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Effect of Fish Diets Supplemented with Vitamin /Mineral Premix on Growth and Yield of Lettuce under Aquaponic System

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Abstract: This experiment was conducted in aquaponic system in a greenhouse at Fish Nutrition Laboratory, Faculty of Agriculture, Cairo University, Egypt, during two growing periods trial 1 started on 15th February and trail 2 started on 1st April 2018, to evaluate the effect of three vitamin /mineral premix levels (0.5, 1.0 and 2.0 %) supplemented in fish diet on leafy lettuce (*Lactuica sativa*) variety New red fire grown in aquaponic system. The aquaponic system consisted of 3 independent fish tanks, every fish tank describe one treatment and feed three hydroponic units (experimental units). Every aquaponic unit was consisted of fiberglass fish tank (1000 L volume), mechanical filter (decanter), biological filter, three floating raft system (hydroponic unit one m^2) for lettuce production and sump. Nile tilapia (*Oreochromis niloticus*) was used. Results show that treatment at 2% of vitamin /mineral premix supplemented in fish diet improved significantly number of leaves, plant height, fresh and dry weight of shoots, roots and increased yield/m^2 , relative growth rate (RGR) and crop growth rate (CGR).

Key words: Aquaponic system · Floating raft system · Leafy lettuce (*Lactuica sativa*) · Vitamin /mineral premix · Yield · Relative growth rate (RGR) · Crop growth rate (CGR)

INTRODUCTION

The world population is increasing steadily and is expected to reach about 10 billion by 2050 [1]. Aquaponic system depends on the use of water loaded with nutrients produced from aquaculture in plant production in a closed system [2]. Aqauponic is the sustainable integrated system consists of water recycling between aquaculture and plants [3, 4] .The advantage of the aquaponic system include: water saving, pesticide removal and multiple production (plant and fish) [5]. Water consumption in agriculture in the Middle East and North Africa reached about 90% of freshwater [6]. Nonrecycling systems consumes a large amount of water and causes pollution of soil and groundwater [7]. Aquaponic system saving approximately 90% of water when compared with traditional agriculture [8]. The application of aquaponic system is beneficial in dry areas that suffer from water shortage [9]. Microorganisms in the biological filter attached by aquaponic system works to convert the fish residues into an easily absorbed nutrients form by the plant, which helps to prevent poisoning that may occur to the fish [10]. That leads to saving water consumption [11]. The nutrients produced by the fish in aquaponic system may be not adequate for growth and development for all plants where, the fish meal does not provide all the nutrient needs by plants [12]. Components of the fish meal affect the nutrients produced by the fish [13]. 80% of the nitrogen and 85% of the phosphorus is released in fish waste [14, 15]. One of the challenges in aquaponic system was access to the most appropriate ingredients of the fish meal [9]. Lettuce is one of the most famous salad crops grown commercially in the world. Leafy vegetables especially lettuce are the main source of nitrate in human food [16]. Harvesting in optimum stage (late harvest) reduce nitrate content [17]. The lettuce produced in the aquaponic system is considered to be more health due to its low nitrate content [12]. The beds used in the aquaponic system are divided to three kind's nutrient film technique (NFT), ebb- and- flow (supported by heavy substrate) and floating system (deep water culture) [18]. The plants productivity in aquaponic system was superior the productivity in traditional cultivation [19]. The technique of growing plants in the floating system is one of the successful hydroponic systems especially with leafy vegetables (lettuce, rocket and spinach) [20]. Which, showed identity in growth and harvest time [21]. Goda *et al*. [22] reported that floating raft system are

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suitable for nine vegetables (head lettuce, red leaf lettuce, green leaf lettuce, tomato, eggplant, bell pepper, broccoli and cucumber) in aquaponic system, the more productivity and economically system . Floating system make a direct contact between the roots and nutrient solution [23]. Production lettuce and rocket under the floating system improved the yield and quality [24]. Lennard and Leonard [25] concluded that lettuce grown in the floating raft system was superior to the grown in gravel and was more efficiency in absorbing nutrients. Lettuce produced in the aquaponic and hydroponic gave similar yield [26]. Lettuce productivity excelled under the aquaponic system than the hydroponic system [27]. The pH is of great importance in aquaponic system and its maintenance within 7pH is suitable for plants, fish and microorganisms [28]. Nile tilapia (*Oreochromis niloticus)* a fish with range of acclimatization and its nutritional needs are few, therefore suitable for the aquaponic system especially in the tropics and equator regions [29]. Tilapia has awide rang of pH, but the best growth is in neutral or alkaline tendency [30]. Therefore, the aim of this investigation was to study the effect of fish diets supplemented with vitamin/mineral premix on growth and yield of lettuce plants grown in aquaponic system.

MATERIALS AND METHODS

This experiment was conducted in aquaponic system in a greenhouse at Fish Nutrition Laboratory, Faculty of Agriculture, Cairo University, Egypt, during two growing periods trial 1 started on 15th February and trail 2 started on 1st April 2018, to evaluate the effect of three vitamin /mineral premix levels (0.5, 1.0 and 2.0 %) supplemented in fish diet on leafy lettuce (*Lactuica sativa*) variety New red fire grown in aquaponic system. The components of vitamin /mineral premix are presented in schedule 1. The aquaponic system consisted of 3 independent fish tanks, every fish tank describe one treatment and feed three hydroponic units (experimental units). Every aquaponic unit was consisted of fiberglass fish tank (1000 L volume), mechanical filter (decanter), biological filter, three floating raft system (hydroponic unit) for lettuce production and sump. Every floating raft system consisted on triangular (2m long ×0.5m wide×0.25m deep) and a raft system consisted of floating sheets (2m long ×0.5m wide×3cm thick) of Styrofoam, with circular holes 24 holes. Each plot formed by 24plan/sheet. Production was covering a total surface of 3m^2 for each treatment. The temperature in the greenhouse was controlled to not exceed 28°Cand the source of illumination was sunlight. The mechanical filter consisted of 200 L plastic drum. The biological filter consisted of 100L plastic drum. The sump was 100 L plastic drum equipped with submersible pump to return the effluent to the fish tank. The effluent from the fish tank flowed into the mechanical filter then to the biological filter. Effluent from the biological filter was drain into the hydroponics units and drain into the sump, which the effluent was pumped to the fish tank, Principal components of aquaponic system as shown in Fig. 1. All fish tanks and biological filters are aerated by using air pump to maintain the level of oxygen. To maintain the pH approximately 7 pH acetic acid was added to the sump. Nile tilapia (*Oreochromis niloticus*) were used in the experiment was average weight 80g/fish. Fish density was 200 fish /m^3. During the experiment the fish was fed 2% of the fish weight divided in two doses daily on diet containing 50% protein, 12% lipid and 35% carbohydrate. The diet prepared in the laboratory and supported by the vitamin /mineral premix by concentration 0.5, 1.0 and 2.0% .The lettuce seedlings were transplanted at the stage of three to four true leaves. Some seedlings were dried to calculate the dry weight at the beginning of the experiment. Lettuce density was 24 plant/m^2. This experiment included three treatments 0.5, 1.0 and 2.0 % vitamin /mineral premix supplemented in fish diet. During the experiment, there were no water exchange water addition done only to replace water lost caused by transpiration and evaporation. All the treatments were replicated three times in a complete randomize block design (RCBD). Ten lettuce plants were selected randomly from each hydroponic unit (experimental unit)in 1, 3 and 5 weeks (at harvest) from transplanting to measured plant height and number of leaves while fresh and dry weight of shoots, roots, root length and dry matter percentage were only measured at harvesting (5 weeks from transplanting). Then crop yield/m^2 was obtained based on shoot fresh weight. The lettuce leaf nutrient content total nitrogen percentage, potassium percentage and phosphorus percentage were determined according to the methods described in AOAC [31]. The following growth parameters were measured at harvest [32]. Relative growth rate (RGR) and crop growth rate (CGR) was calculated: RGR= (accumulated dry matter in plant per base weight unit at time unit) Δ W/W × time, where: Δ W is the change in plant dry matter. (CGR) = (accumulated dry matter in plant at time unit per land area given for each plant) Δ W/ P × time. The L.S.D. method Snedecor and Cochran [33] was used for testing the significance of means in the experiment.

Schedule 1: The components of vitamin /mineral premix each 1kg contains

Vitamin A	4000000 UI	Zn	1666 mg
Vitamin D	700000 UI	Mn	20000 mg
Vitamin B_1	330 mg	Fe	10000 mg
Vitamin B_6	500 mg	Cu	1333 mg
Niacin	10000 mg	$CaCo_3$	Approximately 1kg
Folic acid	330 mg	Vitamin E	3333 mg

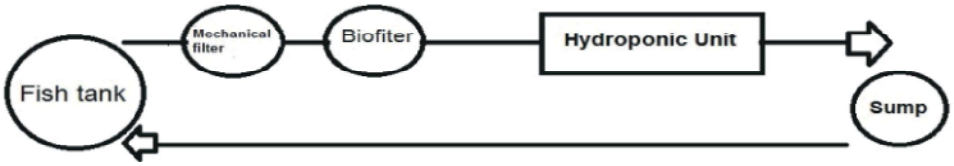

Fig. 1: Principal components of aquaponic system

RESULTS AND DISCUSSION

Number of Leaves and Plant Height: Data presented in Table 1 showed that there were no significant differences between treatments in number of leaves in the first sages of lettuce development at 1 and 3 weeks after transplanting and plant height at 1 week in both trials. Whereas, at the 5 weeks number of leaves increased significantly by increasing vitamin /mineral premix percentage and the plant height showed significantly differences earlier that at stage 3 weeks after transplanting. Vitamin /mineral premix at 2.0% and 1.0% had the similar significant in number of leaves and plant height. The lowest vitamin /mineral premix percentage gave the lowest values of number of leaves and plant height in both trials. Our result in agreement with Rono, *et al*. [2] how concluded that fish diet supplementation by iron amino acid as nutrient source improved the spinach (*Spinacia oleraceae*) growth such as plant height, number of leaves and fresh and dry weight (Table 2). Therefore, some synthetic fertilizer (Ca, Fe, K) may be added to the aquaponic system to compensate the nutrient lack [10].

Fresh and Dry Weight of Lettuce: Data presented in Table 2 showed that supplemented fish diet with vitamin /mineral premix had significant differences between treatments in fresh and dry weight of shoot and root, shoot dry matter percentage and root length of lettuce. In both trials, the average fresh, dry weight of shoots and average roots dry weight of lettuce plants at harvest (5 weeks from transplanting) increased significantly by increasing the percentage of vitamin /mineral premix supplemented in the fish meal. Whereas, the treatment vitamin /mineral premix at 2% gave the highest values followed by 1.0% and 0.5% gave the lowest values. Shoot dry matter percentage and average root fresh weight was higher in treatment of 2.0% of vitamin /mineral premix. Treatment at 0.5% of vitamin /mineral premix supplemented in the fish diet gave the shortest roots length. Whereas, treatments of 2.0% and 1.0% of vitamin /mineral premix gave the similar significant in root length. Elizabeth *et al*. [34] indicated that fish feed consumption increased by making the diet ingredients balanced, which was improving the proportion of the resulting elements in the fish waste.

Yield, RGR, CGR and Leaves Minerals Content: Data presented in Table 3 showed that supplemented fish diet with vitamin /mineral premix had significant differences between treatments in yield/m^2, relative growth rate (RGR), crop growth rate (CGR), Nitrogen, Phosphorus and Potassium percentage. In both trials, treatment at 2.0% of vitamin /mineral premix supplemented in the fish meal showed the highest yield/m^2, RGR, CGR followed by 1.0% vitamin /mineral premix. Meanwhile, the treatment at 0.5% of vitamin /mineral premix gave the lowest values. Mineral content of leaves was affected by vitamin /mineral premix application. Where, treatment at 2.0% of vitamin /mineral premix supplemented in the fish meal showed the lowest minerals content of the lettuce leaves and treatment at 1.0% of vitamin /mineral premix recorded the maximum content followed by treatment at 0.5% of vitamin /mineral premix. Fish diet composition effect on the plant yield produced under aquaponic system [35] .Petropoulos *et al.* [24] reported that lettuce yield increased significantly in floating raft system by increasing N application where, 200mg/l resulted the highly yield, fresh weight and number of leaves. Ajitama *et al*. [36] found that butterhead lettuce produced in aquaponic system at density 10 and 20 plant/m^2 had the similar relative growth rate (RGR).

Table 1: Effect of fish diets supplemented with vitamin /mineral premix on number of leaves and plant height of leafy lettuce variety New Red Fire grown in aquaponic system at 1, 3 and 5 weeks from transplanting during two growing periods in 2018

	No. of leaves			Plant height (cm)		
Treatments	1 week	3 weeks	5 weeks	1 week	3 weeks	5 weeks
			Trial 1 (15th Feb. 2018)			
0.5% VMP	5.8 a	10.8 a	14.1 b	11.92 a	17.20 b	24.44 b
1.0% VMP	5.1 a	12.6 a	16.9 a	12.98 a	20.04 a	27.34 a
2.0% VMP	5.2 a	12.1 a	17.9 a	12.88 a	19.30 a	26.92 a
			Trial 2 (1st April 2018)			
0.5% VMP	5.3 a	10.5 a	13.7 b	11.88 a	17.34 b	24.22 b
1.0% VMP	5.0 a	12.4 a	16.2 a	12.96 a	20.10 a	27.36 a
2.0% VMP	5.8 a	11.8 a	17.5 a	12.92 a	19.02 a	27.30 a

In each column, values followed by the same letter do not differ significantly at P=0.05 by LSD.
VMP: vitamin /mineral premix

Table 2: Effect of fish diets supplemented with vitamin /mineral premix on shoot , root(fresh and dry weight), dry matter percentage and root length of leafy lettuce variety New Red Fire grown in aquaponic system at 5 weeks from transplanting(at harvest) during two growing periods in 2018.

Treatments	Average shoot f.w.(g)	Average shoot dry weight (g)	Shoot dry matter %	Root length (cm)	Average root f.w. (g)	Average root dry weight (g)
			Trial 1 (15th Feb. 2018)			
0.5% VMP	58.78 c	2.87 c	4.99 ab	14.18 b	4.12 b	0.26 c
1.0% VMP	80.24 b	3.70 b	4.67 b	21.95 a	4.03 b	0.28 b
2.0% VMP	84.32 a	4.63 a	5.29 a	21.95 a	5.06 a	0.47 a
			Trial 2 (1st April 2018)			
0.5% VMP	54.70 c	2.66 c	4.62 b	13.98 b	3.86 b	0.22 b
1.0% VMP	72.15 b	3.24 b	4.59 b	22.20 a	3.42 c	0.21 b
2.0% VMP	78.95 a	4.23 a	5.32 a	21.98 a	5.09 a	0.49 a

In each column, values followed by the same letter do not differ significantly at P = 0.05 by LSD.
VMP: vitamin /mineral premix, F. w : fresh weight.

Table 3: Effect of fish diets supplemented with vitamin /mineral premix on yield, RGR, CGR, nitrogen, phosphorus and potassium of leafy lettuce variety New Red Fire grown in aquaponic system at 5 weeks from transplanting(at harvest) during two growing periods in 2018.

Treatments	Yield/m^2 (kg)	RGR(g/g.d)	CGR(g/cm^2.d)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
			Trial 1 (15th Feb. 2018)			
0.5% VMP	1.420 c	0.80 c	33.45 c	2.81 b	0.50 a	8.66 b
1.0% VMP	1.919 b	0.99 b	42.69 b	2.99 a	0.54 a	9.44 a
2.0% VMP	2.023 a	1.32 a	51.28 a	2.21 c	0.41 b	7.73 c
			Trial 2 (1st April 2018)			
0.5% VMP	1.346 c	0.70 c	28.51 c	2.80 b	0.46 a	8.71 b
1.0% VMP	1.751 b	0.89 b	37.60 b	2.99 a	0.49 a	9.40 a
2.0% VMP	1.901 a	1.18 a	50.17 a	2.22 c	0.39 b	7.79 c

In each column, values followed by the same letter do not differ significantly at P=0.05 by LSD.
VMP: vitamin /mineral premix, RGR: Relative growth rate, CGR: Crop growth rate, d: day

De Carmello and Anti [37] concluded that tomato plants absorbed large concentration of potassium followed by nitrogen meanwhile absorbed less amount of phosphorous. Nozzi *et al*. [12] indicated that lettuce grown in aquaponic system without addition micronutrients to the plants exert more energy to absorb the nutrients and produce healthy lettuce. This results may explained by that plants in treatment at 2.0% of vitamin /mineral premix used nitrogen very efficiently in increasing shoot growth and used phosphorus to increase root growth. This is clearly shown in the increasing shoot fresh weight, length and weight of the root (Table 2).

CONCLUSION

From the foregoing results it could be concluded that, supplementation the fish meal by 2% of vitamin /mineral premix in the aquaponic system have positive effect on the lettuce growth such as fresh weight, dry weight, plant

height and number of leaves and increased the yield/m^2 compared to the other concentrations. This experiment indicated the ability of aquaponic system to produce lettuce (*Lactuica sativa*) by addition the vitamin /mineral premix to the fish meal as nutrient source. Moreover, aquaponic system works to produce healthy lettuce plants as a source of nutrients in the human diet, save water and reduce the pollution resulting from drainage aquaculture water.

REFERENCES

1. UN (United Nations), 2017. World Population Prospects: The 2017 Revision. Population Division of the Department of Economic and Social Affairs of the United Nation, New York.
2. Rono, K., J.O. Manyala, D. Lusega, J.A. Sabwa, E. Yongo, C. Ngugi, K. Fitzsimmona and H. Egna, 2018. Growth Performance of Spinach (Spinacia oleracea) on Diets Supplemented With Iron – Amino Acid Complex in an Aquaponic System in Kenya. Int. J. Res. Sci. and Mang., 5(7): 117-127.
3. Roosta, H.R. and S. Afsharipoor, 2012. Effects of different cultivation media on vegetative growth, ecophysiological traits and nutrients concentration in strawberry under hydroponic and aquaponic cultivation systems. Advances in Envir. Biology, 6: 543-555.
4. Knaus, U. and H.W. Palm, 2017. Effects of fish biology on ebb and flow aquaponical cultured herbs in northern Germany (Mecklenburg Western Pomerania). Aquac., 466: 51-63.
5. Martins, C.I.M., E.H. Eding, M.C.J. Verdegem, L.T.N. Heinsbroek, O. Schneider, J.P. Blancheton, E.R. D'Orbcastel and J.A.J. Verreth, 2010. New developments in recirculating aquaculture systems in Europe: A perspective on environmental sustainability. Aquac. Eng., 43: 83-93.
6. FAO.2005. AQUASTAT Survey, Irrigation in Africa in Figures; FAO: Rome, Italy.
7. Gagnon, V., G. Maltais-Landry, J. Puigagut, F. Chazarenc and J. Brisson, 2010. Treatment of hydroponics wastewater using constructed wetlands in winter conditions. Water. Air. Soil Pollut., 212: 483-490.
8. McMurtry, M.R., D.C. Sanders, J.D. Cure, R.G. Hodson, B.C. Haning and E.C. S. Amand, 1997. Efficiency of water use of an integrated fish/ vegetable co-culture system. J. World Aquac. Soc., 28(4): 420-428.
9. Goddek, S., B. Delaide, U. Mankasingh, K. Ragnarsdottir, H. Jijakli and R. Thorarinsdottir, 2015. Challenges of sustainable and commercial aquaponics. Sustainability, 7: 4199-4224.
10. Rakocy, J.E., M.P. Masser and T.M. Losordo, 2015. Recirculating Aquaculture Tank Production Systems. Aquaponics—Integrating Fish and Plant Culture. Southern Regional Aquaculture Center, Publication, 454: 1-16.
11. Ezekiel, O., 2015. Challenges and Opportunities to Sustainability in Aquaponic and Hydroponics Systems. Inter. J. Sci. Res. and Innov. Tech., 2(11): 54-76.
12. Nozzi, V., A. Graber, Z. Schmautz, A. Mathis and R. Junge, 2018. Nutrient Management in Aquaponics: Comparison of Three Approaches for Cultivating Lettuce, Mint and Mushroom Herb. Agronomy, 8: 27-41.
13. Rakocy, J.A. and J.E. Hargreaves, 1993. Integration of vegetable hydroponics with fish culture: A review. In Techniques for Modern Aquaculture, Proceedings Aquacultural Engineering Conference; Wang, J.K., Ed.; Amer. Soc. Agri. Eng.: St. Joseph, MI, USA, pp: 112-136.
14. Schneider, O., V. Sereti, E.H. Eding and J.AJ. Verreth, 2005. Analysis of nutrient flows in integrated intensive aquaculture systems. Aquac. Eng., 32: 379-401.
15. Avnimelech, Y., 2006. Bio-filters: The need for a new comprehensive approach. Aquac. Eng., 34: 172-178.
16. Di Gioia F., M. Gonnella and P. Santamaria, 2013. Contribution of leafy vegetables to dietary nitrate intake and regulations. In: Umar S, N.A. Anjum and N.A. Khan (Eds). Nitrate in leafy vegetables: Toxicity and safety measures. I.K. International Publishing 331 House Pvt Ltd, New Delhi, Bangalore, pp: 2-16.
17. Yosoff, S.F., M.T.M. Mohamed, A. Parvez, S.H. Ahmad, F.M. Ghazali and H. Hassan, 2015. Production system and harvesting stage influence on nitrate content and quality of butterhead lettuce. Bragantia, 74(3): 322-330.
18. Delaide, B., G. Delhaye, M. Dermience, J. Gott, H. Soyeurt and M.H. Jijakli, 2017. Plant and fish production performance, nutrient mass balances, energy and water use of the PAFF Box, a small-scale aquaponic system. Aquac. Eng., 78: 130-139.

19. Rakocy, J.E., D.S. Bailey, R.C. Shultz and E.S. Thoman, 2004. Update on tilapia and vegetable production in the UVI aquaponic system. In New Dimensions on Farmed Tilapia, Proceedings of the Sixth International Symposium on Tilapia in Aquaculture, Manila, Philippines, 12-16 September; pp: 12-16.
20. Rouphael, Y., G. Colla, A. Battistelli, S. Moscatello, S. Proietti and E. Rea, 2004. Yield, water requirement, nutrient uptake and fruit quality of zucchini squash grown in soil and closed soilless culture. J. Hort. Sci. Biotech., 79: 423-430.
21. Gonnella, M., F. Serio, G. Conversa and P. Santamaria, 2001. Yield and quality of lettuce grown in floating system using different sowing density and plant spatial arrangements. Acta Hort., 614: 687-692.
22. Goda, A.M.A.S., M.A. Essa, M.S. Hassaan and Z. Sharawy, 2015. Bio Economic Features for Aquaponic Systems in Egypt. Turk. J. Fisheries and Aquatic Sci., 15: 525-532.
23. Fontana, E. and S. Nicola, 2009. Traditional and soilless culture systems to produce corn salad (*Valerianella olitoria* L.) and rocket (Eruca sativa Mill.) with low nitrate content. J.Food, Agri. and Envi., 7(2): 405-410.
24. Petropoulos, S.A., E. Chatzieustratiou, E. Constantopoulou and G. Kapotis, 2016. Yield and Quality of Lettuce and Rocket Grown in Floating Culture System Not. Bot. Horti. Agrobo., 44(2): 603-612.
25. Lennard, W.A. and B.V. Leonard, 2006. A comparison of three different hydroponic sub-systems (gravel bed, floating and nutrient film technique) in an Aquaponic test system. Aquac. Int., 14: 539-550.
26. Delaide, B., S. Goddek, J. Gott, H. Soyeurt and H. Jijakli, 2016. Lettuce (*Lactuca sativa* L. var. Sucrine) Growth Performance in Complemented Aquaponic Solution Outperforms Hydroponics. Water 2016, 8: 467-477.
27. Rocha, A.F., M.L.F. Biazzetti, M.R. Stech and R.P. Silva, 2017. Lettuce production in aquaponic and biofloc systems with silver catfish Rhamdia quelen. Bol. Inst. Pesca, Sao Paulo, 44: 64-73.
28. Kaiser, D.E., J.A. Lamb and P.R. Bloom, 2011. Managing Iron Deficiency Chlorosis in Soybean; Publ. AG-FO-08672-A. University of Minnesota: Saint Paul, MN, USA.
29. Salam, M.A., N. Jahan, S. Hashem and K.M.S. Rana, 2014. Feasibility of tomato production in aquaponic system using different substrates. Progressive Agri., 25: 54-62.
30. Shelton, W and T. Popma, 2006. Biology. In Lim, C. and Webster, C. (Eds). Tilapia Biology, Culture and Nutrition. The Haworth Press, Inc., Binghamton, New York, pp: 704.
31. A.O.A.C., 1980. Official methods of Analysis. Association of Official Analytical Chemists. Washington D .C. 13th ed.
32. Stoskopf, N.C., 1981. Understanding crop production. Reston Pub. Co., Inc., Reston, Virginia, pp: 433.
33. Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 8th Ed., Iowa State Univ. Press, Ames, Iowa, USA, pp: 476
34. Elizabeth, O., A. Josiah, P.O. Raburu, J.O. Manyala, C. Ngugi, K. Fitzsimmons and H. Egna, 2018. Effect of Lysine and Methionine Supplementation and Cost- Effectiveness in Production of Nile Tilapia Diets (*Oreochromis niloticus*) in Western Kenya. Int. J. Res. Sci. and Manage., 5(3): 12-23.
35. Selek, M., M. Endo, M. Yigit and T. Takeuchi, 2017. The Integration of Fish and Plant Production: Nile Tilapia (*Oreochromis niloticus*) and Basil (*Ocimum basilicum*) Culture in Recirculating and Aquaponic Systems. J. Aquac. Eng. Fisheries Res., 3(1): 28-43.
36. Ajitama, P., H. Effendi and S. Hariyadi, 2018. Usage of Fisheries Rearing Waste for Butterhead Lettuce (*Lactuca sativa* L. var. *capitata*) Cultivation in Recirculation. Nature Envi. and Poll. Tech., 17(1): 145-151.
37. De Carmello Q.A.C. and G.R. Anti, 2006. Accumulation of Nutrients and Growth of Processing Tomato. 9th International Symposium on the Processing Tomato, Acta Hort., pp: 38.