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Usage of Fisheries Rearing Waste for Butterhead Lettuce (*Lactuca sativa* L. var. *capitata*) Cultivation in Recirculation

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ABSTRACT

The aim of this research was to use tilapia farming waste as a nutrient for plant growth in recirculation systems in order to make use of water efficiently and to reduce pollution materials entering the aquatic environment. Aquaculture wastes such as residual feed and faeces, after experiencing decomposition, can be utilized as a nutrient supply for plants. During the 35 days of study, butterhead lettuce could grow well relying on the supply of nutrients from fish farming waste. Relative growth (RGR) of P2 treatment (10 pot plants) was 0.07 ± 0.02. It was almost the same as in the treatment of P3 (20 pot plants) amounted to 0.07 ± 0.01. Similarly, the specific growth of butterhead was of 7.49 ± 1.21 in P2 and 6.86 ± 1.02 in P3. The use of tilapia fish farming waste as a nutrient on water recirculation system was able to support butterhead lettuce growth.

INTRODUCTION

Aquaculture effluent in the form of organic waste from the remains of artificial feed (pellets) and faeces of fish culture will negatively impact the water quality which in turn adversely affected the cultured fish. Avnimelech (2006) reported that fish can only absorb 20-30% of nutrients from the feed, the rest is excreted into the environment in the form of ammonia and organic proteins. According to David et al. (2015), aquaponics is a combination system of aquaculture and hydroponic cultivation. In this system, fish and plants grow in one integrated system, and create a symbiotic system. Some previous researches have successfully implemented aquaponics system such as Graber & Junge (2009) who integrated tilapia, eggplant, tomatoes and cucumbers; Mariscal-Lagarda et al. (2012) who combined the white shrimp and tomatoes; Liang & Chien (2013) who used tilapia and water spinach; and Wahyuningsih et al. (2015) who applied it in tilapia and Romaine lettuce.

Tilapia (*Oreochromis niloticus*) has a high economic value (Diver 2006). According to Tampubolon (2012), tilapia has a flattened body shape in the vertical direction as well as the position of the mouth is situated at the end of the nose (terminal). Tilapia fish is known as a tolerant, capable of living in unfavourable environmental conditions. Additionally, tilapia is classified as diseases-resistant fish that can be maintained in the lowlands to highlands. This fish can grow optimally in the acidity (pH) water of 7-8. The suitable water temperature for tilapia ranges 25-30°C and the optimum temperature is 28°C (Colt 2006).

The use of butterhead lettuce is based on the characteristic of the lettuce plant that likes water and has a high economic value. According to Nonnecke (1989), basically there are approximately six types of lettuce, namely: *crisphead*, *butterhead*, *cos*, leaf lettuce/slice lettuce, stem lettuce and latin lettuce. Lettuce (*Lactuca sativa* var. *capitata*) has a group of varieties consisting of crisphead lettuce and butterhead lettuce. Haryanto et al. (2003) observed that this type of lettuce has rounded crop with cross-docked leaves. In certain types, the leaves at the bottom remain unconnected. The leaves are bright green, but there is also a rather dark colour. The stem is very short and hardly noticeable. This type of lettuce tastes soft and crispy.

In this study, the use of butterhead lettuce in aquaponics system is expected to absorb organic wastes of rearing fish. Aquaponics system can recycle nutrients from fish farming wastewater through the production of vegetables including lettuce (Graber et al. 2009, Dediu et al. 2012). Research of Trang et al. (2010) showed that the capacity of nitrogen uptake by lettuce was 2.2 g/m^2 for 60 days cultivation period. According to Wahyuningsih et al. (2015), nitrogen sewage treatment from tilapia culture (*Oreochromis niloticus*) in aquaponics system can use Romaine lettuce (*Lactuca sativa* L. var. *longifolia*).

The purpose of this study was to assess the effectiveness of butterhead lettuce in utilizing the nutrients derived from rearing fish waste in water recirculation system.

MATERIALS AND METHODS

Research was conducted in Center for Environmental Research, Bogor Agricultural University (IPB) for six weeks (August 30 to October 12, 2016). Water recirculation system was applied using 18 aquariums (9 aquariums for rearing fish and 9 aquariums located under the 9 aquariums (80p × 40l × 60t cm^3) filled with water only, 12 gutters (80p × 15l × 15t cm^3), styrofoam, pot with diameter of 8 cm, media for planting lettuce (rockwool), the PVC pipe (diameter 0.5"), submersible water pumps, valves, thermometer, water heater and filter bath (Fig. 1) (Effendi et al. 2017). Total water used was 200 litres for each installation. This system was equipped with basic pump to regulate water flow. During the experiment, there were no water exchanges. The addition of water was only carried out to replace water lost due to evaporation and transpiration.

Butterhead lettuce (*Lactuca sativa* L. var. *capitata*) used in this study was 1-month-old which was planted on the system for 5 weeks (Effendi et al. 2017). Tilapia (*Oreochromis niloticus*) used had an initial total length of 10-11 cm and average weight of 24 gram. In each aquarium, 20 tilapia were maintained for six weeks. Additional nutrients were not given to the plants in order to obtain information concerning the ability of butterhead lettuce to absorb nutrients derived from tilapia faeces and unconsumed feed.

The treatments consisted of treatment I: without plants as a control (P1), treatment II: butterhead lettuce planted in gutters using a hydroponic container at a density of 10 plants (P2), and treatment III: butterhead lettuce planted in gutters using a hydroponic container with the density of 20 plants (P3).

Fish acclimatization process was carried out for 7 days of which slices of papaya leaves as much as 2 gram were added into 100 mL of water to improve the durability of the fish body. Fish cultivated in the system were given artificial feed every day as much as 3% of the body weight. Feeding was done in the morning, afternoon and evening. Feed had a protein content of 33% with the percentage of N and P of 5.62% and 1.20%, respectively. Measurement of N content on roots and leaves was carried out using the Kjeldahl method, while the measurement of P content was done using UV-VIS spectrophotometer (APHA 2012).

The growth pattern relationship between fish length and weight was calculated by the formula of fish body weight (W) (Le Cren 1951)

$$W = aL^b$$

The linear equation of length-weight relationship is where:

$$\text{Log } W = \text{Log } a + b \text{ Log } L$$

or

$$Y = a + bx$$

The relationship between the two parameters can be seen by linear regression approach. The b value is used to estimate the pattern of the growth. Hypothesis applied is:

If b = 3, the growth is isometric (growth pattern of length and weight is similar).

If b ≠ 3, the growth is allometric, those are:

If b>3, the growth is positive allometric (weight growth is more dominant) and fish becomes fatter, while b<3 means that the growth is negative allometric (length growth is dominant) and the fish is leaner.

Drawing conclusion was done by comparing T_{count} with T_{table} on confidence interval of 95%. If $T_{count} > T_{table,}$ the null hypothesis (H0) is rejected, otherwise if $T_{count} < T_{table}$ then the null hypothesis (H0) is accepted.

Specific growth rate (SGR) and growth rate (GR) of tilapia were calculated using the equation of Zonneveld et al. (1991), and feed conversion rate (FCR) was calculated using the formula of Ridha and Cruz (2001) as follows:

$$SGR = \frac{Ln\,Wt - Ln\,W0\ (g)}{t - t0\ (day)}) \times 100\%;$$

$$GR = (\frac{Wt - W0\ (g)}{t - t0\ (day)})$$

Where, *Wt* and *W0* are wet weight at time *t* and the initial time of observation, and *t* is time of observation.

$$FSR = \frac{No - Nt}{No} \text{ X } 100\ \%$$

Where, No and Nt are initial number of individuals and the number of individuals on day *t*, respectively.

$$FCR = \frac{\sum P\ (g)}{Wt - Wo\ (g)}$$

Butterhead lettuce growth periods, height, leaf width,

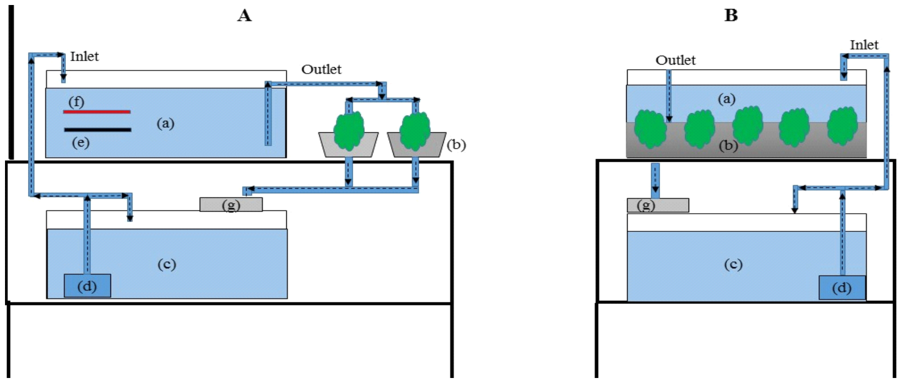

Fig. 1: Side view of aquaponics experimental installations (A), Front view of installation (B). Description: aquarium as fish-rearing place (a) gutter as butterhead lettuce planting media, (b) aquarium as water reservoir, (c) water pump, (d) water heater, (e) thermometer, (f) water flow direction, (g) fitler bath (zeolite stone and filter fabric).

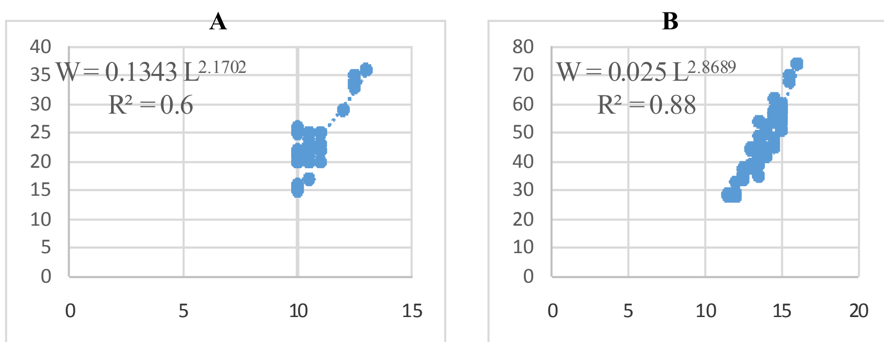

Fig. 2: The initial weight growth pattern (A) and the final growth pattern (B) of tilapia during maintenance on control treatment without plants (P1).

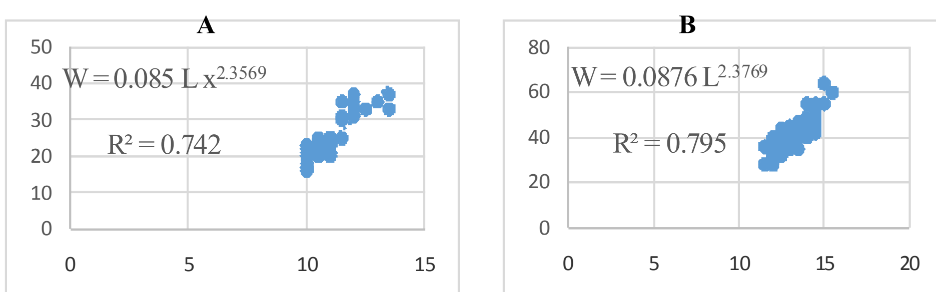

Fig. 3: The initial weight growth pattern (A) and the final growth pattern (B) of tilapia during maintenance on treatment of 10 plants (P2).

and number of leaves were measured every week. The produced biomass was harvested at the end of the experiment. Lettuce daily growth rate (DGR) (Ridha & Cruz 2001) and butterhead lettuce relative growth rate (RGR) (Gaudet in Mitchell 1974) were calculated:

$$\text{DGR} = \frac{[Ht\ (cm) - Ho\ (cm)]}{t\ (day)}$$

Where, *Ht* and *Ho* are romaine lettuce high at time *t* and at time 0, and *t* is the culture period.

$$\text{RGR} = \frac{[Ln\ Wt\ (g) - Ln\ Wo\ (g)]}{t\ (da)}$$

RESULTS AND DISCUSSION

The average growth of tilapia during cultivation showed

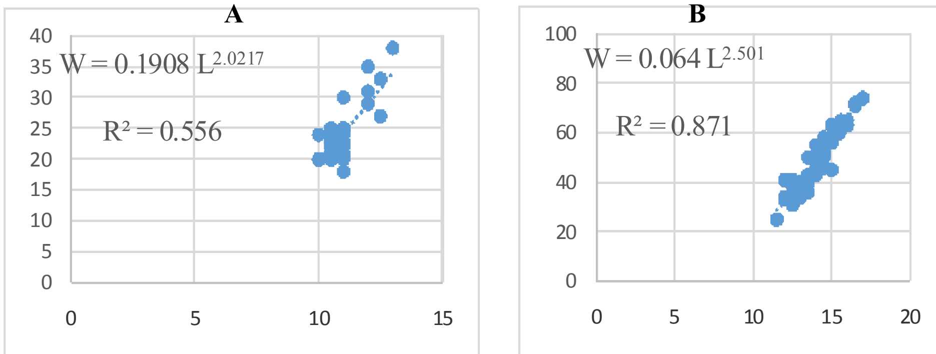

Fig. 4: The initial weight growth pattern (A) and the final growth pattern (B) of tilapia during maintenance on treatment of 20 plants (P3).

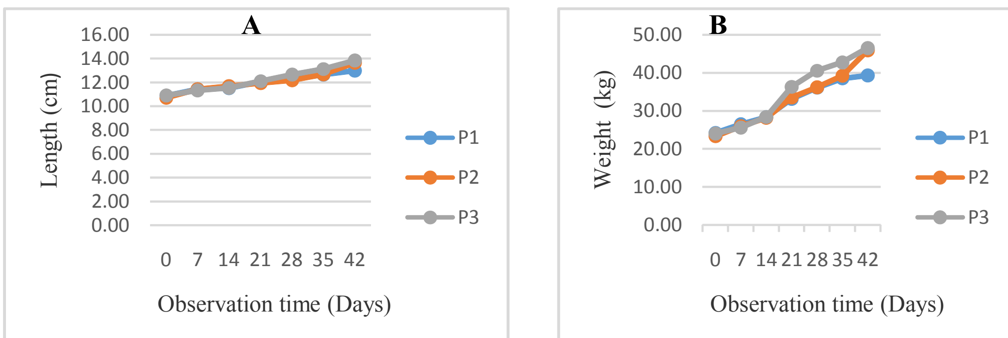

Fig. 5: The average growth of tilapia in length (A) and weight (B).

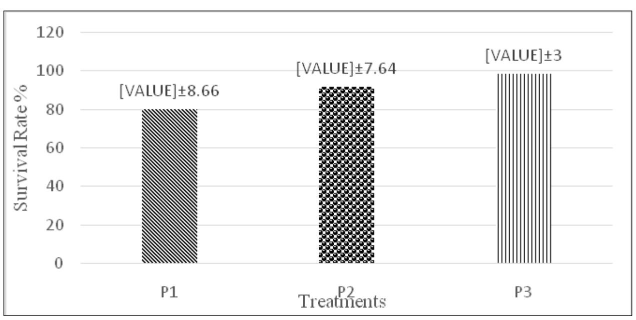

Fig. 6: Survival Rate (SR) of nile tilapia on P1, P2 and P3 treatments.

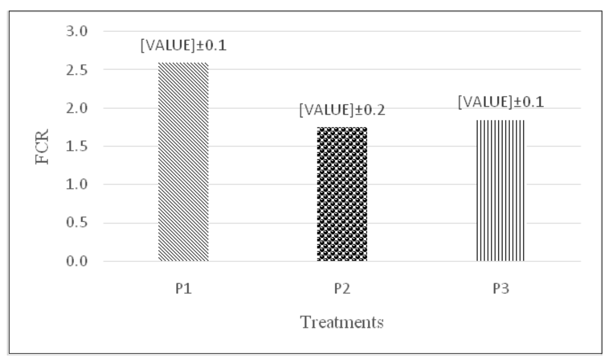

Fig. 7: Feed Conversion Ratio (FCR) of nile tilapia on P1, P2 and P3 treatments.

fairly good changes between the length and weight of fish. The P3 treatment had the highest weight addition and significantly different compared to the other treatments ($p<0.005$). In P3 of 22.52 gram, followed by P2 of 21.88 gram and P1 of 15.15 gram. The fish length in each treatment was not significantly different ($p<0.005$) among treatments, i.e., (P2) 2.10 cm, (P2) 2.93 cm and (P3) 2.93.

The length-weight relationship has a biological basis for describing the growth patterns of fish (Dar et al. 2012). Figs. 2, 3 and 4 show that the negative allometric growth pattern is more dominant and fish is leaner (Khan et al. 2011).

The growth rate in length of tilapia during the study increased significantly along with the increasing amount of feed given during cultivation of 42 days (Fig. 5). At the beginning (0 day) of cultivation, the initial weight of fish ranged from 23.33 to 24.18 gram. Then at the end (42 days)

Table 1: The average growth of tilapia during 42 days maintenance.

Treatment	Weight (mg)		Length (cm)	
	Intial	Final	Initial	Final
P1	24.18±0.36	39.33±0.29	10.88±0.08	12.99±0.21
P2	23.33±0.83	45.22±2.31	10.72±0.13	13.65±0.33
P3	24.02±0.63	46.53±2.05	10.89±0.12	13.81±0.17

Table 2: Growth performance of tilapia (*Oreochromis niloticus*).

Parameters	Treatments		
	P1	P2	P3
Specific growth rate (SGR) (%/day)	1.16±0.03	1.61±0.12	1.57±0.11
Growth rate (GR) (g/fish/day)	0.01±0.03	0.02±0.12	0.016±0.11
Food conversion ratio (FCR)	2.6±0.1	1.7±0.2	1.8±0.1
Survival rate (SR) (%)	80±8.66	91.67±7.64	98±3

of cultivation, final weight of fish ranged from 39.33 to 46.53 gram. Meanwhile, the initial length of the fish (0 days) ranged from 10.88 to 10.90 cm and at the end (42 days) of cultivation the fish length ranged from 12.99 to 13.83 cm (Table 1).

Table 2 shows the growth performance of tilapia in a water recirculation system. Each treatment showed specific growth, which was not much different. The fish growth in P2 (1.61±0.12) was more optimal than in P1 (1.16±0.03) and P3 (1.57±0.11). The statistical test also showed significant results ($p<0.05$).

Fig. 6 shows the survival rate of tilapia during the cultivation period. The highest survival rate was found in treatment of P3 and followed by P2 while the lowest was obtained by P1. Further statistical tests also showed significantly different results ($p<0.05$).

According to Martins et al. (2010), controlled water recirculation system can improve feed efficiency and accelerate the fish growth. Therefore, it is known that each treatment had significant effect during cultivation period and P3 achieved the best survival rate of 98±3 which was better than the research by Effendi et al (2016) which resulted in the highest survival rate of 96.11 ± 1.44.

This result is also better when compared to the research of Kamal (2006) with the values of FCR tilapia were 1.81 and 1.86 on the system with the addition of bell pepper (*Capsicum annuum* L. Godeon), and was 2.2 on the system without the addition of plants. Feed conversion value of this study similar to result of research by Rakocy et al. (2006) that was 1.7 on the cultivation of tilapia with average daily growth in weight of 4.4 g/day in recirculating aquaponics system.

The statistical test of daily growth rate (DGR) and relative growth rate (SGR) shows significant difference ($p<0.05$). This reflects positive growth during cultivation periods of butterhead lettuce in recirculation system with nutrients from tilapia farming waste. Treatment of (P2) with 10 plants showed better growth than treatment of (P3) with 20 plants.

Butterhead lettuce could grow without the addition of extra nutrients so that nutrients are only derived from tilapia farming waste. During the experimental period, butterhead lettuce grew rapidly until the end of cultivation. The lettuce had experienced lack of light (etiolation) at the beginning of the maintenance and demonstrated positive response to nutrients from tilapia farming waste. According to Endutet al. (2009), absorption of nitrogen and phosphorus increased in line with the age of the plant. Dissolved nutrients derived from fish farming waste could be utilized by plants, thus it may directly reduce the sewage release into the environment, and extend the use of water (Rackocy et al. 2006). During the periods of growth, butterhead lettuce showed signs of favourable growth, marked by the color of fresh green leaves, and there were no signs of nutrient deficiency for all the treatments. Butterhead lettuce performance can be seen from the growth in the number and width of leaves and fresh weight of the plant. At the end of the cultivation period, butterhead lettuce reached a positive growth (Fig. 8).

Fig. 9 (A) shows the growth of leaf width at the beginning of cultivation (0 days) which amounted to 1-2.5 cm and at the end of cultivation which ranged from 4.5 to 10.5 cm (35 days) in the recirculation system. The best result was found in the treatment of (P2) with 10 plants. Statistical analysis showed significant differences ($p<0.05$) of leaf width at the beginning and at the end of cultivation.

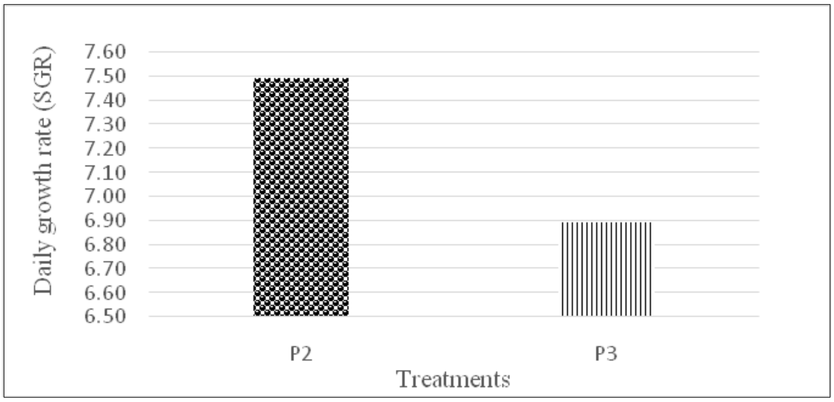

Fig. 8: Daily growth rate (DGR) of butterhead lettuce (*Lactuca sativa* L. Var. *capitata*) in treatment of 10 plants (P2) and 20 plants (P3).

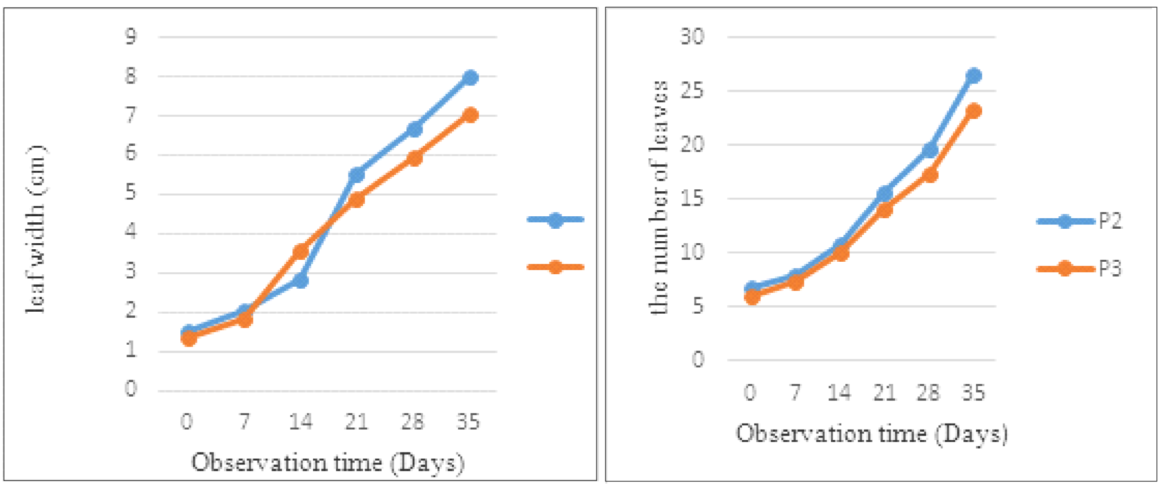

Fig. 9: The average growth of leaf width (a) and the number of leaves (b) of butterhead lettuce plants (*Lactuca sativa* L. Var. *capitata*).

Furthermore, it can be seen in Fig. 9 (B), at the beginning of the cultivation, the number of leaves was as much as 3-9 strands (0 days) and at the end of the cultivation, the number of leaves reached 15-35 strands (35 days). The best result in the number of leaves was obtained by treatment of P2 but it did not much differ from treatment of P3. Based on statistical analysis, the number of leaves at the beginning and at the end of cultivation showed significant differences ($p<0.05$).

CONCLUSION

Fish cultivated using aquaponic system with butterhead lettuce shows better growth than that without lettuce, indicated by the higher RGR and more efficient feed consumption. The growth of butterhead lettuce planted in gutters at a density of 10 plants (P2) showed better growth than treatment with 20 plants (P3). Hence, the use of tilapia farming waste as a nutrient in water recirculation system for growing plants of butterhead lettuce showed favorable result.

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