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Effect of Iron Amino Acid Chelate Supplemented Fish Feeds on Nutrients Composition of Spinach (*Spinacia oleracea)* in an Aquaponic System in Kenya

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Abstract

Aquaponics is an environmentally friendly production system involving reuse of waste and nutrients in production of fish and vegetables. Currently aquaponic system is the only solution for fish and plants production but one unique challenge is the maintaining of micro and macro-nutrient and the pH balance in the system. The study was conducted at the University of Eldoret for 119 days. A complete randomized design was used. The supplementation rates in fish diets constituted 30g, 20g, 10g and 0g Fe kg^{-1} respectively. Nile tilapia fry with a mean weight of 0.475 ± 0.025g and nine spinach (height 3 ± 0.131cm, 2 leaves) were stocked in 12 aquaria in an aquaponic system. 30g Fe kg^{-1} treatment exhibited higher minerals content than other treatments with Phosphorus 67.51 ± 2.42 mgL^{-1}, Zinc 9.06 8± 0.45 mgL^{-1}, Iron 5.2 ± 0.218 mgL^{-1}, Manganese 7.655 ± 0.344 mgL^{-1}, Total Nitrogen 11.248 ± 0.141mgL^{-1} and Sodium 7.218 ± 0.028 mgL^{-1}. There was improved water quality at 30g Fe kg^{-1} compared to other treatments. These results revealed that 30g Fe kg^{-1} iron amino acid chelate supplementation had better nutritional attributes as feedstuff for spinach growth than the three other dietary treatments. The study recommends the incorporation of 30g Fe kg^{-1} iron amino acid chelate in on-farm formulated diets for aquaponic system where complete diets are not easily accessible for small scale farmers.

Key words: Iron amino acid chelate; *Spinacia oleracea* minerals and water quality.

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1. Introduction

Aquaponic is the combination of aquaculture (the raising of fish either in aquariums or in synthetic tanks) and hydroponics (the growing of plants without a soil medium) [1]. The plants are grown in grow beds above the soil, which reduces the surface area required to grow vegetable crops. Toxic waste products from fish are removed by vegetables and aerobic micro-organism. This allows the recirculating aquaponic system to raise large quantities of fish in relatively small volumes [2]. Plants have the potential to grow very quickly when they use the dissolved nutrients from fish excretions, and from the nutrients generated from the microbial breakdown of fish wastes. Fish excrete waste nitrogen through their gills, in the form of ammonia, directly into the water. The bacteria in the water and in the growing medium then convert ammonia to nitrite and then to nitrate. Nitrate is relatively harmless to fish, while ammonia and nitrite are toxic; therefore nitrate is the preferred form of nitrogen for growing higher plants such as fruiting vegetables [3].

The main goals of aquaculture industry are to optimize growth and to produce high quality fish [4]. Aquaculture has evolved as the fastest growing food producing sector and developed as important component in food security [5]. Fish is a high quality food containing first class protein and nutrients, important for human health and growth [6]. In fish culture, supplementary feeding plays a major role in determining the nutritional and economic success of aquaculture.

Feed formulations account for more than 50% of the total production cost in modern intensive aquaculture [5]. Increasing feed efficiency especially by improving the metabolic assimilation of dietary nutrients, is of high priority in contemporary animal production [5]. The aquaculture feed industry relies on the fishmeal, which is the most preferred protein source for fish feed owing to excellent amino acid and fatty acid and minerals traces elements profile. Limited supply, high cost and stagnant production level restrict its use for sustainable fish farming [7]. It is known that fish feed ingredient cannot provide all the essential macro and micro- nutrients to plants in an aquaponic system [8] but there are a large number of micro- nutrient supplement with suitable amino acid profiles used to improve fish growth performance as well as the plants growth. Currently aquaponic system is the only solution but one unique challenges is the maintaining micronutrient specifically iron, magnesium and potassium that are suitable for the plants growth and also the pH balance for both plants and fish component. The ideal water pH for hydroponic plants is 5.5–6.5, while the ideal pH for fish is between 7.0 and 9.0. Plants may experience deficiency of some micronutrients at pH greater than 6.5 because many micronutrients form compounds that do not dissolve in water at these pH levels. According to [9] chelated amino acids can be used as a growth promoter but the mechanism of action of amino acid chelates with traces of micronutrients as a growth promoter is not yet adequately researched. Chelated amino acid iron could have the ability to increase bioavailability of nutrients in plant.

This study was therefore conducted to assess the effect of iron amino acid chelate supplement in fish feeds on minerals composition of spinach (*Spinacia oleracea)* and water quality in a recirculating aquaponic system at the University of Eldoret Fish Farm. The Experiments were used to elaborate on the theoretical, practical and application potential of gravel based aquaponic systems that can be adopted by local farmers.

2. Materials and methods

2.1 Study Area

The study was conducted at University of Eldoret hatchery of the Fisheries and Aquatic Sciences Department for a period of 119 days. The university is situated 9Km north east of Eldoret Municipality, on the Eldoret - Ziwa road. Global position of 0°35°N and 35°N-12°E at an altitude of 2180 m above sea level. Temperatures 8.4 °C - 25 °C, 2 rainy seasons – 900mm to 1,200mm per annum.

2.2 Experimental Design and Setup

The experiment were conducted in an aquaponic system, which was consist of 12 rectangular indoor aquaria fish tank (45cm by 35cm by 35cm each) and 12 rectangular plastic plant components (1m by 0.5m) of gravel substrate area each. Water was continuously recirculated from the rearing tanks through sump and pumped through to the filter plants and gravels then back to the fish culture. Fish with the same initial average wet weight and average length was be selected randomly and stocked with the same stocking densities (30) pieces in each aquaponic system; with plants treatments carries 9 plants each. All the treatments were replicated three times in a completely randomized design layout. Each treatment diets with supplement 10g Fe kg^{-1}, 20g Fe kg^{-1} and 30g Fe kg^{-1} iron amino acid chelate and control (0g Fe kg^{-1}) iron amino acid chelate was be administered respectively for the experiment.

2.3 Mineral Analysis

The elements K, Ca, Na, were determined using flame photometer while Fe, Mn and Zn were determined using an atomic absorption Perkin-Elmer 4000 spectrophotometer. Phosphorous and nitrogen were analyzed by automated colorimetry in a Technicon Acta CIII auto-analyzer. The total nitrogen were measured by automated colorimetry after a Kjeldahl digestion.

2.4 Water sampling

Water quality parameters which were measured include Dissolved oxygen, temperature, pH, Ammonia, nitrite and nitrate. Where water temperature, dissolved oxygen, conductivity and pH were measured using thermometer, an Oxymeter (YSI 200 model) and a portable field pH meter respectively three times a week in fish and plants components. While ammonia (NH_4^+), nitrate (NO_3^-) and iron were measured weekly using YSI 9500 photometer

2.5 Feed Ingredients

Commercial diets were locally purchased and formulated at the same crude protein (30% CP) but with different supplement level of iron amino acid chelate (0g Fe kg^{-1}, 10g Fe kg^{-1}, 20g Fe kg^{-1} and 30g Fe kg^{-1}) respectively which were commercially bought. Example in Diet 1, Diet 2, Diet 3 and Diet 4

Table 1: Feed ingredient required for formulation of experimental Diets

Ingredients	Diet 1 (0g kg^{-1})	Diet 2 (10g kg^{-1})	Diet 3 (20g kg^{-1})	Diet 4 (30g kg^{-1})
	CP (30%)	CP (30%)	CP (30%)	CP (30%)
Yellow corn	48	48	48	48
Soy bean meal (44%)	18.5	18.5	18.5	18.5
Fish meal (72%)	26.0	26.0	26.0	26.0
Corn oil	5	5	5	5
Vitamin premix	1.5	1.5	1.5	1.5
Starch	1	1	1	1
Iron amino acid chelates	0g kg^{-1}	10g kg^{-1}	20g kg^{-1}	10g kg^{-1}

2.6 Data Analysis

All data were subjected to normality test using Kolmogorov–Smirnova. One way analysis of variance (ANOVA) followed by Tukey's multiple-comparison post hoc test were applied to determine differences among all treatment in minerals, proximate composition and water parameters in aquaponic system.

3. Results

3.1 Plants Minerals in Aquaponic System

The concentrations of phosphorus, zinc, iron, manganese, total nitrogen, and potassium and sodium levels in difference treatments in aquaponic system are shown in Table 2. Final iron concentration was no significant ($p > 0.05$) in the 0g Fe kg^{-1} (2.617 ± 0.205mg L^{-1}) and 10 Fe kg^{-1} (0.4089 ± 0.0241 mg L^{-1}) but there was significantly ($p < 0.05$) differences in the 20g Fe kg^{-1} and 30g Fe kg^{-1} treatments. The iron concentration of *S. oleracea* leaves recorded in all treatment was significantly difference ($F_{0.05, 3} = 6.14$; p-value = 0.001). 30g Fe kg^{-1} gave the highest (5.2 ± 0.218 mg L^{-1}) and 0g Fe kg^{-1} gave the lowest (2.617 ± 0.205) of iron concentration.

The 30g Fe kg^{-1} treatment gave the highest mean final phosphorus levels (67.51 ± 2.42mg L^{-1}) as compared with other treatments which had 59.42 ± 1.65 mg L^{-1}, 50.35 ± 1.61 mg L^{-1}, and 38.51 ± 3.61mg L^{-1} mean Phosphorus respectively. Phosphorus (P) showed no significant difference ($F_{0.05, 3} = 1.82$; p-value 0.152) in all treatments. Mean Zinc concentration of *S. oleracea* was significantly ($p < 0.05$) difference among the treatments. The highest mean zinc concentration of *S. oleracea* was recorded in 30g Fe kg^{-1} (9.068 ± 0.45 mg L^{-1}) and the lowest of the same was recorded in 0 Fe kg^{-1} (3.044 ± 0.32 mg L^{-1}). Zinc concentration in leaves among all the treatments was also statistically different ($F_{0.05, 3} = 6.86$; p-value = 0.0001).

The highest mean final total nitrogen concentration (11.248 ± 0.141 mg L^{-1}) was observed in aquaponic system treatment at 30g Fe kg^{-1} iron amino acid chelate supplement, whereas the lowest which was (9.077 ± 0.711 mg L^{-1}) recorded in 0g Fe kg^{-1} treatment. The differences among the treatments were found to be no significant

($F_{0.05,3}$ = 0.65; p-value = 0.586) difference.

Table 2: Minerals concentration for Spinach (*Spinacia oleracea*) leaves in an aquaponic system

Minerals (mg L^{-1})	0g Fe kg^{-1}	10g Fe kg^{-1}	20g Fe kg^{-1}	30g Fe kg^{-1}
Phosphorus	38.51 ± 3.61^a	50.35 ± 1.61^b	59.42 ± 1.65^c	67.51 ± 2.42^d
Zinc	3.04 ± 0.32^a	4.058 ± 0.121^b	5.708 ± 0.569^c	9.068 ± 0.45^d
Iron	2.62 ± 0.205^a	2.94 ± 0.388^a	3.99 ± 0.008^b	5.2 ± 0.218^c
Manganese	3.19 ± 0.142^a	4.10 ± 0.378^b	5.381 ± 0.205^c	7.655 ± 0.344^d
Total nitrogen	9.08 ± 0.711^a	10.31 ± 0.167^b	10.692 ± 0.0824^c	11.248 ± 0.141^d
Potassium	4.04 ± 0.369^a	5.16 ± 0.235^b	5.956 ± 0.235^c	7.329 ± 0.454^d
Sodium	3.26 ± 0.056^a	5.37 ± 0.056^b	5.73 ± 0.097^c	7.218 ± 0.028^d

Superscript in the same row sharing a common letter were not statistically different

The *S. oleracea* plant growth in the 30g Fe kg^{-1} treatment had the highest *S. oleracea* Manganese concentration and was significant ($p < 0.05$) different from plants grown in 20g Fe kg^{-1}, 10g Fe kg^{-1} and 0g Fe kg^{-1} treatments. Similarly, the Manganese concentration were also significant difference ($F_{0.05,3}$ = 6.00; p-value = 0.001) in all treatment, but no significant ($p > 0.05$) difference in treatment 20 Fe kg^{-1} and 30g Fe kg^{-1} and in treatment 0g Fe kg^{-1} and 10g Fe kg^{-1} were recorded.

Mean final Potassium (K) concentration was significant ($F_{0.05,3}$ = 7.06; p-value = 0.0001) difference among all treatments 7.329 ± 0.454 mg L^{-1}, 5.956 ± 0.235 mg L^{-1}, 5.16 ± 0.235 mg L^{-1} and 4.039 ± 0.369 mg L^{-1} for 30g Fe kg^{-1}, 20g Fe kg^{-1}, 10g Fe kg^{-1} and 0g Fe kg^{-1} treatments respectively.

The final mean Sodium (Na) concentration was also significantly ($F_{0.05,3}$ = 5.08; p-value = 0.003) different of *S. oleracea* in all treatment and was 3.258 ± 0.056 mg L^{-1}, 5.365 ± 0.056 mg L^{-1}, 5.73 ± 0.097 mg L^{-1} and 7.218 ± 0.028 mg $L^{-1}$for 0g, 10g, 20g and 30g Fe kg^{-1} treatments respectively (Table 2).

3.2 Water Quality in Aquaponic System

The physico-chemical parameters of aquaponic water have been represented in Table 3. The ammonia value between treatments was significant difference ($F_{0.05,3}$ = 8.29; p-value = 0.0001).The mean ammonia in aquaponic component was (0.524 ± 0.127mg L^{-1}), (0.3952 ± 0.0593 mg L^{-1}), (0.2944 ± 0.0477mg L^{-1}) and (0.248 ± 0.0397) (Table 3) for 0g, 20g, 10g and 30g Fe kg^{-1} treatment respectively.

The highest mean nitrate concentration was recorded in 30g Fe kg^{-1} (1.568 ± 0.157 mg L^{-1}) followed by 20g Fe kg^{-1} (1.230 ± 0.145 mg L^{-1}), 10g Fe kg^{-1} (0.6864 ± 0.0937 mg L^{-1}) and 0g Fe kg^{-1} treatment (0.4085 ± 0.0419mg L^{-1}), nitrate in all treatments showed significantly ($F_{0.05,3}$ = 19.54; p-value = 0.0001) different. The mean iron concentration on fish aquaria was significant ($F_{0.05,3}$ = 33.92; p-value = 0.0001) different. The highest mean iron concentration was recorded in 30 Fe kg^{-1} (1.029 ± 0.122 mg L^{-1}) followed by 20g Fe kg^{-1} (0.5763 ± 0.0471 mg L^{-1}), 10g Fe kg^{-1} (0.03907 ± 0.00633 mg L^{-1}) and 0g Fe kg^{-1} treatment (0.03907 ± 0.00633 mg L^{-1}). The pH values ($F_{0.05,\,3}$ = 73.27; p-value = 0.0001) in fish aquarium were significant different. The highest was recorded in treatment 0g Fe kg^{-1} (7.8249 ± 0.0434) followed by 10g Fe kg^{-1} (7.7549 ± 0.0307), 20g Fe kg^{-1} (7.2782±0.0384) and 30g Fe kg^{-1} (7.1227 ± 0.0478) treatments.

The results further showed that conductivity was statistically significant ($F_{0.05,\,3}$ = 31.2; p-value = 0.0001) differences between the treatment but there was no significant (p>0.05) difference in treatment 30g Fe kg^{-1} (976.1 ± 53.9) and 20g Fe kg^{-1} (1118.1 ± 71.9). However Dissolved oxygen and temperature indicated no significant difference ($F_{0.05,\,3}$ = 2.59; p-value = 0.054) and ($F_{0.05,\,3}$ = 0.07; p-value = 0.976) respectively between the treatment.

Table 3: Mean water chemistry parameters for the four treatments (0g, 10g, 20g and 30g Fe kg-1) (iron amino acid chelate) in aquaponic system

Parameter	Fish Component			
	0g Fe kg^{-1}	**10g Fe kg^{-1}**	**20g Fe kg^{-1}**	**30g Fe kg^{-1}**
Ammonia (mg L^{-1})	0.524±0.127^{a}	0.2944±0.0477^{b}	0.3952±0.0593^{c}	0.248±0.0397^{d}
Nitrate (mg L^{-1})	0.4085±0.0419^{a}	0.6864±0.0937^{b}	1.230±0.145^{c}	1.568±0.157^{d}
Iron (mg L^{-1})	0.03907±0.00633^{a}	0.5296±0.0454^{c}	0.5763±0.0471^{c}	1.029±0.122^{d}
Ph	7.8249±0.0434^{a}	7.7549±0.0307^{b}	7.2782±0.0384^{b}	7.1227±0.0478^{d}
DO (mg L^{-1})	3.6820±0.0955^{a}	3.5069±0.0884^{a}	3.8576±0.0862^{a}	3.7406±0.0925^{a}
Temperature (^{o}C)	22.949±0.217^{a}	23.065±0.194^{a}	23.057±0.201^{a}	23.016±0.194^{a}
Conductivity (μS cm^{-1})	421.7±26.1^{a}	795.6±53.6^{b}	1118.1±71.9^{c}	976.1±53.9^{c}
Parameter	**Plants component**			
	0g Fe kg^{-1}	**10g Fe kg^{-1}**	**20g Fe kg^{-1}**	**30g Fe kg^{-1}**
Ammonia (mg L^{-1})	0.5522±0.0889^{a}	0.1889±0.0342^{b}	0.2970±0.0512^{c}	0.2067±0.0361^{d}
Nitrate (mg L^{-1})	1.397±0.154^{a}	1.677±0.182^{b}	2.373±0.220^{c}	2.949±0.259^{d}
Iron (mg L^{-1})	0.03907±0.00633^{a}	1.083±0.118^{b}	2.237±0.206^{c}	2.890±0.153^{d}
Ph	7.8618±0.0348a	7.7537±0.0287b	7.2924±0.0374c	7.1363±0.0454^{d}
Conductivity (μS cm^{-1})	427.3±25.7^{a}	794.6±53.5^{b}	1108.0±70.4^{c}	972.4±53.2^{c}
Temperature (^{o}C)	22.650±0.240^{a}	23.014±0.198^{a}	22.903±0.213^{a}	22.858±0.204^{a}

Superscript in the same row sharing a common letter were not statistically different

In plants component results of one-way ANOVA test indicated a significant difference in ammonia, nitrate, iron, pH and conductivity ($F_{0.05,\,3}$ = 8.63; p-value = 0.0001), ($F_{0.05,\,3}$ = 11.34; p-value = 0.0001), ($F_{0.05,\,3}$ = 79.88; p-value = 0.0001), ($F_{0.05,\,3}$ = 89.95, p-value = 0.0001) and ($F_{0.05,\,3}$ = 30.74; p-value = 0.0001) respectively among the treatments. However, there was no significant difference ($F_{0.05,\,3}$ = 0.5; p-value = 0.679) in temperature between treatments respectively (Table 3).

4. Discussion

4.1 The minerals composition spinach (Spinacia oleracea) in aquaponic system

Nutrient content of leaves in aquaponic treatments is represented in Table 2. There was a significant difference ($P < 0.05$) in all the treatments in terms of nutrient contents of plant organs. Regardless of the treatments, the concentrations all of the studied elements were lowest in 0g Fe kg^{-1} treatment compared to other treatments. The authors [10] found similar result for Zn, but they reported that K, Mg and Fe content of the leaves and the fruits of 'Blizzard' cultivar of tomato were in the same levels. The results showed that supplementation of iron amino acid chelate in aquaponic statistically difference affecting N, P, Na, K, Zn, Mn and iron absorption of spinach leaves, 0g Fe kg^{-1} treatment had lower N, P, Na, K, Zn and Iron as compared to other treatments. The result indicated that supplementation of iron amino acid chelate affect the macro and micronutrient of the plants in aquaponic system. P concentration was higher in treatment 30g Fe kg^{-1} followed by 20g Fe kg^{-1}, 10g Fe kg^{-1} and lower in 0g Fe kg^{-1} which might be due not suffice released of phosphate in the other treatments and also probably because of lower availability and release of nutrients from un-supplemented iron amino acid chelate and in fish excretion.

The concentrations of Mg, Na, Fe and Zn were higher in the leaves of aquaponic-grown plants at 30g Fe kg^{-1} followed by 20g Fe kg^{-1}, 10g Fe kg^{-1} and lower at 0g Fe kg^{-1} treatment. This is may be due to various fractions of dissolved organic matter and traces of mineral in the diets (as a result of microbial decomposition of fish food and feces), which form organometallic complexes with Fe and Zn, thereby increasing the availability of these micronutrients to plants. Authors [11] report similar result in concentration of Mn, Na, Fe, and Zn in high supplementation of foliar fertilizers with high supplementation of iron. 0g Fe kg^{-1} had the lowest Mn, Na, Fe, and Zn this is partly due to low or lack concentrations of iron amino acid chelate in aquaponic system as well as the low mobility of them in plant. Thus, the translocation of them is limited from old shoot tissues to young tissues, and heir xylem transport into organs that do not have a high transpiration rate are low. On the other hand, in contrast of the results related to the leaves, chelated application of iron amino acid supplementation caused a significant increment of macro and micronutrients element concentrations in the spinach leaves in aquaponic system. This is due to high concentrations of the nutrients used during iron amino acid chelate in fish diet supplementation. The authors [10] found similar results for Zn chelate, in which the concentration of Zn in the leaves and fruits of hydroponic-grown tomatoes increased linearly with the increasing Zn chelate levels as a foliar spray.

4.2 Water quality in aquaponic system

Physico- chemical parameters played a significant role in the maintenance of a healthy aquatic environment and production of natural food organism. Aquaculture waste nutrients should ideally meet the requirements of plants co-cultured in aquaponic systems [13]. In fish and plants component temperature and dissolved oxygen showed no significant ($p > 0.05$) difference among the treatments. Water temperature for all treatment varied with the average value of (23^{o}c) was within the normal range for the survival of Nile tilapia, but according to author (14) optimal temperature for the life of tilapia is 28^{o}C. The concentration of dissolved oxygen indicated no significant difference among the treatments ($p > 0.05$). Dissolved oxygen is an important parameter, in the process of oxidation of ammonia and the major limiting factor for the survival of fish. Dissolved oxygen concentration was higher in treatment 20g Fe kg^{-1} followed by 30g Fe kg^{-1}, 10g Fe kg^{-1} and least in treatment 0g Fe kg^{-1} but was within the optimal levels, low DO in treatment 0g Fe kg^{-1} might be probably due to high concentration of ammonia recorded in the treatment. The optimum DO concentration for optimal fish growth should be maintained above 5 mg L^{-1} [14], and the DO concentration below 2 mg L^{-1}, ammonia and nitrite oxidation by nitrifying bacteria becomes inefficient anymore as described by authors (15).

The observed and recorded pH values were within the accepted levels for Nile tilapia and Spinach plants significant difference ($p < 0.005$) was also recorded among all the treatments. High pH was recorded in 0g Fe kg^{-1} followed by 10g Fe kg^{-1}, 20g Fe kg^{-1} and low in 30g Fe kg^{-1} where supplementation of iron amino acid chelate was high. Supplementation of iron amino acid reflects reduction in pH that is likely caused by the respiration of fish and bacteria that produce carbon dioxide. The presence of CO_2 will shift the equilibrium carbonate reaction, produces H^+ ions, and lowers the pH. Decrease in the pH was presumably associated with the oxidation process undertaken by bacteria in the system. According to authors [16], in environments with high inputs such as ammonia from aquaculture wastewater, oxidation of this compound produces CO_2 and lowers the pH. The present result agrees with the findings of authors [17] who reported that treatments with supplementation of micronutrients result to decrements of pH in relation to increment of the micronutrient in the diets and vice versa in aquaponic system.

In fish component ammonia and nitrate in fish culture units were minimal to none detectable during the experiments for all treatments. Ammonia levels were undetectable after two weeks in all the experiment treatments. Nitrite range from 0.1mg L^{-1} to 0.19mg L^{-1} throughout the entire experiment for all treatments. Significant differences were recorded in all treatments. However, high ammonia content was recorded in aquaponic system with treatments of 0g Fe kg^{-1} iron amino acid supplement which might be due to poor utilization of the diets by the fish resulting to high accumulation of waste in the system also might be because of high pH more than 7.5 which cannot support survival of bacteria which can easier nitrification process to occur these findings are in conformity with the findings of the authors [18] and the authors [19]. Nitrate concentration also increased during the experiment, and the concentration at the end is greater than the beginning of the experiment. Ammonia (NH_4) assimilation occurs relatively rapidly by plants and metabolic reactions are more efficient than NO_3. The low NO_3 removal by lettuce has been documented in other aquaponic systems [20]. During the experiment, the concentration of NO_3 was still supportive for the life of Nile tilapia and spinach in aquaponic system. According to author [21], NO_3 should be maintained below 100 mg L^{-1}. Nitrate concentration was highest in treatment 30g Fe kg^{-1} and lowest in 0g Fe $kg^{-1.}$ The possible cause was the amount of oxygen supply. At 30g Fe kg^{-1} treatments oxygen supply was adequate for NO_3 oxidation process and offered favorable condition for bacteria to convert ammonia level to nitrate. However, in plants component ammonia and nitrate varied among all the treatments, ammonia was high in 0g Fe kg^{-1} treatment as compared with other treatments probably due to poor nitrification of ammonia by bacteria to nitrate which was also reflected to be low nitrate at 0g Fe kg^{-1} treatment. Lower nitrate removal rate and higher ammonia concentration rate which were accounted for in 0g Fe kg^{-1} treatments were in accordance with the findings of authors (22) in a study of aquaculture effluent treatments under different hydraulic loading rates using *Ipomoea aquatica*. Supplementation of iron amino acid chelated indicated that it affect ammonia and nitrate concentration in aquaponic system, this might be also due to the influence of iron amino acid chelate on lowing the pH and thus influence the nitrification process by bacteria. In plants and fish components iron concentration varied among the treatments 30g Fe kg^{-1} had the highest and 0g Fe kg^{-1} had the lowest. There was an increase of iron concentration in aquaponic system in relation with the increment supplementation of iron amino acid chelated. The increase of iron concentration might be due to the present of iron traces in the diet.

5. Conclusion

It is concluded that supplementation of iron amino acids chelate at 30g Fe kg^{-1} resulted in high concentrations of Mn, Na, Fe, K, N, P and Zn macro and micro- nutrients in the leaves of spinach while the non-supplemented control diets consisted of lower macro and micro- nutrients composition. The study reports that an increase in macro and micro nutrients composition corresponds with an increase in the supplementation of iron amino acids chelates in the fish diet. Therefore the findings indicated that 30g Fe kg^{-1} iron amino acids chelate supplementation can effectively alleviate macro - nutrients and micro - nutrient deficiencies in the leaves of spinach grown on aquaponic. Water quality parameters in iron amino acids chelate supplementation treatments in fish component indicated significance differences in both plants and fish component where 30g Fe kg^{-1} treatment resulted in high nitrate, conductivity, iron concentration, oxygen with low ammonia and pH levels compared to the other treatments in both plant and fish components.

6. Recommendation

The study recommends 30g Fe kg^{-1} iron amino acid supplementation for spinach growth pertaining to the improved results in macro and micro- nutrients parameters and water quality obtained in both plant and fish components. Further studies should consider power consumption rate and mineralization of fish in aquaponic system.

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