

# The Effectiveness of Using Palm Kernel Shells as Growth Medium in a Flood and Drain Aquaponic System.

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## ORIGINAL RESEARCH

**Abstract**— An aquaponic system was developed with palm kernel shells as growth medium, to test the efficacy of palm kernel shells as biofilter and plant support medium in aquaponic systems. The system was developed based on specific parameters which was operated 6 hours daily for 45 days under controlled condition. Two culture tanks were considered and a total of 20 African catfish (*Clarias gariepinus*) of average initial weight of 148 g were stocked in each culture tank at 15kg/m<sup>3</sup> density. Twelve days old healthy *Amaranthus cruentus* seedlings were transplanted to the grow bed after stocking of the fish. Water parameters such as Dissolved Oxygen (DO), pH, Total Dissolved Solid (TDS), Electrical Conductivity (EC) and Temperature were monitored every 48 hours; in addition, Ammonium Nitrogen, Nitrite and Nitrate were analyzed every two weeks. The range values of pH, DO, TDS, EC and temperature were 6.4-7.2, 4.1-6.75 mg/L, 126-201 ppm, 255-403  $\mu$ S/cm and 28-33 °C, respectively and the values were suitable for aquaponic organism (the fish, the plant and bacteria) when compared with W.H.O specification and optimal water quality for aquatic lives. The average gained in weight per fish was 109.83 g and average feed consumed was 188.26 throughout the experiment, the average Feed Conversion Ratio (FCR) was found to be 1.71 compared to that of control tank of 103.8 g, 187.43 g, and 1.80, respectively. The paired t-test was computed for fish conversion ratio for aquaponic and control systems to check the significant differences at significant level of 0.05 and the results revealed a significant difference in favour of weight gained in aquaponic system as calculated value of  $t(t_{cal})$  was 2.57 which is greater than tabulated value 2.01. The plant growth rates were 1.06cm/day and 1.01 cm/day in both aquaponic and traditional method.

**Keywords**— Aquaponic, Palm Kernel Shell, and Amaranth.

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## 1 INTRODUCTION

Aquaculture is one of the fast growing businesses in Nigeria. It is one of the major sources of high quality protein of less cost and easy assessable. The need for producing aquacultural (especially fish production) food will increase as the world population increases because these days the primary question is whether food production and the human population can grow simultaneously while adhering to environmental standards (Aslanidou *et al.*, 2024). Aquaponic production of fish and plant is one of the environmentally sustainable farming methods of the twenty-first century as the suitability of the system in areas with limited land and water resources cannot be over emphasized (Oladimeji *et al.*, 2020). Fish farming is a major aspect of aquaculture that requires more attention of the farmer and it is required technological knowledge to improve its production in order to meet consumer demand as the population increases. Recirculatory Aquaculture System (RAS) had been developed for fish culture since the 1960s (Timmons *et al.*, 2002). However, the expansion in awareness of aquaponics' ability to address important

global concerns including food security, water conservation, and sustainable agriculture is seen in the expanding trend of aquaponic research, especially in areas that are susceptible to resource constraints and climate change (Nair *et al.*, 2024; Okomoda *et al.*, 2023). Masser *et al.* (1999) reported that many commercial RAS have failed because of poor design and inferior management. Also, Graber and Junge (2008) reported that Aquaponics take advantage of nutrient cycles by utilizing fish waste as potential crop biomass. They conducted research comparing aquaponic yields to hydroponic yields, to determine how much of a gain is experienced using this advantage. A Recirculatory Aquaponic System (RAPS) reuse most of its water, the system consumes relatively less amount of water compared to other types of culture systems which make it affordable especially in areas with water scarcity. Some of Aquaponic System designs include; gravel bed, clay bed, floating raft, and deep water culture (Rackocy *et al.* 2006). However, Oladimeji *et al.* (2020) worked extensively on two agricultural wastes (periwinkle shell and palm kernel shell) for their suitability as growth beds in the propagation of pumpkin *Telfaria occidentalis*. In their studies, the researchers observed a superior growth and yield of the pumpkin plant and therefore concluded that the use of periwinkle shells and palm kernel shells are suitable as media beds in aquaponics production of fluted pumpkin, *Telfaria occidentalis*.

Hence, there is a need to check for the effectiveness of using palm kernel shells as growth

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Section A- AGRICULTURAL ENGINEERING AND RELATED SCIENCES

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medium in a flood and drain aquaponic system. Therefore, the objectives of this study were to determine the effectiveness of using palm kernel shells as growth medium in a flood and drain aquaponic system, and also to check the possible effect of the water on fish and plant growth rate of Amaranth plant.

## 2 MATERIALS AND METHODS

### 2.1 DESCRIPTION OF STUDY AREA

The experiment was conducted in Ilorin. Ilorin (longitude 4°35'E, latitude 8° 30'N), the capital of Kwara State, Nigeria, has two main seasons: wet (March-October) and dry (November-February). The experiment was conducted for a period of 45 days. Borehole water was used for the experiment and the system was under a total monitoring to avoid intervention of external factors.

### 2.2 EXPERIMENTAL SET-UP

The aquaponic system consists of two rectangular culture tanks of 0.5m<sup>3</sup> (500 liters) capacity which was constructed according to (Dunn, 2014). A medium bed (1.5 m × 1.4 m × 0.3 m) was constructed of wood and waterproof polythene material and prepared for cultivating vegetable (*Amaranthus cruentus*). Palm kernel shells of range 2-20 mm sizes were arranged in three layers (wet, wet-dry and dry) in the media bed. The wet layer is 2-5cm from the bottom of the growth bed, the wet-dry layer covers 5-20cm from the bed bottom while the dry layer is 5cm above the standpipe. The juvenile catfish of initial weight 148 g were purchased and stocked in the tank at the density of 15 kg/m<sup>3</sup>. Also, 40 strands of healthy 12 days old amaranth were transplanted into the bed media. The fish was fed with commercial feed (DURANTE consists of Crude protein 45%, crude fat 14%, fibre 2.8%, Ash 7%, calcium 1.5%, sodium 0.3%, phosphorus 1%) twice daily (9am and 5pm) at 1.5% of their body. The waste water was used to flood the vegetable beds using a 0.5hp pump and drained back through auto-bell siphon (Figure 1) from 11:00 am to 5:00 pm (operation Time)



Figure 1: Experimental Set-Up (Recirculating Aquaponic System (RAPS))

### 2.3 WATER QUALITY

The physico-chemical parameters of fish tank water were

monitored at every 48 hours to determine the pH, Total Dissolved Solid (TDS), Electrical Conductivity, Dissolved Oxygen and Temperature of both effluent and influent using combo pH probe produced by HANNA instruments (Model No; HI 98129). In addition, chemical analyses were carried out at Central Research Laboratory every two weeks (15 days) interval, to determine the Dissolved Oxygen, Total Dissolved Solid (TDS), Ammonia, Nitrite ion, Nitrate ion, Temperature, Electrical Conductivity and pH of both effluent and influent.

### 2.4 FISH AND PLANT GROWTH RATE

Over the period of the experiment, the growth rate of fish and was monitored the growth performance was determined based on weight gain (g), percent weight gain, food conversion ratio (FCR), and survival rate (%), also the plant height and number of leaves were used to determine the plant growth rate.

### 2.5 DATA ANALYSIS

Water quality parameters such as dissolved oxygen (DO), pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS) and temperature expressed as mean ± (standard deviation). A linear graph comparison was carried out among using Microsoft Excel 2007, with an alpha set at 0.05 and 0.01 (significance at p<0.05 and p<0.01). Mean values of fish conversion ratio, plant height, and average number of leaves tested with a simple t-test to check the significant differences at significant level of 0.05.

## 3. RESULTS AND DISCUSSION

### 3.1 WATER QUALITY PARAMETERS

The results of the water quality parameters were within the suitable range of fish culture throughout the experiment. The range values of pH, DO, TDS, EC and Temperature were 6.4-7.2, 4.1-6.75, 126-201, 255-403 and 28-33, respectively. In the study, the range values of pH for the effluent and three influents samples were; 6.3 - 7.4, 6.4-7.2, 6.4-7.1 and 6.4-7.2. These range values of the effluent all influent samples which presented in Table 1, were suitable for fish and vegetable production, as pH between 6.5 and 9.0 is considered the most desirable range for fish, based on established standards by WHO as reported by Utang and Akpan, (2012). Also, these values were within the optimal range values as compared to FAO, (2014) report that the best pH range values for aquaponic ecosystem are 6-7.5. Although, Villaverde *et al.*, (1997) reported that the pH range values of 6 to 8.0 are the most suitable values for nitrification processes.

Table 1: Range Values of Water Quality Parameters throughout the Experimental Period

| Parameter  | Effluent | Influent (S.1) | Influent (S.2) | Influent (S.3) | WHO Specification |
|------------|----------|----------------|----------------|----------------|-------------------|
| Temp (°C)  | 26-31    | 28-32          | 28-33          | 28-33          | 22-40             |
| Ph         | 6.3-7.4  | 6.4-7.2        | 6.4-7.1        | 6.4-7.2        | 6.5-9.0           |
| DO (mg/L)  | 2.1-6.3  | 2.4-6.5        | 3.7-6.6        | 4.1-6.75       | < 5               |
| TDS (ppm)  | 177-277  | 128-241        | 128-241        | 126-201        | <1000             |
| EC (µs/cm) | 352-554  | 257-470        | 258-431        | 255-403        | <2000             |

S.1 is influent into culture tank after 2 hours of operation, S.2 is influent into culture tank after 4 hours of operation and S.3 is influent into culture tank after 6 hours of operation.

The Dissolved Oxygen (DO) concentration in this study was found to vary from 2.1 to 6.8 mg/L which was within the suitable range of catfish. The result also reveal that DO concentration was decreased with time from the starting of the experiment, this might be due to the microbial community and roots respiration. According to FAO (2014) report, catfish has a high tolerance of temperature, with the optimal growth at 18- 40°C. Nitrifying bacteria can operate between 7 to 35°C temperatures with the optimum of 25°C (Wortman and Wheaton, 1991). The Electrical Conductivity and Total Dissolve Solid were also within the range for aquatic organism, the maximum tolerant values were 1000 µS/cm and 2000ppm, respectively.

Other parameters which were carried out at 15 days interval include the nitrate, nitrite and ammonium nitrogen. The results revealed that there was decrease in ammonium nitrogen over the time of the experiment, increase in nitrate due to its accumulation and decreased Sin nitrite (approximately absent) which shows the effectiveness of the biofilter (palm kernel shells). However, the Line graph comparison of physico-chemical parameter of effluent and influents is as presented in Figure 2.

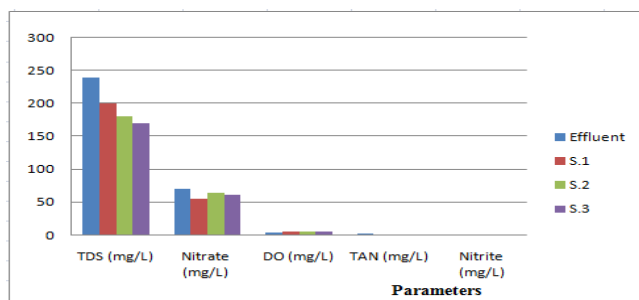


Figure 2: Line Graph Comparison of Physico-Chemical Parameter of Effluent and Influent

As reported by Masser *et al.* (1999), the optimum concentrations of Un-ionized ammonia nitrogen ( $\text{NH}_3$  –

N) must be between 0.02–0.07 mg/L for good performance of aquatic organism. The obtained results of Nitrate, Nitrite and Ammonium Nitrogen were also in line with WHO specification as reported by Utang and Akpan, (2012), Rackocy *et al.* (2006) and optimal water quality for aquaponic organism (FAO, 2014).

### 3.3 FISH AND PLANT GROWTH RATES

The average weight gain and food conversion ratio was a bit higher in the aquaponics system than the control experiment. The FCR for both were higher 1.71 and 1.80 respectively. Tables 2 and 3 presents the summary of fish feed conversion ratio for both aquaponic and control systems

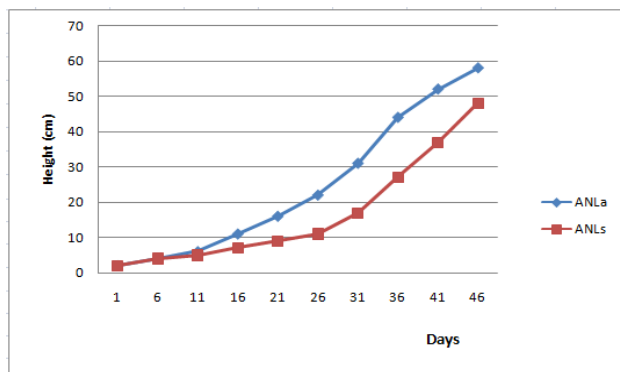
Table 2: Feed Conversion Ratio (FCR) of Aquaponic Fish

| Day       | Average initial weight/fish (g) | Average final weight/fish (g) | Average gain in weight/fish (g) | Average feed consumed/fish (g) | FCR     |
|-----------|---------------------------------|-------------------------------|---------------------------------|--------------------------------|---------|
| At day 1  | 148.00                          | 148.00                        | -----                           | -----                          | 22-40   |
| At day 15 | 148.00                          | 166.29                        | 18.29                           | 33.75                          | 6.5-9.0 |
| At day 30 | 166.29                          | 186.15                        | 19.86                           | 37.525                         | < 5     |
| At day 45 | 186.15                          | 217.30                        | 31.13                           | 51.75                          | <1000   |

Table 2: Feed Conversion Ratio (FCR) of Aquaculture (control) Fish

| Day       | Average initial weight/fish (g) | Average final weight/fish (g) | Average gain in weight/fish (g) | Average feed consumed/fish (g) | FCR   |
|-----------|---------------------------------|-------------------------------|---------------------------------|--------------------------------|-------|
| At day 1  | 148.00                          | 148.00                        | -----                           | -----                          | ----- |
| At day 15 | 148.00                          | 166.29                        | 18.29                           | 33.75                          | 2.07  |
| At day 30 | 166.29                          | 178.15                        | 18.16                           | 36.68                          | 2.01  |
| At day 45 | 178.15                          | 206.30                        | 28.13                           | 51.75                          | 1.75  |

The plant growth rate was estimated based on increase in height of the plant per day and the result was compared with conventional method of planting. The result shown a little difference in the growth rate which favours the aquaponic system as presented in the Figure 3 below.



**Figure 3: Line graph comparison of average length of Amaranthus in Aquaponic and the Control Samples.**

ANLa- Average Number of Leaves for Aquaponic Plant

ANLs-Average Number of Leaves for Soiled Plant

## 4 CONCLUSIONS

The use of palm kernel shells as growth medium and biofilter in aquaponic system has no negative effects on growth rate of Amaranth plant and fish. The material is good as other medium such as pebble clay, quartz, gravels and clay balls. Based on the result of water analysis, the parameters were within suitable range for aquatic lives when compared with W.H.O standard. Its availability and ability to act as mechanical filter and biofilter is a major advantage over other materials.

## 5 RECOMMENDATIONS

Further research should be conducted to determine the best operation time for the system since operation time has effect on water cleanliness. Also, a comparative study should be done on palm kernel shell and other materials that are commonly used as growth media in aquaponic systems such as quartz, gravels, clay balls and pebbles.

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