USE OF MAIZE COB-ACTIVATED CHARCOAL FOR WASTEWATER TREATMENT IN AQUACULTURE FOR REUSE

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ABSTRACT

This study investigated the efficacy of activated charcoal made from maize cobs for processing wastewater obtained from aquaculture. The main objective was to develop a low-cost and efficient way to recycle wastewater for aquaculture, part of efforts to tackle water scarcity in Northeast Nigeria. The research evaluated the efficiency of activated charcoal derived from maize cobs in treating aquaculture wastewater, optimal treatment duration, and its impact on the survival rate of *Clarias gariepinus*. Carbonizing maize cob charcoal was achieved by burning dry maize cobs in a 5L tin as a makeshift kiln with little or no air and activated using lemon juice. The treatment efficiency of the activated charcoal was tested by assessing water quality parameters before and after treatments. Results of pH and ammonia in this study reduced from 8.60 to 7.68 and 1.50 to 0.31 mg/l respectively while dissolved oxygen increased from 3.06 to 3.51 mg/l after a 24-hour treatment period. *Clarias gariepinus* cultured for 56 days in the treated water had a growth of 12.11g from 2.00g, a total length of 4.82cm, a specific growth rate of 3.22%/d, and an 86.67% survival rate. This study concludes that the use of maize cob-activated charcoal is a suitable and affordable method for treating aquaculture wastewater for reuse, improving fish survival and growth rates.

Keywords: Activated carbon, Corn cobs, Recycled aquaculture wastewater, Treated wastewater

INTRODUCTION

Aquaculture generates various types of waste, including solid waste, chemicals, bacterial pathogens, and farm species escapees, all of which can negatively impact the environment (Akinrotimi *et al.*, 2011). Solid wastes such as organic matter, feces, and uneaten food accumulate at the bottom of recirculation systems and suspend throughout the water column, dissolving over time and causing health issues like gill irritation in fish, which reduces production (Xinxin *et al.*, 2012). Accumulated solid waste also leads to oxygen depletion and increased ammonia concentration, further harming fish health (Xinxin *et al.*, 2012). Hazardous pollutants are also of major environmental concern in aquaculture systems (Gross *et al.*, 2017). The discharge of fish wastes such as urine and faeces increases ammonia and nitrogen levels and increases the biochemical oxygen demand (BOD) of water bodies.

Globally, water scarcity is a critical issue, especially in Northern Nigeria, including Wukari Local Government Area in Taraba State, which has long struggled with limited rainfall and insufficient water supply (Mekannen, 2016). Methods such as irrigation and cover crops have been used to mitigate against water scarcity in agriculture (Singh *et al.*, 2012) however, fish farming remains hindered by the high water demands of fish farming (Ozigbo *et al.*, 2014).

Research on low-cost activated carbons derived from agricultural waste for water treatment has shown promising results. These include materials like coconut shells (Yang *et al.*, 2010), rice husks (Isoda *et al.*, 2014), pineapple waste (Mahamad *et al.*, 2015), orange peels (Foo and Hameed, 2012), and Bambara nutshells (Adeniyi, 2010). These studies highlight the potential for water conservation in aquaculture through the reuse of treated water (Gabriel *et al.*, 2009). Advanced technologies for wastewater purification, such as filtration, recirculating systems, and ultraviolet irradiation, are effective but often too costly and complex for local farmers (Shpigel and Ben-Ezra, 2013).

Maize is a widely cultivated cereal crop, and its processing generates significant waste, including corn cobs (Omoigui *et al.*, 2016). These carbonaceous cobs are often discarded, causing environmental issues (Kazmirczak *et al.*, 2013). Activated charcoal, increasingly used for water purification, offers a solution for recycling water for multiple purposes, including aquaculture (Korotta *et al.*, 2017). Activated carbon can remove organic pollutants from water, benefiting fish and plants (Mohammad, 2018). Activation of carbon involves thermal or chemical processes, enhancing its adsorption properties (Ajayi and Olawale, 2009).

The current study assessed the use of maize cob-activated charcoal to treat aquaculture wastewater for reuse in culturing *Clarias gariepinus*.

MATERIALS AND METHODS

Research site

The study was conducted at the Federal University Wukari Fish Farm. Wukari Local Government Area lies along Latitude 7° 52' 47.86"N and Longitude 9° 46' 37.66"E covering an area of 4,308 km^2 with an elevation of 189m above the level sea level (Magomya and Ataitiya, 2023).

Collection of maize cobs and preparation of charcoal

Maize cobs were obtained from small-scale farmers within Wukari Community and weighed. They were washed thoroughly using clean water to remove unwanted particles and sun-dried. The maize cobs were cut into smaller sizes making them burn uniformly and completely.

Maize cob carbonization

Carbonization of maize cobs was carried out following the procedures of Sichula *et al.* (2011). This was achieved using a regulated burning procedure with restricted airflow. To maximize the carbonization process, the maize cobs were firmly packed inside a 5L tin which was used as a temporary kiln for the carbonization process. To ensure partial combustion, the tin's lid was pierced to create holes to limit airflow. The tin was heated to a high temperature and allowed to burn for three hours for each batch of maize cobs. This limited oxygen environment facilitated the formation of charcoal by preventing complete combustion. After the carbonization process, the tin was allowed to cool before retrieving the charcoal. The charcoal was ground into small chunks with mortar and pestle, sun-dried, and weighed.

Activation of carbonized maize cobs

To activate the carbonized maize cobs, the methods of Efeovbokhan *et al.* (2019) were used in this study. After pulverizing the carbonized maize cobs, 5kg of the carbonized material was mixed thoroughly in 1250 ml of *Citrus limon* (lemon) juice and allowed to sit for 24 hours. After 24 hours, the excess activating solution was decanted and the soaked charcoal was placed in the tin and heated for one hour. The tin was allowed to cool before the activated charcoal was retrieved, washed to remove residual activating agent and, sun-dried (plate 1). The activated charcoal was weighed (4.6kg), and stored in a dry, air-tight container for further use.

Plate 1: Carbonizing and sun-drying maize cobs

Experimental Fish

Two hundred and twenty five fingerlings of *Clarias gariepinus* with an average weight of 2.00g were purchased from a reputable fish farm, conditioned for 14 days, and fed commercial diets. The fish were randomly distributed into experimental tanks in three replicates.

Wastewater treatment

Aquaculture wastewater was collected from fish production tanks from the Federal University Wukari Fish farm and treated with activated charcoal before use in culturing experimental fish. Initial water quality parameters were measured and recorded (0 hours, T_1) before 500g of activated charcoal was weighed into saran cloth, tied, and placed into experimental tanks each containing 40L of wastewater for 3 hours (T_2), 6 hours (T_3), 12 hours (T_4), 24 hours (T_5). The water quality parameters of each treatment were measured and recorded before fish were randomly stocked into it.

Experimental Procedure

Fifteen *Clarias gariepinus* were stocked randomly in each of the respective experimental tanks (60L) and fed feed (40% CP) at 5% body weight. Water quality parameters; pH, Temperature, Dissolved Oxygen, Ammonia, and Nitrite were monitored every week. Ammonia, dissolved oxygen, nitrite, and pH were assessed with Hach® Surface Water Test

Kit (Omitoyin *et al.*, 2013) while the temperature was determined with the use of a mercury-in-glass thermometer. The weight and length of fish were measured fortnightly using B5003T electronic balance (0.01g –500g) and were reared for 56 days. Growth parameters such as Weight Gain, Specific Growth Rate, and Survival rates were monitored and determined using the formula;

$$\textbf{Weight gain (g)} = W_2 - W_1$$

$$\text{SGR} = \frac{inW_2 - inW_1}{T_2 - T_1} \times 100$$

$$\text{Survival Rage (\%)} \frac{\text{Number of Fish that survives}}{\text{Total number of Fish Stocked}} \times 100$$

Where;
W_1 = initia1 weight of fish,
W_2 = fina1 weight of fish and
T (T_1-T_2) = duration of experiment (day).

Statistical analysis
Data were subjected to descriptive analysis, regression, one–way Analysis of Variance (ANOVA) procedure of SPSS (version 23) and means were separated using Duncan Multiple Range Test (DMRT).

RESULT AND DISCUSSION

The use of activated charcoal for treating wastewater has been widely studied due to its high adsorption capacity and ability to improve various water quality parameters. The result of the water quality parameters of aquaculture wastewater treated with activated charcoal is presented in Table 1. The initial pH of the wastewater was 8.60±0.19, this, gradually decreased with the duration of treatment with activated charcoal, reaching 7.68±0.46 after 24 hours of treatment. The significant decrease in pH ($p<0.05$) suggests that activated charcoal can effectively neutralize the alkaline nature of wastewater. This trend is consistent with findings from other studies that show activated charcoal adsorbs alkaline substances, resulting in a more neutral pH (Ahmedna *et al.*, 2004). Changes in the temperature of treated wastewater ranged from 24.60±0.50^{0}C to 25.1±0.23^{0}C but were not statistically significant ($p>0.05$), indicating that the activated charcoal treatment does not significantly affect the thermal properties of the wastewater. This aligns with the literature that suggests adsorption processes involving activated charcoal typically do not involve significant thermal changes (Gupta *et al.*, 2011). The absence of significant changes ($p>0.05$) in dissolved oxygen levels suggests that the activated charcoal treatment does not adversely affect the oxygenation of the wastewater. This finding is supported by previous research indicating that while activated charcoal can adsorb various contaminants, it does not significantly influence DO levels (Simate *et al.*, 2012). A notable decrease in ammonia concentration was observed in the study, from an initial 1.50±0.69 mg/L to 0.13±0.25 mg/L after 24 hours. This significant reduction ($p<0.05$) indicates the efficiency of activated charcoal in removing ammonia from wastewater, corroborating studies that have demonstrated the efficacy of activated charcoal in adsorbing ammonia due to its large surface area and porous structure (Li *et al.*, 2013; Sichula *et al.* 2011; Cecen and Aktaş 2011). The nitrite levels showed slight fluctuations but remained low throughout the treatment period. The water quality parameters of the culture water of *C. gariepinus* after different durations of treatment with activated charcoal (Table 2) were within the standard levels for *C. gariepinus* culture.

Table 1: Water Quality Parameters of Wastewater treated with activated charcoal

Parameters	T_1	T_2	T_3	T_4	T_5
pH	$8.60±0.19^a$	$8.51±0.37^a$	$8.33±0.68^{ab}$	$7.96±0.53^b$	$7.68±0.46^b$
Temperature	$24.60±0.50^c$	$24.95±0.58^{bc}$	$25.47±0.51^a$	$25.1±0.28^{ab}$	$25.1±0.23^{bc}$
DO (mg/L)	$3.06±0.79^a$	$3.21±0.96^a$	$3.09±0.80^a$	$3.15±0.76^a$	$3.51±0.68^a$
Ammonia (mg/L)	$1.50±0.69^a$	$1.13±0.82^b$	$1.09±0.70^{bc}$	$0.18±0.25^{bc}$	$0.13±0.25^c$
Nitrite (mg/L)	$0.00±0.00^a$	$0.07±0.17^a$	$0.12±0.35^a$	$0.06±0.17^a$	$0.12±0.23^a$

Means with the same superscripts along rows are not significantly different ($p>0.05$)

Table 2: Water Quality Parameters culture water

Parameters	T_1	T_2	T_3	T_4	T_5
pH	$7.68±0.46^a$	$7.21±0.45^b$	$7.07±0.32^{bc}$	$6.80±0.20^c$	$6.75±0.23^c$
Temperature (^{0}C)	$24.73±0.23^a$	$25.18±0.61^a$	$25.23±0.65^a$	$25.25±0.68^a$	$25.21±0.75^a$
Dissolved oxygen (mg/L)	$3.51±0.68^a$	$3.55±1.29^a$	$3.47±0.70^a$	$3.38±0.62^a$	$3.53±1.22^a$
Ammonia (mg/L)	$0.08±0.2^a$	$0.07±0.14^a$	$0.08±0.16^a$	$0.07±0.30^a$	$0.08±0.27^a$
Nitrite (mg/L)	$0.12±0.23^b$	$0.13±0.39^a$	$0.14±0.97^a$	$0.12±0.27^a$	$0.13±0.23^{ab}$

Means with the same superscripts along rows are not significantly different ($p>0.05$)

The growth performance of *Clarias gariepinus*, commonly known as African catfish, in water treated with activated charcoal was assessed. The study monitored various parameters including weight gain, specific growth rate (SGR), and survival rates. The result of the growth parameters of *C. gariepinus* reared in activated charcoal-treated water is in Table 3. Significant differences were observed in the final weights of cultured fish, which increased progressively from 9.08±0.95g to 12.11±2.03g. This indicates that the activated charcoal treatment had a positive effect on the weight gain of *C. gariepinus* ($p<0.05$). The highest weight gain (10.11±2.51g) was observed in fish cultured in water treated for 24 hours, suggesting that prolonged exposure of wastewater to activated charcoal can enhance growth performance. These findings align with previous studies that have shown the effectiveness of activated charcoal in improving water quality by adsorbing toxins and organic matter, which can otherwise hinder fish growth (Eyo *et al.*, 2014; Dauda *et al.*, 2016). Improved water quality likely reduces stress and promotes better nutrient absorption, leading to increased weight gain. The SGR values demonstrate that the activated charcoal-treated water significantly boosts the growth rate of catfish ($p<0.05$). Higher SGR values are indicative of efficient feed utilization and optimal growth conditions, which are essential for aquaculture productivity (Kumar *et al.*, 2019). Activated charcoal is known to remove contaminants and improve overall water parameters, contributing to better growth rates. The survival rate of *C. gariepinus* cultured in activated charcoal-treated water ranged from 73.33% to 86.67%. The highest survival rate observed in fish cultured in water treated for 24 hours suggests that activated charcoal treatment not only enhances growth but also improves the overall health and survivability of the fish ($p<0.05$). Activated charcoal likely contributes to higher survival rates by maintaining water quality and reducing the presence of harmful substances that could cause mortality (Ayoola *et al.*, 2012). This is particularly important in intensive aquaculture systems where water quality can deteriorate rapidly.

Table 3: Growth rate of *Clarias gariepinus* cultured in activated charcoal water

Parameters	T_1	T_2	T_3	T_4	T_5
Initial Weight (g)	2.00±0.25^{a}	2.00±0.25^{a}	2.00±0.25^{a}	2.00±0.25^{a}	2.00±0.25^{a}
Final Weight (g)	9.08±0.95^{c}	9.98±1.64^{c}	10.76±1.93^{bc}	11.63±2.39^{ab}	12.11±2.03^{a}
Weight Gain (g)	7.08±0.13^{c}	7.98±0.61^{c}	8.76±1.23^{bc}	9.63±1.84^{ab}	10.11±2.51^{a}
Initial Length (cm)	0.78±0.40^{a}	0.78±0.40^{a}	0.78±0.40^{a}	0.78±0.40^{a}	0.78±0.40^{a}
Final Length (cm)	2.45±0.31^{d}	2.98±0.21^{cd}	3.06±0.63^{bc}	3.27±0.75^{ab}	4.82±1.89^{a}
Length Gain (cm)	1.67±0.10^{d}	2.20±0.33^{cd}	2.28±0.68^{bc}	2.49±0.80^{ab}	4.04±0.94^{a}
SGR (%/d)	2.70±0.67^{b}	2.87±0.32^{b}	3.00±0.19^{a}	3.14±0.23^{a}	3.22±0.18^{a}
Survival rate (%)	77.78±0.71^{ab}	73.33±0.68^{b}	82.22±0.11^{ab}	80.00±0.54^{ab}	86.67±0.71^{a}

Means with the same superscripts along rows are not significantly different (p>0.05)

CONCLUSION

The treatment of wastewater with activated charcoal significantly improved water quality by reducing pH and ammonia levels without adversely affecting temperature, dissolved oxygen, or nitrite concentrations. These results support the use of activated charcoal as an effective adsorbent for wastewater treatment, particularly for ammonia removal. Further research could focus on optimizing the conditions for nitrite removal and exploring the long-term stability of treated water. The use of activated charcoal in water treatment for the culture of *C. gariepinus* significantly improves growth performance, as evidenced by increased weight and length gains, higher specific growth rates, and improved survival rates. These results support the adoption of activated charcoal as a beneficial water treatment method in aquaculture to enhance fish health and growth.

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