WATER HYACINTH (*Eichhornia crassipes*) LEAVES AS AN ALTERNATIVE PROTEIN SOURCE FOR FEEDING EARLY PHASE OF TILAPIA (*Oreochromis niloticus*)

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SUMMARY: Water hyacinth (*Eichhornia crassipes*) is a fast growing invasive aquatic plant often covers water bodies. It has been a problem worldwide. Fast-growing and rapidly expanding omnivorous tilapia is likely the suitable species for aquaculture. Since the fish farmers are adversely affected by high cost feed, the use of water hyacinth as a protein source in fish feed could offer solutions to both the problems. The present study therefore was carried out to perceive the use of water hyacinth as a cheap protein source in the diet of tilapia (*Oreochromis niloticus*). Four types of fish feeds were formulated replacing the fish meal and soybean meal by water hyacinth at 0% (control, feed 1), 5 % (feed 2), 15 % (feed 3) and 20% (feed 4). Two weeks old tilapia fry of $0.8g \pm 0.3g$ mean body weight were stocked in 12 tanks in four treatments, each with three replicates and fed with respective feed at the rate of 4% of body weight for 63 days (Each tank was stocked with fifteen tilapia fries). Body weight and body length of each fish were measured every fortnight while the initial measurement was taken after one week of acclimatization period. Feed cost for one kg of each feed samples was also calculated. The results revealed that the feed conversion ratio (1.54 ± 0.18 , 1.46 ± 0.25 , 1.45 ± 0.16 and 1.46 ± 0.42) and growth rates (0.11, 0.106, 0.106 and 0.124 g/day) among fish groups fed with feed 1, 2, 3 and 4 respectively were not significantly different ($P > 0.05$). Costs per kg of feed decreased with the increasing of replacement of fish meal by water hyacinth i.e. Rs. 120, 110, 93, and 84 respectively. There were no significant differences in feed utilization among four types of feed by the replacement of protein source with water hyacinth. Thus, water hyacinth leaves could be used to replace 20% of the high cost protein source in the diet of tilapia.

INTRODUCTION

The most expensive component in fish farming is the feed due to the high cost protein ingredients such as fish meal and soybean meal (Soliman, 2000). Protein itself represents about 50% of feed cost in intensive culture (El-Sayed, 2004). When fish have balanced diet, they grow fast and stay healthy. In natural waters and well fertilized ponds, phytoplankton, zooplankton, insects, crustaceans, copepods and molluscs are consumed by fish as natural protein foods. In the absence of natural foods in commercial fish farming setup, nutritionally balanced artificial feeds that contain all essential nutrients must be fed to fish for their optimum growth. Furthermore, feeding fish with natural foods to commercially oriented intensive fish farms is impractical. When practical fish diets are formulated, all nutrients such as crude protein should be in the optimum level to fulfil the requirements of the fish (Hardy, 1980). Recommended dietary crude protein (CP) requirements for fast and healthy growth of fish vary with fish species. General requirements could be 20-25% CP for a semi-intensive culture with natural foods, or 40-48% CP for an intensive culture for fingerlings, or 30-35% CP for juveniles (NAERLS, 2002) and 28% for adult tilapia (Twibell and Brown, 1998).

Recently, wide varieties of non-conventional protein of both plant and animal origin have been evaluated and used to formulate fish diets. Plant protein concentrate produced from rye grass, alfalfa, water hyacinth, marrow stem kale and leucaena leaf were used in diets of many fish (Campos *et al.*, 1990). Water hyacinth is a free-floating perennial aquatic plant (or hydrophytes) that is widely recognized as one of the world's worst weeds. With broad, thick, glossy and ovate leaves, water hyacinth may rise above the surface of the water as much as 1 meter in height. The Leaves are 10 -20 cm across, and float above the water surface. Water hyacinth reproduces primarily by way of runners or solons, which eventually form daughter plants. Each plant can produce thousands of seeds each year, and these seeds can remain viable for more than 28 years. The common water hyacinth is vigorous growers and known to double their population in two weeks. The control of water hyacinth plant is aimed at managing infestations to the acceptable levels of about 10 % cover instead of its complete eradication (Téllez *et al.*, 2008; Patel, 2012), as re-infestation occurs easily either from vegetative growth or from the seed bank. At a subsistence level, water hyacinth can be utilized as a fertilizer, fodder, paper and fibre source, or for mineral nutrient removal from polluted water. Water hyacinth which grows in the polluted water may contain heavy

metals such as arsenic, cadmium, lead, mercury, zinc and inorganic compounds such as phosphates, and sulphates (Lakra *et al.*, 2017; Muramoto and Oki, 1983; Rezanian *et al.*, 2015). Water hyacinth can effectively remove excess nutrients in a water body. Leaf of water hyacinth can absorb nutrient more than the petioles can utilize and that is why the leaves are always very luxurious in a rich water body (Okoye *et al.*, 2002). Saha and Ray (2011) indicated that water hyacinth leaf could be used as an alternative protein source in the diet of tilapia as its leaf contained 55.4% protein on dry matter basis with most essential amino acids and particularly rich in leucine (5.1%) and phenylalanine (3.1%). Furthermore, Saha and Ray (2011) added that highest crude protein level is found in the leaves and lowest level in the petioles. However, fish don't generally consume water hyacinth directly unless it is processed in the form of a meal or concentrate.

Tilapia is known as 'aquatic chicken' because of its herbivorous and omnivorous habit, feeding lowdown on the food chain in the culture systems providing a major source of protein for rural poor in Asia (Sakr *et al.*, 2015). Historically, tilapia has been of major importance in artisan fishing in Africa and the Levant and is of increasing importance in aquaculture and aquaponics. Tilapia can become problematic invasive species in new warm-water habitats but generally not in temperate climates due to their inability to survive in cooler waters below about 21° C (70 °F). Genetically Improved Farmed Tilapia (GIFT) strain of Nile tilapia is considered to have superior growth qualities over the commonly cultured strains of the same species in Asia (Eknath and Acosta, 1998). Several factors including fish size or age, dietary protein source, energy content, water quality and culture conditions have been reported to affect protein requirements of tilapia. Protein requirement for maximum performance of tilapia during larval stages is relatively

high (35 - 50%), and decreases with increasing fish size. For tilapia juveniles, the protein requirement ranges from 30-40%, while adult tilapia requires 20-30% dietary protein for optimum performance (Twibell and Brown, 1998). On the other hand, tilapia brood stock requires 35-45% dietary protein for optimum reproduction, spawning efficiency, and larval growth and survival (Abdel-Tawwab and Ahmad, 2009). Conventional protein sources such as fish meal and soybean meal are expensive and becoming limited in availability. Therefore, the need for finding of alternative sources of protein in the animal feed has become a huge challenge for animal nutritionists. Thus the present study was carried out to perceive the use of water hyacinth as a cheap protein source in the diet of tilapia culture replacing fishmeal and soybean meals to determine the percentage of water hyacinth that could be used in the tilapia feed to get highest growth rate.

METHODOLOGY

Collection of water hyacinth

Water hyacinth plant was collected from uncultivated paddy field (Figure 1) and washed to remove the mud. Very lush or over matured plants were avoided, all the stem parts were removed and only leaves were taken. Leaves were dried under the hot sun for two weeks. Dried leaves were ground to make a powder. A sample was submitted to the Veterinary Research Institute, Gannoruwa, Sri Lanka for proximate analysis.

Formulation of feed using water hyacinth

Feed 1(0% Water hyacinth) was formulated using the "Format feed formulation software" and prepared using raw materials as per the formulation. Percentage of the raw material in the feed 1(0% water hyacinth) formulation is mentioned in the Table 1. Feed 1 contains crude protein

Figure 1: The water hyacinth plants in uncultivated paddy field

22% and used as the control feed in the experiment. Feed 2, 3 and 4 were prepared by adding 5%, 15%, 20% dried water hyacinth leaves to the feed 1, respectively with replacing soy bean meal and fish meal as indicated in Table 1. Therefore, Feed 1, 2, 3 and 4 were made to contain same amount of protein. Each type of feeds were pelleted and dried.

Table 1: Composition of the control and experimental feeds

Raw material	Feed 1 %	Feed 2 %	Feed 3 %	Feed 4 %
Water hyacinth leaf meal	0	5	15	20
Soy bean meal	38	35	28	25
Fish meal	15	13	10	8
Maize	33	33	33	33
Rice polish	11	11	11	11
Rice bran	2.0	2.0	2.0	2.0
Sea shell	0.8	0.8	0.8	0.8
Mineral premix	0.1	0.1	0.1	0.1
Vitamins	0.1	0.1	0.1	0.1

Feeds 1-4 were formulated using 'Format feed formulation software' and feed 1 was used as the control feed

Experimental design

Experiment was designed with four treatments each with three replicates. Totally twelve fiberglass tanks (for 4 treatments x 3 replicates) were cleaned and filled with 250 liters of de-chlorinated water. Totally 300 tilapia fries from a single batch were purchased and brought from the national fresh water fish breeding Centre of National Aquaculture Development Authority of Sri Lanka in Dambulla. Each tank was stocked with fifteen tilapia fries. Prior to stocking of the tanks, body weight and body length of the individual fish were measured. Tanks were named as 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, 3c, 4a, 4b, 4c randomly. The replicates were a, b and c for each treatment. Then the fish in all tanks were fed with feed 1 for a week to acclimatize. The water in all four tanks was very clear without visible plankton. Feed type 1, 2, 3 and 4 were fed to the fish in the treatment groups of 1, 2, 3, and 4 respectively at the rate of 4% of their body weight twice daily. In every two weeks, body weight and body length of each fish were measured and the amount of feed was adjusted according to the total body weight. Water quality of each tanks were checked and 50% of the water was changed in all tanks twice a week. In every water changes precipitated particles in the bottom of the tank were collected and the dried weight was measured. Total weight of the precipitated particles in each tanks are mentioned in the Table 4.

Sample collection

Samples were collected every two weeks. The individual fish in every tank were caught and the body weight and body length were measured. Mortality was checked and the dead fish was replaced with a fish that was of the same weight and same length, every day.

Measurements of growth rate and statistical analysis

Mean bodyweight and body length in each tank in every sampling time was calculated. Body weight and body length change in every 2 weeks was analysed using General linear model in which time (weeks) was fitted as a covariate and feed was fitted as a factor in the model using MINITAB 15 statistical software. The body weight and length were transformed into logarithm scale in stabilizing the variance. Regression fit for the four different feeds were made and prediction equation for each feed was obtained. Feed conversion ratio was calculated by using feed amount and weight change.

RESULTS

Feed analysis

Proximate analysis of the water hyacinth after processing revealed that it had 18% crude protein (on dry matter basis) and 96% Moisture. All the feed 1, 2, 3 and 4 (containing 0%, 5%, 15%, 20% water hyacinth) samples contained 22% crude protein; pellet size is same in all the feed.

Analysis of the cost of feed

Raw materials that were used to formulate each feed samples with their unit price are given in the Table 2.

The cost to formulate 1kg of feed 1, 2, 3 and 4 were Rs. 120, 110, 93, and 84 respectively. Feed cost is becoming less with increasing water hyacinth percentage as the expensive protein sources were replaced by inexpensive water hyacinth partially. Feed cost to prepare 1 kg of feed 4 is 36 rupees less than feed 1, saving 30% from the conventional feed without water hyacinth.

Table 2: Unit price of raw materials

Raw material	Unit price (Rs/ kg)
Soybean meal	120
Fish meal	290
Maize	60
Rice polish	44
Rice bran	35

Mean value of body weight (g), body length (cm) and their standard errors for four types of feed at the end of the study period are given in the Table 3.

Table 3: Mean value of body weight, body length and the standard error in each treatment

Waterhyacinth in the feed (%)	Mean body weight (g)	Mean body Length (cm)
0	6.95±0.511	5.57±0.136
5	6.7±0.465	5.4±0.142
10	6.8±0.468	5.48±0.157
20	7.66±0.683	5.55±0.186

Mean values of the body weight of fish fed with feed 1, 2, 3, 4 containing 0%, 5%, 15% and 20% water hyacinth, respectively in each sampling is reflected in Figure 2 while mean body length is reflected in the Figure 5. Every sampling was done at two weeks interval.

Maximum mean body weight was observed in the fish fed with feed 4. Body weight increased from 6 to 8 weeks in an exponential manner (Figure 3 and 4).

The simple linear regression model equations in Figure 4 for four types of feed are: $\text{Ln (BW, Feed1)} = -0.92 + 0.54t$, $\text{Ln (BW, Feed2)} = -0.93 + 0.54t$, $\text{Ln (BW, Feed3)} = -0.87 + 0.52t$, $\text{Ln (BW, Feed4)} = -0.97 + 0.56t$, where 't' is for times of measurement (1, 2, 3, 4, 5) at two week intervals and 'BW' is body weight.

Since the change in body weight follows exponential pattern (Figure 3) lack of fit was significant in simple linear regression model. The quadratic model was fitted for the prediction of weight (on logarithm scale) at given time (t). The prediction equations for the body weight change with time of different feeds are: $\text{Ln (BW Feed1)} = -0.603 + 0.272t + 0.045t^2$, $\text{Ln (BW Feed2)} = -0.67 + 0.313t + 0.038t^2$, $\text{Ln (BW Feed3)} = -0.389 + 0.106t + 0.069t^2$ and $\text{Ln (BW Feed4)} = -0.79 + 0.404t + 0.0267t^2$.

Figure 2: Mean body weight of fish fed on the experimental feeds

Figure 3: Interval plot for the body weight (g) change with time (9 weeks)

Figure 4: Regression between the body weight (g) and time (9 weeks)

Figure 5: Mean body length of fish fed with different feeds

Figure 6: Interval plot for the body length (cm) change with time (9 weeks)

Figure 7: Regression between the body length (cm) and time (9 weeks)

Figure 8: Growth rate variation among the fish fed with different feed

The simple linear regression model equations in Figure 7 for four types of feed are: $\ln(L, \text{Feed1}) = 0.87 + 0.15t$, $\ln(L, \text{Feed2}) = 0.87 + 0.146t$, $\ln(L, \text{Feed3}) = 0.89 + 0.14t$, $\ln(L, \text{Feed4}) = 0.85 + 0.15t$, where 't' is for times of measurement (1, 2, 3, 4, 5) at two week intervals and 'L' is body length.

The change in body length also follows exponential pattern (Figures 5 & 6) and therefore the quadratic model was fitted for prediction of weight (on logarithm scale) at given time (t). The prediction equations for the body weight change with time of different feeds are; $\ln(L, \text{Feed1}) = 1.17 - 0.105t + 0.042t^2$, $\ln(L, \text{Feed2}) = 1.139 - 0.082t + 0.038t^2$, $\ln(L, \text{Feed3}) = 1.206 - 0.13t + 0.045t^2$ and $\ln(L, \text{Feed4}) = 1.09 - 0.052t + 0.035t^2$ where 't' is for times of measurement at two week intervals and 'L' is body length.

Growth rate of the fish fed on the experimental diets is shown in the Figure 8. Growth rate is presented as

gram/day/fish (g/day/fish) in y axis. Highest growth rate was observed in fish fed with 20% water hyacinth. There were no statistically significant differences between the mean growth rates among the four feeds (Figure 8).

Maximum growth rate was observed in fish fed with feed 4 (20% water hyacinth). Feed conversion ratios (FCR) of the fish fed with feed 1, 2, 3 and 4 are 1.54 ± 0.18 , 1.46 ± 0.25 , 1.45 ± 0.16 and 1.46 ± 0.42 respectively. There were no significant difference in the FCR between the treatment groups. Furthermore, eight fish were dead only in the first week, two fish from each treatment group out of 45 fish. Mortality rate was 4.4% in all treatment groups.

Deposited particles contain feed particles and faecal material. Weight of deposited particles in each tank is almost same as feed consumption which is same in all treatment (Table 4). This shows the digestibility of the feed is not significantly different among the four feeds.

Table4: Total weight of the deposited particles at bottom of the experimental tank

Experimental tank (treatments)	Mean weight of deposited particles (g)
1 (0%)	71.66 ± 2.1
2 (5%)	70.66 ± 2.31
3 (15%)	71.03 ± 3.85
4 (20%)	70.2 ± 3.4

Changes of body weight and length with the percentage of water hyacinth in the feed

There were no significant ($P>0.05$) differences in total body weight or length among the fish that were fed on the experimental feeds. Body weight gain or length measurements were not affected by adding water hyacinth in to the tilapia feed. It was interesting to note that even 20% addition of the water hyacinth in the feed did not significantly ($P>0.05$) affect the body weight or length gain of tilapia.

Changes of the growth rate with the percentage of water hyacinth in the feed

There were no significant ($P>0.05$) differences in growth rate among fish fed on the experimental feeds. Growth rate is not affected by adding water hyacinth in to the tilapia feed. It was interesting to note that even 20% addition of the water hyacinth in the feed did not significantly ($P>0.05$) affect the growth rate of tilapia.

DISCUSSION

The present study revealed that, no significant difference in growth between fish that were fed with feed 1 (no water hyacinth), 2 (5% water hyacinth), 3(15% water hyacinth) and 4 (20% water hyacinth). These results showed that, water hyacinth could be used as a protein source by replacing soybean meal and fish meal. Similarly, Mohapatra and Patra (2013) reported that, the feed with water hyacinth by 15% replacement of fish meal would be optimum for the maximum growth of *Cyprinus carpio*. Alternative plant protein sources also have been experimentally used to replace fish meal in the tilapia feed such as alfalfa (Novoa *et al.*, 1990). However, Johansson *et al* (1991) reported that, low quality protein is present in water hyacinth due to limited availability of some essential amino acids such as lysine and the sulphur containing amino acids. Saha and Ray (2011) reported that, water hyacinth contain several anti-nutrient factors such as tannin and phytic acid. Tannins affect the protein and dry matter digestibility either by inhibiting the activity of protease and possibly other digestive enzymes or by forming indigestible complexes with dietary protein (Krogdahl, 1989). Phytic acid acts as a chelator, forming protein and mineral-phytic acid complexes which reduce bioavailability of protein and mineral (Spinelli *et al.*, 1983). Therefore, we suggest limited use of water

hyacinth without total replacement of the whole protein source in a fish feed ration. Our findings indicated that it could go up to 20% of the protein in the feed of tilapia. However, it could be studied in the future to find the optimum water hyacinth percentage that could be used to replace conventional protein source.

Water hyacinth absorbs phosphate, sulphate (Moyo *et al.*, 2013) and heavy metals such as arsenic, cadmium, lead, mercury, zinc (Muramoto and Oki, 1983; Rezanian *et al.*, 2015) from the polluted water. This process is called as phytoremediation and this will lead to accumulation of toxins and heavy metals in the water hyacinth plant (Bioaccumulation). If fish eat these plants those toxins and heavy metals accumulate in the body tissues of the fish. These toxins and heavy metals are deposited in the human body in higher concentration when consuming these fish (Biomagnification). As the mortality was not increased with increasing water hyacinth in the feed, obvious toxicity to the lethal level was not observed by adding water hyacinth in the tilapia feed up to 20%. The residuals of the pollutants and heavy metals in the fish body were not analysed in this study to relate with the pollutants in the water hyacinth. Nevertheless, prior to replacement, it is important to assess the level of toxins and heavy metals that are present in water hyacinth. Further studies could focus to test the effects of higher level of inclusion and also to mitigate constraints of water hyacinth, such as presence of toxins and heavy metals to use it as an alternative source of protein in fish feed.

Present study however revealed that water hyacinth could be used up to 20% replacing other protein source. Soliman (2000) reported that, growth rate of the tilapia fish is reduced with increased replacement of soybean meal with black seed meal in the feed. However, Sri Lankan water hyacinth could be different as the environment and nutrient composition in the soil are different. In support of this, Mako *et al* (2011) reported that crude protein percentage of water hyacinth that was collected from four different water sources is different. Nutritional composition of the aquatic plants differs according to the water source. Present study was conducted using water hyacinth grown in the uncultivated paddy field and their nutritional level may be different to the experimental diets used by Soliman (2000). However, the nutrient composition of water hyacinth as well as tilapia growth may be affected by the Sri Lankan climatic conditions. The results of deposited particles which were not significantly different among the four treatments could be an indirect measurement of the palatability and the digestibility of the diet, which indicates that the palatability and digestibility of diet was not affected by the inclusion of water hyacinth up to 20%.

CONCLUSION

Current study reveals that, water hyacinth could be used as a protein source to replace conventional protein source in the tilapia feed successfully. Growth rate of

tilapia fed with feed containing 0%, 5%, 15% and 20% water hyacinth was not significantly different. However, it was noted that the growth rates ranged from 0.110 to 0.124 (g/day/fish). Feed cost to prepare 1 kg of feed 4 (20% water hyacinth) is 36 rupees is less than feed 1 (0% water hyacinth), saving 30% from the conventional feed by using water hyacinth. In the future, water hyacinth could be used to replace the high cost protein source in fish feed industry. It may help to encourage the farmers in the aquaculture industry to increase the profit margin. Furthermore, use of water hyacinth in the fish feed could be beneficial to control the spread of this invasive plant in the water bodies. However, detail study could be performed on analysis of water hyacinth for toxicants.

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REFERENCES

- Abdel-Tawwab M. and Ahmad, M.H. (2009). Effect of dietary protein regime during the growing period on growth performance, feed utilization and whole-body chemical composition of Nile tilapia, *Oreochromis niloticus* (L.), *Aquaculture Research*, **40**: 1532-37.
- Campos, S.G., Novova, M.A.O., Sabido, M.G. and Palacios, C.A.M. (1990). The use of alfalfa leaf protein concentrates as a protein source in diets for tilapia (*Oreochromis mossambicus*). *Aquaculture*, **90** (3-4): 291-302.
- Eknath, A.E. and Acosta, B.O. (1998). Genetic Improvement of Farmed Tilapias (GIFT) Project: Final Report. March 1998 to December 1997, working Papers, The World Fish Center, and number 13451, August.
- El-Sayed, A.F.M. (2004). Protein Nutrition of Farmed Tilapia: Searching for Unconventional Sources. New Dimensions on Farmed Tilapia. Proceeding of 6th International Symposium on Tilapia Aquaculture, 12-16 September 2004, Manila, Philippines: 364-378.
- Hardy, R., (1980) Fish Feed Formulation. In: ADCP (Eds.), Fish Feed Technology. Rome, FAO, ADCP/REP/80/11:233-39.
- Johansson, L., Kiessling, A. and Carlsson, R. (1991). Eating Quality and Growth of Rainbow Trout (*Oncorhynchus mykiss*) on Feed with Different Admixture of Leaf Nutrient Concentrate. *Journal of Science and Food Agriculture*, **57**: 217-234.
- Kroghdahl, A. (1989). Alternative protein sources from plants containing anti-nutrients affecting digestion in salmonids. In: M. Takeda and T. Watanabe (Eds.) Proceedings of the Third International Symposium in Feeding and Nutrition in Fish. Tokyo University of Fisheries, Tokyo: 253-261.
- Lakra, K. C., Lal, B. and Banerjee, T.K. (2017). Decontamination of coal mine effluent generated at the Rajrappa coal mine using phytoremediation technology. *International Journal of Phytoremediation*, **19** (6): 530-536, DOI: 10.1080/15226514.2016.1267698.
- Mako, A. A., Babayemi, O. J. and Akinsoyinu, A. O. (2011). An evaluation of nutritive value of water hyacinth (*Eichhornia crassipes* Mart. Solms-Laubach) harvested from different water sources as animal feed. *Livestock Research for Rural Development*. Volume 23, Article #106. Retrieved June 26, 2015, from <http://www.lrrd.org/lrrd23/5/mako23106.htm>.
- Mohapatra, S.B. And Patra, A.K. (2013). Utilization of Water Hyacinth (*Eichhornia crassipes*) Meal as Partial Replacement for Fish meal on the Growth Performance of *Cyprinus carpio* fry. *International Research Journal of Biological Sciences*, **2**(12): 85-89.
- Moyo, P., Chapungu, L., Mudzengi, B. (2013). Effectiveness of water Hyacinth (*Eichhornia crassipes*) in remediating polluted water: The case of Shagashe River in Masvingo, Zimbabwe. *Advanced Applied Science Research*, **4**(4):55-62.
- Muramoto, S. and Oki, Y. (1983). Removal of some heavy metals from polluted water by water hyacinth. *Bulletin of Environmental Contamination and Toxicology*, **30**: 170-177.
- NAERLS (2002). National Agricultural Extension and Research Liaison Services. Feeds Formulation and Feed Practices in Fish Culture. Extension Bulletin No. 152, Fisheries series No.7. Ahmadu Bello University, Zaria, Nigeria.
- Novoa, M.A.O., Campos, S.G., Sabido, M.G. and Palacios, C.A.M. (1990). The use of alfalfa leaf protein concentrates as a protein source in diets for tilapia. *Aquaculture*, **90**: 291-302.
- Okoye, F.C., Daddy, F. and Ilesanmi, B.D. (2002). The nutritive value of water hyacinth (*Eichhornia crassipes*) and its utilization in fish feed, In: Proceedings of the International conference on water hyacinth, 27th November-1st December, 2000, New Bussa, Nigeria.
- Patel S. (2012). Threats, management and envisaged utilizations of aquatic weed *Eichhornia crassipes*: An overview. *Reviews in Environmental Science and Biotechnology*, **11**: 249259. DOI 10.1007/s11157-012-9289-4.
- Rezania, S., Ponra, M., Talaiekhosani, A., Mohamad, S.E., Din, M.F.M., Taib, S.M., Sabbagh, F. and Sairan, F.M. (2015). Perspectives of phytoremediation using water hyacinth for removal of heavy metals, organic and inorganic pollutants in waste water. *Journal of Environmental Management*, **163**: 125-133. doi.org/10.1016/j.jenvman.2015.08.018.
- Saha, S. and Ray, A. K. (2011). Evaluation of nutritive value of water hyacinth (*Eichhornia crassipes*) leaf meal in compound diets for Rohu, *Labeorohita* (Hamilton, 1822) fingerlings after fermentation with two bacterial strains isolated from fish gut. *Turkish Journal of Fisheries Aquatic Sciences*, **11**: 199-207.
- Sakr, E.M., Shalaby, S.M., Wassef, E.A., Abdel-Fattah M., El-Sayed and Abdel Moneim, A.I., 2015. Evaluation of Periphyton as a Food Source for Nile Tilapia (*Oreochromis niloticus*) Juveniles Fed Reduced Protein Levels in Cages, *Journal of Applied Aquaculture* **27** (1): 50-60, DOI: 10.1080/10454438.2014.967073
- Soliman, A. K. (2000). Partial and complete replacement of soybean meal by rocket seed (*Erucasativa*) of Nile tilapia, *Oreochromis niloticus*. In: International symposium in tilapia aquaculture, 5. Rio de Janeiro. Proceedings. Rio de Janeiro: Panorama da Aquicultura, **1**: 209-214.
- Spinelli, J., Houle, C.R. and Wekell, J.C. (1983). The effect of phytates on the growth of rainbow trout (*Salmo gairdneri*) fed purified diets containing varying quantities of calcium and magnesium. *Aquaculture*, **30**: 71-83.
- Téllez, T.R., López, E.M.R., Granado, G.L., Pérez, E.A., López, R.M. and Guzmán, J.M.S. (2008). The Water Hyacinth, *Eichhornia crassipes*: an invasive plant in the Guadiana River Basin (Spain). *Aquatic Invasions*, **3**(1): 42-53.
- Twibell, R. G. and P. B. Brown. (1998). Optimal dietary protein concentration for hybrid tilapia (*Oreochromis niloticus* × *Oreochromis aureus*) fed all-plant diets. *Journal of World Aquaculture Society*, **29**: 9-16.