three replicates in a completely randomized design (CRD): treatment 1 contained activated charcoal from mango wood; treatment 2 contained activated charcoal from coconut shell; treatment 3 contained activated charcoal from Indian bamboo wood and treatment 4 had no charcoal and served as control. Twenty grams (20 g) of activated charcoal in a sealed muslin sack was used in each replicate. The following physiochemical parameters were monitored three-hourly for nine hours to determine if there were changes: alkalinity, total ammonia nitrogen, total phosphorus, nitrites, pH, temperature, dissolved oxygen and conductivity.

Sample Collection for Charcoal production

Fresh Indian bamboo and Mango Wood were collected from Awka environment while the coconut shell was sourced from Eke-Awka, a daily market in Awka. The mango woods were freshly harvested from a mango tree in Nise Village, Awka while the Indian bamboos were collected from a building site in Ifite, Awka . They were then transferred to the laboratory where they were then dried for about two weeks and then weighed before being subjected to carbonisation through the use of an incinerator according to FAO (1987) standard.

Prior to carbonisation they were all weighed and cut into small pieces. After which 3 kg was weighed using sensitive scale KERRO BL2000 and taken from each sample of Mango wood, Coconut shell and Indian bamboo were then subsequently carbonised in furnace at the following temperatures and time: 700℃ for 5hours, 690℃ for 3 hours and 640℃ for 2 hours respectively.

Carbon black Yield: This was determined using the formula;

$$yield\ (\%) = \frac{W_c}{W_o} \quad \text{(i)}$$

Where;

Wc = dry weight (g) of the sample after carbonization

Wo = initial dry weight (g) of the sample (AOAC, 2000)

Determination of iodine number: The iodine number is determined according to the ASTM D4607-94 method. The iodine amount adsorbed per gram of carbon (X/M) was calculated as;

$$Iodine\ \left(\frac{g}{c}\right) = N_1 \times 126.92 \times V_1 - (V_1 + V_{Hcl}) \times \frac{\left(N_{Na_2S_2O_3} \times 126.93\right)}{V_F} \times \frac{V_{Na_2S_2O_3}}{M_C} \quad \text{(ii)}$$

Where,

N_1 = the iodine solution normality

V_1 = added volume of the iodine solution

V_{HCl} = the added volume of 5% Hcl

V_F = volume of filtrate

$N_{Na_2S_2O_3}$ = volume of sodium thiosulfate normality

$N_{Na_2S_2O_3}$ = Consumed volume of sodium thiosulfate solution

M_C = Mass of activated carbon

Determination of volatile content: To determine the volatile content, 7g of each sample was oven-dried in a ceramic crucible and the weight of each crucible and the biomass were noted. The crucibles were then placed in the furnace at a temperature of 900℃ for 7 min. After cooling, the volatile content was calculated as;

$$Volatile\ (\%) = \frac{100 \times m^2}{m^3} \quad \text{(iii)}$$

Where;

M^2 = Mass of oven-dry sample (g)

M^3 = Mass of sample after heating in furnace (g)

Determination of Ash content: Furnace incineration gravimetric method (AOAC, 2000) was used. The ash content of the sample was then calculated using the formula:

$$Ash\ (\%) = \frac{W_2 - W_1}{W} \times 100 \quad \text{(iv)}$$

Where;

W = weight of sample (g)

W_1 = weight of empty crucible (g)

W_2 = weight of crucible + ash (g)

Determination of Moisture content: The moisture content of the samples was determined by gravimetric method as described by Bansode *et al*. (2003). It was calculated using the formula:

$$Moisture\ (\%) = \frac{W_3 - W_2}{W_2 - W_1} \times 100 \quad \text{(v)}$$

Where;

W_1= initial weight of empty crucible

W_2= weight of empty crucible+ sample

W_3= final weight of empty crucible + sample after drying to constant weight

Determination of fixed carbon content: Fixed carbon was determined using the formula (AOAC, 2000).

$$FC = 100 - (VM + AC + MC) \quad \text{(vi)}$$

Where;

FC = Fixed carbon (%)

VM = volatile matter of carbon black (%)

AC = Ash content (%)

MC = moisture content of the sample (%)

Determination of Bulk Density: Bulk density (gcm^{-3}) is defined as the mass of a unit volume of the sample in air including both the pore system and the voids among the particles. In this test, 10ml measuring cylinder was dried in oven at 110℃ for 30 minutes. Sample was filled into cylinder with three layers and tapped about 300 times for each layer until it's fully compacted and reweighed. Bulk

density was calculated following the formula of (AOAC, 2000)

$$BD = \frac{Wb_c - W_C}{Vb_s} \quad \text{(vii)}$$

Where;
BD = Bulk density
W_{bc} = Mass of the sample and container,
W_c = Mass of the container and
V_s= volume of sample in container

Determination of P^H: The standard test method for determination of carbon black P^H ASTMD 3838-80 was used.

Activation of Charcoal Samples: The chemical method of activation was adopted because of its low energy cost, high carbon yield, easy recovery of activation agent, tar formation inhibition and bond cleavage promotion (Ekpete *et al*., 2017). The Activation agent was orthophosphoric acid (H_3PO_4) and the process was as described by Ekpete *et al*. (2017). The Activated charcoal were then pulverized to fine sizes of 1mm using a SETHI Standard test sieve to achieve uniform sizes of the carbon before they were then transferred to containers for storage until usage.

Application of Activated Carbon: Twenty grams of the activated carbon from each source was weighed out using sensitive scale KERRO BL2000 and tied in muslin bags and applied to each of the experimental tanks containing fingerlings.

The culture media physicochemical parameters

The following physiochemical parameters of the culture media were determined during experimental treatments: alkalinity, total ammonia nitrogen, total phosphorus, nitrites, pH, temperature and conductivity. These were measured using the recommended procedures in APHA (2005) while the dissolved oxygen was assayed using the Winkler's method as described in Stirling (1985).

Statistical Analysis.

The data collected during this experiment was presented as percentages and means and were subjected to Analysis of variance (ANOVA) using SPSS statistical package (version 20)..

Results and Discussions

The result of carbonization and characterization of biomass was shown in table 1. The carbonization temperatures fell within the recommended range (200-1100°C) for carbonization (Ekpete *et al.*, 2017). It revealed that mango had 78%, coconut shell had sample yield of 64 % and Indian bamboo had 33 %. The highest sample yield recorded for mango wood may have resulted from higher accumulation of carbon in mango as compared to coconut shells and Indian bamboo. Volatilities were 42.20 %, 57.10 % and 38.50 % for mango wood, coconut shell and Indian bamboo respectively. The volatile contents were within the range (23-72%) reported by Ekpete *et al*. (2017) for plantain stem. The ash content was lowest for mango wood followed by coconut shell and Indian bamboo in that order. These are higher than those reported for plantain stem by Ekpete *et al*. (2017). The lower the ash content of activated charcoal, the higher the adsorptive strength of the charcoal (Ekpete *et al*, 2017). The higher values of the ash content may have also been influenced by the relatively higher carbonization temperatures as compared to those of Ekpete *et al*. (2017). The moisture contents were 8.50 %, 9.00 % and 13.90 %, for mango wood, coconut shell and Indian bamboo respectively. The moisture content was within the range (7-10%) reported by Ekpete *et al*. (2017) for plantain stem. This may be resulting from the similarities in the carbonization method. The mango wood recorded the highest fixed carbon content and bulk density followed by coconut shells and Indian bamboo in that order. This may be indicative of mango wood as more efficient in carbon accretion than coconut shell and Indian bamboo and (or) may be reflective of the unique environmental conditions in the locations where these samples were taken. The bulk densities were 2.01gcm^{-3}, 1.62gcm^{-3} and 0.86 gcm^{-3}, for mango wood, coconut shell and Indian bamboo respectively. The bulk densities are higher than those reported for *Eucalptus* by Noumi *et al*. (2014); this may have resulted from the higher ash content because higher mineralization leads to higher bulk densities. The recorded bulk density values are in line with the report of Adinaveen *et al*. (2014) who stated that bulk density is a function of carbonization temperature. Iodine numbers were highest for MWAC followed by CSAC and IBAC in that order. It is noteworthy that mango wood has iodine number within the range of 600-900 recommended for use in water treatment (Mianowski *et al.*, 2007). The differences recorded in iodine number may be due to differences in chemisorptions potential resulting from varied nature of pores in each of these sources of activated charcoal. It has been stated that the adsorptive capacity of activated carbon is a function of its internal surface area, poor volume, pore size distribution and surface chemistry (Mianowski *et al.*, 2007; Saleem *et al*., 2019).

Generally, the result shows that after 3hours of application of activated charcoal from different sources there was a visible decline in the physiochemical parameters (refer to table 2) that were tested for. This result corresponds with the findings obtained from the research carried out by Nwabuisi (2018). This also agrees with the adsorption kinetic theory which states that the higher the time, the more the amount of fluid is adsorbed on the adsorbent. Initially, there were large number of vacant active binding sites available at the first phase of experiment and large amount of chemicals were bound rapidly on activated carbon at a faster adsorption rate. The binding site shortly became limited and the remaining vacant surface sites were difficult to be occupied. (Anwar *et al*, 2010). The study showed that ACs appear to be approaching saturation points as at the 9th hour which was not the case with the corn cob in Sichula *et al*. (2011).

Following the treatment, CSAC recorded the least alkalinity in 3 hours. This was followed by that of MWAC and IBAC respectively. The record follows a similar pattern for the 6th and 9th hours. The control treatment is markedly higher than all the treatment in all the test periods. The trend in alkalinity showed that AC from coconut shell recorded the least alkalinity in relation to those of mango wood and Indian bamboo. This may be suggestive of an intrinsic property of coconut shell of the presence of acidic chemical species on the AC surface. The gradual rise generally recorded in the 6th and 9th hours shows that the ACs may be getting saturated in timescale.

The result of total ammonia nitrogen is presented in table 3. The average ammonia adsorption by ac from mango wood was 43.4% of the initial concentration in three hours while those of 6thand 9th hours are 24.5% and 3.8% respectively. Adsorption in AC from coconut shell was slightly lower than those of mango wood and were 23% for 3rd and 6th hours and 17.3% for the 9th-hour. The ammonia adsorption of AC from Indian bamboo was still further lower than those of mango wood and coconut shell, having 16% for 3rd and 6th hours and 8% for the 9th hour. The trend in the result showed that AC from Mango wood had the best adsorptive strength in removal of ammonia followed by that of coconut shell both in the 3rd and 6th hours; while AC from Indian bamboo had the least adsorptive strength. The best reductions were 0.23mg/l(0.23mg/g) and 0.12mg/l (0.12mg/g) for AC from Mango wood and coconut shell respectively. Ammonia removal strength was in similar pattern as the order of decreasing iodine number from AC of mango wood to that of coconut shell and Indian bamboo which is in line with the report of Mianowski *et al* (2007). The result was slightly different from those reported by Sichula *et al.* (2011) which had a 3-hour reduction of 38.7% for ammonia and a 55.1% and 65.3% reduction for 6-hour and 9-hour respectively in their study using activated charcoal from corn cob. This difference could have resulted from the varied methods of carbonization and activation or arose from the intrinsic properties of the materials used for the production of the activated charcoals. ACs from coconut shell and Indian bamboo appears to have a generally lower adsorption rate in comparison to mango wood as they were relatively farther from saturation points as at the 9th-hour.

The result of phosphate concentrations is presented in table 4. The result indicated CSAC adsorbed phosphate the most, followed by MWAC and IBAC in that order in the 3rd, 6th and 9th hours. The observed values for the control were remarkably different and higher. The best reduction in culture media phosphate level were within the first three hours of treatment and recorded 0.08mg/l (0.08mg/g), 0.04mg/l (0.04mg/g) and 0.03mg/l (0.03mg/g) for CSAC, MWAC and IBAC respectively. The generally high phosphate values in the different culture media may have resulted from excretions from the experimental fish, left over from uneaten feed and their excreta. The relatively better adsorptive strength of the CSAC for phosphates may be suggestive of presence of some positively charged zones on the carbon surface enabling phosphate attraction to the adsorbent. It could also have resulted from a cascade of interactions between other adsorbents and the carbon surface. Ghouma *et al.* (2014) highlighted that presence of hydroxyl and oxygenated groups on the activated carbon surface enhance adsorption. The result was lower than those reported by Zhang *et al*. (2011) for activated carbon fibre loaded with lanthanium oxide. They reported 97.6% removal of phosphate when the concentration was 30mg/l while ours was 80% removal from an initial 100µg/l in three hours.

The result of nitrite is presented in table 5. The result indicated that MWAC and CSAC had the best adsorptions of nitrite from the culture water. These culture media remained at 0.1mg/l for the 3rd,6th and 9th hours giving a nitrite adsorption capacity of 0.5mg/g for both ACs in these periods. The adsorption of nitrite by IBAC was the least. The control treatment remained relatively stable during the period being clearly different from other treatments. Nitrite removal from the aquaculture water appears to be rapid for MWAC and CSAC and less for IBAC. This may have arisen from a possible presence of oxygenated groups on the surface of the AC from mango wood and coconut shell, micropores and their unique surface chemistry; these play important roles in the adsorption phenomena (Ghimbeu *et al*., 2010 cited in Ghouma *et al*., 2014). Generally,the nitrite adsorptions recorded in our study are lower than those reported by Ghouma *et al*. (2014) who recorded a nitrite adsorption of 131.1mg/g in a gas phase study using activated carbon from olive stones. The differences may have arisen from the difference in phase and (or) the varying activation methods.

The result of pH is presented in table 6. The pH of the control was the highest while that the treatment with MWAC in the first three hours was the least. The pH of the treatment with MWAC relatively stabilized by the 6th and 9th hours. There was a relatively marginal variation and fluctuation the pH of the CSAC and IBAC in the 6th and 9th hours. The generally low adsorptions for the various measured parameters could have resulted from the relatively higher pH and temperature values. Ghouma *et al*. (2014) suggested that activated carbon adsorption is more efficient at neutral or slightly acidic pH values and lower temperatures respectively. The high pH recorded may have been caused by increased levels of ammonia generally observed in all the tanks in addition to the usual protonation action suggested by Bernal *et al*. (2018) to take place once ACs prepared via high temperature and reducing environments are introduced to wastewater.

The result of temperature is presented in table 7. The highest temperature recorded during the study was 29.2°C in the MWAC treatment at the 3rd hour while the least was 26.8°C in the coconut shell treatment at the 9th hour. The temperature values remained relatively stable across treatments with minor variations. The ambient temperature though fairly stable was relatively higher than the least reported in Ghouma *et al*. (2014) for nitrite adsorption and that higher temperature hinders absorption of nitrite adsorption; this could also explain the low adsorption levels generally observed. The marginal variations in temperature may have resulted from the variation in solar irradiance in the different parts of the laboratory where the study was conducted.

The result of dissolved oxygen is presented in table 8. The result showed that the 6th hour record of the CSAC was the least 0.4mg/l (0.4mg/g) while the control treatment maintained the highest values in all the test periods. MWAC treatment showed the least fluctuation within the period besides the control treatment; while those of CSAC and IBAC had a similar fluctuation pattern except for the lower values recorded in CSAC treatment. The generally low dissolved oxygen recorded indicated a gradual development of anoxic state in the tanks due to the non-renewal of the culture water from the 9th day of acclimatization. The variations observed in dissolved oxygen levels of the control and other treatments suggested that there were some interaction between dissolved oxygen of the culture water and the

ACs, with CSAC having the strongest adsorptive strength for dissolved oxygen.

The results of conductivity are presented in table 9. Observations on conductivity showed that IBAC treatment had the highest conductivity in all the test period followed by the control treatment, CSAC and MWAC in that order, an apparent reverse trend in relation to their iodine numbers. The conductivity range was between 293.5 μScm^{-1} in the 3rd hour of MWAC to 440 μScm^{-1} in the 9th hour of IBAC treatments. The values of conductivity may give a fair idea of the ionic strength of given water. The generally low values recorded in the third hour in comparison to the initial values indicated that adsorption process removed some of the ions originally in the culture waters. It is evident that MWAC was best in removal of ionic species from water. This is strongly associated to its earlier highest value of iodine number, suggesting a better adsorption capacity than CSAC and IBAC. The heightened conductivity values of IBAC may be reflective of some leaching of substances into the water, it appears that interaction between the culture water and the Indian bamboo AC causes the release of some radicals from the AC surface. It has been previously shown that the conductivity of activated charcoals is a function of the carbonization temperature (Adinaveen *et al*., 2014). The effect of carbonization temperature on the culture water conductivity seem to have a reverse function in this study: IBAC which had the lowest carbonization temperature (640°C) generated the highest conductivity in the culture media while the least conductivity was recorded in culture media treated with MWAC with highest carbonization temperature.

Conclusion

Adsorption processes have been shown to be the most effective method for the removal of contaminants from effluent. Activated charcoal from mango wood had the greatest adsorption strength among the three sources, followed by Coconut shell activated charcoal (CSAC). Activated carbon obtained from mango effectively controlled aquaculture physicochemical parameters better than CSAC and IBAC in thisstudy

Activated carbon as found from this study could serve as a vital adsorption material for the adsorption of molecular contaminants from aquaculture water. The use of activated carbon prepared from mango for the adsorption of inorganic materials and other water parameters could serve as cheap adsorption material alternative. With the great prospects recorded in this study for Activated charcoal of mango wood and coconut shell, there is need for higher precision studies with complete characterization to be carried out on them. It is recommended that Mango Wood Activated Carbon and Coconut Shell Activated Carbon be optimized for use in pollutant removal in aquaculture and related processes.

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Appendix

Table 1: Carbonization and Characterization of Biomasses

Parameters	Mango wood
Sample yield (%)	78.00
Volatility (%)	42.20
Ash content (%)	46.90
Moisture (%)	8.50
Fixed carbon content (%)	76.30
Bulk Density (gcm^{-2})	2.01
Iodine number (mg/g)	653.0

Table 2: Total alkalinity measurements of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo (mg/l , $Mean \pm$ SD.)

Treatment	0 hour	3rd hour	6th hour	9th hour

MWAC	102±1.3[a]	58.0±2.8[a]	90.0 ±5.3[a]	100.0±24.0[a]
CSAC	100±0.5[a]	20.0±2.8[b]	65.5±2.9[b]	90.0±5.6[c]
IBAC	105±3.6[a]	70.0±11.3[c]	103.0±56.7[c]	102.0±5.6[a]
Control	101±2.2[a]	103.5±7.7[d]	105.50 ± 7.8[c]	107.5 ±2.1[b]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05

Table 3: Total Ammonia Nitrogen concentrations of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo (TAN in mgL^{-1} = Milligram per litre, $\boldsymbol{Mean} \pm$ SD.)

Treatment	0 hour	3rd hour	6th hour	9th hour
MWAC	0.53±0.00[a]	0.30±0.00[a]	0.40± 0.00[a]	0.51±0.00[b]
CSAC	0.52±0.00[a]	0.40±0.00[a]	0.40±0.01[a]	0.43±0.01[a]
IBAC	0.50±0.00[a]	0.42±0.02[a]	0.42±0.00[a]	0.46±0.01[a]
Control	0.50±0.00[a]	0.55±0.00[b]	0.62±0.00[b]	0.65±0.00[c]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05

Table 4:Phosphate levels measured as total phosphorus of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo (μgL^{-1}= Microgram per litre, $\boldsymbol{Mean} \pm$ SD.)

Treatment	(0 hours)	3rd hour	6th hour	9th hour
MWAC	100.0±0.0[a]	58.0±2.8[a]	90.0 ±5.3[b]	100.0±4.0[a]
CSAC	100.0±0.0[a]	20.0±2.8[b]	65.5±2.9[c]	90.0±5.6[b]
IBAC	100.0±0.0[a]	70.0±11.3[c]	103.0±6.7[a]	102.0±5.6[a]
Control	100.0±0.0[a]	103.5±7.7[d]	105.50 ± 7.8[a]	107.5 ±2.1[c]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05

Table 5: Nitrite measurements of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo for nine hours (mgL^{-1} = Milligram per litre, $\boldsymbol{Mean} \pm$ SD.)

Treatment	0 hour	3rd hour	6th hour	9th hour
MWAC	0.6±0.0[a]	0.1±0.0[a]	0.1±0.0[a]	0.1±0.0[a]
CSAC	0.6±0.0[a]	0.1±0.0[a]	0.1±.0.0[a]	0.1±0.0[a]
IBAC	0.7±0.0[a]	0.6±0.1[b]	0.7±0.1[b]	0.7±0.1[b]
Control	0.8±0.0[a]	0.9±0.1[b]	0.8±0.1[b]	0.9± 0.1[b]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05

Table 6: pH measurements of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo for nine hours ($\boldsymbol{Mean} \pm$ SD.)

Treatment	0 hour	3rd hour	6th hour	9th hour
MWAC	10.5±0.0[a]	9.6 ±0.1[a]	10.6±0.1[a]	10.6±0.4[a]
CSAC	10.6±0.0[a]	10.3±0.0[a]	10.5±0.1[a]	10.4±0.1[a]
IBAC	10.6±0.0[a]	10.2±0.7[a]	10.5±0.2[a]	10.4±0.1[a]
Control	10.7±0.0[a]	10.8±0.7[a]	10.9±0.1[a]	10.7±0.2[a]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05

Table 7: Temperature measurements of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo for nine hours (℃, $\boldsymbol{Mean} \pm$ SD.

Treatment	0 hour	3rd hour	6th hour	9th hour
MWAC	28.5±0.2[a]	28.5±0.7[a]	28.5± 0.1[a]	28.5±0.7[a]
CSAC	27.5±0.0[a]	27.5±0.7[a]	28.0± 0.0[a]	27.5±0.7[a]
IBAC	28.0±0.0[a]	28.0±0.0[a]	28.5±0.1[a]	27.0±0.0[a]
Control	27.7±0.0[a]	27.7±0.0[a]	27.0± 0.0[a]	28.5±0.7[a]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05

Table 8: Dissolved Oxygen measurements of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo for nine hours (mgL^{-1} = Milligram per litre, $\boldsymbol{Mean} \pm$ SD.)

Treatment	0 hour	3rd hour	6th hour	9th hour
MWAC	0.6±0.0[a]	0.5±0.1[a]	0.4±0.1[a]	0.4±0.0[b]
CSAC	0.6±0.0[a]	0.4±0.0[b]	0.2±0.0[b]	0.3±0.1[b]

IBAC	0.6±0.0 [a]	0.6±0.1 [a]	0.5±0.1 [a]	0.7±0.0 [a]
Control	0.6±0.0 [a]	0.7±0.1 [a]	0.7±0.3 [a]	0. 7±0.2 [a]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05

Table 9: Conductivity measurements of aquaculture water treated with activated charcoal from Mango wood, coconut shell and Indian Bamboo for nine hours (µScm^{-1}, $\boldsymbol{Mean} \pm$ SD.**)**

Treatment	**0 hour**	**3rd hour**	**6th hour**	9th hour
MWAC	313±2.4 [a]	293.5±14.8 [a]	301.5±16.9 [a]	312.5±18.0 [a]
CSAC	312±0.8 [a]	300.0±14.5 [a]	305.2± 15.0 [a]	351.5±19.8 [c]
IBAC	316±1.5 [a]	414.0±15.6 [c]	433.1±17.0 [ba]	440.0±21.4 [d]
Control	309±1.2 [a]	320.5±12.1 [b]	336.7±21.1 [c]	367.5±23.3 [c]

MWAC: mango wood activated carbon; CSAC: coconut shell activated carbon; IBAC: Indian bamboo activated carbon; values with same superscript column-wise are not significantly different P>0.05 while those with different superscripts are significantly different P<0.05