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Addition of Eco-enzyme In Lemna minor Cultivation as Alternative Feed to Support SDG 2 in Kampoeng Oase

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ABSTRACT

Catfish farming still faces the problem of high feed costs, so economical and sustainable alternative feeds are needed. Lemna minor has the potential to be used as an alternative feed due to its high nutritional content, but its growth productivity is relatively low without added nutrients. The use of eco-enzymes made from household organic waste as organic liquid fertilizer is a solution to increase the productivity of Lemna minor while supporting sustainable waste management. This study aims to describe the content of eco-enzymes from organic waste, describe the effect and determine the most effective concentration of eco-enzymes in increasing the cover area (LCA) and biomass of Lemna minor, as well as assess its impact as an alternative feed supporting SDG 2. The research was conducted from September to November 2025 at Kampoeng Pintar Oase and consisted of two stages, namely observation of the eco-enzyme production process and experimentation with its implementation in Lemna minor cultivation. The parameters observed included the macro nutrient content of eco-enzymes, cover area (LCA), Lemna minor biomass, and cultivation media quality. Nutrient content analysis was conducted at the Surabaya Laboratory of the Agency for Standardization and Industrial Services (BSPJI) based on the 2011 standard for liquid organic fertilizer quality. The data were analyzed descriptively quantitatively, followed by one-way analysis of variance and Duncan's test at a 5% level. The results showed that eco-enzyme met the standards for liquid organic fertilizer and had a significant effect on the growth of Lemna minor. A concentration of 20 ml of eco-enzyme produced the highest LCA and biomass values, while a concentration of 60 ml showed the lowest growth. These findings indicate that eco-enzyme at the optimal concentration effectively increases Lemna minor production and supports sustainable food security in line with SDG 2.

Kata Kunci
Lemna minor
Eco-enzyme
Biomassa
Pakan lele
Budidaya berkelanjutan

Penambahan Eco-enzyme dalam Budidaya Lemna minor sebagai Pakan Alternatif untuk Mendukung SDG 2 di Kampoeng Pintar Oase. Budidaya ikan lele masih menghadapi permasalahan tingginya biaya pakan sehingga diperlukan pakan alternatif yang ekonomis dan berkelanjutan. *Lemna minor* berpotensi dimanfaatkan sebagai pakan alternatif karena kandungan nutrisinya tinggi, namun produktivitas pertumbuhannya relatif rendah tanpa penambahan nutrisi. Pemanfaatan *eco-enzyme* berbahan limbah organik rumah tangga sebagai pupuk cair organik menjadi solusi untuk meningkatkan produktivitas *Lemna minor* sekaligus mendukung pengelolaan limbah berkelanjutan. Penelitian ini bertujuan mendeskripsikan kandungan *eco-enzyme* dari limbah organik, mendeskripsikan pengaruh dan menentukan konsentrasi *eco-enzyme* yang paling efektif dalam meningkatkan luas *cover* area (LCA) dan biomassa *Lemna minor*, serta mengkaji dampaknya sebagai pakan alternatif pendukung SDG 2. Penelitian dilaksanakan pada September–November 2025 di Kampoeng Pintar Oase dan terdiri atas dua tahapan, yaitu observasi proses pembuatan *eco-enzyme* dan eksperimen implementasinya dalam budidaya *Lemna minor*. Parameter yang diamati meliputi kandungan hara makro *eco-enzyme*, luas *cover* area (LCA), biomassa *Lemna minor*, serta kualitas media budidaya. Analisis kandungan hara dilakukan di Laboratorium Badan Standardisasi dan Pelayanan Jasa Industri (BSPJI) Surabaya berdasarkan standar baku mutu pupuk organik cair tahun 2011. Data dianalisis secara deskriptif kuantitatif dan dilanjutkan dengan analisis ragam satu arah serta uji Duncan pada taraf 5%. Hasil penelitian menunjukkan bahwa *eco-enzyme* memenuhi standar pupuk cair organik dan berpengaruh nyata terhadap pertumbuhan *Lemna minor*. Konsentrasi *eco-enzyme* 20 ml menghasilkan nilai LCA dan biomassa tertinggi, sedangkan konsentrasi 60 ml menunjukkan pertumbuhan terendah. Temuan ini menunjukkan bahwa *eco-enzyme* pada konsentrasi optimal efektif meningkatkan produksi *Lemna minor* dan mendukung ketahanan pangan berkelanjutan sesuai SDG 2.

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INTRODUCTION

The aquaculture sector plays an important role in meeting the demand for animal protein in Indonesia. Catfish production continues to increase, from 55,691 tons in 2004 to 543,774 tons in 2014, with an average increase of 29.62% per year (Ministry of Maritime Affairs and Fisheries, 2014 in Sukoco et al., 2019). The latest data also shows an average increase of 1.61% for the period 2020–2024 (Ministry of Maritime Affairs and Fisheries, 2025). This increase is supported by a farming system that is easy to implement, land efficient, and has high economic value. However, feed costs, which account for 60–70% of total production costs, remain a major obstacle (Laheng et al., 2020), compounded by feed residues that can pollute the cultivation media and reduce water quality (Rahmawati et al., 2020).

One potential feed alternative is Lemna minor, a small aquatic plant that can cover 40-100% of the water surface (Boti et al., 2018). Lemna minor contains important nutrients, such as 27.68% protein, 41.95% BETN, 14-15% crude fiber, 2-3% fat, and 18.01% ash (Firdaus et al., 2017). Under optimal conditions, the biomass of Lemna minor can increase within two days (Nopriani et al., 2014).

Organic fertilizers come from various local resources such as household waste, plant waste, crop residues, market waste, and livestock waste, with varying nutrient and microbial content (Sumakud & Pangemanan, 2021; Safe'i et al., 2022). One form of liquid organic fertilizer is eco-enzyme, which is a product of fermenting organic waste such as fruit and vegetable scraps mixed with sugar and water in a ratio of 1:3:10. This liquid contains nitrate (NO_3), which can be a source of nitrogen for plants and can improve the physical, chemical, and biological properties of the soil (Novianto & Bahri, 2023).

Based on previous research, adding nutrients to Lemna minor cultivation can stimulate plant growth, as shown by research using cow manure as a source of nutrients for Lemna minor, which can increase the growth and biomass of Lemna minor due to the presence of macro nutrients such as nitrogen, phosphorus, and potassium, which are important for the vegetative growth process of plants (Boti et al., 2018). In addition, based on research on the use of eco-enzymes on lettuce plants (Lactuca sativa L.), eco-enzymes have a significant effect on the growth and yield of lettuce plants, especially in terms of plant height, number of leaves, and fresh weight. This is because the natural content of eco-enzymes can effectively increase soil fertility. Eco-enzymes facilitate the conversion of carbon dioxide (CO_2) into carbonate (CO_3), which plays an important role in the natural cycle and aids plant growth as a natural fertilizer (Nangoi et al., 2022).

Kampoeng Pintar Oase, Surabaya, is an educational area that implements a bucket catfish farming system (budikdamber) (Naghiesa et al., 2024). The community uses Lemna minor as supplementary feed, but large-scale biomass production remains a challenge due to the lack of additional nutrients. Therefore, this study was conducted to describe the eco-enzyme content of organic waste, describe its effects, and determine the most effective concentration in increasing the coverage area (LCA) and biomass of Lemna minor, as well as describe its role as an alternative fish feed that has the potential to reduce feed costs, increase aquaculture productivity, and support sustainable food security in accordance with Sustainable Development Goal (SDG) 2.

METHOD

This study was conducted from September to November 2025 at Kampoeng Pintar Oase. The study consisted of two stages, namely the observation stage on the eco-enzyme production process and the experiment stage on the application of eco-enzyme in Lemna minor cultivation. The eco-enzyme concentration treatments included E0 (PDAM water (control)), E1 (20 ml eco-enzyme + 3980 ml PDAM water), E2 (40 ml eco-enzyme + 3960 ml PDAM water), and E3 (60 ml eco-enzyme + 3940 ml PDAM water), each with three replicates.

The eco-enzyme was made from household organic waste in the form of orange, pineapple, and banana peels. The raw materials were washed, chopped, and then fermented using sugar and water in a ratio of 1:3:10 (1,000 g sugar, 3,000 g fruit peels, and 10 L water), with the addition of yeast as a fermentation accelerator. The fermentation process lasted for 30 days. The resulting eco-enzymes were then tested for pH and macronutrient content at the Surabaya Industrial Standardization and Service Agency (BSPJI) Laboratory to ensure their quality as organic liquid fertilizer.

The experimental stage used a treatment design with eco-enzyme concentrations, namely E0 (PDAM water as a control), E1 (20 ml eco-enzyme + 3,980 ml PDAM water), E2 (40 ml eco-enzyme + 3,960ml PDAM water), and E3 (60 ml eco-enzyme + 3,940 ml PDAM water). Each treatment was repeated three times. The culture medium was prepared in used 15 L gallons with a final solution volume of 4 L.

The Lemna minor inoculum was acclimatized for two days, then 5 g of initial biomass was spread on each experimental unit and maintained for 14 days. The cultivation medium quality parameters observed included temperature, pH, and light intensity, which were measured daily at 08.00 WIB using a thermometer, pH meter (Milwaukee), and lux meter (Intellsmart), then analyzed descriptively.

The growth parameters of Lemna minor included wet biomass and cover area, which were measured periodically during the maintenance period. Cover area (LCA) was calculated using the formula:

$$\text{Coverage area (\%)} = \frac{\text{area covered by Lemna minor (cm)}}{\text{Total Surface Area of Container (cm)}} \text{X } 100\%$$

Growth data were analyzed using one-way analysis of variance (ANOVA), and if there were significant differences, Duncan's test was performed at a 5% confidence level. Lemna minor was harvested on the 14th day to evaluate the effect of eco-enzyme concentration on plant growth.

RESULTS AND DISCUSSION

Based on the research results, the data obtained included the nutrient content of eco-enzymes (Table 1), light intensity of the Lemna minor medium (Table 2), temperature and pH level of the Lemna minor cultivation medium (Table 3), and the results of the Cover Area (LCA) and Biomass of Lemna minor (Table 4, Figure 1, Figure 2, and Figure 3).

Table 1. Nutrient Content of Eco-enzymes

No.	Parameters	Nutrient Analysis Results (%)	Level Comparator (%)	Testing
1.	pH	3,4	≤ 4,0	pH meter
2.	Macro elements			
	- N	0,17	<0,10	Kjeldahl
	- P_2O_5	0,02	<0,1	Spektofotometri
	- K_2O	2,47	<0,1	AAS

*Quality standards for liquid organic fertilizer (2011)

The nutrient content of eco-enzymes shows a pH value of 3,4 and macro element content of N (0,17%), P (0,02%), and K (2,47%). In general, these values are still below the standard range for eco-enzyme quality (Table 1).

Table 2. Light Intensity Levels during the Study

Treatment	Day-		
	3	9	14
E0 (0 ml)	6457 *lux*	7249 *lux*	7392 *lux*
E1 (20 ml)	5756 *lux*	7472 *lux*	7604 *lux*
E2 (40 ml)	6423 *lux*	6703 *lux*	8143 *lux*
E3 (60 ml)	6186 *lux*	6253 *lux*	7739 *lux*

Light intensity during the study showed variation in each treatment. Light intensity values tended to increase from day 3 to day 14 in all treatments. The light intensity obtained during the study was still within the range that supports the growth of Lemna minor (Table 2).

Table 3. Temperature and pH Level of Cultivation Media during Research

Treatment	Temperature on Day-			Acidity Level (pH) Day-		
	3	9	14	3	9	14
E0 (0 ml)	27˚C	30˚C	34˚C	7.8	7.4	9.2
E1 (20 ml)				7.3	7.0	10
E2 (40 ml)				7,0	7,1	9,2
E3 (60 ml)				6,4	6,4	8,7

The temperature and acidity (pH) of the medium changed during the study. The medium temperature ranged from 27°C to 34°C, while the pH value tended to be lower in the treatment with eco-enzyme addition. The pH changes that occurred were still within the tolerance limits of Lemna minor (Table 3).

Table 4. Cover Area (LCA) and Biomass of Lemna minor During the Study

Treatment	Cover Area of Lemna minor Day-			Lemna minor biomass Day-		
	3	9	14	3	9	14
E0 (0 ml)	7,67 cm^2 ± 0,58	14,67 cm^2 ± 0,58	18,33 cm^2 ± 1,44^b	7,33 gram ± 0,58	12,67 gram ± 0,58	20,00 gram ± 1,00^b
E1 (20 ml)	9,33 cm^2 ±0,58	15,83 cm^2 ± 0,29	20,00 cm^2 ± 0,00^a	9,33 gram ± 0,58	13,67 gram ± 1,53	25,67 gram ± 1,53^a
E2 (40 ml)	6,95 cm^2 ± 0,48	11,50 cm^2 ± 1,32	19,17 cm^2 ± 1,44^b	7,33 gram ± 0,58	10,33 gram ± 1,15	18.67 gram ± 1,15^b
E3 (60 ml)	5,56 cm^2 ± 0,96	7,83 cm^2 ± 0,00	13,67 cm^2 ± 1,15^c	6,33 gram ± 0,58	8,00 gram ± 1,00	13,33 gram ± 1,53^c

The growth of Lemna minor based on cover area (LCA) and biomass showed an increase in all treatments. Treatment E1 showed the highest increase, while treatment E3 showed the lowest increase. These changes in LCA and biomass illustrate the growth response of Lemna minor to variations in eco-enzyme concentration (Table 4).

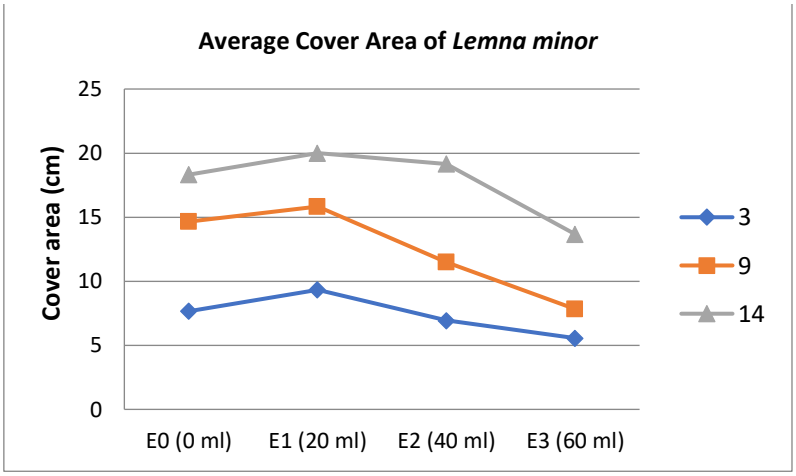


Figure 1. Graph of the average LCA of Lemna minor

Treatment with various concentrations of eco-enzyme also affected the LCA value of Lemna minor (Figure 1). At the end of the observation period, all treatments showed an increase in LCA from day 3 to day 14. Treatment E1 (20 ml) had the highest LCA value compared to the other treatments, while treatment E3 (60 ml) showed the lowest LCA value. These results indicate that the higher the concentration of eco-enzyme used, the lower the increase in the cover area of Lemna minor.

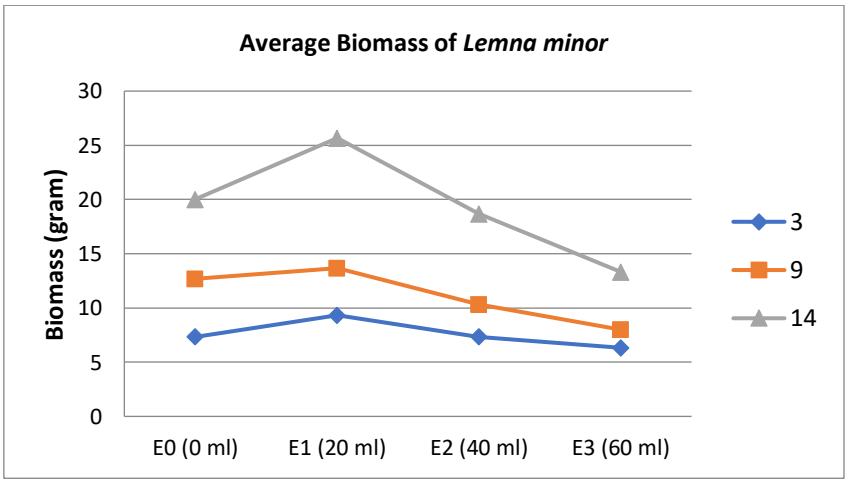


Figure 2. Graph of Average Biomass of Lemna minor

The eco-enzyme treatment also affected the biomass of Lemna minor (Figure 2). At the end of the study, biomass increased in all treatments, with the highest value found in treatment E1 and the lowest in treatment E3. This pattern shows that lower concentrations of eco-enzymes can produce greater biomass growth than higher concentrations.

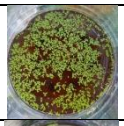
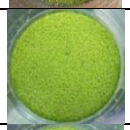
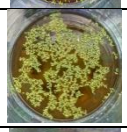
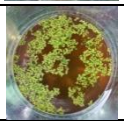
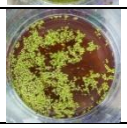
Day- / Treatment	3	9	14
E0 (0 ml)			
E1 (20 ml)			
E2 (40 ml)			
E3 (60 ml)			

Figure 3. Area of Lemna minor Cultivation

Variations in eco-enzyme concentration affected the cover area (LCA) and morphology of Lemna minor (Figure 3). Treatment E1 (20 ml) showed the highest LCA with denser fronds and bright green color, while E3 (60 ml) had the lowest LCA with sparser fronds at the end of the observation period.

Eco-enzyme is a fermented product of household organic waste with a ratio of sugar, organic matter, and water of 1:3:10, which functions as an organic liquid fertilizer because it contains nitrate as a source of nitrogen and is able to improve the physical, chemical, and biological properties of the growing medium (Novianto, 2022). In this study, eco-enzyme was made from orange, pineapple, and banana peels, which are rich in bioactive compounds and nutrients (Agustin et al., 2019; Salsabila et al., 2024). During fermentation, microorganisms break down these compounds into simpler compounds that are more easily absorbed by plants (Nazim & Mera, 2015). The analysis results showed a content of 0,17% N, 0,02% P, and 2,47% K, which is still relatively low because the fermentation has not reached a stable phase, but it is still within an appropriate range and suitable for use as organic liquid fertilizer when compared to previous studies (Illahi et al., 2023; Hastuti & Titiaryanti, 2020). The eco-enzyme pH value of 3,4 also indicates that fermentation is proceeding optimally and meets quality standards, as the formation of organic acids during fermentation causes acidic conditions that indicate the process is running well (Samriti & Arya, 2019; Rasit et al., 2019; Nurdin et al., 2023).

Growing media play an important role in determining the survival of plants from the beginning to the end of their growth. Growing media serve as a place for roots to develop as well as a means of absorbing water and nutrients needed by plants (Meriaty, 2021). According to Sugianto & Jayanti. (2021), ideal growing media must be able to provide water, air, nutrients, and support optimal plant growth. In addition to the quality of the growing medium, environmental factors also affect plant growth and productivity, one of which is the intensity of sunlight. Each type of plant has different light requirements to carry out photosynthesis. Photosynthesis requires light as an energy source to convert carbon dioxide (CO_2) into carbohydrates, so adequate light intensity will increase photosynthesis (Nopriani et al., 2014).

The relationship between the growing medium and light intensity is evident in the results of this study. The light intensity during the cultivation of Lemna minor, as presented in Table 2, ranged from 5,756 to 8,143 lux. This range is still within the ideal range to support the growth of Lemna minor, as stated by Nopriani et al. (2014) that the required light intensity ranges from 400 to 8000 lux. The appropriate intensity allows plants to optimally utilize light energy for metabolic processes and biomass formation.

In addition to light intensity, media conditions such as temperature also affect plant growth. In this study, water was used as the growing medium, and the temperature measurements in Table 2 showed values of 27–34°C, which is still within the tolerance range of Lemna minor, namely 5–35°C with an optimum temperature of 20–31°C (Fitriana & Kuntjoro, 2020). Increased temperature can accelerate metabolism and photosynthesis, thereby increasing nutrient absorption, but temperature fluctuations can affect the stability of the medium's pH.

The pH value as an indicator of water quality also shows dynamics during cultivation. In treatments E0, E1, and E2, the pH tended to be neutral, while in treatment E3 it was more acidic. Overall, the pH ranged from 6.4 to 10 and was still within the tolerance range of Lemna minor, with the best growth at a pH of 6.5–7.5 (Fitriana & Kuntjoro, 2020). In treatment E3, the pH on days 3 to 9 tended to be acidic, inhibiting nutrient absorption, in line with Karoba et al. (2015), who stated that overly acidic conditions reduce nutrient absorption efficiency. This decrease in pH is related to plant respiration activity, which produces dissolved CO_2 that forms carbonic acid (Prihantoro et al., 2015). On day 14, the pH increased again, in line with the decrease in microbial activity at high eco-enzyme concentrations (Wulandari & Winarsih, 2024). This condition also explains why growth in treatments E2 and E3 occurred more slowly than in E1.

The plant growth observed next included the cover area (LCA) and biomass of Lemna minor. In general, Lemna minor showed a good growth response, marked by an increase in LCA in all treatments. Based on Table 3, Figure 1, and Figure 3, the highest increase occurred on day 14, especially in treatment E1 (20 ml). A large LCA value reflects increased plant productivity because the larger the area covered, the higher the physiological activity that takes place.

This development is inseparable from the physiological characteristics of Lemna minor as a C3 plant that is sensitive to light and environmental conditions. Light intensity plays a role in balancing photosynthesis and photorespiration, while external factors such as temperature, humidity, and evapotranspiration also affect the growth rate (Konasih et al., 2024). In addition, the increase in LCA is also influenced by the nutrient content in the eco-enzyme. The nitrogen, phosphorus, and potassium content in it has been proven to increase plant greenness and health. Nitrogen plays a role in the formation of proteins and chlorophyll (Manasikana et al., 2019), while phosphorus supports energy metabolism and tissue development (Septinar et al., 2024). The combination of these elements allows Lemna minor in the E1 treatment to grow faster than without treatment.

The LCA measurement results obtained were reinforced by ANOVA analysis, which showed that the eco-enzyme treatment had a significant effect on the growth of Lemna minor. Duncan's test at the 5% level showed that there were significant differences between treatments. The lowest average LCA was found in the E3 treatment, followed by E2, E0, and the highest in E1. A concentration of 20 ml of eco-enzyme gave the best results because the nutrient content was at the optimal level for photosynthesis and cell division. Conversely, high doses such as E3 caused the medium to become cloudier, reducing light penetration and inhibiting photosynthesis, thereby slowing growth.

Observations of Lemna minor biomass (Table 4 and Figure 2) showed a similar pattern. ANOVA results showed that the treatment had a significant effect on fresh weight, and Duncan's test confirmed that there were significant differences between treatments. The increase in biomass was influenced by higher photosynthetic activity as the availability of nutrients from eco-enzymes increased. Iqbal et al. (2021) stated that aquatic plants show high productivity when grown in media with optimal nutrient levels. This was evident in this study, where biomass increased as leaf diameter and LCA increased.

The differences in response to each eco-enzyme concentration became increasingly apparent. Treatment E3 produced the lowest biomass, followed by E2 and E0, while E1 showed the highest biomass. Although the significance value of 0.151 indicates that the differences between treatments were not significant at the 5% level, E1 still showed the most stable growth trend. This condition indicates that a 20 ml concentration of eco-enzyme is the most optimal dose to support the growth of Lemna minor, as nutrients are available in sufficient quantities without disturbing the clarity of the medium (Lubis et al., 2022). However, the growth of Lemna minor declined on days 14 to 21, marked by plant death and a change in leaf color to yellow. This decline is thought to be related to the relatively short lifespan of Lemna minor (Nurrasyida et al., 2024). Thus, although eco-enzyme can enhance growth in the early stages, plant lifespan remains a limiting factor in long-term cultivation.

The addition of eco-enzymes in the cultivation of Lemna minor at Kampoeng Oase contributes to the achievement of SDG 2 (Zero Hunger). SDG 2 emphasizes the importance of increasing food security, improving nutrition, and implementing sustainable agriculture (Kaslam et al., 2022) through increasing plant biomass as an alternative feed source. Eco-enzymes made from organic waste function as liquid fertilizers that enrich the nutrients in the medium (Salsabila, 2023), thereby supporting the growth of Lemna minor. This plant has a protein content of 27.68%, BETN 41.95%, crude fiber 14–15%, fat 2–3%, and ash 18.01% (Firdaus et al., 2017). Therefore, the increase in biomass in the optimal treatment has the potential to improve its quality as catfish feed and reduce feed costs, which are the largest component in catfish farming. The use of eco-enzymes also supports organic waste management and sustainable farming practices. Thus, the use of eco-enzymes strengthens the availability of economical feed and supports food security in line with SDG 2.

CONCLUSION

Eco-enzymes produced from the fermentation of household organic waste in the form of orange, pineapple, and banana peels have an acidic pH (3,4) and macro nutrient content of N (0,17%), P (0,02%), and K (2,47%) that can potentially be used as organic liquid fertilizer. The application of eco-enzymes to Lemna minor cultivation media affects the increase in cover area (LCA) and plant biomass, with different growth responses at each concentration. A concentration of 20 ml of eco-enzymes provides the highest increase in LCA and biomass, while a concentration of 60 ml tends to reduce growth due to changes in media pH that are less than optimal. Thus, the 20 ml concentration is the most effective dose for enhancing Lemna minor growth and has the potential to support the provision of alternative feed for catfish and sustainable organic waste management, while also supporting sustainable cultivation practices and the achievement of SDG 2 through the utilization of organic waste as a plant nutrient source.

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