Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(6): 898-902

Received: 14-09-2018
Accepted: 18-10-2018

Gaurav Shankar Tripathi
Department of Applied Aquaculture and Zoology, Barkatullah University Bhopal, Madhya Pradesh, India

Girish Tripathi
Department of Applied Aquaculture and Zoology, Barkatullah University Bhopal, Madhya Pradesh, India

Paramveer Singh
Department of Applied Aquaculture and Zoology, Barkatullah University Bhopal, Madhya Pradesh, India

Shriparna saxena
Department of Applied Aquaculture and Zoology, Barkatullah University Bhopal, Madhya Pradesh, India

Mukta Singh
Department of Aquatic Health & Environment, College of fisheries, CAU, Lembucherra, Tripura, India

Correspondence
Paramveer Singh
Department of Applied Aquaculture and Zoology, Barkatullah University Bhopal, Madhya Pradesh, India

Assessment of different water quality parameters under bottle aquaponic system and normal controlled conditions with *Trichopodus trichopterus* (Blue Gourami)

Gaurav Shankar Tripathi, Girish Tripathi, Paramveer Singh, Shriparna Saxena and Mukta Singh

Abstract
This experiment was conducted to assess the water quality comparative study under bottle aquaponic Tank (AT) and Normal controlled Tank (NT) *with* early fingerlings of *Trichopodus trichopterus* (Blue gourami) as fish. During this 45 days study we used three distinct kinds of plants like; tomato (*Solanum lycopersicum),* Eggplant (*Solanum melongena*) and Spinach (*Spinacia oleracea*). Two experimental medium sized tanks of (2ftx1ftx1.5ft) used as rearing purpose and bottles of capacity near about 1 liter that accommodate riverine small pebbles as grow bed. Experimental feed of 30% protein was used as a diet for fish having ingredients Rice bran 17%, Soya bean 36%, Curry leaves 12.5%, Chicken liver 27% and Moringa 2.1%. This whole experiment was mainly based upon a water quality parameter like pH, Dissolved Oxygen, Temperature, Ammonia, Nitrite, Nitrate and one- fourth of the tank water is exchanged with fresh water in every 15 days. During starting days of the experiment (1-5 days) all parameters were same in both systems at optimum level but After 5-15 days water quality parameters were start showing fluctuations in NT like; pH 7.6-7.8, Ammonia 0.25-2.50,Nitrite 0-1.0, Nitrate 0-3.5mg/l and similarly pH 7.6-7.7, Ammonia 0-0.50, Nitrite 0-0.25, Nitrate 0 mg/l in AT system respectively. At the end of the experiment, water quality parameters were showing drastic changes that was pH 7.8-6.8, Ammonia 3-4, Nitrite 2-3, Nitrate 4-5 mg/l in NT system and pH 7.7-7.2, Ammonia 0.25, Nitrite 0, Nitrate 0 mg/l in AT system respectively. We observed in this experiment that optimum range of nitrate can be produce for better plant growth by aquaponic system.

Keywords: *Trichopodus trichopterus*, water quality parameters, experimental feed

1. Introduction

1.1 Aquaponics Concept

Worldwide aquaculture is the rapidly booming sector that needs to be sustainable and must also meet bio-economic demands. On the other side, Aquaponics will be the principle key of success in the aquaculture sector during the forthcoming days because aquaponics is the combination of hydroponics and is gaining increased attention as a bio-integrated food production system. In aquaponics, nutrient-rich effluent from fish tanks is used to ferti gate hydroponic production beds. Aquaponics serves as a model of sustainable food production by following certain principles like; waste products of one biological system serve as nutrients for a another biological system. The integration of fish and plants results in a polyculture that increases the diversity and yields multiple products. Water is re-used through biological filtration and recirculation. Local food production provides access to healthy foods and enhances the local economy (Diver, S., & Rinehart, L. 2010) [1]. This is good for the fish because plant roots and rhizobacteria remove nutrients from the water. The fish waste provides an organic food source for the growing plants and the plants provide a natural filter for water in which fish live in. Rather these two participants the third participants are the microbes (nitrifying bacteria). They do the job of converting the ammonia from the fish waste first into nitrites, then into nitrates and the finally nitrate absorbed by plant for their growth. Aquaponics also knew as the addition of two major systems simultaneously i.e. Hydroponics and Aquaculture. This advanced system is gaining increased attention as bio-integrated food production. With right choice of fish and plant species aquaponics serve as a sustainable and compatible system for food production (Mustafa, Saleem. 2010) [2]. Besides this, The integration of aquaculture and hydroponics appears to be an excellent system for rearing both plant and fishes with Significant reduction in the usage of water, no need to use artificial fertilizer, no need to dispose of fish waste or provide an artificial filtration, reduction in land is required to grow the same crops and finally fully organic food is cultivated.

In order to fulfill global needs for valuable animal protein, aquaculture is by far the fastest-growing sector of agriculture to supply humans with fish (FAO 2014) [3]. However, not all aquaculture production technologies for fishes are environmentally sustainable and meet the daily protein requirement of the whole population. Thus there is an urgent need to integrate aquaculture within the water-food-energy nexus into agricultural production systems using value-added chains concomitant with lowering adverse environmental impacts. Aquaponics is a growing form of aquaculture that easily fits into a local and regional food system model in part because it can be practiced in or near large population centers [4]. The Dissolved oxygen had significant, strong but negative relationship with Nitrite-nitrogen and Nitrate-nitrogen; this suggested that increase in dissolved oxygen may lead to decrease in Nitrate nitrogen and Nitrite-nitrogen. pH had significant but negative correlation with Nitrite-nitrogen, this is indicated that increase in pH may lead to decrease in Nitrite-nitrogen and can be linked to the fact that nitrifying bacteria are pH sensitive and at a level above 8 will be inhibited (Michael *et al*.1995) [20]. It is crystal clear that, aquaponics is only a way via we can control most lethal parameters in our culture system with help of plants like; In aquaponics, water from the fish tank is fed to a plant where naturally occurring, beneficial micro-organisms break the ammonia into Nitrite and then Nitrate respectively. Nitrate and other nutrients are absorbed by the plants to assist in their growth and in turn, serve to clean the water. Solid waste will also be filtered out of the water by either the grow beds or some other mechanical process [5]. Temperature of water is far more important than air temperature for hydroponic plant production. The best water temperature for most hydroponic crops is about 75 F (Michael *et al*.1995) [20].

This study was totally different from other studies because in this experiment we cultured ornamental fish with bottles aquaponics concept (First study of aquaponics system with bottles). Mainly experiment based on water quality parameter comparative study under bottle aquaponic Tank (AT) and Normal controlled Tank (NT) with early fingerlings of *Trichopodus trichopterus* (Blue gourami) as fish. Besides this, use of waste bottles was a concept of utilizing plastic in hydroponics behind this concept we can save our environment from plastic pollution in water bodies like ocean beds and rivers etc. lastly, Aquaponics is a technique that has its place within the wider context of sustainable intensive agriculture, especially in family-scale applications. It offers supportive and collaborative methods of vegetable and fish production and can grow substantial amounts of food in locations and situations where soil-based agriculture is difficult or impossible. The sustainability of aquaponics considers the environmental, economic and social dynamics [6].

1.2 Blue Gourami

Gourami also known as three spot gourami or blue gourami belongs to order-Perciformes and family Osphronemidae. The Three-spot or Blue gourami, Trichogaster trichopterus, is a member of the anabantoid group of air-breathing fishes consisting of three families, 19 genera and about 120 species, all occurring in freshwater and indigenous to Africa and southern Asia (Nelson 2006)[8]. T. trichopterus was assigned to the family Belontiidae, subfamily Tricogastrinae, with other gouramis (Nelson 1994) [7], but has recently been placed with the osphronemids (including the Giant gourami, Siamese fighting fishes and Paradise fishes) in the subfamily Luciocephalinae, which consists of six genera and about 20 species (Nelson 2006) [8]. T. trichopterus is elongate, moderately compressed laterally and grows to about 15-20 cm Total length. Ventral pelvic fins form a pair of long thin sensory filaments. Adult males tend to be larger with a more elongate dorsal fin than females. Both male and female are uniform blue with a pale olive ground color and two characteristic dark spots of varying intensity on the mid lateral flank and on the caudal peduncle. Dorsal, anal and caudal fins have a series of whitish spots forming parallel bands. It has a very small, dorsally directed mouth, with a vertical, somewhat protractile upper jaw and prominent lower jaw. The species has scales that are moderate in size and irregularly arranged with a curved, irregular lateral line (Froese & Pauly 2007) [9]. Feeding habit omnivorous but feeds mainly on zooplankton, macro invertebrates (insect larvae), detritus and occasionally on terrestrial macro phyto (Conlu 1986; Chung *et al*. 1994; Talde *et al*. 2004) [11, 10, 12]. T. trichopterus is an extremely hardy fish, and can tolerate wide ranges of several water parameters including hardness, pH, temperature, salinity and dissolved oxygen conditions (Priest, 2002)[14]. The species is native to the Mekong Basin, South-east Asia in Laos, china, Cambodia, Thailand, Vietnam, Myanmar and Indonesia as well as Malaysia (Kottelat *et al*. 1993) [15], (Vidthayanan *et al*. 1997) [13]. According to the IUCN Red List of Threated Species, the three-spot gourami is of “Least Concern”. They might be killed in polluted water ways but it is able to move to other areas. Invasive in some counties, such as The Republic of Trinidad and Tobago and Jamaica, they feed on smaller fish and are very aggressive and territorial [16].

2. Material & Method

2.1 Site of study and concept

Experiment on Bottle Aquaponics was successfully completed in hatchery of the Department of Applied Aquaculture at Barkatullah University Bhopal campus area. Complete set installment in large dimension experimental lab which was very efficient for aquaculture experiments. Firstly experiment was initiated with fabrication of medium sized aquarium with dimensions of 2ft x1ft x1.5ft which was suitable for study. Tank's volumes were approximately 5,184.0 cubic inches or 22.4 U.S. gallons, which was approximately 85.1 liters. These tanks were big enough to stock 5 number of Blue gourami. Level of water throughout the experiment was 15 inch or 37.5 cm height in both the tanks. So, that total water level volume maintained 18.7 U.S. gallons, which is approximately 70.9 liters. Then collection of waste bottles for bottle aquaponics concept for plants and finally we installed all supporting instruments, tools, and precaution aids etc to run experiment correctly without any hurdles. Selection of fish and plant species was an important issue in my research. Blue gourami was select as fish species and green spinach (Spinacia oleracea), Eggplant (*Solanum melongena*) and Tomato (*Solanum lycopersicum*) as plants for aquaponic system (Nelson & paid) [5].

During this study, we observed numerous water quality parameters like; Temperature, Dissolve Oxygen (O_2), Ammonia (NH_3), pH, Nitrite (NO_2) and Nitrate (NO_3). On the other hand, the heights of plant were initially considered as seed and final height taken at the last of experiment.

2.2 Selection of fish and plants

Firstly, Blue gourami collected from nearby ornamental fish shop similarly purchased Spinach, Eggplant and tomato seed from vegetable seed shop; finally follows seed germination procedure for germination of spinach seedlings. Blue gourami is an ornamental fish which was taken for this experiment and scientific name of Blue gourami is *Trichopodus trichopterus.* Secondly, we initiated the seed germination process of green spinach (Spinacia oleracea), Eggplant (*Solanum melongena*) and Tomato (*Solanum lycopersicum*) for bottle aquaponics system. According to their germination transferred (seedlings) to nursery floating raft system and finally shifted to bottles set up.

2.3 Seed Germination Process

2.3.1 Material Required

Tissue paper, Scissor, jig jack plastic bags, Quality seed, Beaker and Dropper.

2.3.2 Chemicals

Hydrogen per oxide (H_2O_2) @ 5ml and Distilled water 500ml. Hydrogen per oxide (H_2O_2) @ 5ml was mixed with 500ml distilled water.

2.3.4 Intensive care of seedlings

Seedlings are very sensitive to environment and need extra care for their survival. Now these seedlings were shifted from tissue paper and accommodated to floating raft under aquarium. During 24 hour aeration was provided initially with proper day light. Seedling requires nutrition for their development and for we used 2-3 drop churry leaves extract which contain large amount of minerals and nutrients for their development.

2.4 Grow bed

This is a place where the nitrification bacteria can grow and convert ammonia into nitrates, which are usable by the plants. Riverine pebbles of small approximate similar sized was choose for bed. Pebbles arranged in bottle in a specific manner which was not harmed the root of plant and make suitable substrate bed and pebble height was 2 Inch.

2.5 Installments of bottles and pumps

Bottles of 1 liter capacity were designed as required for experimental purpose and vertical positioned in such a way that water can easily pass out with limited interval of time (for easily flow of water, holes were made on the cap portion). Now, bottles are suitable for plant growth. Every bottle accommodates 2-3 seedlings/bottles/plant species taken and similar 3 set of bottles are installed which carry spinach (Spinacia oleracea), Eggplant (*Solanum melongena*) and Tomato (*Solanum lycopersicum*) individually. Further, Water pumps were placed inside the aquarium by mean of uplifting wastewater from aquarium tank to bottles accommodating plants. Water uplifting done with the help of irrigation tube of 3 meter which connected with water controller. Water flow maintained during the experiment is 750 ml of water /min. Timing for water flow: Day time for 12 hours.

2.6 Food and Feeding

Feed was prepared in the present experiment which was scientifically formulated considering the specific nutritional need of *Blue gourami* (30% protein) for the proper growth and survivability rate in this experiment by Pearson's square method. Pearson Square Method or box method of balancing rations is a simple procedure that has been used for many years. Diets are formulated to fulfill the energy, protein and energy protein ratio of the diet. If protein and energy content of the diet is satisfied then other nutrients are automatically augmented. However, marginal supplementation of the nutrient is required, if necessary. The following ingredients that were used to prepare experimental feed with 30% protein value used during the whole experiment Hence different percentages were; Rice bran: 17%, Soya bean: 36%, Curry leaves: 12.5%, Chicken liver: 27%, Moringa: 2.1% respectively. As a general rule fish should be fed twice daily, first in the morning and evening at the rate of 3-5% of the body weight per/day which will ensure appropriate supplementary feeding. Size of the feed particles was increased gradually from 0.2-0.3mm at the start to about 1mm by the end of the experiment. Regular sampling, weighing and estimation of actual total weight of stock were carried out to determine whether or not the given feeds were well utilized. Feeding rate was twice a day @ 3% body weight during the whole experiment.

2.7 Water Quality Parameters

Water quality parameter has significant role in fisheries. Fish are equilibrium with potential organisms and their environment. Changes in this equilibrium, such as deterioration in water quality can result in fish becoming stressed and vulnerable to diseases. Therefore, it is important to know about water quality parameters and their management is necessary for better growth and survival (Singh et. al, 2017) [17]. Besides this, maintenance of good water quality is essential for both survival and optimum growth of culture organisms. The higher levels of metabolites in aquarium water that can have an adverse effect on growth are generally an order of magnitude lower than those tolerated by ornamental fishes for survival. Good water quality is characterized by adequate oxygen and limited levels of metabolites. The major source of nutrients in aquaculture is the feed. Water quality parameter like; Dissolved oxygen (DO), pH, Ammonia, Nitrate and Nitrite done by API freshwater master test kit (manufactured by: MARS fishcare, North America). This testing kit generally used for household aquarium keeping and withdraw results by comparison of color works as colorimeter and contains total six bottles along with four test tubes and testing manual. On the other hand, we used Aquasol @ pen type thermometer for temperature reading.

3. Result and Discussion

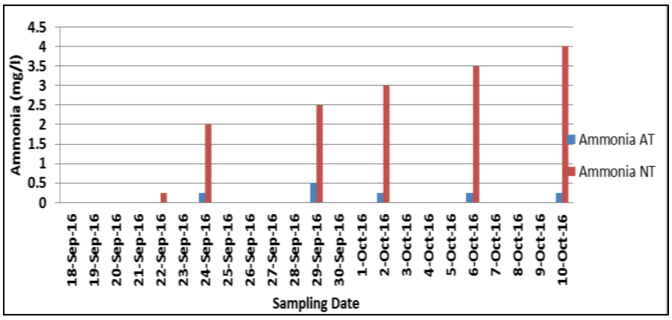
Present study was basically to reveals the water quality parameter comparative experiment under bottle aquaponic Tank and Normal controlled Tank with early fingerlings of *Trichopodus trichopterus* (Blue gourami) as fish. Whole experiment was based on water quality parameter like pH, Dissolved oxygen (DO), Ammonia, Temperature, Nitrite and Nitrate. In this experiment water quality parameters were like Ammonia 0 to 0.25 in AT system and in NT system Ammonia value was very lethal after few days of experiment 0.25 to 4 mg/l (ppm) respectively (Table & Graph no.1). Besides this, values of Nitrite and Nitrate were also on high scale in NT system as compare to AT like; 0 to 3 and 0 to 6 mg/l (ppm) respectively (Table no.1 & Graph no. 2, 3). On the other hand, pH and temperature values were almost same in both systems with minute fluctuations like; pH readings were 7.2 to 7.8 and 27.5 to 29.2 ºC respectively (Table no.1 & Graph no.4). In AT system all water quality parameters were normal as required for better growth of fish in aquarium culture but these parameters were totally opposite in NT system which was very dangerous for fish survival or lethal for fish health. On the other hand, Vegetable used for an aquaponics system is chosen on the basis of the market demand, the handiness for growing fish and vegetables in an aquaponics, and the equivalency between nutrient input and supplies Bosma *et al*. (2017) [21]. Hence, only a small number of plants have been productively grown in aquaponics systems including lettuce, cucumbers, bell peppers, tomatoes, eggplant and root crop such as carrot (Graber and Junge, 2009, Kamal, 2006, Sajjadinia *et al*., 2010, Roosta, 2014) [22, 23, 24, 27]. In our study we used tomato (*Solanum lycopersicum*), Eggplant (*Solanum melongena*) and Spinach (*Spinacia oleracea*) seedlings. Lastly, Nitrate is the essential and enviable nutrient in aquaponics as its excessive levels in tanks can be an indication that all the nitrates that are being produced by the nitrifying bacteria are not taken up efficiently by the plants or may be not enough plants are being grown in the grow beds to take up whole nitrate. To overcome high levels of nitrate either more plants can be introduced into grow beds or more fish could be harvested to reduce the amount of ammonia being produced. However, the finding of reduced ammonia concentration in this study is also supported by the results of Tyson *et al*., 2004, Graber and Junge, 2009, Maucieri *et al*., 2017 [26, 22, 25] who had observed significantly lower values of ammonia in the aquaponics experimental tank as compared to the control fish tanks. The low levels of ammonia and nitrate observed in this study is an indication of a well-developed microbial population in the aquaponics tank.

4. Conclusion

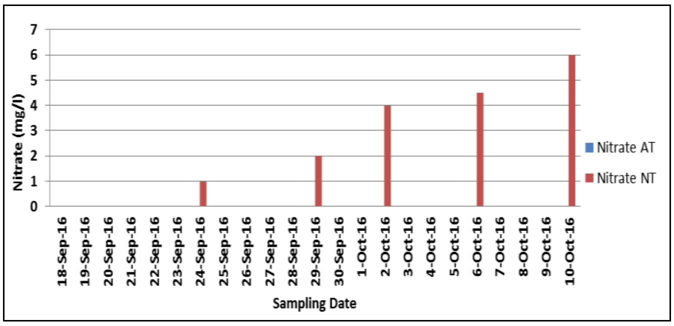
Proper maintaining and monitoring optimum water quality parameters is very vital and healthy for aquaponics system. Obtaining conditions that are optimal for fish growth, nitrifying bacteria and for plants growth is crucial and key of water quality parameters such as pH, temperature, nitrate and ammonia should be regulated at proper intervals to avoid loss of culture quality and economy of aquaponics system. These all are simple protocols and precautions that need to be followed to manage a healthy and productive aquaponics system. In aquaponics system we observed that we can control most dangerous water quality parameters ammonia with help of hydroponic culture.

Table 1: representing water quality parameters like; pH, Ammonia, Nitrite and Nitrate

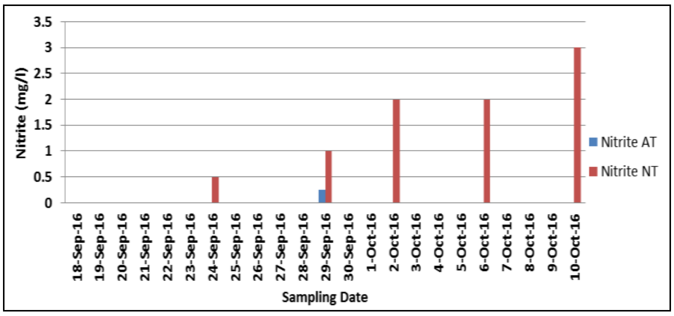
Date of experiment	pH (AT)	pH (NT)	Ammonia (AT)ppm	Ammonia (NT) ppm	Nitrite (AT)	Nitrite (NT)	Nitrate (AT)	Nitrate (NT)
18-Sep-16	7.2	7.2	0	0	0	0	0	0
22-Sep-16	7.6	7.6	0	0.25	0	0	0	0
24-Sep-16	7.2	7.2	0.25	2	0	0.5	0	1
29-Sep-16	7.7	7.7	0.5	2.5	0.25	1	0	2
02-Oct-16	7.8	7.7	0.25	3	0	2	0	4
06-Oct-16	7.2	7.7	0.25	3.5	0	2	0	4.5
10-Oct-16	6.8	7.2	0.25	4	0	3	0	6



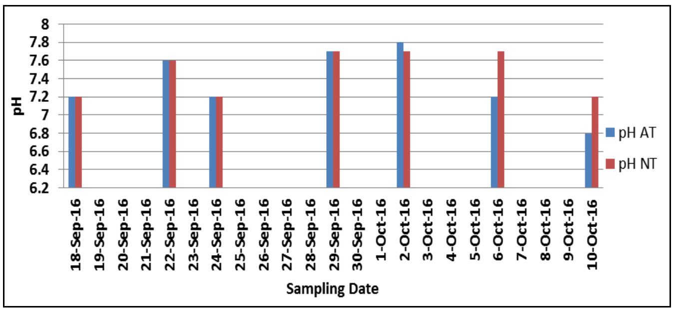
Graph 1: representing Ammonia



Graph 3: representing Nitrate



Graph 2: representing Nitrite

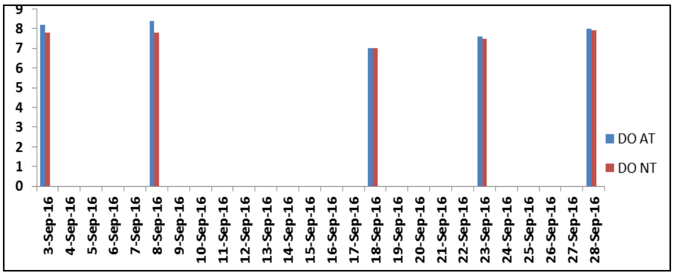


Graph 4: representing pH

Dissolved oxygen (DO) during the Experiment

Table 2: representing Dissolved Oxygen mg/l

Date of experiment	DO (AT) mg/l	DO (NT) mg/l
18-Sep-16	7	7
23-Sep-16	7.6	7.5
28-Sep-16	8	7.9
03-Sep-16	8.2	7.8
08-Sep-16	8.4	7.8



Graph 5: representing Dissolved Oxygen mg/l

References

1. Diver S, Rinehart L. Aqua ponics Integration of Hydroponics with Aquaculture, 2010, 1-13.
2. Mustafa, Saleem. Producing Organic Fish and Mint in an Aquaponic System. Aquaponics Journal. 2010; 58:3.
3. FAO, The state of world fisheries and aquaculture. FAO Rome, 2014.
4. David C Love, Jillian P Fry, Elizabeth S Hill, Laura Genello, Ken Semmens, Richard E. Thompson. Commercial aquaponics production and profitability: Findings from an international survey, Aquaculture. 2015; 435:67-74.
5. Nelson and paid, info@aquaponics.com http://www.aquaponics.com and http://www.japan-aquaponics.com
6. Somerville C, Cohen M, Pantanella E, Stankus A, Lovatelli A. Small-scale aquaponic food production. Integrated fish and plant farming. FAO Fisheries and Aquaculture Technical Rome, FAO. 2014; 262:589
7. Nelson JS. Fishes of the World Third, Edition. John Wiley and Sons, Inc. NY, 1994.
8. Nelson JS. Fishes of the World, Fourth Edition. John Wiley & Sons, Inc. Hoboken, NJ, 2006.
9. Froese R, Pauly D. (Eds.), FishBase [online] version. Available from: www.fishbase.org Accessed April 2007.
10. Chung DSL, Ng PKL, Murphy DH. Preliminary studies of the feeding ecology of black water Belontiidae of North Selangor, Peninsular Malaysia In: Proc. 4th Indo-Pacific Fish, 1994.
11. Bangkok Con Thailand. Systematics and Evolution of Indo-Pacific Fishes. Faculty of Fisheries, Kasetart University. Conlu P.V. Guide to Philippine flora and fauna. Fishes. Natural Resources Management Center, Quezon City, 1986; 9:76-86
12. Talde CM, Mamaril AC, Palomares MLD. The diet composition of some economically important fishes in the three floodplain lakes in Agusan Marsh wildlife sanctuary in the Philippines. Sri Lanka J Aquat. Sci. 2004; 9:45-56
13. Vidthayanon C, Karnasuta J, Nabhitabhata J. Diversity of freshwater fishes in Thailand. Office of Environmental Policy and Planning, Bangkok, 1997.
14. Priest A. When two are three and gold is blue. Osphronemid. 2002; 4(4):6-11.
15. Kottelat M. Technical report on the fishes from fresh and brackish waters of Leyte, Philippines. Technical Report prepared for the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and ViSCA-GTZ Ecology Program, Visayan State College of Agriculture, Philippines. Route de Fregiêcourt 96c, Case postale 57, CH-2952 Cornol, and Switzerland, 1993, 54.
16. Vidthayanon C. Trichopodus trichopterus. The IUCN Red List of Threatened Species. Version 2012 & 2014.3.
17. Paramveer Singh, Sunil Kumar Nayak, Dhalongsaih Reang, Rishabh Singh. To study the Survivavility of Ompok pabda Hamilton fingerlings fed with different ingredients under earthen ponds like, Rice bran, Mustard oil cake, Fish meal and Floating feed, International Journal of Fisheries and Aquaculture Sciences. 1822, ISSN 2248-9975 Volume 7, Number 1 (2017), pp. 23-32.
18. Dauda A Babatunde, Akinwole A. Olusegun. Interrelationships among Water Quality Parameters in Recirculating Aquaculture System. Nigerian Journal of Rural Extension and Development, 2014, 8.
19. Ayoola Olusegun Akinwole, Akeem Babatunde Dauda and Eniitan Bolanle Oyewole. Influence of partial and total static culture water withdrawal on water quality, growth and feed utilization of African catfish (Clarias gariepinus Burchell, 1822), Juveniles International Journal of Fisheries and Aquatic Studies. 2016; 4(6):175-178.
20. Michael PM, James R, Losordo TM. Recirculating Aquacultue Tank Production Systems: Management of Recirculation Systems, Louisana State University Agricultural Centre and Louisana Cooperative Extension service. Publ. No 2584 (500) 2/95, 1-12 (1995).
21. Bosma RH, Lacambra L, Landstra Y, Perini C, Poulie J, Schwaner MJ, *et al*. The financial feasibility of producing fish and vegetables through aquaponics. Aquacult. Eng. 2017; 78:146-154
22. Graber A, Junge R. Aquaponic systems: nutrient recycling from fish wastewater by vegetable production. Desalination. 2009; 246(1):147-156
23. Kamal SM. Aquaponic production of Nile tilapia (Oreochromis Niloticus) and Bell pepper (Capsicum Annuum) in recirculating water system. Egypt. J Aquat. Biol. Fish. 2006; 10(3):85-97
24. Sajjadinia AR, Ershadi A, Roosta HR. Comparison of eco-physiological characteristics of pepper in hydroponic and aquaponic systems. J Sci. Technol. Greenh. Cult. 2010; 1(2):1-8
25. Maucieri C, Forchino AA, Nicoletto C, Junge R, Pastres R, Sambo P Borin M. Life cycle assessment of a micro aquaponic system for educational purposes built using recovered material. J Cleaner Prod. 2018-2017; 172:3119-3127
26. Tyson RV, Simonne EH, White JM Lamb EM. Reconciling water quality parameters impacting nitrification in aqua ponics: the pH levels. Proc. Fla. State Hort. Soc. 2004; 117:79-83
27. Roosta HR. Effects of foliar spray of K on mint, radish, parsley and coriander plants in aquaponic system. J. Plant Nutr. 2014; 37(14):2236-2254.