Advanced and Sustainable Technologies (ASET)
Volume 1, No 1, June 2022 [34-42]

Feasibility Study of Sustainable Biomass Water Filtration Material for Fish Tanks using Fruit Peels

Yu Ze Wong[1*]

[1]Faculty of Mechanical Engineering Technology, Universiti Malaysia Perlis, Perlis, Malaysia.

Received 5 April 2022, Revised 25 May 2022, Accepted 31 May 2022

ABSTRACT

Nowadays, aquaculture is searching for a sustainable and eco-friendly water filtration system for their fish farming tank. This paper presents the use of biomass as the filtration layer in the fish tank. Biomass from fruit peels (apple peels, pear peels, and orange peels) was prepared to add as the second layer, while filter sponge cartridges as a primary filtration system for the fish farming tank. Tilapia fish, a significant farming fish species worldwide, was chosen as a fish source. The temperature was controlled between 20-35 °C because suitable for Tilapia fish. The pH value suitable for Tilapia fish was pH 5.0-11.0. The results revealed that apple and pear peels have the potential to enhance nitrification for ammonia (NH_3) to nitrite (NO_2) and finally to nitrate (NO_3). The orange peels do not encourage the nitrification of ammonia. In addition, biomass efficiency still needs further research since 27.8g of fruit peels can only allow 2 hours of filtering the ammonia acid. The experimental results revealed that the pear peels are most suitable for filtration materials than other fruit peels. Thus, fruit peel is potentially helpful for a sustainable and eco-friendly water filtration system but still needs further improvement and development.

Keywords: Filtration system, Aquaculture, Biomass, Sustainable

1. INTRODUCTION

Fish farming or aquaculture is the production of the aquatic organism for human consumption. This sustainable food production provides high protein food, creates jobs, and alleviates fish pressure in wild stocks. Fish farming can be carried out in freshwater, brackish, or marine water [1]. Those fish are farmed under controlled conditions to enhance production, such as stocking, feeding, water filtration system, aeration, temperature control, and protection from predators and diseases. In Western Europe, fish farming is carried out by intensive and semi-intensive systems, while in Eastern, was carried out by extensive fish farming [2]. The water filtration system of those fish farming is well recognised. The wastewater treatment is typically disinfection using UV, hypochlorite, ozone and chlorine. The efficiency of these methods can reduce parasite ova, cysts and some bacteria (removal of fish pathogenic).

Besides, there also have water treatments such as using the activated carbon treatments (powdered or granular), chemical oxidation, multi-media filtration, demineralisation (ion exchange), membrane processes (microfiltration, ultrafiltration, and reverse osmosis) [3]. Since the effluent from fish farming usually consists of suspended solids, organic matter and different types of microorganisms, there is a need to investigate other disinfection methods that can handle the effluent. Thus, optimising production efficiency while reducing environmental load is challenging in the aquaculture industry. Sustainable water filtration treatment technologies are

*Corresponding author: ezuy88@yahoo.com

needed to reduce nutrient and chemical discharge in the water. It is to reduce the environmental impact and water abstraction to preserve the survival and reproduction of aquatic organisms [4]. So, the aquaculture farmer used a new method to control the water supply and quality and fish feeding with vegetarian feed, which can give better rearing conditions to fish to increase the production. The growth and regulations associated with a clean environment encourage fish farming to adopt a recirculation system to reduce and treat the waste treatment [5] and improve water quality.

Ammonia production depends on feed quality, feeding rate, fish size and water temperature [6]. Fish usually absorb only 20-25 % of protein from the food. The rest, 80 %, will discharge into the water to form ammonia nitrogen, food remains and excrement, which will reduce the water quality. High ammonia nitrogen in the water level will cause disease or kill the fish [7]. Nitrate levels can be reduced by changing the water, but this is difficult for the large fish pond and the fish farming tanks. When too much Nitrate (NO_3) is present in a fish tank's water, this chemical compound can be toxic to the fish and other life. It can also cause stress making a fish's organs work harder to adjust to their environment, especially at levels higher than 100 ppm in many fish [8]. Therefore, a highly effective water filtration system is crucial to ensure water quality and provide a suitable environment for the fish.

There are two water filtration systems: a system where water was microbially matured in a Bio-filter (MMS) and a system where a bio-filter fed microbially matured to increase Microbial Carrying Capacity (F-MMS) [9]. Bio-filtration is the aerobic (oxygen) breakdown of dissolved nitrogenous fish waste. The process is accomplished by two or more strains of autotrophic bacteria. These bacteria are naturally occurring and will colonise the bio-media in the bio-filter, tank, and pipe walls. This process's speed depends on temperature, pH, salinity, surface area, and flow rate. The process can be accelerated by adding aerobic bacteria to the system. The autotrophic bacteria use oxygen in a two-step process to convert the toxic ammonia (NH_3 or NH_{4+}) to nitrite (NO_{2-}). Another strain of bacteria converts nitrite (NO_{2-}) to nitrate (NO_{3-}). Nitrate is much less toxic and typically tolerated by most cultured species until it reaches very high levels. Controlling nitrate is accomplished by diluting with clean water or using a denitrification chamber that converts nitrate into nitrogen gas. Using plants is a third method to keep nitrate levels in check [10]. A green water system (using algae), a vegetative filter, or a hydroponic plant system can remove nitrate. In this system, the nitrate is absorbed by the plant, reducing the nitrate concentration in the fish tank.

Biomass is an organic matter derived from living or recently living organisms. Biomass can be used as a source of energy. It most often refers to plants or plant-based materials not used for food or feed called lignocellulosic biomass [11]. Wood and wood wastes, agriculture products and wastes, algae, animal wastes, municipal sewage and fruit wastes are all of this category in biomass. The function of biomass in a water filtration system is adsorption. The adsorption process is an excellent alternative water filtration system because of its convenience, ease of operation and simplicity of design. This process also can remove different pollutants, so it is applicable to control water pollution [12]. Biomass such as fruit peels is rich in bioactive components, which are suitable for promoting fish health [13]. Other low-cost adsorbents are functionless in adsorption and have less potential to remove water waste than commercial available active carbon.

As the sources of adsorbents, fruit peels can be used to remove a diverse type of aquatic pollutants and reduce it. Besides, the biomass (fruit peels) contains polyphenols that are anti-oxidation ingredients, and the contents in peels are more than fresh fruit by about 2-9 times [14]. Polyphenol has two phenolic hydroxyl groups in a molecule, which strengthens immunity and bacterial activity. Antioxidants such as ascorbic acid, tocopherol and carotenoid are essential for slowing down and controlling the degeneration of bio function [15]. Thus, the current study focuses on finding suitable biomass materials for the water filtration system of fish farming tanks.

A small-scale aquarium tank was considered in the experiment. In the study, the fruit peels (apple peels, pear peels, and orange peels) were applied to the filter layers of the water filtration system. The characteristics of the biomass materials used and the nitrogen removal in ammonia level were studied.

2. MATERIAL AND METHODS

In this study, the choice of fish depends on the availability, legal status, growth rate and tolerance to a wide range of environmental conditions (such as temperature, salinity and low dissolved oxygen). At last, the Tilapia fish was chosen as a species of cichlid fish. It is mainly freshwater fish inhabiting shallow streams, ponds, rivers and lakes and is less commonly found living in brackish water. Tilapia fish was considered in the experiment as AgroTech UniMAP supported the fish source. Tilapia fish is popular in aquaculture because it can be farmed as food sources for recreational fishing, aquatic weed control, and research purposes. Besides that, Tilapia fish is a fast-growth fish that can feed on low trophic levels and accept artificial feeds, is resistant to stress disease, can reproduce in captivity and has a short generation time [16].

The geographical range for Tilapia fish farming in outdoor tanks is depended on the water temperature. While for indoor Tilapia fish farming, the recirculating systems are more critical because they can control the heat, and the heated water can be recycled. In the experiment, the temperature of the water was controlled at around 20-35 °C, and the pH value of the water was about 5.0-11.0. This water quality is suitable for Tilapia to survive [17]. Since Tilapia fish have limited access to natural foods in tanks, they must be well fed with a complete diet containing vitamins and minerals.

2.1 Selected Biomass as the Filtration Materials

Since biomass removal of such anions from water using low-cost biomass is an efficient and affordable treatment process. Due to the easy availability and biodegradability, apple peels, pear peels and orange peels were chosen as a substrate for the investigations (Figure 1). Zirconium cations were immobilised onto this apple peel's surface and used for the extraction of anions. Zirconium-loaded apple peels had been used to extract anions such as phosphate, arsenate, arsenite, and chromate ions from aqueous solutions [18]. The previous studies of adsorption and desorption revealed that the adsorption mechanism involves electrostatic interactions. Batch adsorption studies estimated the anion removal efficiency. Adsorption kinetic parameters for all anions at different concentrations were described using pseudo-first-order and pseudo-second-order rate equations [18]. Langmuir and Freundlich's isotherms had been used to validate the adsorption data. Arsenate and chromate anions were strongly adsorbed at the pH range from 2 to 6. At the same time, arsenite was extracted efficiently between pH 9 and 10. Overall, the Zirconium immobilised apple peel is an efficient adsorbent for common anionic pollutants. Besides apple peel, orange peel is mainly composed of cellulose, hemicellulose, lignin: chlorophyll and other hydroxyl functional groups as the absorbent. The orange peel can remove Zn, Ni, Cu, and Cr from the water solution by the adsorption. Ni (II) adsorption depends on the pH value when it reaches pH6. It also functions to remove cadmium ions in water solution. Lastly, it is prone to microbial spoilage to valorise the bio-component on the fruit peel. So drying is essential before further exploitation [12].

(a) Pear peel (b) Apple peel (c) Orange peel

Figure 1: Fruit peels used in the experiment.

2.2 Experiment Setup

The small-scale fish tank dimensions are 17 cm in height, 20 cm in length, and 37 cm in width. The total volume of the fish tank is 12 L, so only five small Tilapia fish were considered as the fish sources. The filtration system was set up on the tank. In the experiment, the feeding was done twice a day because the feed is the major problem of the wastewater produced. Thus, the weight fed was the same as feeding the Tilapia fish until the end of the research. This is set as the constant parameters in this study.

First, filter sponge cartridges were placed as the first layer for the constant variable in this experiment without any biomass. However, biomass was placed at the second layer. Apple peels, pear peels, and orange peels were the biomass filtration material. In preparing biomass filtration materials, the apple, pear and orange peels were dried under the sun for about 15 minutes to kill the bacteria or fungi on the peels. The weight of peels was controlled at 27.5g and placed as the second layer. The water flows through the filter sponge cartridges and then secondary filter by biomass and released to the fish farming tank. The multiparameter instrument measured the water quality (Figure 2). This multiparameter instrument can check the pH, temperature, conductivity, nitrate, chloride, salinity, total dissolved solids, and barometric pressure. The measured values on the water were analysed.

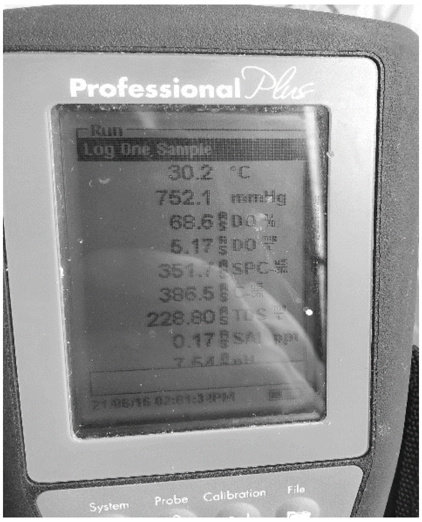

Figure 2: Example of multiparameter reading used in the study.

3. RESULTS AND DISCUSSION

The discussion begins with a brief explanation of the materials used as the bio-filter to filter the wastewater of the fish tank. No Tilapia fish died during this experiment. All data were recorded at the end of the experiment according to the value collected and the time presented in the table. The value of data was collected every 15 minutes until 2 hours. Ammonia (NH_3) was not recorded after 2 hours because the value kept increasing. This situation occurred because the biomass used had reached its maximum absorption capability. Besides, it may also be due to the high rate of fish waste production.

The collected results were plotted in Figures 3-7. Figure 3 shows the temperature variation during the experiment of different biomass used as the filtration medium. The water temperature depends on the surrounding temperature. The water temperature of pear peels decreases because of the rainy day. The water temperature of apple peels and constant plot increases due to the sunny day in the middle of the afternoon. The constant plot is referred to the typical filtration layer without any biomass. Theoretically, the rate of ammonia excretion is directly proportionally related to temperature. However, this minor temperature change may only slightly affect the pH and ammonia as nitrogen excreted by fish.

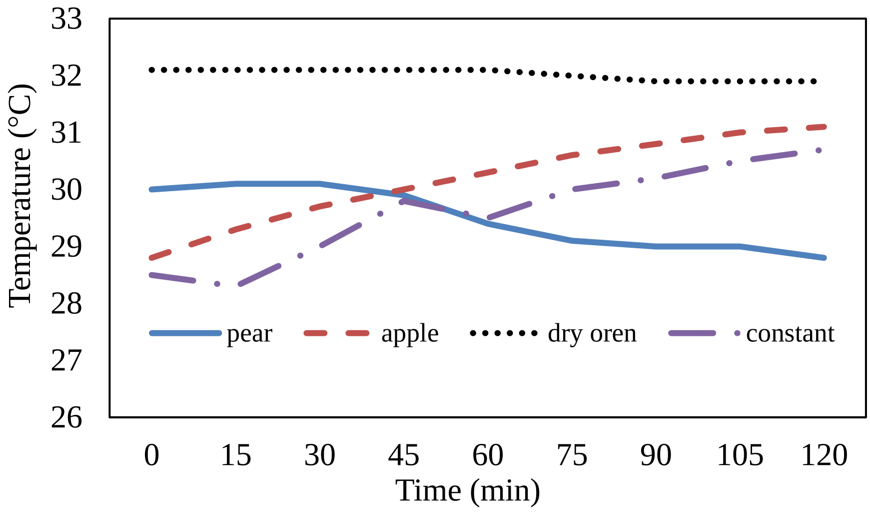

Figure 3: Temperature against time.

Figure 4 and Figure 5 show the percentage of dissolved oxygen and dissolved oxygen (mg/L) in the fish tank. The result by using apple peels and pear peels clearly showed a decrease. In contrast, the constant showed an increase in DO percentage, and orange peels showed a slight increase in DO percentage and DO. The experimental results revealed that apple peels and pear peels as second layer processing nitrification to filter the excess waste ammonia from 68.1% to 54.8% (pear peels) and from 62.4% to 51.5% (apple peels). The orange peels only processed a small amount of nitrification to remove ammonia from 51.2% to 58.5%, about 7.3%. The difference between the highest and lowest DO percentages was about 13.3% (pear peels) and 3.3% (orange peels). Figure 6 shows the pH of water against time. Pear and apple peels can decrease the pH of the water quality. The pear peels decrease the pH of water which is about 0.11. Apple peels decrease from pH 7.81 to pH 7.67. In comparison, orange peels as a filter showed a decreasing pH level of about 0.03. Without biomass, the filter sponge cartridges also slightly decrease the pH value from pH 7.88 to pH 7.83.

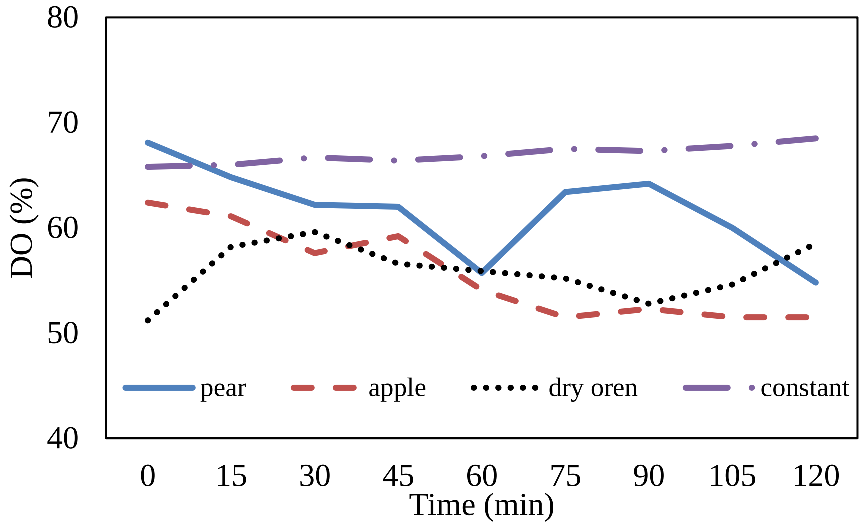

Figure 4: Percentage of Dissolved Oxygen (DO) against time.

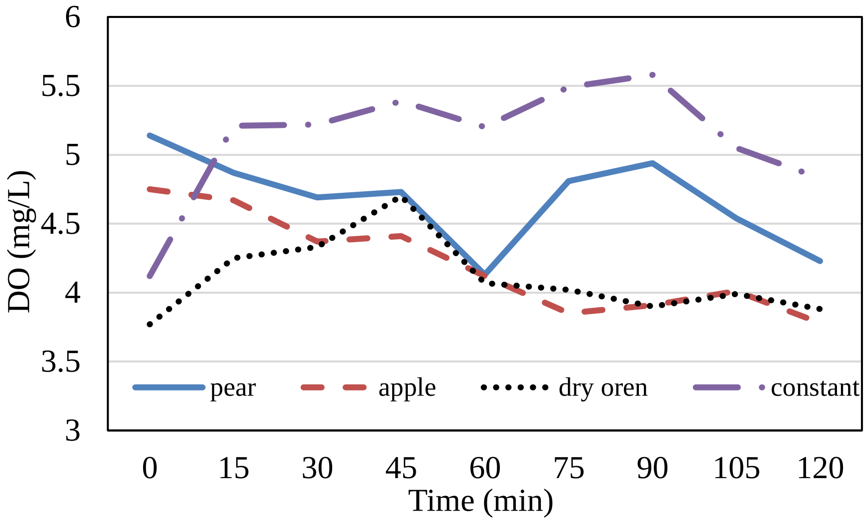

Figure 5: Dissolved Oxygen (DO) against time.

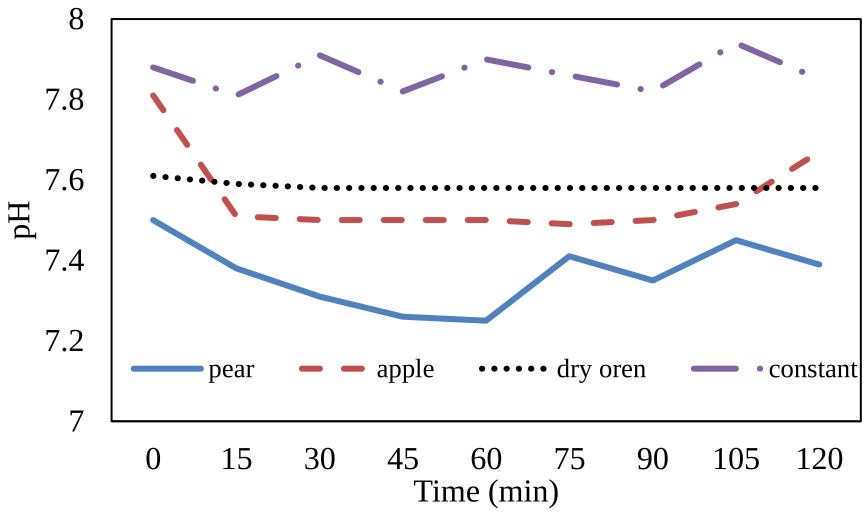

Figure 6: Water pH against time.

Figure 7 shows the graph of ammonium against time. All conditions show a slight increase in ammonium because the pH value is decreased for the ammonium changes. The relationship between pH value and ammonium was inversely proportional. The pH level decreases when the ammonia (NH_3) is converted to ammonium (NH_4), and the ammonium levels increase. Then, the water quality will become less toxic when the ammonium increase. The chemical equation that drives the relationship between ammonia and ammonium is $NH_3 + H_2O \leftrightarrow NH_4+ + OH-$.

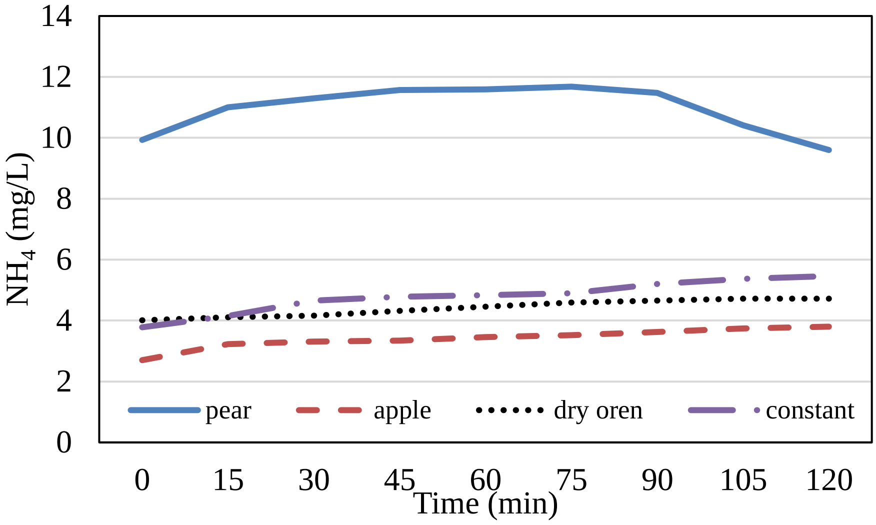

Figure 7: Ammonium (NH_4) against time.

Figure 8 shows the graph of ammonia against time. The water quality with biomass shows a reduction in ammonia level in the first hour but continued increase in the second hours. It showed that the oxidation agents in biomass reacted with ammonia to process nitrification. From ammonia (NH_3) into nitrite (NO_2) and turn into nitrate (NO_3). However, the ammonia level was increased almost in a straight line without biomass. This situation is because no nitrification process occurs in the fish tank. The use of pear peels as a filter material shows a reduction from 0.22 mg/L to 0.16 mg/L, which is about a 0.6 change in the ammonia level. Apple was from 0.13 mg/L to 0.08 mg/L, and it about 0.5 mg/L changing. In contrast, the orange peel showed that the ammonia levels increased from 0.15 mg/L to 0.17 mg/L. This observation indicated that the orange peel is not suitable to be used as the filter material. However, the orange peels in the powder form effectively absorb the ammonia and nitrates from water [19]. Thus, the feasibility of the orange peels used as the filtration material still requires further investigation in terms of the particle form. The experimental results demonstrated that the pear peels mostly decreased the ammonia level among the fruit peels.

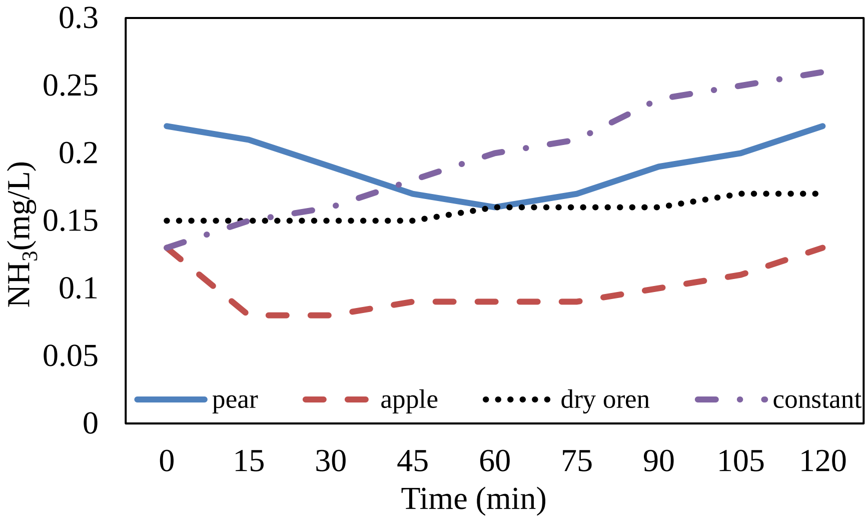

Figure 8: Ammonia (NH_3) against time.

4. CONCLUSION

The case study on using fruit peel as the filtration material in the fish tank was successfully conducted. The presence of fruit peels showed a positive effect in removing the ammonia. The highest is pear peels (0.13 to 0.9), followed by apple peels (0.22 to 0.19). The pear peels can remove the ammonia level from the water. The ammonia level was inversely proportional to the ammonium level. The orange peels slightly increase the ammonia level (0.15-0.17). The Dissolved Oxygen of apple and pear peels decreases while orange peels slightly increase during these 2 hours. These show that the nitrification was processed. The experimental results indicated that the pear peels are the most suitable as the filter material among these fruit peels in the water filtration system. Thus, this study will be extended to investigate the weight of biomass used in fish tank filtration systems.

ACKNOWLEDGEMENT
The author gratefully thanks Madam Nurul Afidah Umoruddin, Mr Mohammad Sallehhuddin Mohd Mohadzir and AgroTech UniMAP for the technical support.

REFERENCES

[1] Soliman, N. F., & Yacout, D. M. Aquaculture in Egypt: status, constraints and potentials. Aquaculture International, vol 24, issue 5 (2016), pp.1201-1227.

[2] Bulc, T. G., Istenič, D., & Klemenčič, A. K. The efficiency of a closed-loop chemical-free water treatment system for cyprinid fish farms. Ecological Engineering, vol 37, issue 6 (2011), pp.873-882.

[3] Wimalawansa, S. J. Purification of contaminated water with reverse osmosis: effective solution of providing clean water for human needs in developing countries. International Journal of Emerging Technology and Advanced Engineering, vol 3, issue 12 (2013), pp.75-89.

[4] Carey, R. O., & Migliaccio, K. W. Contribution of wastewater treatment plant effluents to nutrient dynamics in aquatic systems: a review. Environmental Management, vol 44, issue 2 (2009), pp.205-217.

[5] Martins, C. I. M., Eding, E. H., Verdegem, M. C., Heinsbroek, L. T., Schneider, O., Blancheton, J. P., d'Orbcastel, E. R. and Verreth, J. A. J. New developments in recirculating aquaculture

systems in Europe: A perspective on environmental sustainability. Aquacultural Engineering, vol 43, issue 3 (2010), pp.83-93.

[6] Lall, S. P., & Tibbetts, S. M. Nutrition, feeding, and behavior of fish. Veterinary Clinics of North America: Exotic Animal Practice, vol 12, issue 2 (2009), pp.361-372.

[7] Yu, Z., Li, L., Zhu, R., Li, M., Duan, J., Wang, J. Y., Liu, Y. H. and Wu, L. F. Monitoring of growth, digestive enzyme activity, immune response and water quality parameters of Golden crucian carp (Carassius auratus) in zero-water exchange tanks of biofloc systems. Aquaculture Reports, vol 16, (2020), pp.100283.

[8] Malhotra, N., Ger, T. R., Uapipatanakul, B., Huang, J. C., Chen, K. H. C., & Hsiao, C. D. Review of copper and copper nanoparticle toxicity in fish. Nanomaterials, vol 10, issue 6 (2020), pp.1126.

[9] Attramadal, K. J., Minniti, G., Øie, G., Kjørsvik, E., Østensen, M. A., Bakke, I., & Vadstein, O. Microbial maturation of intake water at different carrying capacities affects microbial control in rearing tanks for marine fish larvae. Aquaculture, vol 457, (2016), pp.68-72.

[10] Boxman, S. E., Nystrom, M., Capodice, J. C., Ergas, S. J., Main, K. L., & Trotz, M. A. Effect of support medium, hydraulic loading rate and plant density on water quality and growth of halophytes in marine aquaponic systems. Aquaculture Research, vol 48, issue 5 (2017), pp.2463-2477.

[11] Cherubini, F. The biorefinery concept: using biomass instead of oil for producing energy and chemicals. Energy Conversion and Management, vol 51, issue 7 (2010), pp.1412-1421.

[12] Bhatnagar, A., Sillanpää, M., & Witek-Krowiak, A. Agricultural waste peels as versatile biomass for water purification–A review. Chemical Engineering Journal, vol 270, (2015), pp.244-271.

[13] Hosseini, S. M., Hoseinifar, S. H., Mazandarani, M., Paknejad, H., Van Doan, H., & El-Haroun, E. R. The potential benefits of orange peels derived pectin on serum and skin mucus immune parameters, antioxidant defence and growth performance in common carp (Cyprinus carpio). Fish & Shellfish Immunology, vol 103, (2020), pp.17-22.

[14] Łata, B., Trampczynska, A., & Paczesna, J. Cultivar variation in apple peel and whole fruit phenolic composition. Scientia Horticulturae, vol 121, issue 2 (2009), pp.176-181.

[15] Kim, K. S., & Roh, K. S. Comparative study of antioxidant activity of apple and pear peel. Korean Journal of Plant Resources, vol 26, issue 3 (2013), pp.347-354.

[16] Seden, M. E. Effect of onion powder used as a feed additive on growth performance, feed utilisation and whole body composition of nile tilapia fingerlings challenged with pathogenic aeromonas hydrophila. ABBASSA International Journal For Aquaculture., vol 16, issue 2 (2013), pp.389-406.

[17] Hu, W. T., Bai, J. Y., Fei, X., Hu, Y. N., Wu, M. X., Zhang, Y. Z., Guo, W. L. and Zhou, Y. C., Metabolomic responses of Nile tilapia (Oreochromis niloticus) maintained under different temperatures and challenged with Streptococcus agalactiae. Aquaculture, vol 524, (2020), pp.735209.

[18] Dey, S., Basha, S. R., Babu, G. V., & Nagendra, T. Characteristic and biosorption capacities of orange peels biosorbents for removal of ammonia and nitrate from contaminated water. Cleaner Materials, vol 1, (2021), pp.00001.