Performance of a Constructed Homestead Aquaponics System Used For Fish Culture and Lettuce Production

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Abstract

Two identical Aquaponics systems were constructed to evaluate the growth of Catfish (*Clarias gariepinus*) and Lettuce (*Lactuca sativa*) and also to evaluate water quality and nutrient dynamics. A repeated measure design (RMD) was used in all the experiments. Lettuce was grown in three grow beds (GB) containing substrates of gravel and biochar. GB A contained only gravel, GB B contained gravel and biochar in a ratio of 1:1 and GB C only biochar. The fish of 50 grams average weight were reared in two tanks A and B. Fish from tank B had the highest biomass of 5,880 grams as against those from tank A with a biomass of 5,400 grams, tank A had a survival rate of 90% while tank B had 93.33% survival. The biomass and height of lettuce was also compared, GB C had the highest biomass and weight of 16.34 grams and 20.96 cm as compared to GB B 13.3 grams and 12.08 cm and GB A 12.19 grams and 8.87 cm respectively. The physic-chemical parameters of water which include temperature, pH, dissolved oxygen electrical conductivity ammonia nitrite, nitrate hardness alkalinity and biological oxygen demand were measure. It was observed that there was no significant difference (P>0.05) between all the water quality parameters. GB C had the highest 5.8mg/l followed by GB B 5.0mg/l and GB A with the least 4.63mg/l. The nutrient dynamics studied in the experiment are Fe^{2+}, NO_3-N, PO_4-P, K^+, Mg^{2+}, Na^+ and Ca^{2+} in the three grow beds did not differ significantly (P>0.05). In conclusion, biochar can be used as an effective substrate in Aquaponics system for the culturing of plants.

Keywords: Aquaponics; Biochar; Grow bed; Clarias; Lettuce.

Introduction

Aquaponics combines aquaculture and hydroponic production systems into one system (Morshuizen, 2013) and has been described as superior since it combines these two systems together (FAO, 2014). Aquaponics is common and well known overseas being most popular in Australia (*et al*, 2015). However, Aquaponics is still a new and emerging technology in most

African countries, including Nigeria. This opens a new niche for sustainable food production, which is necessary and important for South Africa to optimize it's food availability. In order to make good use of Aquacultural effluent and wastes, Aquaponics systems have been designed with dual potential effect, (a) assist mitigate Aquacultural fish waste product that has negative potential to the environment, and (b) to use nutrient-rich Aquacultural effluent to produce healthy food (Khater *et al.,* 2015).

Aquaponics is the production of fish and vegetable at the same time through linking Aquacultural fish waste to hydroponically growing plants as natural nutrient source material to support plant life cycle (Sace *et al.,* 2011). Aquaponics related benefits include the use of less water than conventional agriculture and in particular, provides an option for nutrient recycling and reuse (Munguia-Fragozo, *et al*, 2015). This, in particular, is suitable and important for Africa to address water scarcity and food insecurity problems. The Aquaponics re-circulating systems are designed to raise large quantities of fish in relatively small volumes of water (20kg of fish per 1000l volume of water), making Aquaponics system a most innovative and ideal food producing method suitable to generation of today, also playing a critical role in agricultural evolution and advancement. In Aquaponics system, effluent that is generated from the fish tanks is pumped and used to fertigate growth medium beds (GMB) in hydroponic culture (Rakocy ,2007). In return, this process is worthy to the fish, because crop plants roots system together with rhizobacteria helps to extract available nutrients from water solution. The nutrients materials produced from fish algae, manure, and decomposing uneaten fish feed are pollutants that could build up to lethal levels in fish tanks, however, this instead waste serve as liquid mineral fertilizer in hydroponic culture (Monnet *et al.,* 2002). The hydroponic culture functions as a biofilter (Graber and Junge, 2009), removes off ammonia, nitrates, nitrites, and phosphorus and other trace elements, so the freshly cleansed water can then be recirculated back into the fish tanks (Liang and Chien, 2013). The nitrifying bacteria living in the gravel and in association with the plant roots play a crucial role in nutrient cycling (Palm *et al.*, 2014). In the absence of these microorganisms the whole system would be dysfunctional (Munguia-Fragozo *et al.*, 2015). Water is the most crucial input parameter of an Aquaponics system, water is critical and essential component of an aquaponic system (Rafiee and Saad, 2005). Even though fish is a water creature, a fish well-being could also be affected if water quality is poor (FAO, 2014) Small-scale). In particular, a fish raised in re-circulating tank culture, requires good water quality conditions since fresh water fish are very strict to environmental conditions (Endut *et al,* 2010). Hence, to maintain good water quality requires a testing kit, and this can be sourced from local Aquacultural supply companies. Critical water quality parameters include dissolved oxygen (to be kept between the ranges of 4-8 mg/l), carbon dioxide, ammonia, nitrate, nitrite (to be kept between the ranges of 3-100 mg/l), pH, chlorine, and other characteristics (FAO 2015, Liang and Chien, 2013). The stocking density of fish, the growth rate of fish, feeding rate and volume, and related environmental fluctuations can prompt rapid changes in water quality; as such a constant and vigilant water quality monitoring is very important to keep the system running smooth (Fox *et al,* 2010).

MATERIALS AND METHODS

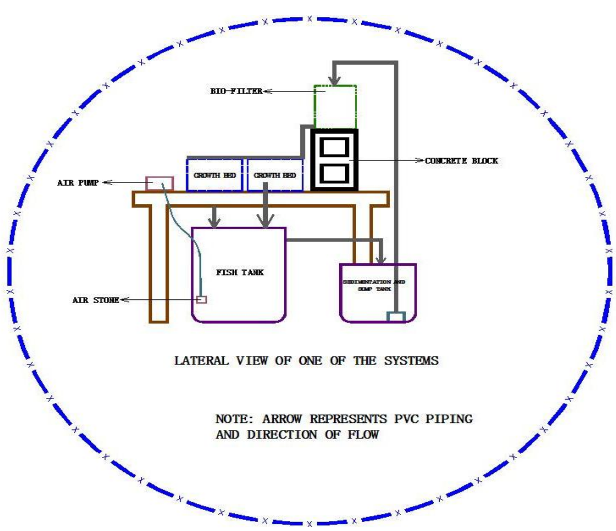
Location of the Study Area

The study was carried at the laboratory of the department of Water Resources Aquaculture and Fisheries Technology, Federal University of Technology Minna Niger State Nigeria. Located between Latitude 9^0 31'58.998'' N and Longitude 6^o 27' 7.29'' E.

Experimental Setup

Two identical Aquaponics systems were designed and constructed, each system comprised of a rearing tank (fish tank) 300 litres, a mechanical filter, sump tank, bio-filter, and two grow beds (0.8mx 0.63mx 0.3m) each. One submersible water pumps was placed in each of the sump tanks to move water round the system. An aquarium air pump was placed in the rearing tank to aerate the water.

Two plastic tanks were used for rearing of fish (300 litres each), the grow beds were constructed with wooden planks, lined with tarpaulin to prevent water leakage. The grow beds were be filled with gravel and biochar. The first grow bed was filled with gravel only and the second one was filled with both gravel and biochar at a ratio of 1:1. The third grow bed was filled with biochar only. The plumbing for each system comprised of 3/4'' PVC pipe, two ball valves for regulation of water flow. Water was pumped from the sump tank round the system.



Schematic diagram of the Re-circulatory Aquaponics System

Biochar Production

Coconut husk were procured from Kasuwan Gwari Minna and then charred at a temperature of about 400^{o}C in a Ceramic firing kiln at Al-Habib pottery Tunga Minna.

Procurement of Gravel

The gravels used in the grow beds for the study was procured from a stone quarry in Minna, washed with water and then placed in the grow beds.

Fishless Cycling

Urea fertilizer was added to the system as a source of ammonia and to establish nitrifying bacteria colonies for mineralization before adding fish and plants. This took about 21 days.

Sowing of Lettuce Seeds

Lettuce seeds were raised in a nursery using a plastic container filled with loam soil and wetted; the seeds were broadcasted on the soil and allowed to germinate. After germination the seedlings were transplanted into the grow beds at a density of 20 plants per m^2.

Procurement of Fish Seed

60 African catfish (*Clarias gariepinus*) average 50 grams of weight were obtained from Jibson fish enterprise Minna. 30 fish were stocked in two 300 litres plastic tanks each.

Fish Feeding

The fish were fed with a commercial diet containing 30% crude protein and 3mm size. The fish were fed twice a day (morning and evening) on a 5% body weight for 3 months.

Water Quality Management and Nutrient Dynamics

All water quality parameters and nutrient dynamics were measured using standard laboratory procedures.

Measuring Lettuce Growth and Biomass

The height (cm) of lettuce grown in different grow beds will be measured using meter rule at the end of the experiment to determine their development in relation to the substrate and nutrient in the used in growing them.

The weight of the lettuce in each grow bed will the measured using a sensitive scale in grams at the end of the experiment to also determine their development in relation to the substrate and nutrient used in growing them.

Evaluation of *Clarias gariepinus* growth parameters

Nutrient utilization and growth performance were analysed in terms of final weight gain (FWG), percentage survival rate (% SR), specific growth rate (SGR), feed conversion ratio (FCR) and feed conversion efficiency (FCE) they were calculated using the formulae as described by Bake *et* al., (2014).

Data Analysis

A repeated measure design was used in all the experiments. Data generated were subjected to one way Analysis of variance (ANOVA) Tukey test analysis, the difference in mean, standard deviation of mean (±SDM) were tested for significance using the Duncan multiple range test at 95% confidence level (P<0.05). Water physic-chemical parameters, nutrient dynamics, lettuce and fish yield were all presented in tables.

RESULTS

Table 1: Physico-chemical Parameters of Water for the Different Treatments.

Table 4.1 depicts the water physico-chemical parameters for the different treatments. There was no significant variation (P>0.05) in water temperature among the three treatments. Similar mean temperatures of (25.83^oC±1.09) were recorded for all the treatments. Also, There was no significant relationship (P>0.05) in pH values for all the treatments. The pH values were 6.91-7.23, and 7.06 for GBA, GBB and GBC respectively. There was a significant relationship (P<0.05) in dissolved oxygen (DO) among the three treatments. The highest mean value for the dissolve oxygen was recorded from GBC (5.81-mg) while the lowest of 4.53mg/l was recorded for GBA had the highest value 5.00mg/l, followed by GB B 5.00 mg/l and GB A with the least 4.53mg/l. The electrical conductivity (E.C) also did not vary significantly (P>0.05) ranging between 737.00-872.66 μ^s/cm, GB C had the highest 872.66μ^s/cm then GB A 808.33, with GB B having the least value 737.00μ^s/cm, the mean value is (806.00±133.98 μ^s/cm). Values in ammonia (NH_3) did not vary significantly (P>0.05) ranging between 2.37-3.87mg/l GB A had the highest 3.87mg/l followed by GB B 3.54mg/l with GB C having the least 2.37mg/l with a mean value of (3.26±1.88). There was also no significant relationship (P>0.05) between treatment 3 and the other 2 treatments in nitrite (NO_2) with a range of 0.62-0.12 mg/l GBC had 0.62mg/l while both GB A and GB B had the same value 0.12mg/l. The nitrite value had a mean value of (0.10±0.77). Nitrate (NO_3) values also did not vary significantly (P>0.05) ranging between 3.00-4.08mg/l, GB A had the highest 4.08mg/l GB B had 4.00mg/l and the GB C 3.00mg/l with a mean value of (3.69±2.55). No significant relationship was observed (P<0.05) in hardness among the three treatments with a range of 158.60-195.50mg/l, GB C had the highest value 195.50mg/l followed by GB B 166.95mg/l and then GB A having the least 158.60mg/l, the mean value is (173.68mg/l±34.65). The alkalinity in the three treatments did not vary significantly (P>0.05) with a range of 118.66-145.33mg/l, GB C had the highest value 145.33 mg/l then GB B 143.33 and GB A having the least 118.66mg/l. the mean value is(135.77±35.02). There was no significant difference in Biological oxygen demand (BOD) values for the three treatments also varied significantly (P>0.05) with a range of 3.33-5.00 mg/l GB C had the highest 5.00mg/l followed by GB B 4.33mg/l and GB A having the least 3.33mg/l (BOD) had a mean value of (4.22±0.97).

Table 1: Mean Water Quality Parameters During the Experimental Period.

Parameter	GB A	GB B	GB C	X±SD
Temp. (^oC)	25.83^a	25.83^a	25.83^a	25.83±1.09
pH	7.23^a	7.06^a	6.91^a	7.07±1.00
Dissolved Oxygen (mg/l)	4.53^b	5.00^a	5.81^a	5.11±0.79
Conductivity (μ^s/cm)	808.33^a	737.00^b	872.66^a	806.00±133.98
Ammonia (mg/l)	3.87^a	3.54^a	2.37^b	3.26±1.88
Nitrite (mg/l)	0.12^a	0.12^a	0.62^b	0.10±0.77
Nitrate (mg/l)	4.08^a	4.00^a	3.00^b	3.69±2.55
Hardness (mg/l)	158.60^a	166.95^a	195.50^b	173.68±34.65
Alkalinity (mg/l)	118.66^a	143.33^b	145.33^b	135.77±35.02
Biological Oxygen Demand (mg/l)	3.33^a	4.33^b	5.00^b	4.22±0.97

Values in the same row with different superscript letters are significantly different (P<0.05) from each other

where: GB A= Grow Bed A; GB B= Grow Bed B; GB C=Grow Bed C; X±SD=Mean and standard deviation

Table 2: Mean Nutrient Dynamics during the Experimental Period

There was a significant relationship (P<0.05) between the three treatments in iron (Fe) concentrations ranging between 3.82-5.21 mg/l (Table 4.2) GB B had the highest 5.21mg/l followed by GB C 3.88mg/l and then 3.82mg/l with a mean value of (4.30±0.67). Nitrogen (N) also varied significantly (P<0.05) ranging between 0.55-0.26mg/l, GB B had the highest 0.55mg/l followed by GB C 0.27mg/l and GB A having the least 0.26mg/l having a mean of (0.36±0.14). Values in phosphorus (P) among the three treatments did not differs significantly (P<0.05) with a range of 0.23-0.36mg/l, GB C had the highest 0.36mg/l followed by GB B 0.28mg/l and GB A having the lowest 0.23mg/l with a mean value of (0.29±0.11). There was a significant relationship (P<0.05) in potassium (K) levels among the three treatments ranging between 6.24-7.35mg/l, GB B had the highest value 7.35mg/l then GB C 6.83mg/l and the lowest 6.24mg/l having a mean value of (6.81±0.47). The concentrations of magnesium (Mg) did not vary in treatments GB A and GB B significantly (P<0.05) in the three treatments ranging between 6.56-12.82mg/l although GB A and GB B are having close values of 6.56mg/l and 6.63mg/l respectively GB C had the higher value of 12.82mg/l. The mean value for the three treatments is (8.67±5.11). There was also a significant relationship (P<0.05) among the three treatments in sodium (Na) concentrations with a range of 17.58-21.99mg/l GB B had the highest 21.99mg/l, GB A had 18.33mg/l and the GB C had the lowest 17.58mg/l with a mean value of (19.10±1.78). Calcium (Ca) concentrations did not vary significantly (P<0.05) among the treatments ranging between 54.31-55.83mg/l, GB C had the highest 55.83mg/l followed by GB A 54.73mg/l and the least GB B with 54.31mg/l having a mean value of (54.95±8.86).

Table 4: Mean Nutrient Dynamics During the Experimental Period.

Parameter	GB A	GB B	GB C	X±SD
(Iron mg/l)	3.82[a]	5.21[b]	3.88[a]	4.30±0.67
Nitrogen (mg/l)	0.26[a]	0.55[a]	0.27[a]	0.36±0.14
Phosphorus (mg/l)	0.23[a]	0.28[a]	0.36[a]	0.29±0.11
Potassium (mg/l)	6.24[a]	7.35[a]	6.83[a]	6.81±0.47
Magnesium (mg/l)	6.56[a]	6.63[a]	12.82[b]	8.67±5.11
Sodium (mg/l)	18.33[a]	21.99[b]	17.58[a]	19.10±1.78
Calcium (mg/l)	54.73[a]	54.31[a]	55.83[a]	54.95±8.86

Values in the same row with different superscript letters are significantly different (P<0.05) from each other

Where: GB A= Grow Bed A; GB B= Grow Bed B; GB C=Grow Bed C; X±SD=Mean and standard deviation

Mean Biomass Length and of Lettuce after the Experimental period.

There was no significant difference (P>0.05) in the biomass of lettuce among the three treatments ranging between 12.19-16.34 grams, GB C had the highest 16.34 grams followed by GB B13.23 grams and then GB A with the least 12.19 grams with a mean value of (13.93±2.19)

Lettuce growth and production was affected by different substrate composition. There was a significant relationship (P<0.05) in the length of lettuce among the three treatments with a range of 8.87-20.98 grams, GB C showed the highest length of 20.96 grams followed by GB B 12.08 grams and GB A with the least 8.87 grams having a mean value of (13.92±9.10). According to some early workers aquaculture effluent provides most of the nutrients required by plants if the optimum ratio between daily feed input and plant growing area is maintained.

Table 4.3 Mean Biomass and Length of Lettuce after the experimental period.

Parameter	GB A	GB B	GB C	X±SD
Weight (g)	12.19[a]	13.23[a]	16.34[b]	13.92±2.19
Height (cm)	8.87[a]	12.08[b]	20.96[c]	13.97±9.10

Values in the same row with different superscript letters are significantly different (P<0.05) from each other.

Where: GB A= Grow Bed A; GB B= Grow Bed B; GB C=Grow Bed C;
X±SD=Mean and standard deviation

Discussions

The mean temperature of the water recorded across all the growing bed was 25.83^{o}C±1.09 and this is in line with the report of Madu *et al.,* (2003) and Boyd (1979) as cited in Okey *et al.,* (2013) that the optimum water temperature for tropical fish culture is 22^{o}C-32^{o}C.

The pH of the water obtained for the experiment was within the tolerable range of (6.91-7.23) for the culture of *Clarias gariepinus*. This is in consonant with the result of (Akinwole *et al.,* 2006). Although they further reported that higher levels pH triggered elevation of some water quality parameters.

The dissolve oxygen range between 4.53 to 5.8mg/l. This is in conformity with Brown (1957), who stated that the survival of *Clarias gariepinus* is not dependent on oxygen in the water since it can gulp air from the atmosphere. While inadequate dissolve oxygen is not lethal itself, but can seriously affect the health of fish and facilitate the spread of disease.

Conductivity throughout the study period for the three treatments prevailed between 737.00-872.66µ^{s}/cm. This partly agrees with the findings of Ryan (2013) who reported values of 1319±62.18 and 1078±46.50 for Aquaponics media and Aquaponics deep water respectively. Water conductivity of between 150 and 500µ^{s}/cm was said to be ideal for fish (Russell *et al.,* 2011) Stone *et al,* (2013), however, they further concluded that the desirable range of conductivity for fish ponds should fall between 100 and 2000µ^{s}/cm.

The results of the ammonia obtained in this study ranges between 2.37-3.87ppm which is within the guidelines from Endings and Kamstra, (2001) who stated that the value less than 8.8mg/l are considered tolerable for the culture of *Clarias gariepinus*. Dangerously high ammonia concentrations are usually limited to water recirculatory systems or hauling tanks where water is continually recycled and in pond culture after phytoplankton die-offs.

Also nitrite levels throughout the experimental period ranged between 0.12-0.62 mg/l. This corresponds with the acceptable limit of less than 4ppm (DWAMD, 1994). The nitrate concentrations ranged between 3.00-4.00 mg/l. This results also agree with Stone and Thomforde (2004) whom revealed that nitrate is relatively non-toxic to fish and do not cause any health hazard except at exceeding high levels above 90 mg/l/. Hardness ranges between 158.60-195.50mg/l. According to Bhatnagar *et al.,* (2004) hardness values less than 20ppm causes stress, 75-150ppm is optimum for fish culture and >300 mg/l is lethal to fish life as it increases pH, resulting in non-availability of nutrients.

The biological oxygen demand ranged between 3.33 to 5.00mg/l. The results recorded for this parameter is in tandem with Bhatnagar *et al.,* (2004) where they reported that the BOD levels between 3.6-6.0ppm is sub lethal to fishes and >12.0 mg/l can usually kill fish due to suffocation.

Alkalinity ranged 118.66to 145.33. This also conforms with Santhosh and Singh (2007) who suggested that the ideal value for fish culture is 50-300mg/l.

Iron, Calcium and Potassium are the most limiting mineral nutrients in fish feeds and are significantly important for crop plant production. The concentration of iron (Fe^{2+}) in from the three grow beds ranged between 3.82-5.21 mg/l, this result does not agree with that reported by Shete *et al.*,(2015) who recorded values between 0.018-0.023 mg/l. The total ammonia nitrogen (TAN) ranged between 0.26-0.55 mg/l, this closely resembles the values observed by Shete *et al.*,(2015) who reported values within the range of 0.378-0.867 mg/l. Phosphate phosphorus (PO_4-P) ranged between 0.23-0.36 mg/l, Shete *et al.*,(2015) reported slightly higher values between 0.48-1.16 mg/l. The values recorded in potassium (K^+) were within the range of 6.24-7.35 mg/l, Shete *et al.*, (2015) reported higher values of 13.54-19.02 mg/l. The magnesium (Mg^{2+}) values recorded in this study ranged between 6.56-12.82 mg/l, these values are far lower than those recorded by Shete *et al.*,(2015) who reported values ranging between 45.00-50.43 mg/l. Sodium (Na^+) concentrations ranged between 17.58-21.99 mg/l, these values are too low as compared to those reported by Shete *et al.*,(2015). The calcium (Ca^{2+}) concentrations in this study ranged between 54.31-55.83 mg/l, this also does not agree with those recorded by Shete *et al.*, (2015) who reported values between 125.90-127.64 mg/l.

Plants require 17 essential nutrients without which they are unable to complete a normal life cycle (Epstein and Bloom, 2005). Of these nutrient elements oxygen (O), hydrogen (H), and carbon (C) are typically categorized as non-mineral. Nitrogen (N), phosphorus (N), and potassium (K) are considered as primary macro-Nutrients, and calcium (Ca), sulfur (S), and magnesium (Mg) as secondary ones. Boron (B), chlorine (Cl), manganese (Mn), iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo), and nickel (Ni) are categorized as micronutrients or trace minerals. All plants, with the exception of parasitic and carnivorous ones, absorb the essential nutrient elements from the air or soil solution (Epstein and Bloom, 2005). It should be noted that in contrast to plants, fish nutrition is very different. The composition of fish feeds depends on the nature of the fish: whether it is carnivorous, omnivorous, or herbivorous. Typically, fish feed contains an energy source (carbohydrates and/or lipids), essential amino acids (10 amino acids that fish cannot synthesize out of the 20 protein-building ones), vitamins, as well as other organic molecules that are necessary for normal metabolism but that fish cells cannot synthesize, and altogether 21 different macro- and micro-minerals Nutrient deficiencies in fish are often accompanied by disturbances in the balance of other minerals (Bijvelds *et al.*, 1998). Microbial communities (consisting of bacteria, protozoa, and micrometazoa, located in the biofilter and on the roots of plants) play major roles in the nutrient dynamics in Aquaponics systems (Munguia-Fragozo *et al.*, 2015). Their primary role is to convert ammonium to virtually non-toxic nitrate but they also contribute to the processing of particulate matter and dissolved waste in the system. Both functions are absolutely crucial for the stability of an aquaponic system (Goddek *et al.*, 2015, Munguia-Fragozo *et al.*, 2015). Unfortunately, very little is known about the nutrient requirements and potential sensitivities of these microbial communities to variations in the availability of nutrients (Kantartzi *et al.,* 2006).Unfortunately, a clear interpretation of the data is very challenging. The reason is that very recently (Parent *et al.*, 2013, Baxter, 2015) in plant nutrition the nearly two-century-old "Liebig's law" (briefly, plant growth is controlled by the scarcest resource) has been superseded by complex algorithms that take the interactions between the individual nutrient chemicals into account. These methods do not allow a simple evaluation of the effects of changes in nutrient concentrations in a hydroponic or Aquaponics system. Also, we must bear in mind that a perfect formulation of nutritional requirements for a particular crop does not exist. The nutritional requirements vary with variety, life cycle stage, day length, and weather conditions. Usually, in Aquaponics, with appropriate fish stocking rates the levels of nitrate are sufficient for good plant growth, whereas the levels of K+ are generally insufficient for maximum plant growth. Additionally, phosphorous, calcium and iron could be limiting (Mathis, unpublished).

Conclusions

Properly managed Aquaponics systems can yield highly productive plants. Aquaponics systems can be built and operated successfully using locally available materials. Base on the water quality data collected, the water quality parameters were within the tolerable range for the culture of African catfish (*Clarias gariepinus*). The results obtained for nutrient dynamics reveals that the there was insufficient amounts of nutrients necessary for plant growth; this is typical of new Aquaponics systems. The substrates used in this research served as an anchorage for the lettuce plants and also provided a surface area for the proliferation of nitrifying bacteria. These substrates which are gravel and coconut biochar influenced the nutrient dynamics and also lettuce development, Both gravel and biochar and also combination of the two have proven to be good growth medium for Aquaponics plants even though the grow bed with complete biochar had the best performance.

References

Akinwole A. O. & Faturoti E. O. (2006). Biological performance of African Catfish (*Clarias gariepinus*) culture Recirculating System in Ibadan. *Aquaculture engineering*, 36: 18-23.

Bake G. G., Martins, E. I. & Sadiku, S. O. E. (2014). Nutritional evaluation of varying Levels of cooked flamboyant seed meal (*Delonix regia*) on the growth performance and body composition of Nile tilapia (*Oreochromis niloticus*) fingerlings. *Journal of Agriculture, Forestry and Fisheries,* 3 (4), 233-239. doi:10.11648/j.aff.20140304.14 ISSN:2328-5648.

Baxter, I., (2015). Should we treat the ionome as a combination of individual elements, or should we be deriving novel combined traits? *Journal of Experimental Botany.* 66, 2127–2131

Bhatnagar, A., Jana, S.N., Garg, S.K. Patra, B.C., Singh, G. & Barman, U.K. (2004).Water quality management in aquaculture, *In Course Manual of summerschool on development of sustainable aquaculture technology in fresh and saline waters.*CCS HaryanaAgricultural, Hisar (India), pp 203- 210.

Boyd C.E. (1979). Water quality in warm fish ponds. Crafter master printers, INC Opelika, Alabama. 72.

Brown M.E. (1957). The physiology of fishes Volume. 1, *Academic Press Incorporation*. New York, pp. 44.

DWAMD. (1994). Division of Water Ambient Monitoring Database.18thEdition. 325p.

Ending & kamstra. (2001). Design and performance of recirculating Systems For European eel Anguilla and African Catfish *Clariasgariepinus*, in Proceeding of AES Workshop, Florida, U.S.A. pp 15-25.

Endut A., Jusoh A., Ali N, Nik W.B.W,& Hassan A. (2010). A study on the optimal hydraulic loading rate and plant ratios in recirculation Aquaponics system.BioresourcesTechnology :101:1511-1517.

FAO. (2014). Small-scale aquaponic food production.FAO fisheries and aquaculture technical paper, Rome, Italy.

FAO. (2015). Land and property rights: Junior Farmer Field and Life School, Facilitator’s guide. Aquaculture, Rome, Italy.

Fox B.K, Howerton R., & Tamaru C.S. (2010). Construction of automatic bell siphons for backyard aquaponic systems. Biotechnology.

Goddek S, Delaide B, Mankasingh U, Ragnarsdottir K, & Jijakli H, .(2015). Challenges of sustainable and commercial aquaponics. Sustain 7:4199-4224.

Graber A. & Junge R. (2009). Aquaponics systems: Nutrient recycling from fish wastewater by vegetable production. Desalination 246:147-156.

Kantartzi, S.G., Vaiopoulou, E., Kapagiannidis, A., & Aivasidis. (2006). Kinetic characterization of nitrifying pure cultures in a chemostat. *Global Nest Journal*. 8, 43–51.

Khater E.S.G., Bahnasawy A.H, Shams A.E.H.S, Hassaan M.S, & Hassan Y.A. (2015). Utilization of effluent fish farms in tomato cultivation. EcolEng 83:199-207.

Liang J.Y, & Chien Y.H. (2013). Effects of feeding frequency and photoperiod on water quality and crop production in a tilapia-water spinach raft aquaponics system. *International journal of Biodeteriorable Biodegradable.* 85:693-700.

Madu, C.T., Sogbesan, A. O. & Ibiyo, L. M. O. (2003). Some non-conventional fish feed resources in Nigeria. In: National Workshop on Fish Feed and Feeding Practice in Aquaculture. A.A. Eyo (Ed) *Published by FISON, NIFFR, FAO-NSPFS*. 73-83.

Monnet F., Vaillant N., Hitmi A, Vernay P, & Coudret A.(2002) .Treatment of domestic wastewater using the nutrient film technique (NFT) to produce horticultural roses. Water Resources 36:3489-3496.

Morshuizen T.L. (2013). The commercial viability of aquaponics. *Journal Chemical Information Modelling* 53:1689-1699.

Munguia-Fragozo P., Alatorre-Jacome O., Rico-Garcia E., Torres-Pacheco I., & Cruz-Hernandez A. (2015). Perspective for aquaponic systems: "omic" technologies for microbial community analysis. Bio-medical Resources International 2015:1-10.

Okey, I. B., Gabriel, U. U. & Keremah, R. I. (2013). Acute toxicity of *Lepidagathis alopecuriodes* (Vahl) to *Heterobranchus bidorsalis* fingerlings. *Journal of Environmental Chemistry and Ecotoxicology,* 5 (8), 208-215. DOI: 10.5897/JECE2013.0285. ISSN 2141-226X

Palm H.W, Seidemann R., Wehofsky S.,&Knaus U. (2014). Significant factors affecting the economic sustainability of closed aquaponic systems. Part I: System design, chemo-physical parameters and general aspects. AACL Bioflux 7: 20-32.

Parent S.-É., Parent L.E., Egozcue, J.J., Rozane, D.-E., Hernandes A., Lapointe, L., Hébert Gentile, V., Naess, K., Marchand, S., Lafond, J., Mattos, D., Barlow, P., & Natale, W., (2013). The plant ionome revisited by the nutrient balance concept. *Frontier Plant Science.* 4.

RafieeG., & Saad C.R. (2005). Nutrient cycle and sludge production during different stages of red tilapia Oreochromis sp. growth in a re-circulating aquaculture system. Aquaculture 244:109-118.

Rakocy J. (2007) Ten guidelines for aquaponic systems. *Aquaponics Journal 3rd Quarter* 2: 14-17.

Russell M., Shuke R, Samantha S. Effects of Conductivity on Survivorship and weight of Goldfish (Carassius auratus). 2011. Retrieved from: *www.: //departments .juniata .edu/biology/eco/documents/Russell_et al.pdf. 23 Apr 2017*

Ryan K. (2013). Aquaponics and Hydroponics: the Effects of Nutrient Source and Hydroponic Subsystem Design on Sweet Basil Production. Retrieved from *https://centralspace.ucmo.edu/handle/123456789/308*

Sace C.F., & Fitzsimmons K.M. (2013). Vegetable production in a recirculating aquaponic system using Nile tilapia Oreochromisniloticus with and without freshwater prawn Macrobrachium rosenbergii. Academic Journal of Agricultural Resources 1:236-250.

Santhosh, B. & Singh, N.P. (2007). Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Center, Publication no.29

Shete A. P., VermaA.K., Chadha N.K., Chandra Prakash, & Chandrakant M.H. (2015). A Comparative Study on Fish to Plant Component Ratio In Recirculating Aquaponic System with Common Carp and Mint. *Journal of environmental bioscience*, 2015: Vol. 29 (2):323-329 ISSN 0973-6913 (Print), ISSN 0976-3384.

Stone N., Shelton J.L,Haggard B.E, & Thomforde H.K.(2013). *Interpretation of Water Analysis Reports for Fish Culture.Southern Regional Aquaculture Centre (SRAC)* Publication No. 4606.12 pg. Google Schorlar.