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PRODUCTIVITY AND QUALITY OF AQUAPONICALLY GROWN TOMATO (*Solanum lycopersicum* L.) SUPPLEMENTED WITH DIFFERENT NUTRIENT SOLUTIONS

WILSON U. LLEGUNAS, JR. [1] and ROSARIO A. SALAS[2]

[1]*Agriculture Department, College of Agriculture and Natural Resources, Bohol Island State University, Zamora Bilar, Bohol*
[2]*Department of Horticulture, Visayas State University, Visca 6521-A, Baybay City, Leyte, Philippines*

ABSTRACT

Tomato (*Solanum lycopersicum* L.) is an important vegetable in the country which is consumed both raw and as processed product. This study aimed to evaluate the growth, yield, postharvest qualities and profitability of aquaponically grown tomato supplemented with different nutrient solutions. The study was laid out in Randomized Complete Block Design with 8 treatments replicated 3 times. Tomato fruits were first harvested 60 days after transplanting with 100 percent survival rate. Early flowering of tomato plant was observed when applied with VSU liquid nutrient formulation (VSU-LNF) with node number ranging from 13.33-14.00 bearing the first flower. Growth parameters such as plant height, number of lateral shoot, root length and fruit size are stimulated by the application of VSU liquid nutrient formulation and in combination with ferments. This also resulted to high number and weight of marketable fruit in tomato plant. Carotenoid and chlorophyll contents of the fruits were higher in aquaponically grown tomato supplemented with fermented *kuhol (Pomacea canaliculata* L.*)*. Free radical scavenging activity was found highest in the fruit of tomato grown in aquaponic system supplemented with combined VSU liquid nutrient formulation with fermented *malunggay (Moringa olifera)*. However, vitamin Cand sugar content of tomato fruits were found highest when

Correspondence : W. Llegunas. Agriculture Department, College of Agriculture and Natural Resources, Bohol Island State University, Zamora Bilar, Bohol. Address: E-mail: junllegunas@gmail.com

supplemented with combine VSU liquid nutrient formulation and fermented *kuhol*. No significant differences were obtained on firmness, percent weight loss, respiration rate at 2 and 4 weeks after storage, titratable acidity, fruit nitrogen, pH of fruit, oxidation reduction potential, electrical conductivity and total dissolved solids. On the other hand, higher moisture content of the tomato fruits were observed with the application of VSU liquid nutrient formulation and in combination with ferments. Therefore, high yield was produced with the application of VSU liquid nutrient formulation which resulted to higher net return. Aquaponically grown tomato supplemented with VSU-LNF produced lesser yield but with considerable net return.

Key words: aquaponics, tomato, growth, yield, postharvest qualities, liquid formulations

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a warm season crop which belongs to the Solanaceae family. It is one of the most important consumed vegetable in the country because of its dietary fiber, vitamins B and C, iron, phosphorus, essential amino acids, sugars and high levels of lycopene, an antioxidant that reduces the risks associated with several cancers and neurodegenerative diseases (Srinivasan, 2010).

Tomato production often focused on the yield of the crop. It is necessary that yield is optimum to ensure profit. However, qualities of tomato are now often a limiting factor for consumers (Fanasca et al., 2006). These qualities include size, color, aroma, texture and especially flavor which is the most important factor according to several reports (Yilmaz, 2001; Zoran et al., 2014). Variation of these qualities may trigger or limit the preferences of the consumer. Qualities are highly affected by genetic and environmental conditions. The environmental condition influences greatly during transition of production affecting the growth and quality of the tomato as well as after its harvest.

During the first quarter of 2016, tomato production reached

87.68 thousand metric tons which is 2.5% lower than year 2015 which is 89.93 thousand metric tons. This implies that production has been greatly affected due to lower prices, lesser area planted, intermittent rains and intense heat resulted to dry spell (PSA, 2016). In other words, quality of tomato is really affected with the adverse environmental conditions resulting to low quality produce.

The production of tomato through hydroponic system promotes year round supply with improved quality of harvested fruits. Hydroponic production system is often better than the classic agricultural production because growing of plants in soil is difficult to maintain (Jones, 2005). The production in either soil or in hydroponic system demands good quality of products (Gruda, 2009). Therefore, optimum nutrient availability is the most important aspect in plant nutrition by which growth and quality of vegetable commodity are highly dependent.

In order to sustain an aquaponic vegetable production, nutrient supplementation is a necessity. This is the main focus of the study by which productivity and quality of tomato were assessed. Aquaponics is a method of growing plants in a combined culture of fish and plants in a soil less recirculating system (Rakocy et al., 2003; Diver, 2006). The nutrient rich effluents from the aquaculture component are circulated through the hydroponic component where a proportion of these nutrients are taken up by the plants before the water is returned to the fish tanks (Hambrey, 2013; Diver, 2006). Therefore, effluent from fish tanks served as fertilizer to the crops (Diver, 2006; Rackocy et al., 2003).

However, organic nutrient solution such as fermented *Malunggay* (*Moringa olifera*) and fermented golden apple snail had been reported to support needed nutrient by plants specifically on sweet pepper (Pagluanan and Anical, 2010), pechay (Tagotong and Corpuz, 2015; Llegunas and Salas, 2015) kale, lettuce (Salas and Salas, 2014; Barcenas, 2015, Llegunas and Salas, 2014 & 2015) and honeydew melon (Cabilllo, 2016) grown in aggregate hydroponic system which gave positive effects not only on crops but as well as the soil condition of the field. The application of nutrient solutions may possibly promote production and improve quality of tomato. Therefore, this study was conducted in order to evaluate the growth and yield response, assess the postharvest qualities and determine the profitability of growing tomato in aquaponic system supplemented with different nutrient solutions. It is recommended to increase the concentration of ferments applied in crop.

MATERIALS AND METHODS

Provision of Materials

The study was conducted at the Vegetable Production Area of the Department of Horticulture, College of Agriculture and Food Science, Visayas State University, Visca, Baybay City, Leyte from the month of December 2016 to May 2017.The existing protective structure at the experimental vegetables area of the Department of Horticulture was used. It was made up of improvised structure using bamboo poles as the skeleton within its structure with UV plastic film roofing materials with a thickness of 0.005 inch. The total experimental area was 20m x 4.5m (90 m^2).The fish tank was made of concrete wall with 10m^3 capacity of water with the provision of coconut leaves that served as roof protecting the fish from direct heat of the sun. Approximately four-five hundred (400-500) pieces of three-month old Malaysian strain tilapia were used. The tilapias were provided by the Department of Agriculture, Bureau of Fisheries – Babatngon Leyte. The fish was fed two times daily with commercial feed grower pellet at a rate of 100 grams per day and gradually increased as they grow. The commercial pellet available in the market has a guaranteed analysis of crude protein (31%), crude fat (6%), crude fiber (6%), ash (12%) and moisture content (12%).

The bedding material was made up of flat galvanize iron that was formed into rectangular shapes. It is about 2m long and 25 cm wide. There were two (2) pieces of pond per replication in a treatment with a total of 48 ponds that were used for tomato production. These served as the container of the aggregates composed of fine river sand and coco coir for the plants to grow. The mixture was composed of 3 parts fine river sand and 1 part coco coir by volume.

Fermentation Process and Seedling Preparation

Fifty kilograms of fresh leaves of *malunggay* were prepared. It was added with 50 kilograms of distilled water and 50 kilograms of molasses and were mixed thoroughly in a container. The sealed container was kept in cool and dry place, then allowed to ferment for a month. The mixture was harvested one month after the fermentation. The same process was done with golden apple snail (*kuhol*) meat after its removal from the shell. Tomato (Diamante Max F1) variety was used in the study from the local market distributor of East-West Seed company in Baybay City, Leyte. The seeds were sown in the seedbox and pricked individually into seedling tray 7 days after sowing. The hardened seedlings were transplanted into the aggregate pond with a planting distance of 33.33 cm between plants and 30 cm between beds. Transplanting was done during afternoon to reduce the stress of the experimental plants.

Application of Nutrient Solutions

The water effluent from the fish tank was pump out to the storage tank and distributed into growing beds by manual application every day in experimental plants except for the plants treated with VSU liquid nutrient formulation (VSU-LNF) of Salas and Salas (2014). The amount applied was approximately 3-5 liters per application per pond and was done every morning and afternoon. Five hundred (500) ml of ferments (golden *kuhol* and *Malunggay)* was dissolved in 16 liters of tap water as describe by Calub et al., (2012) while VSU-LNF was dissolved in 50 liters of tap water for every pack. One liter of corresponding nutrient solution as well as its combination was applied everyday per pond from transplanting of tomato plant until harvest in all treatments. The combination nutrient solution was done by mixing VSU-LNF and specific ferment in a 1:1 ratio by volume. The nutrient solutions were applied to the base of the plant to ensure direct contact of nutrients to the roots.

Experimental Design and Treatments

The study was laid out in Randomized Complete Block Design with eight (8) treatments replicated 3 times. The experiment was conducted with the following treatments: (T_1) Tomato grown in aggregate aquaponic system, (T_2) Tomato supplemented with fermented *kuhol*, (T_3)Tomato supplemented with fermented *malunggay*, (T_4)Tomato supplemented with mix fermented *malunggay* and *kuhol,* (T_5) Tomato supplemented with VSU liquid nutrient formulation (VSU-LNF), (T_6)Tomato supplemented with fermented *kuhol* plus VSU liquid nutrient formulation (VSU-LNF), (T_7)Tomato supplemented with fermented *malunggay* plus VSU liquid nutrient formulation (VSU-LNF) and (T_8) Tomato applied with VSU liquid nutrient formulation (VSU-LNF).

Data Gathered

Horticultural characteristics such as number of days to flowering, node number bearing the first flower, number of days to maturity, percent survival, plant height, number of lateral shoots or branch and root length of tomato fruit were taken during and until the termination of the study. However, yield and yield components of tomato such as fruit size, weight (kg) and number of fruits per plant, total number of fruits, yield per plot, weight (kg) and number of marketable and non-marketable fruits and yield tons ha^{-1} were taken at first harvest and until termination of the study.

Postharvest parameters such as firmness, percent weight loss, visual quality rating, respiration rate, moisture content of the fruit, titratable acidity (TA), fruit pH and pH of the medium were analyzed in the postharvest laboratory in the Department of Horticulture, VSU. The total carotenoids**,** chlorophyll *a, b* and total chlorophyll**,** free radical scavenging activity**,** vitamin C, oxidation reduction potential, electrical conductivity and total dissolved solids were analyzed at the Department of Pure and Applied Chemistry in VSU while total sugar and total fruit nitrogen were analyzed in Central Analytical Service Laboratory, Philippine Root Crops, VSU.

Cost and Return Analysis was done by recording all production expenses incurred and income generated from the harvested crops. Crops income was calculated by multiplying the total weight of marketable fruit (kg) by the prevailing market price of tomato fruit per kilogram. The difference between the gross income and the expenses represented the net income.

Data Analysis

Data was subjected to Analysis of Variance (ANOVA) using Statistical Tool for Agricultural Research (STAR) version 2.0.1 statistical software. When significant difference existed, treatment means were compared using Tukey's Honestly Significant Difference (HSD) test at 5% level of significance.

RESULTS AND DISCUSSION

Horticultural Characteristics

Figure 1 shows the number of days to maturity, number of days to flowering, node number bearing the first flower and survival rate of aquaponically grown tomato supplemented with different nutrient solutions. Tomato fruit was harvested 60 days after transplanting and onwards with 100 percent survival rate. This implies that application of different organic nutrient solutions together with VSU liquid nutrient formulation (VSU-LNF) had no deleterious effect. In addition, application of VSU-LNF on tomato plant promote dearly to flowering compared to the sole application of fermented *kuhol* and *malunggay* on aquaponically grown tomato, although it showed comparable result on the node number bearing the first flower. Of the four horticultural characteristics considered, only the number of days to flowering was significantly affected by the different nutrient solutions. The application of VSU-LNF significantly enhanced attainment of reproductive growth of tomato as shown by the least number of days to flowering (22.67 days) which did not significantly differ with each of the combination of VSU-LNF with effluent, fermented *kuhol* and *malunggay*. The sole application of effluent, fermented *kuhol* and combination of fermented *kuhol* and *malunggay* were less effective in promoting flowering. On the other hand, it took 60 days from transplanting to harvest the tomato fruit in all treatments. Likewise, first there was tomato, produced at node 13 to 14 regardless of the treatment. Furthermore, a 100% survival was obtained in all treatments. This means that application of VSU-LNF as well as their combination with fermented organic nutrient solutions has sufficient and available nutrients needed for the flowering of tomato plant (Fig. 1, Fig. 2 and Fig. 3). Some studies reported that application of fermented plant juice cannot cause detrimental effects to the plants, however, growth was reduced due to insufficient nutrient content (Cabillo, 2016). Similarly, the study of Culver et al. (2012) pointed out that foliar application of Moringa leaf extract promoted the growth of tomato plants with 100 percent success. Similar observation was also found on lettuce plants applied with fermented kuhol in aggregate hydroponic system (Salas and Salas, 2014).

Figure 2 shows the plant height, number of branch and root length of aquaponically grown tomato supplemented with different nutrient solutions. The result revealed significant difference on plant height supplemented with fermented organic nutrient solution and in combination with VSU-LNF. Tallest plant was obtained in tomato applied with VSU-LNF followed by effluent plus VSU-LNF, fermented *malunggay* plus VSU-LNF, fermented *kuhol* plus VSU-LNF, fermented *malunggay*, F. *kuhol* plus F. *malunggay*, effluents and fermented *kuhol* in descending order. Furthermore, number of lateral branches of tomato was highest in VSU-LNF and effluent plus VSU-LNF application with shortest plants obtained with the application of fermented organic nutrient solutions. In terms of root length, tomato applied with effluent plus VSU-LNF had the longest length followed by sole application of VSU-LNF as well as its combination with fermented organic nutrient solutions. However, application of fermented organic nutrient solution had shorter roots than other treatments. Results of the study implies that

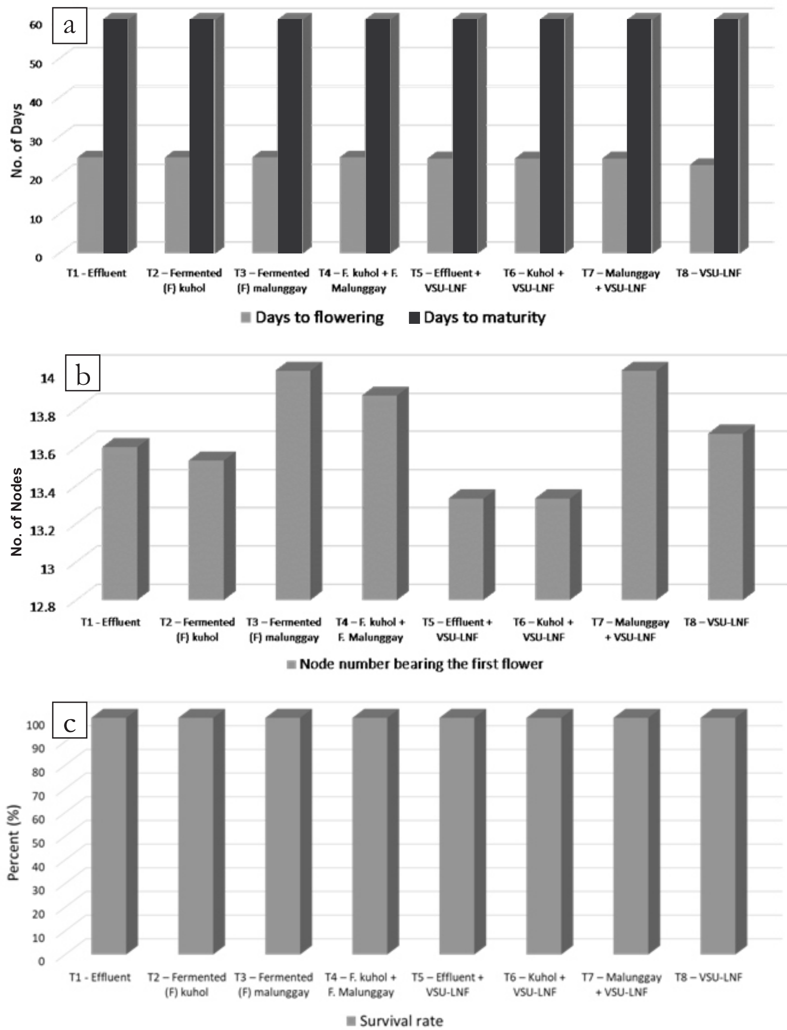

Figure 1. Days to flowering and maturity (a), node number bearing the first flower (b), and survival rate (c) of aquaponically grown tomato supplemented with different nutrient solutions

the complete nutrition given to tomato plant by VSU-LNF as well as in combination with fermented organic nutrient solution promoted the growth of the plant which resulted to the production of numerous branches. As a result, tall tomato plants had longer roots than those plants supplemented with fermented organic nutrient solutions. The result of this experiment is similar to the study of Culver et al. (2012) on tomato plants grown in commercial fertilizer application supplemented with *malunggay* leaf extract. Goodman (2011) stated that tomato plants can grow in aquaponic system but fruit production may not be robust. Another study was conducted by Roosta and Hamidpour (2011) in which foliar application of some macro and micro nutrients on tomato plants in aquaponic system promoted the growth of the plants by effectively alleviating nutrient deficiencies of the tomato plant, thus, increasing its yield. However, the fermented *malunggay* and *kuhol* supplementation as well as its combination in this study did not improve the growth of tomato compared to those plants applied with VSU-LNF. This may be due to the nutrient content and better availability of nutrients in VSU-LNF though ferments had mostly larger amount of nutrients compared to fish effluent and the VSU-LNF (T 1). However, microbial population and activity in the ferments might have influenced the availability of the nutrients to the plants.

Yield and Yield Components

Figure 3 shows the fruits size of aquaponically grown tomato supplemented with different nutrient solutions. There was significant difference on the polar and equatorial diametersof the tomato fruit. Application of VSU-LNF as well as in combination with organic ferments obtained larger fruits than tomato grown in aquaponic system without supplementation as well as application of fermented *malunggay* and *kuhol*. Fruit size of the tomato is attributed by the nutrient content of its solution even though ferments have larger amount than VSU-LNF and fish effluent, their availability is in question because the effect is inversely proportional to the size of tomato fruit (Table 1). With this, VSU-LNF application as well as its combination with organic ferments promoted the growth of the tomato plant such as height, number of lateral branches and root length which also resulted to larger fruit size. In addition, because of shorter plant, few lateral branch and lesser root length were observed which resulted to smaller sizes of the tomato fruits. These might be due to the nutrient content and availability of each solution that influenced the growth of the plant in order to attain the optimum yield of the plant (Marschner, 1995; Tyson et al., 2007).

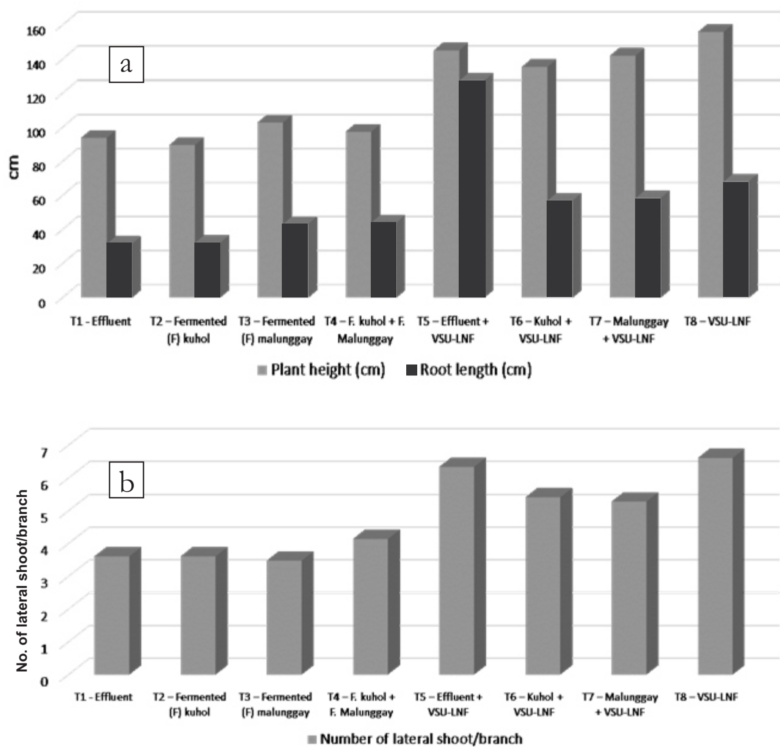

Figure 2. Plant height and root length (a), and number of lateral shoot/branch (b) of aquaponically grown tomato supplemented with different nutrient solution

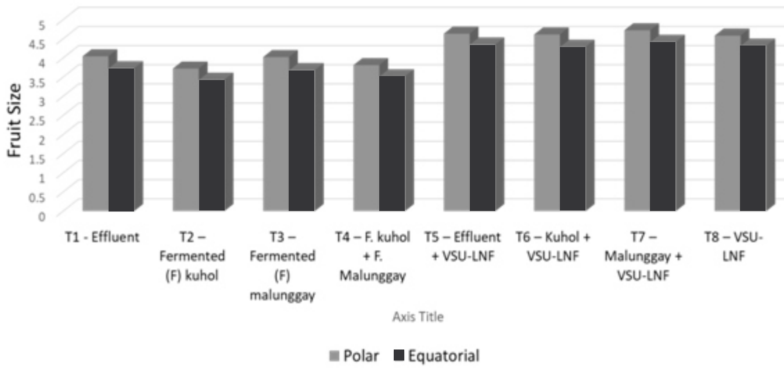

Figure 3. Fruit size of aquaponically grown tomato supplemented with different nutrient solutions

Figure 4 shows the number of fruit and yield of aquaponically grown tomato supplemented with different nutrient solutions. Weight and number of fruits per plant are significantly different between each treatment. Application of VSU-LNF resulted to numerous and highest number of fruits followed by the combined application of fermented solutions and VSU-LNF. As a result, treatments with numerous fruits had the highest total yield. The number and weight of tomato fruits can be attributed to the horticultural characteristics such as the plant height, number of lateral branches and longer root length. Therefore, weight is directly proportional to the number and size of fruits which resulted correspondingly to the total yield of the tomato plants. Nutrient content and its availability of each solution is the prominent cause which influenced its growth and yield. Noticeably, nutrient content of each solution is variable with the ferments consisted mostly large amount of nutrients than VSU-LNF and the fish effluent. However, the yield of tomato supplemented with organic nutrient solutions was lesser than those plants applied with VSU-LNF. This means that VSU-LNF has readily available nutrient for plant uptake.

A positive result was obtained by the study of Castro et al. (2006) in cherry tomato production in which fish effluent was used to increase its yield. A report of Wilson (2005) indicated that yield of tomato grown in aquaponic system is superior than in inorganic hydroponics. On the other hand, Graber and Junge (2008) reported that yield of tomato in aquaponic system is comparable to that of hydroponic system. However, Goodman, (2011) reported that vegetable production in aquaponic system has more positive impact to leafy vegetables in which nutrients found in the effluent cannot suffice the nutrient requirement in fruit vegetables. Therefore, it is necessary to have supplementation in order to attain the desired nutrients for the optimum plant yield (Roosta and

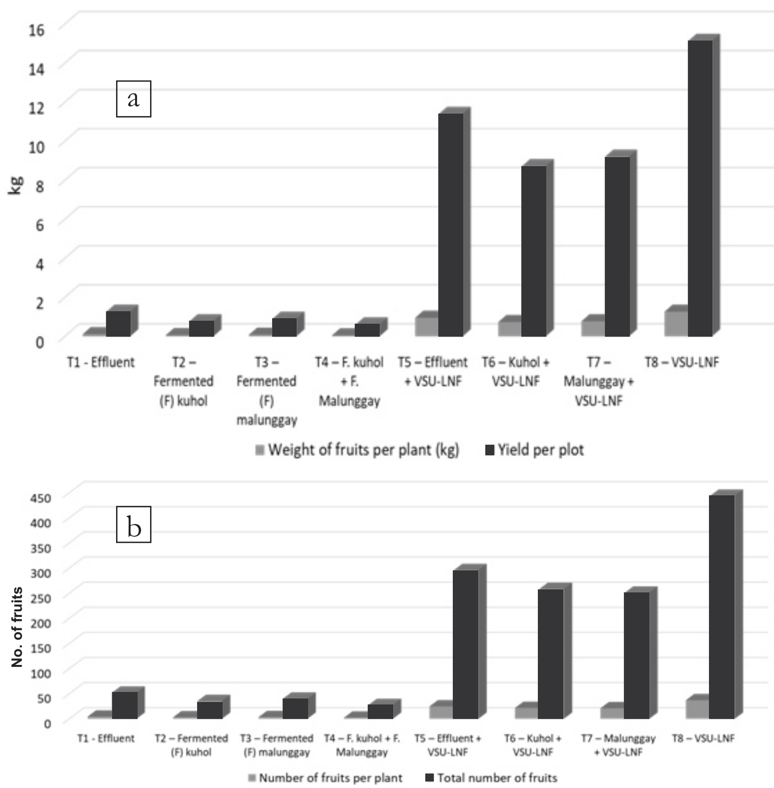

Figure 4. Weight of fruit per plant, total yield (a), number of fruits per plant and total number of fruits (b) of aquaponically grown tomato supplemented with different nutrient solutions

Figure 5 shows the marketable and non-marketable fruits as well as total yield of aquaponically grown tomato supplemented with different nutrient solutions. Number and weight of marketable fruits and fruit quality of tomato grown in aquaponic system was affected by the supplementation of different nutrient solutions. Highest number of marketable fruit was obtained in VSU-LNF application followed by the combined application of ferments (*kuhol* and *malunggay).* As a result, marketable fruit weight is directly proportional to the number of marketable fruits where VSU-LNF nutrition has the highest marketable weight among other treatments. Likewise, VSU-LNF and the combined application of fermented *kuhol* and *malungay* produced numerous number of fruits and highest non-marketable fruits among other treatments, respectively. The marketable and non-marketable fruits contributed to the total yield of tomato plants. The non-marketable fruits of tomato are attributed by its fruit size (Fig. 3) where smaller fruits size was obtained on plants receiving no supplementation as well as on plants solely applied with fermented *malunggay* and *kuhol*. Smaller fruits are caused by the horticultural characteristics such as shorter root length, plant height and less number of branches that contribute to the production of fruits. Nutrient content of each solution is the main reason that influenced its growth and yield because nutrient content in each solution is variable though fermented *kuhol* and *malunggay* had larger amount than the fish effluent but its availability is unknown. Therefore, its effect can be shown on tomato which produced lower yield than tomato applied with VSU-LNF. In addition, pH of the fermented organic nutrients might have greatly influenced the availability of the nutrients favorable for the crop growth and development (Tyson et al., 2007). For this reason, the application of VSU-LNF as well as its supplementation to aquaponic production of tomato gave the highest yield. However, considerable yield was also obtained with the application of VSU-LNF with fermented *malunggay* and *kuhol*. The yield of tomato on this study is lower than the yield obtained by Capuno et al. (2015) under protective structure. Crop yields are highly dependent on crop management, irrigation management, pest control and climatic conditions.

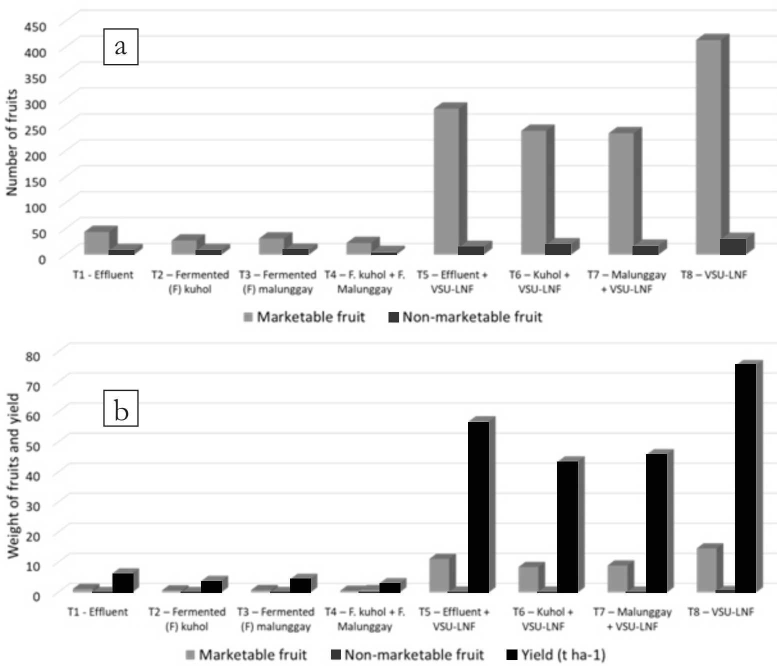

Figure 5. Number of marketable fruit and non-marketable fruits (a), and total yield (t ha^{-1}) (b) of aquaponically grown tomato supplemented with different nutrient solutions

Postharvest Qualities

Figure 6 shows the firmness of aquaponically grown tomato supplemented with different nutrient solutions. No significant difference was observed by the application of different nutrient solutions on tomato in an aquaponic system. The fruits were harvested at breaker stage, stored and its firmness is measured by hand penetrometer. This method of quantification measures the force required to physically compress or penetrate external tissues and may change during softening as a result of reduced integrity of cell wall components as well as changes in the hydrostatic pressure (turgor) within fruit cells (Shackel et al., 1991). During storage, firmness was reduced because of ripening process that alter the texture of the fruit accompanied by structural changes of the cell wall component such as cellulose, hemicellulose and pectin (Gray et. al., 1994). Firmness is attributed to its metabolic process as it decreased towards ripening. It is considered as one factor for consumer preference (Wu, 2006; Ahmed et. al., 2010). The result of this experiment supports the findings of other researchers (Shackel et al., 1991; Wu, 2006; Gray et al., 1994).

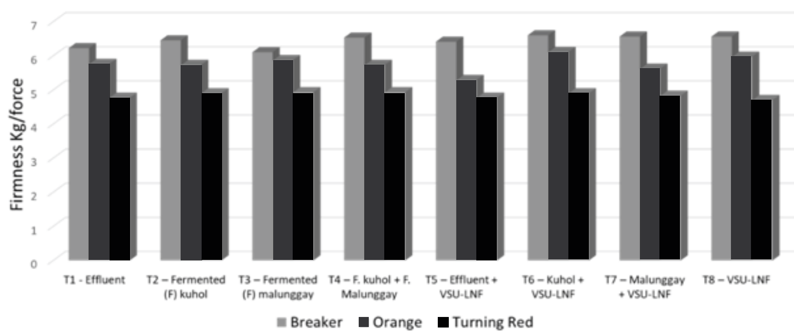

Figure 6. Firmness of aquaponically grown tomato supplemented with different nutrient solutions

Figure 7 shows the percent weight loss of aquaponically grown tomato supplemented with different nutrient solutions. Tomato fruit was stored at ambient condition with a temperature that ranged from 27°C to 28°C and 83-84% relative humidity. Comparable weight loss of tomato fruits was observed among treatments. Weight loss of tomato fruit is a function of different metabolic process such as respiration and other oxidative processes. Respiration is a process of breaking down of stored carbohydrates for the production of energy to be used by different biological processes thus the reduction in weight. In fact, respiration rate (Fig. 8) was higher at the start of the experiment and gradually decreased with time upon storage (Ahmed et al., 2010; Sing et al., 2013). Respiration rate was comparable within 2 and 4 weeks after storage while it is significantly different after 6 weeks. Higher respiration rate was obtained within 6 weeks of storage of fruits from tomato supplemented with VSU-LNF combined with fermented *malunggay* and *kuhol* in aquaponic system. The result implies that application of nutrient solution did not influence the weight loss and respiration rate within 2 to 4 weeks of storage. Sing et al. (2013) reported that the respiration rate of stored tomato was hastened at 35°C and therefore rapid losses of weight resulted to shorter shelf life, thus storing at lower temperature reduces the rate of respiration to prolong the shelf life of the commodity.

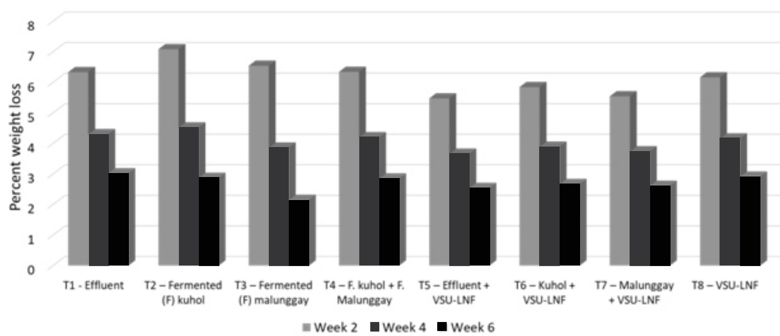

Figure7. Percent weight loss of aquaponically grown tomato supplemented with different nutrient solutions

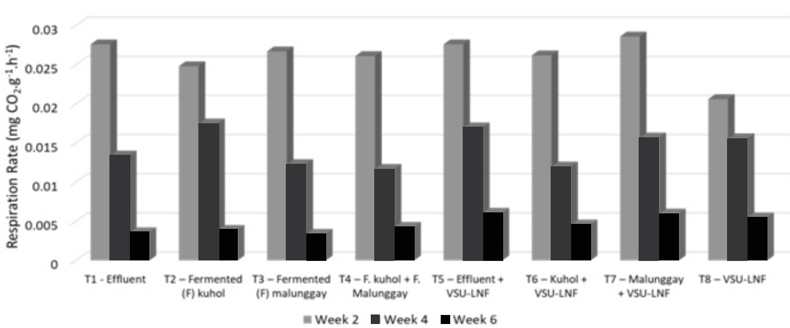

Figure 8. Respiration rate of aquaponically grown tomato supplemented with different nutrient solutions

Figure 9 shows the visual quality rating of aquaponically grown tomato supplemented with different nutrient solutions. The visual quality rating uses the hedonic scale in rating the stored tomato fruit at ambient condition. The values corresponded to the visual perception where it is rated as 9 when tomato fruit is excellent, field fresh or no defect, 7 for good with minor defects and 5 for fair, moderate defects and or limits its marketability. Visual quality rating in all period of storage had comparable result and its limit of marketability (VQR = 5) was observed after 6 weeks of storage. In this rating, shelf life of tomato fruit is culminated. The result implies that application of different nutrient solutions was not able to promote the visual quality rating at longer storage period. Visual quality rating is attributed by the firmness, weight loss and respiration rate that contributed to the defects of tomato fruit. Some study reported that shelf life of mature red tomato is 13-14 days (Boko and Salas, 2015; Salas et al., 2015) after harvest. Metabolic processes such as respiration is responsible for degradation of reserve food in the fruit which can alter the whole ripening process. Although respiration rate (Figure 8) was comparable in all treatments for the second and fourth week, it is presumably high after harvest and increased towards ripening and decreased in time until the fruit showed defects that limit its marketability (Ahmed et al., 2010).

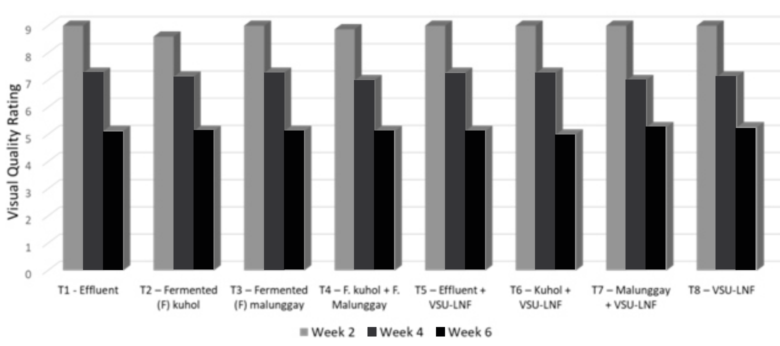

Figure 9. Visual quality of aquaponically grown tomato supplemented with different nutrient solutions

Figure 10 shows the total carotenoids and chlorophyll content of aquaponically grown tomato supplemented with different nutrient solutions. Nutrient content of a solution and its availability is the main cause of the growth, yield, and quality of the crop (Gruda, 2009). However other factors such as light, temperature, day length, water balance, management (Gruda, 2009) and medium used (Gruda et. al., 2000) are also features to be considered. In this study, carotenoids content of tomato fruit is significantly affected by different nutrient solutions. Plants supplemented with fermented kuhol yielded fruits with the highest total carotenoids though it is comparable to tomato grown in aquaponic system without supplementation, supplemented with fermented malunggay, supplemented with VSU-LNF as well as its combination with fermented kuhol. Regulation of carotenoids and its biosynthesis is a complex process from a differentiation of chloroplast into chromoplast that changes the organoleptic properties during tomato fruit development and ripening. As a result, accumulation of large amount of lycopene during ripening will occur especially in mature red tomato fruits (Bramley, 2002; Salas et al., 2013). Fiedor and Burda (2014) reported that carotenoids posessed antioxidant activity that prevent degenerative disorder. With adequate supplementation in the human diet, the risk of several disorders (cancer, cardiovascular or photosensitivity disorders) mediated by reactive oxygen may be significantly reduced.

Furthermore, chlorophyll a content is highest in tomato fruits supplemented with fermented kuhol but it is comparable to other treatments except for the combined supplementation of fermented kuhol and malunggay. No significant difference was observed on chlorophyll b content of tomato fruits in all treatments, however, total chlorophyll was found least on tomato plants treated with VSU-LNF. However, sole application of fermented organic solution and the combined application of organic ferments with VSU-LNF gave comparable result on total chlorophyll. Lee et al. (2007) reported that plants with higher nitrogen content had higher chlorophyll content. Total leaf nitrogen is proportional to the photosynthetic proteins thus nitrogen availability and supply influences the leaf growth and leaf area of plants, its rate of photosynthesis, and increases its yield (Bojović and Marković, 2009). However, increased nitrogen application could increase yield up to a certain limit (Hoque et al., 2010).

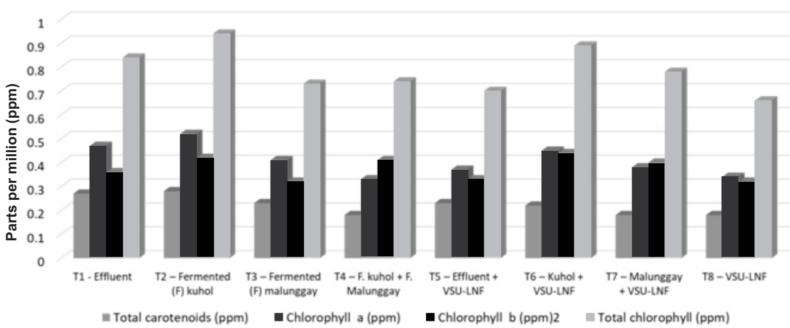

Figure 10. Total carotenoids and chlorophyll content of aquaponically grown tomato supplemented with different nutrient solutions at breaker stage

Figure 11 shows the free radical activity, vitamin C, total soluble solids and sugar content of aquaponically grown tomato with different nutrient solutions. Free radical scavenging activity of tomato was significantly affected by the different nutrient solutions. Using VSU-LNF and in combination with *malunggay* and effluent resulted to highest free radical scavenging activity of tomato fruit followed by application of combined fermented *kuhol* and VSU-LNF, tilapia fish effluents, fermented *malunggay,* fermented *kuhol* as well as its combination. Free radical scavenging activity is related to the antioxidant activity, metal chelation, radical scavenging effects and reducing power as well as destructive activities against active oxygen species such as the superoxide anion radical, hydroxyl radical, and hydrogen peroxide (Shimada et al., 1992). The report of Salas et al. (2013) stated that freshly harvested mature red tomato fruits contained high free radical scavenging activity compared to the mature green and breaker fruits due to the developments of antioxidant components in mature red fruits. However, this report was only focused on the antioxidant activity of coated tomato fruit stored under ambient conditions and the fruit was harvested under a single organic cultural practice. Lee and Kader (2000) stated that antioxidant content of most vegetables is attributed by its genotypic differences, preharvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures.

The vitamin C content of tomato fruit was highest on tomatoes grown in aquaponic system supplemented with fermented *kuhol* together with VSU-LNF having a value of 1.17% compared to other treatments. It is followed by tomato grown in aquaponic system supplemented with VSU-LNF alone, fermented *malunggay* with VSU-LNF, combination of fermented *malunggay* and *kuhol*, no supplementation or grown in aquaponic alone, fermented *malunggay*, fermented *kuhol* and application of VSU-LNF, respectively. This implies that vitamin C content of tomato applied with VSU-LNF was improved with the addition of fermented organic nutrient solution as it grew in aquaponic system. Moreover, it indicates that the lower content of vitamin C as reported by Leong and Shui, (2002) having 29.1% of vitamin C in tomato fruit. This is contrary to the report of Lee and Kader (2000) which stated that application of high rate of nitrogen fertilizers tend to decrease the vitamin C content in most fruits and vegetables. They also reported that less frequent irrigation would increase Vitamin C content of most vegetable crops. In this particular study, the ferments consisted of high nitrogen content as shown in Table 1 and water is amply supplied throughout the experiment.

Sugar content of tomato fruit were higher on plants applied with VSU-LNF and in supplementation with fermented organic nutrient solution and their combination with VSU-LNF in aquaponic system. Tomato plants supplemented with fermented organic nutrient solution exhibited lower sugar content. This means that supplementation of VSU-LNF in combination with the ferments can improve the sugar content of tomato fruits as it grows in aquaponic system than supplementation of organic nutrient solution alone. In general, the sugar content of tomato fruit is a function of the stage of maturity that increases uniformly from small and green mature to large and red-ripe tomatoes (Salunkhe et al., 1974). Sugar content of tomato fruit is positively correlated with soluble solids, glucose, fructose, pH and titratable acidity of the fruits (Georgelis et al., 2004). Thus, sugar content of tomato fruit increased towards ripening while a decrease in acidity was also observed. This is influenced by the nutrition given during the production.

In aquaponic system, tomato plant was grown and supplemented with different nutrient solutions. Comparable moisture content of tomato fruit was observed with combined supplementation of organic ferments and VSU-LNF. This is significantly different from plants supplemented with fermented *kuhol* and without supplementation in aquaponic system. Even though the result is significantly different and or comparable, moisture content is still really high for a perishable commodity. Tomato fruit is mainly composed of water, carbohydrates and salts with a moisture content accounting for about 94% of fresh weight of tomato fruits according to Jones (1999).

Figure 12 shows the titratable acidity, nitrogen and pH of aquaponically grown tomato supplemented with different nutrient solutions. No significant difference was recorded in terms of titratable acidity (0.29-0.39% citric acid), nitrogen content (1.18-2.47%), and pH (4.12-4.60) of tomato. Titratable acidity is referred to the citric acid content which is the most dominant acid in tomato fruit (Yilmaz, 2001). However, during postharvest, this acid decreases and there is an increase synthesis of malic and glutamic acid. The decreasing citric acid content during postharvest is due to its participation in the first step of tricarboxylic acid cycle (Missio et al., 2015; Oms-Oliu et al., 2011).Malic acid is the second most abundant acid in tomato fruit while in normal tomatoes its content decreases evidently during ripening and more slowly during postharvest (Missio et al., 2015).Glutamic acid is one of the major amino acids present in tomato fruits and its content increases 10 folds during ripening (Oms-Oliu et al., 2011). Thus, these organic acids are

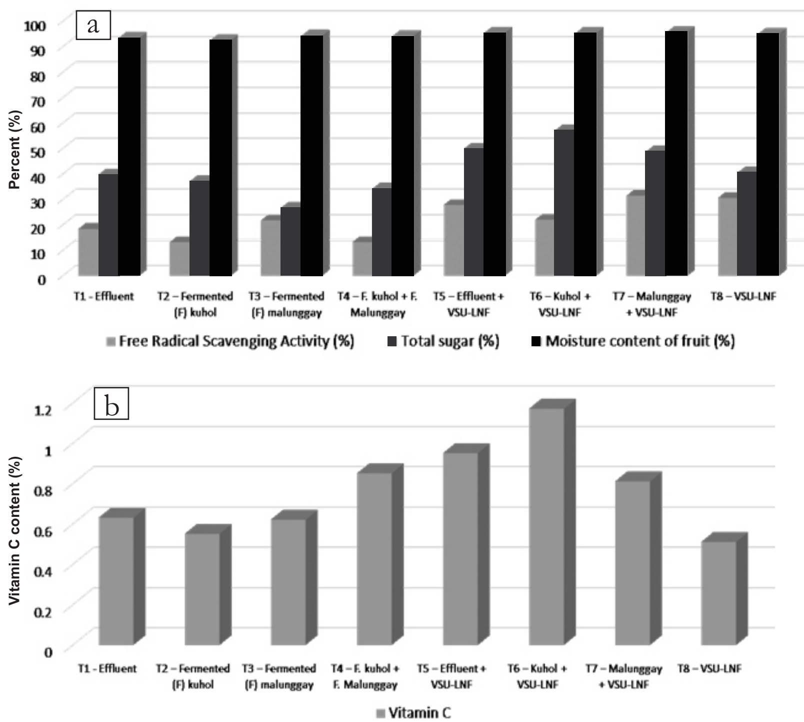

Figure 11. Free radical scavenging activity, total sugar and moisture content (a), and Vitamin C content (b) of aquaponically grown tomato supplemented with different nutrient solutions

important components in tomatoes that strongly influence fruit taste and overall quality (Oms-Oliu et al., 2011). On the other hand, pH measurement in tomato during ripening is increased (toward neutral) due to the conversion of stored starch in plastids into sugars such as d-glucose and d-fructose which accumulate at high levels above the requirement for respiration(Oms-Oliu et al., 2011). It should be noted into account that daily intake of nitrate causes adverse effect to the human body (Alexander et al., 2008), therefore measurement of nitrogen in tomato fruit was done. Mirmohammad-Makki and Ziarati (2015) reported that the acceptable daily intake (ADI) of nitrate is 0-3.7 mg/kg b.w. and 0-0.07 mg/kg b.w. for nitrite. Thus, the obtained value for fruit nitrogen helps in the calculation for tomato intake even though the research is focusing on the effect of supplementation of nutrient solution in tomato.

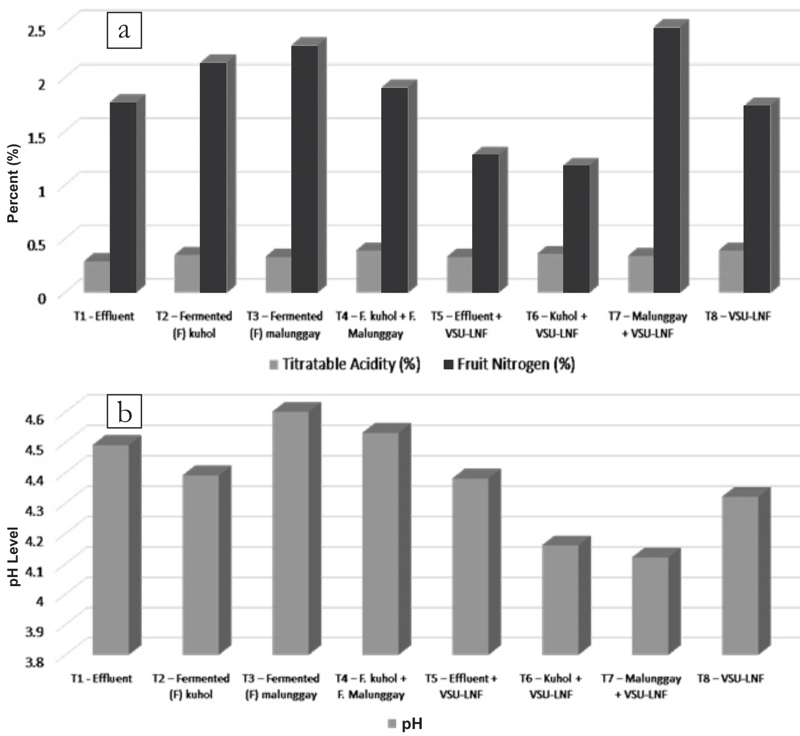

Figure 12. Titratable acidity, nitrogen (a) and fruit pH (b) of growing medium of aquaponically grown tomato supplemented with different nutrient solutions

Figure 13 shows the oxidation reduction potential (ORP), electrical conductivity (EC) and total dissolved solids (TDS) of aquaponically grown tomato supplemented with different nutrient solutions. These parameters were not significant affected by the supplementation of different nutrient solutions. Oxidation reduction potential (0.57-1.10mV), EC (0.51-0.60mS) and TDS (0.02-0.03%) were taken at breaker stage of the fruit. The ORP is related to the redox reaction in a cell which stimulate respiratory activity that hasten ripening. It involves oxidation of stored substrate by the presence of oxygen into different compound responsible in different biochemical processes. However, electrical conductivity is an index measuring the electrolytes leakages within the cell. As it increases fruits tend to ripened while its total dissolved solids are increased.

Figure 14 shows the pH of the growing medium of aquaponic tomato supplemented with different nutrient solutions. The pH of the medium varied significantly on supplementation with different nutrient solutions. The level of acidity of medium contentiously applied with fermented *malunggay* combined with VSU-LNF, fish effluent and its combination with VSU-LNF showed a more or less neutral pH ranging from 6.93 to 7.27. However, other treatments such as VSU-LNF application and in combination with fermented *kuhol*, combination of fermented *kuhol* and *malunggay* as well as their sole application gave below neutral pH. With the application of fermented organic nutrient solution, pH in the medium tends to decrease which can influence the availability of certain nutrients for plant uptake. The pH investigation of the growing medium used in the study is in consonance with the suggestion and findings of Emongor (2007), Hochmuth (2001a), Hochmuth (2001b), and Resh (2004) that the pH of the medium for optimum growth of tomato plants should be 6.5 - 7.0, 5.5 - 6.0, 5.5 - 6.5, and 5.8 - 6.4, respectively. This is to ensure the availability of nutrient such as Fe^{2+}, Mn^{2+}, PO_4^{3-}, Ca^{2+} and Mg^{2+}. On the other hand, pH of the effluent at 7.27 is within the recommended pH of 7.0 – 7.5 for aquaponics described by Timmons et al. (2002) for better absorption of nutrients from effluent. However, chemical nutrient analysis of effluent and fermented organic nutrient solution used in the study had lower nutrient composition than the one described by Marschner (1995) for optimal growth of the plants. This factor had contributed to the productivity of aquaponically grown tomato supplemented with different nutrient solutions.

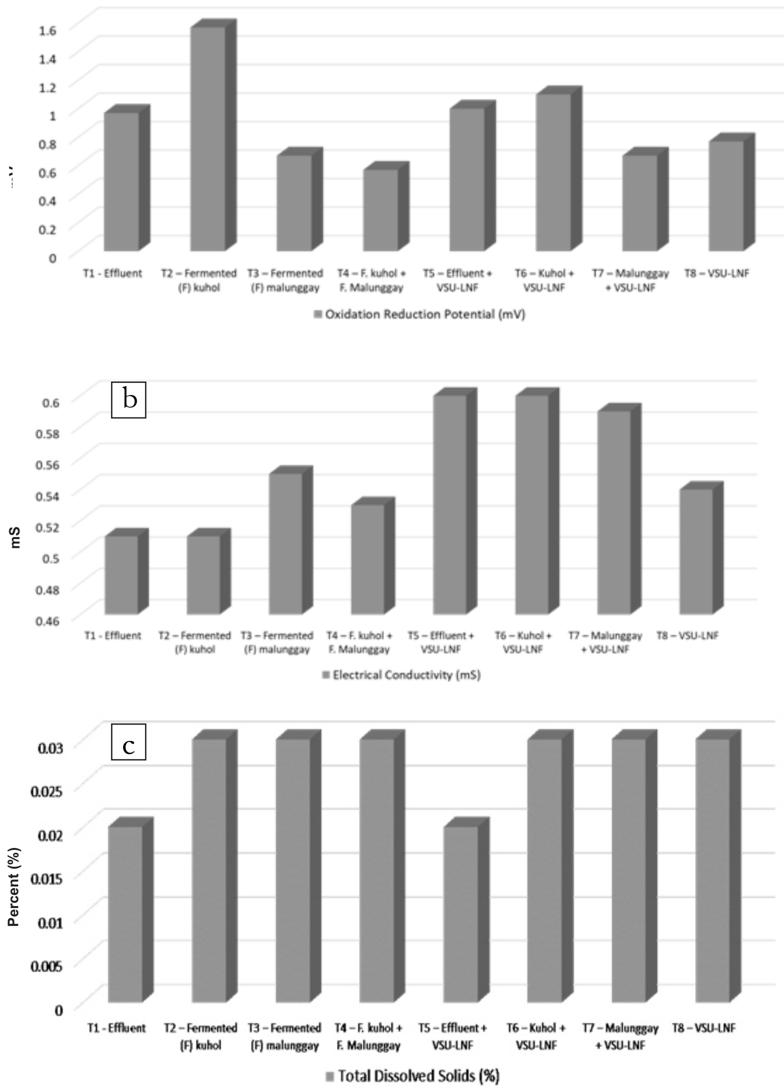

Figure 13. Oxidation reduction potential, electrical conductivity (a), and total dissolve solids (b) of aquaponically grown tomato supplemented with different nutrient solutions

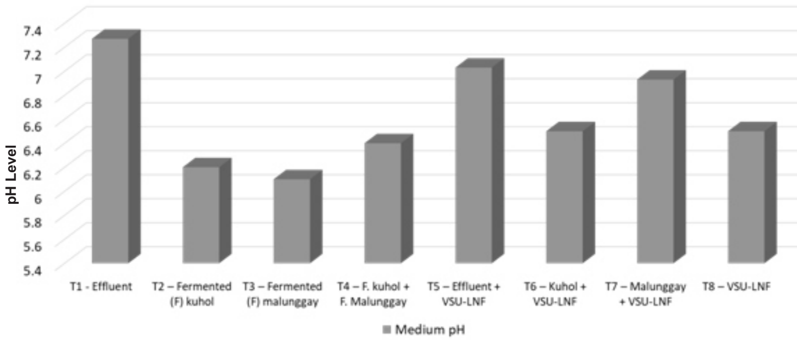

Figure 14. pH of the medium of aquaponically grown tomato supplemented with different nutrient solutions

CONCLUSION AND RECOMMENDATION

Conclusion

The growth and yield of tomato were influenced by the application of nutrient solutions. Application of VSU liquid nutrient formulation either in hydroponic or aquaponic system promoted the growth and yield of tomato. However, postharvest qualities were variably affected by the application of different nutrient solutions. No significant difference was obtained in firmness, percent weight loss, visual quality rating, titratable acidity, fruit nitrogen, fruit pH, oxidation reduction potential, electrical conductivity, total dissolved solids and respiration rate though significant difference was observed six (6) weeks after storage. Comparable result was obtained in total carotenoids of tomato grown in aquaponic system without supplementation, supplemented with fermented kuhol and malunggay, supplemented with VSU liquid nutrient formulation and supplemented with fermented kuhol combine with VSU liquid nutrient formulation. Higher chlorophyll *a* content was found on tomato fruit supplemented with fermented *kuhol* while no significant difference in chlorophyll *b* content. Higher total chlorophyll content of tomato fruit supplemented with fermented kuhol. Higher moisture content and free radical scavenging activity of tomato fruit with combined supplementation of fermented malunggay and VSU liquid nutrient formulation, while vitamin C and total sugar were higher on tomato fruits with combined supplementation of fermented kuhol and VSU liquid nutrient formulation. Medium of the pH ranged from 6.10 to 7.27.

Highest and best net return was obtained for tomato grown in aggregate hydroponic system applied with VSU liquid nutrient formulation followed by combined supplementation of VSU-LNF with tilapia fish effluent.

Recommendation

To improve and enhance the feasibility of aquaponic system, research on plant to fish ratio in tomato production, increase the concentration of ferments applied in crop, research on another fruit vegetables using the same method of production, and combined application of the different organic ferments with VSU liquid nutrient formulation is highly and strongly recommended.

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