ASUU JOURNAL OF SCIENCE
A Journal of Research and Development
Vol. 8 No. 1 & 2 June, Dec. 2021: 60-74

Biotechnical and limnological effects of different growth media in a Pyramid Nutrient Film (PNF) Aquaponic System on Giant African catfish (*Heterobranchus bidorsalis*) and tomato (*Lycopersicum esculentum*)

[*] ***Gbadamosi, O.K. and Adebayo, O.T.***

Abstract
This study was carried out to assess the biotechnical and limnological effects of different growth media in a Pyramid Nutrient Film (PNF) Aquaponic System on Giant African catfish (Heterobranchus bidorsalis) and tomato (Lycopersicum esculentum) raised in the aquaponic system. The aquaponic system was designed with a Poly Vinyl Chloride circular base of 10cm diameter perforated to produce a 5cm diameter hole made for the plant to float. Disposable plastic cup of 5cm diameter were filled with four growth media namely Palm kernel shells (PKS), Gravel (GRA), Crushed Snail Shell (CSS) and conventionally used loamy soil which was used as control to support the plants. Fish were fed for 56 days during which the water was recycled to serve as a source of nutrient for the plant. Water quality parameters were monitored throughout the experimental period and at the end of the experiment, yield of L. esculentum, growth performance and nutrient utilisation of H. bidorsalis were recorded. Significantly better ($p<0.05$) biometric parameters in terms of plant yield and fish zootechnical performance were recorded in H. bidorsalis and L. esculentum raised on the control, loamy soil and Palm kernel shells (PKS) in treatment one. This study showed that PKS is a suitable media bed in aquaponic for the production of tomatoes and H. bidorsalis. Palm kernel shells also enhanced the symbiotic integration of aquaculture and hydroponics in utilising waste as raw material to keep the aquaponic system sustainable and revolving.

[*] **Gbadamosi, O.k. And [*] Adebayo, O.t.**
okgbadamosi@futa.edu.ng
[*] *Department of Fisheries and Aquaculture Technology, P.M.B 704, Akure, Ondo State, Nigeria Telephone number: 234-7053332818*

Keywords: Aquasystems, Catfish, Media, Zootechnical, Hydroponic And Limnology

Introduction

Aquaponics is a form of sustainable agriculture that combines fish and plant in a closed recirculating system (FAO, 2020). A typical aquaponic system consists of a fish rearing tank, a solid removal tank, a biofilter, a hydroponic unit, and optionally a sump tank (Rakocy and Hargreaves, 1995). In RAS, it is important to maintain good water quality for the fish health by removing solid waste and dissolved nutrients that would become toxic to the fish at high concentration. The release of large amounts of nutrients into the environment can cause eutrophication, leading to imbalance in the ecosystem such as algal boom and change in the local fauna (Effendi *et al,* 2015). In aquaponic unit, water from the fish tank cycles through filters, plant grow beds and then back to the fish (Rakocy and Hargreaves, 1995). In the filter, the water is cleaned from the fish wastes by a mechanical filter that removes the solid part, and a bio filter processes the dissolved wastes. The bio filter provides a location for bacteria to convert ammonia, which is toxic for fish, into nitrate, a more accessible nutrient for plants. This process is called nitrification. As the water (containing nitrate and other nutrients) travels through plant grow beds the plants uptake these nutrients, and finally the water returns to the fish tank purified (Mader, 2012). The process allows the fish, plants and bacteria to thrive symbiotically and work together to create a healthy growing environment for each other, provided that the system is properly balanced.

Heterobranchus bidorsalis, also called the giant African catfish is an air breathing catfish found in Africa. It is a highly economic species that performs better than other species in the family *Clariidae*. It is identified from other species in its genus by the presence of a longer dorsal fin compared to its adipose fin with presence of black spot at its tail end (Adebayo and Fagbenro, 2004). *H. bidorsalis* meat is palatable and of high quality. Tomato (*Lycopersicum esculentum*) is one of the most important vegetables grown for their edible fruits. Tomato is cultivated in Nigeria with an annual production of six million tonnes (Asiegbu and Uzo, 1984; Idah et al., 2007). It is an excellent source of vitamins, minerals, and antioxidants which help control cancer, health disease as well as improve the general health of man (El Shkweer et al, 1998). The availability of new cultivars, growing methods and the demand for tomato have encouraged world production of tomato (FAO, 2020). Despite the fact that tomato has been inculcated successfully in different aquaponic systems, knowledge of the suitability of different non-conventional growth medias in the production of tomato when combined with giant African catfish in an aquaponic system is still scarce. The characteristics of the various materials used as substrate directly and indirectly affect plant development and production. Therefore, substrate structure influences crop development, mainly for soil less crops. In brief, the choice of substrate in an aquaponic system must meet the appropriate water and air proportions that meet the plant needs (Asiegbu and Uzo, 1984; Roosta, 2014).

Materials and Methods (Methodology):

Experimental site and system design

This study was carried out in at the Teaching and Research Farm of the Department of Fisheries and Aquaculture Technology, Federal University of Technology, Akure, Nigeria. The design of the aquaponics system used in the current study was a Pyramid Nutrient Film (PNF) Aquaponic System with a combined culture of Giant African catfish (*Heterobranchus bidorsalis*) and tomato (*Lycopersicum esculentum*) (Figure 1). The aquaponic system was designed with a Poly Vinyl Chloride circular base of 10cm diameter perforated to produce a 5cm diameter hole made for the plant to float. Disposable plastic cup of 5cm diameter were filled with four growth media namely Palm kernel shells (PKS), Gravel (GRA), Crushed Snail Shell (CSS) and conventionally used loamy soil which was used as control to support the plants. The aquaponic system was set up in the Aqua-system laboratory of the Department of Fisheries and Aquaculture, Federal University of Technology, Akure, Ondo State, Nigeria.

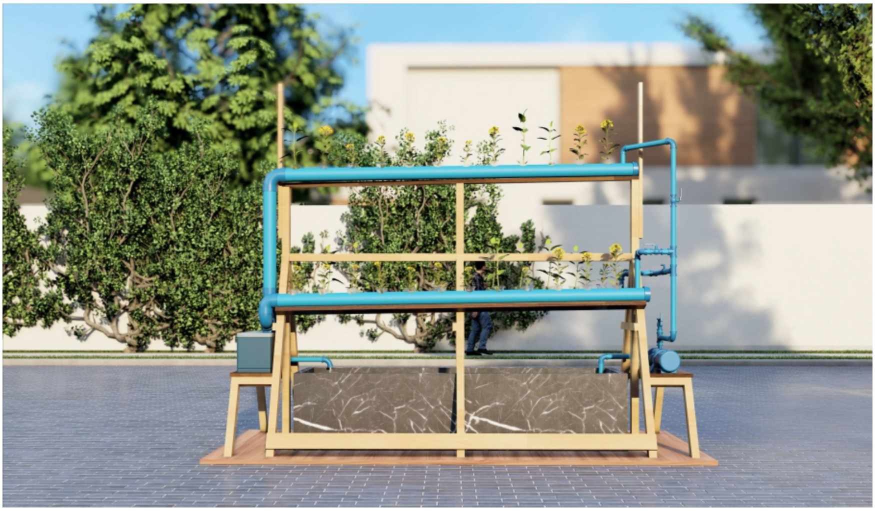

Figure 1: Pyramid Nutrient Film(PNF) Aquaponic System used in the study

Experimental fish and feeding trial

Apparently healthy *H. bidorsalis* fingerlings (15.05g ± 0.01 body weight) used in this study were obtained from the hatchery of the Department of Fisheries and Aquaculture Technology, Federal University of Technology, Akure. The fish were acclimatized to laboratory condition for seven days. Healthy fish were randomly distributed into the aquaponic tanks of dimension 40 ×30×35(cm^3) at a stocking density of ten fish per tank (9grams per liter). Each experimental diet was fed to five groups of fish in three replicates for 56 days. Fish were fed between 08:00-09:00h and 18:00-19:00h GMT. All groups were fed their respective diets at the same fixed rate of 5% body weight per day. Each group of fish were batch weighed fortnightly to monitor growth and adjust feeding rates accordingly. During the four months of this study, the fish were fed commercial diet Coppens (45% CP, 1.5% fiber, 8.2% moisture, 9.5% ash) at 5% of the total weight.

Collection and preparation of plant materials

Seedlings of *L. esculentum* were identified, authenticated and acquired from the Department of Crop, Soil and Pest Management, Federal University of Technology, Akure. In the nursery, seeds of tomato hybrid (ROMA V) were sown on a flatbed for one month before transplanting to the field. The seedlings were transplanting at the rate of one-plant-per-hole at a spacing of 5.0cm which make up three stands per treatment. Determination of yield of tomato was recorded at the end of the growing period for each treatment and was expressed in gram per treatment. After each harvest, the individual fruits were weighed and the data on fruit weight was summed up and expressed in gram. The observations on yield were recorded at the time of harvesting. After harvesting, the tomato fruits were weighed from each treatment. Proximate Analysis of *L. esculentum* and experimental fish were as described by AOAC (2005).

Monitoring of water quality Parameters

Water quality parameters such as temperature, pH and dissolved oxygen (DO) were monitored weekly in the system using a digital multi-parameter water checker (Hanna water tester Model HL 98126). Water samples for these were collected from the fish tank and from the inlet as well as outlet of each growth bed across the system.

Bio-technical performance of *H. bidorsalis* and *L. Esculentum*

Bio-technical performance in terms of growths and yield of the fish and plants were evaluated according to the methods of Gbadamosi and Salako (2015) for fish and Oladimeji *et al* (2020b) for tomatoes as follows.

Weight gain = $W_2 - W_1$; where W_2 is the final weight of fish and W_1 is the initial weight of fish in each tank (1)

Percentage Weight Gain = Final mean weight of fish / Initial mean weight of fish x 100 (2)

Specific Growth Rate

Specific Growth Rate (SGR) (%d^{-1}) $= \frac{100\left(\ln W_2 - \ln W_1\right)}{t}$ (3)

Where; W_1 and W_2 are the initial and final fish weight, respectively, and t represents the duration of the feeding trial.

Survival Rate (%) = N_1 /N_0 x 100 (4)

Where: N_1 = Total number of fish survival in pond at end of experiments.

N_0 = Total number of fish in tank at the beginning of experiments.

Feed Conversion Ratio (FCR)

FCR = dry weight of feed intake (g) / Wet weight gain by fish (g) (5)

Protein Efficiency Ratio (PER)

PER = Weight gain (g) / Protein fed (g) (6)

Measurement of Parameters for Tomatoes

Plant height was evaluated using three randomly selected plants measured in centimeters from the surface of the media to the tip of the plant. The number of fruits per plant were determined by counting the number of fruits on each plant. The yield parameters were evaluated using the total fruit production for each plant in gramme (g).

Data collection, analysis and basic assumptions

The experiment was laid out in a completely randomized design (CRD) in the aqua-system laboratory with three replications to investigate the effects of the different growth media on the growth of giant African catfish and yield of tomato. All data collected were analyzed using the analysis of variance (ANOVA) using general linear model procedure of the statistical analysis system (SAS Institute, 2003) and means were compared using Tukey test at p = 0.05 probability level. The basic assumption upon which this study was based stipulated that the number of fish reared and vegetable seedling propagated matches between nutrient input and requirements. It was also hypothesised that water flow rate of 5.0 liter/hr was sufficient for recycling the water in the hydroponics system of this setup. Lastly, it was assumed that daily addition of 5% of the total water in the aquaponics system was adequate to compensate for evaporation and transpiration losses as proposed by Effendi *et al* (2015).

Results

The water quality parameters monitored in the aquaponic system during the experimental period is shown in Table 1. The pH value ranged between 7.05-7.23, temperature 24.7-24.8°C, conductivity ranged between 19.50-20.19 micro siemens and dissolved oxygen concentrations 5.75-5.90ppm. There were no adverse effects of different media on the water quality parameters of the culture water. As shown in Table 2, the better performance of crop in terms of growth and yield observed followed the same trend of Control > PKS (treatment 1)> GRA (treatment 2) > CSS (treatment 3), when the control was compared with PKS, there was no significant difference ($p > 0.05$) in the fruit weight/plant, plant height (cm) and fruit yield (g). Furthermore, number of fruits did not differ significantly ($p > 0.05$) between treatments one and the control. The highest fruit yield was recorded in the control (78.05g) while the least value of fruit yield (63.83g) was recorded in treatment 4 with crushed snail shell growth media. In terms of growth performance and nutrient utilization of as presented in Table 3, the weight gain (WG), feed conversion ratio (FCR) and specific growth (SGR) of fish in the control and those in treatment 1 with PKS growth medium performed better fed than those in treatment 2 and 3 with GRA and CSS growth media respectively ($p < 0.05$). However, zootechnical parameters of fish in the control and treatment 1 were not significantly influenced ($p > 0.05$) by supplementation the different growth media. The survival rate among the different treatments were not significantly different ($p > 0.05$).

Discussion

The importance of water quality parameters in aquaponic systems cannot be overemphasized, poor water quality will cause the death of the plant, fish and the loss of investment (Estim and Mustafa, 2020). In the current study, the water quality parameters in the aquaponic system were within the recommended range for aquaculture (Ajani *et al.,* 2011). Moreover, the water parameters showed no significant differences during the culture period and were within the suggested range for Clariid catfish culture. Water quality parameters such as temperature, dissolved oxygen and pH. are also an important factor in nitrification, for instance Lukmantoro *et al* (2020) reported that when temperature is lower than 20ºC the bacterial metabolic activity will decrease in the aquaponic system. The optimal pH value for nitrifying bacteria is between 7.5-8.5 and grow optimally between 20-30ºC. Oxygen is required in the metabolic processes of nitrifying bacteria, low dissolved oxygen concentration will cause the denitrification process to occur, for instance reduction of nitrate to nitrite followed by reduction of nitrite to ammonia, nitrate reduction can increase under dissolved oxygen conditions below 2 mg/L (Lukmantoro *et al*., 2020). Furthermore, Boyd (1982) opined that dissolved oxygen should be above 5 mg/L to support the survival and development of African catfish. The water quality values in the present remained within acceptable limits as earlier recorded by Viveen *et al.,* (1985) who reported that water quality parameter of African catfish should be within the following ranges: dissolved oxygen of ≥5ppm and pH levels of 6.5-8.0 as good for catfish culture. The water quality parameters recorded in this present study showed that the filter media supported efficient nitrification in the aquaponics system with no adverse effect on the fish and tomatoes reared in the study.

The fruit yield of tomatoes in the aquaponic system in the present study was consistent with the range of values reported by Saufie *et al* (2015) in a study on the growth performance of tomato and tilapia in an aquaponic system. Faster growth of the plant was reported in a closed recirculating aquaculture system. However, in the present experiment there was no significant difference in the fruit yield of tomato grown under the different media. The present study further corroborated previous findings stating that tomato plant is well suited for aquaponic system, using different media.

The better biotechnical performance of plant and fish in the control and treatment one could be attributed to the humus soil and PKS growth media which agreed with earlier finding of Oladimeji *et al* (2020a). They reported increase in growth and yield of tomato combined with African catfish. The finding in this experiment also corroborated the findings of Maucieri *et al.* (2019) which concluded that water characteristics, together with nutrient availability, affected many characteristics of vegetable production especially its final yield. In aquaponic systems, the water quality dynamics is very important and must be well monitored to prevent imbalances leading to fluctuations from the acceptable water physico-chemical parameters' limits. Oladimeji *et al* (2020a) reported that different growth medium in African catfish and pumpkin aquaponic system resulted in better water qualities for fish and plant growth, through more efficient nitrification of nitrogenous waste and uptake of nutrient by plant and fish.

The specific growth rates and feed conversion ratio observed in fish in the control were better than fish in other treatments. However, there was no significant difference in the SGR and FCR of fish in the control and PKS medium in treatment one. Furthermore, fish in treatment one with PKS medium significantly performed better than those in treatments two and three with gravels and CSS media. This may be attributed to the ability of the PKS to effectively utilise the nitrogenous waste better than the other media through better absorption of ammonium, nitrite and nitrate concentrations as reported by Lukmantoro *et al.,* (2020) in a study on the effect of different filter media used on aquaponics system on ammonium (NH4 +), nitrite (NO2) and nitrate (NO3) concentrations of African catfish. This affected the plant utilization and uptake of nutrient and consequently the yield and nutrient utilisation in fish. This hypothesis is reinforced by the findings Mader (2012) which opined that different growth media may be connected to the differences in the level of nitrification occurring in the different media. The survival rate of fish in the current study was not significantly affected by the different growth media, suggesting that *H. bidorsalis* tolerated the different media used without any adverse effects on their survival.

The better performance of treatment with PKS corroborated the result of Oladimeji *et al*, (2020b) which reported that palm kernel shells media supported the best tomato yield in a drip African catfish and pumpkin aquaponic system. This is further corroborated by the findings of Sikawa and Yakupitiyage (2010) which stated that a good medium for plant growth in an aquaponics system should create a nutrient pool as well as provide adequate air space for respiration around the plant. Although the use of palm kernel shell is not conventional in aquaponic systems, Rakocy and Hargreaves (1993) reported that most media base systems utilise sand, gravel and clay pebbles as growth media. Although all the control treatments were significantly better in terms of plant and fish biotechnical performance than the other treatments, there was no significant difference between the control treatment and treatment one with the palm kernel growth media. This indicated that the protein contents of the experimental diets were effectively utilised to improve fish growth.

Conclusion

In conclusion, this study demonstrated that non-conventional growth beds like palm kernel shell (PKS) is a suitable media bed in aquaponic production of tomatoes and giant African catfish. The water quality parameters of the culturing system was not negatively affected by non-conventional growth bed like Palm kernel shells (PKS), Gravel (GRA), Crushed Snail Shell (CSS) when compared with conventionally used loamy soil. Furthermore, the findings of this study showed that the use of PKS, a non-conventional and agricultural waste material was superior to conventional growth media like gravel in supporting the biotechnical performance of tomatoes and giant African catfish combined in aquaponic system. Palm kernel shell (PKS) is considered waste which makes it readily available, affordable and hence choice alternative to conventional media, thereby promoting the circular economy.

Table 1: Water quality parameters in the aquaponic system during the experimental period

Treatments (Support media)	Temperature (^{O}C)	Conductivity (siemens)	Dissolved oxygen (ppm)	pH
Control	24.70 ± 0.13^{b}	19.50 ± 1.32^{a}	5.80 ± 1.13^{a}	7.05 ± 0.32^{a}
Treatment 1 Palm Kernel Shells (PKS)	24.75 ± 0.02^{b}	19.72 ± 1.12^{a}	5.83 ± 1.32^{a}	7.10 ± 0.62^{a}
Treatment 2 Gravel (GRA)	24.80 ± 0.32^{a}	20.17 ± 1.36^{a}	5.90 ± 0.82^{a}	7.15 ± 0.35^{a}
Treatment 3 Crushed Snail Shell (CSS)	24.70 ± 0.14^{a}	20.19 ± 1.34^{a}	$5.85 \pm .032^{a}$	7.23 ± 0.32^{a}

Means followed by same superscript in the same column for each parameter are not significantly different from each other at 5% level of probability by Tukey test.

Table 2: Effect of different media beds on the botanical parameters of tomatoes in aquaponic system

Treatments (Support media)	Numbers of fruits/plant	Fruit weight/plant	Plant height (cm)	Fruit yield (g/treatment)
Control	7.50 ± 0.13^{b}	34.15 ± 2.32^{a}	17.80 ± 1.13^{a}	78.05 ± 1.32^{a}
Treatment 1 Palm Kernel Shells (PKS)	7.00 ± 0.02^{b}	32.92 ± 1.12^{a}	17.63 ± 1.32^{a}	76.33 ± 1.32^{a}
Treatment 2 Gravel (GRA)	5.50 ± 0.32^{a}	24.92 ± 1.36^{a}	14.94 ± 0.82^{a}	68.50 ± 1.32^{a}
Treatment 3 Crushed Snail Shell (CSS)	4.50 ± 0.14^{a}	21.25 ± 1.34^{a}	$13.83 \pm .32^{a}$	63.83 ± 1.32^{a}

Means followed by same superscript in the same column for each parameter are not significantly different from each other at 5% level of probability by Tukey test.

Table 3: Growth performance and nutrient utilization of *H. bidorsalis* in the aquaponic system

PARAMETERS	CONTROL	Treatment 1 PKS	Treatment 2 GRA	Treatment 3 CSS
Initial mean weight(g)	15.06±0.02[a]	15.04±0.02[a]	15.07±0.03[a]	15.06±0.03[a]
Final mean weight (g)	37.23±1.33[a]	37.18±0.41[a]	35.88±0.77[a]	32.03±2.20[b]
Mean weight gain(g)	22.17±1.32[a]	22.14±0.47[a]	20.81±0.75[b]	16.96±2.18[c]
SR (%)	97.63±0.67[a]	97.23±3.33[a]	97.67±13.33[a]	97.33±8.82[a]
SGR (%/day)	1.78±0.05[a]	1.73±0.02[a]	1.56±0.03[b]	1.55±0.07[b]
FCR	1.66±0.07[b]	1.68±0.17[a]	1.71±0.04[a]	1.75±0.15[a]
PER	1.48±0.14[a]	1.44±0.03[a]	1.24±0.04[b]	1.19±0.12[a]
FER	0.57±0.06[a]	0.56±0.01[a]	0.47±0.02[b]	0.46±0.05[a]

Figures in each row having the same superscripts are not significantly different (P>0.05)
SR: survival rate, SGR: specific growth rate, FCR: food conversion ratio, PER: protein efficiency value, FER: feed efficiency ratio.

References

Adebayo, O.T. & Fagbenro, O.A. (2004) Induced Ovulation and Spawning of Pond Raised African Giant Catfish, *Heterobranchus bidorsalis* by Exogenous Hormones. *Aquaculture*. 13:229-236.

Ajani, E. K., Akinwole, A. O., & Ayodele, I. A. (2011). Fundamentals of fish farming in Nigeria (p. 158). Ibadan, Nigeria: Wale Crown Publishers. p 67.

AOAC (Association of Official Analytical Chemists) (2005). Official methods of analysis. Arlington Virginia. pp 634.

Asiegbu, J.E & Uzo, F.O (1984). Yield and yield component s response to vegetable crops to farm yard manure rates in the presence of inorganic fertilizer. *Journal of Agriculture Pueterico* 68:243-252.

Boyd, C. E. (1982). Water quality management of pond fish culture. Developments in *Aquaculture and Fisheries Science*.9:318-323.

Effendi H, Delis PC, Krisanti M, & Hariyadi S (2015) The performance of Nile tilapia (*Oreochromis niloticus*) and Vetiver grass

(*Vetiveria zizanioides*) concurrently cultivated in aquaponic system. *Adv Environ Biol.* 9(24):382–388.
El Shkweer, M.H.A, El sayed, E.A & Ewees, M.S.A, (1998). Soil and plant analysis as a guide for the interpretation of the improvement efficiency of organic conditioners added to different soil in Egypt. *Communication soil science plant anal:* 29:2067-2088.
Estim, A. and S. Mustafa, (2020). Aquaponic application in a marine hatchery system. *Aquaponics J.*, 57: 26-34
Food and Agriculture Organization FAO, (2020).The State of World Fisheries and Aquaculture Meeting the Sustainable Development Goals; Food and Agriculture Organization of the United Nations: Rome, Italy.
Gbadamosi, O.K. & Salako, F. (2015) Gustation and Growth Performance of African Catfish, *Clarias gariepinus* Fed Varying Levels of Dietary African Basil, *Ocimum gratissimum* Leaf Supplementation. *Egyptian Academic Journal of Biological Sciences*. 6 (1): 9-15.
Idah, P.A., Ajigiri, E.S.A & Yisa, M.G. (2007). Fruits and vegetables handling and transportation in Nigeria AU J.I 10(3): 175-183 (Jan. 2007) Department of Agriculture Engineering, Federal University of Technology, Minna, Niger State, Nigeria.
Lukmantoro, T.A, Handayani, R and Dinoto, A (2020). Effect of different filter media use on aquaponics system on ammonium (NH4 +), nitrite (NO^2) and nitrate (NO^3) concentrations of catfish (*Clarias* sp.) aquaculture. *Environ. Sci. 441.*
Mader, J. (2012). Plant Growth in Aquaponic System through Comparison of Different Plant Media. Senior Honors Project, Westover Honors Program. pp89.
Maucieri, C., Forchino, A.A., Nicoletto, C., Junge, R., Pastres, R., Sambo, P., & Borin, M., (2017). Life cycle assessment of a micro

aquaponic system for educational purpose built using recovered material. *J. Cleaner Prod.* 172 (2018), 3119– 3127.

Oladimeji ,S.A, Okomoda, V. T, Olufeagba, S.O, Solomon, S.G, Abol-Munafi, A.B. Alabi, K.I. Ikhwanuddi, M. Martins, C.O. Umaru, J. & Hassan, A. (2020). Aquaponics production of catfish and pumpkin: Comparison with conventional production systems. *Food Sci Nutr.* 2020;8:2307–2315. https://doi.org/10.1002/fsn3.1512.

Oladimeji, A. S., Olufeagba, S. O., Ayuba, V. O., Solomon, S. G., & Okomoda, V. T. (2020). Effects of different hydroponics growth media on water quality and plant yield in a Catfish-pumpkin Aquaponics system. *Journal of King Saud University - Science,* 32, 60– 66.

Rakocy, J.E., & Hargreaves, J.A., (1993). Integration of vegetable hydroponics with fish culture: a review. In: Techniques for Modern Aquaculture, Proceedings Aquacultural Engineering. American Society of Agricultural Engineers, St. Joseph, MI, USA, pp. 112–136.

Roosta, H.R., (2014). Effects of foliar spray of K on mint, radish, parsley and coriander plants in aquaponic system. *J. Plant Nutr.* 37 (14), 2236–2254.

Saufie, S., Abentin, E., Masran, T., Salleh, and Salem, M, (2015). Growth Performance of Tomato Plant and Genetically Improved Farmed Tilapia in Combined Aquaponic Systems. *Asian Journal of Agric. Research, 9:95-103.*

Sikawa, D.C., & Yakupitiyage, A., 2010. The hydroponic production of lettuce (*Lactuca sativa* L) by using hybrid catfish (*Clarias macrocephalus* X *C. gariepinus*) pond water: Potentials and constraints. *Agr. Water Man.* 97, 1317–1325.

Viveen, W., Richter, C., Van- Ordt, P., Janssen, J.& Huismsan, E. (1985) Practical Manualfor the Culture of the African Catfish

(*Clarias gariepinus)*. Directorate General for International Technical Cooperation, The Hague, The Netherlands, pp. 121.