

UTILIZATION OF LIQUID ORGANIC FERTILIZER (LOF) FROM GOAT MANURE ON *Lemna* sp. BIOMASS IN THE MAINTENANCE MEDIA FOR SNAKEHEAD FISH (*Channa striata*)

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ABSTRACT

Snakehead fish (*Channa striata*) culture produces waste in the form of leftover feed that can reduce water quality. One approach to improving water quality is the use of the aquatic plant *Lemna* sp. for phytoremediation. However, *Lemna* sp. growth requires sufficient nutrients; therefore, liquid organic fertilizer (LOF) derived from goat manure was applied. This study aimed to determine the optimal dose of goat manure LOF for *Lemna* sp. biomass production in snakehead fish culture water. The study was conducted from September to October 2025 at the Integrated Laboratory of Marine Sciences, Universitas Riau. A completely randomized design with five treatments and three replicates was used. Treatments were P0 (control), P1 (0,5 mL/L), P2 (1,0 mL/L), P3 (1,5 mL/L), and P4 (2,0 mL/L). The results showed that goat manure LOF significantly affected *Lemna* sp. biomass ($P < 0.05$). The best treatment was P4, producing the highest biomass (362.58 g/m²) and specific growth rate (6.56%). Application of goat manure LOF also supported snakehead fish growth, resulting in a final mean weight of 3.20 g, mean length of 3.88 cm, daily weight gain of 2.60 g/day, and survival rate of 98%. In total organic matter ranged from 16.43–55.72 mg/L, nitrate 0.1813–10.0229 mg/L, phosphate 0.6991–5.1416 mg/L, CO₂ 5–18 mg/L, DO 4.10–5.21 mg/L, pH 6.2–7.4, and temperature 27.1–28.9°C. These findings indicate that goat manure LOF at 2.0 mL/L effectively increases *Lemna* sp. biomass, promotes phytoremediation, and improves snakehead fish growth and survival.

Keywords: Biomass of *Lemna* sp., Liquid Organic Fertilizer, Goat manure, Snakehead fish

1. INTRODUCTION

Snakehead fish are predatory freshwater fish with feeding habits classified as carnivorous fish¹. Madusari et al.² reported that feed containing 40% protein produced the best results in terms of growth and feed efficiency, particularly during the fry stage. Dhearesta et al.³ stated the decline in water quality in fish farming media is caused by leftover fish feed and fish waste (feces). According to Lin et al.⁴, the accumulation of uneaten feed and fish excreta during culture activities often causes a decline in pond water quality, resulting in toxic effects on fish. One of the common problems encountered in snakehead fish

culture is related to the culture environment, which may lead to high mortality rates.

Aquaculture waste contains nitrogen (N), phosphorus (P), and other organic compounds which, when present in excessive amounts, can pollute the water environment and disrupt the survival of aquatic organisms⁵. The deterioration of water quality is one of the major constraints in snakehead fish culture, as it can negatively affect fish growth and survival. Aquatic plants generally possess highly beneficial capabilities in wastewater treatment processes, as they can be used to reduce specific substances present in aquatic environments⁶. One aquatic plant that has

the ability to absorb pollutant compounds from aquaculture media is *Lemna* sp.

Lemna sp. is an aquatic plant that functions as a phytoremediation agent because it is capable of absorbing compounds resulting from the decomposition of uneaten feed and fish metabolism, particularly nitrogen and phosphorus, thereby potentially improving water quality in aquaculture systems. Amalia⁷ reported that *Lemna* sp. was effective in reducing nitrogen levels by 4.48 ± 0.04 g N in a biomass of 594.9 g derived from catfish aquaculture waste and resulted in a survival rate of 76.3%.

The advantages of *Lemna* sp. as a phytoremediation agent have been demonstrated in numerous studies. The use of liquid organic fertilizer is important to provide growth for plants, because liquid organic fertilizer is able to supply the nutrients needed by plants⁸. Although aquaculture waste contains nutrients required by plants, their availability is often insufficient to support optimal growth⁹. Therefore, additional nutrients from other sources are required to fulfill plant nutrient requirements.

One effort to optimize the management of livestock waste, which has been underutilized, is the use of liquid organic fertilizer (LOF) derived from goat manure, which is considered an alternative solution with considerable potential. Liquid Organic Fertilizer (LOF) is a type of liquid fertilizer produced from various natural organic materials¹⁰. Liquid organic fertilizer (LOF) derived from goat manure contains essential nutrients such as nitrogen, phosphorus, and potassium, which are beneficial for plant growth.

According to Safitri & Linda¹¹, goat manure LOF contains 0.19% organic carbon, a C/N ratio of 0.17, 1.15% nitrogen, 60.68 ppm phosphorus, and 519.07 ppm potassium. The utilization of goat manure LOF to increase the biomass of *Lemna* sp. and its effectiveness in improving water quality in snakehead fish rearing media has not previously been investigated. Therefore,

this study aimed to determine the utilization of goat manure liquid organic fertilizer on the biomass of *Lemna* sp. in snakehead fish rearing media and to obtain the optimal dosage for *Lemna* sp. biomass production in snakehead fish rearing media.

2. RESEARCH METHOD

Time and Place

This study was conducted from September to October 2025, starting from making research proposals, preparing forums, and making research report results. This research was conducted at the Integrated Laboratory of Marine Sciences, Faculty of Fisheries and Marine Sciences, Universitas Riau, Pekanbaru.

Method

This study used an experimental method with a one-factor Complete Random Design (CRD), consisting of five levels of treatment and three replicas, so that there were 15 experimental units. The dosages of liquid organic fertilizer derived from goat manure used in each treatment were based on Saputri¹², who found the optimal dose for *Azolla microphylla* to be 1.5 mL/L. Treatment levels were: P0 (control, no goat manure liquid organic fertilizer), P1 (0.5 mL/L), P2 (1.0 mL/L), P3 (1.5 mL/L), and P4 (2.0 mL/L).

Procedures

Production of Liquid Organic Fertilizer

Goat manure liquid organic fertilizer (LOF) was produced according to the procedure of Saputri¹². The manure was sun-dried and finely ground prior to use. Subsequently, 600 g of dried goat manure was mixed with 1.2 L of water, 30 g of dissolved palm sugar, and 7.2 mL of EM4 microbial activator. The mixture was homogenized and incubated in a sealed container for 14 days to allow fermentation. This fertilizer can be stored for up to six months at room temperature, provided that it is not exposed to direct sunlight¹³. After fermentation, the liquid phase was separated from the solid residue through cloth

filtration. Laboratory analysis revealed that the resulting LOF contained 1.80% organic carbon, 0.17% nitrogen, 0.14% phosphorus, and 0.07% potassium.

Preparing the Rearing Container

The container used in this study is a round plastic bucket measuring 60 cm in diameter and 45 cm high with a maximum capacity of 100 L of water $\pm$ 15 units. Before use, the container is first washed using KMnO₄ with a dose of 1 g/ 10 L of water. Furthermore, the container is filled with peat water to a height of 80 L. After that, aeration is installed to supply oxygen in the maintenance container.

Fertilization Process

Goat manure liquid organic fertilizer (LOF) was directly applied to experimental units containing 80 L of water. The experimental treatments consisted of five LOF dosages: P0 (control, no goat manure liquid organic fertilizer), P1 (0.5 mL/L), P2 (1.0 mL/L), P3 (1.5 mL/L), and P4 (2.0 mL/L). A single fertilizer application was performed at the initiation of the experiment.

Measurement of Water Quality Parameters

Water quality monitoring included measurements of total organic matter (TOM), phosphate, nitrate, carbon dioxide (CO₂), and dissolved oxygen (DO), which were conducted at the beginning, midpoint, and end of the experiment. Meanwhile, water temperature and pH were recorded daily throughout the experimental period.

Cultivation of *Lemna* sp.

The *Lemna* sp. used in this study was collected from Bangau Sakti Street, Simpang Baru Village, Tampan District, Pekanbaru, Indonesia. Prior to stocking, the plants were cleaned and acclimatized in freshwater-filled containers for three days according to the method of Astuti & Indriatmoko¹⁴. The initial stocking biomass was established based on the recommendation of Nisa¹⁵ at a density of

208.33 g m⁻². Therefore, each experimental unit, with a surface area of 0.2826 m², was stocked with 58.88 g of *Lemna* sp. Biomass was measured every three days to evaluate biomass accumulation during the culture period.

Snakehead Farming

The Snakehead juveniles used were 4–6 cm in total length, with a stocking density of 5 fish per 20 L^[16]. Thus, each experimental container held 20 fish in 80 L. Fish were fed commercial pellets (PF-800) ad libitum. Feeding was carried out for 30 days during the rearing period at a frequency of three times daily (08:00, 13:00, and 16:00). Sampling was performed in the afternoon by weighing 50% of the fish in each experimental container. Fish were weighed every 10 days over the 30-day period.

Measured Parameters

Absolute Biomass Growth of *Lemna* sp.

The absolute biomass gain of *Lemna* sp. was calculated according to Effendi⁵ using the following equation:

$$W_n = W_t - W_o$$

Description:

- W_n = Absolute biomass gain (g)
- W_o = Average biomass at the end of the experiment (g)
- W_t = Average biomass at the beginning of the experiment (g)

Specific Growth Rate of *Lemna* sp.

The specific growth rate (SGR) of *Lemna* sp. was calculated according to Zonneveld et al.¹⁷ as follows:

$$LPS = \frac{\ln w_t - \ln W_o}{t} \times 100\%$$

Description:

- LPS = Specific growth rate (%/day)
- W_t = Average biomass at the end of the experiment (g)
- W_o = Average biomass at the beginning of the experiment (g)
- t = Culture period (days)

Absolute Weight Gain of Snakehead Fish (*C. striata*)

The absolute weight gain of snakehead fish was calculated according to Effendie¹⁸ using the following equation:

$$W = W_t - W_o$$

Description:

W = Absolute weight gain (g)

W_o = Average final weight of fish (g)

W_t = Average initial weight of fish (g)

Specific Growth Rate of Snakehead Fish (*C. striata*)

The specific growth rate (SGR) of snakehead fish was calculated according to Zonneveld et al.¹⁷ as follows:

$$LPS = \frac{\ln w_t - \ln W_o}{t} \times 100\%$$

Description:

LPS = Specific growth rate (%/day)

W_t = Average final weight of fish (g)

W_o = Average initial weight of fish (g)

T = Culture period (days)

Survival Rate of Snakehead Fish (*C. striata*)

The survival rate (SR) was calculated according to Effendie¹⁸ using the following equation:

$$SR = \frac{N_t}{N_o} \times 100\%$$

Description:

SR = Survival rate (%)

N_t = Number of fish at the end of the experiment

N_o = Number of fish at the beginning of the experiment

Data Analysis

Water quality data, including total organic matter (TOM), phosphate, nitrate, carbon dioxide (CO₂), dissolved oxygen (DO), temperature, and pH, were tabulated and evaluated descriptively. Growth performance data of *Lemna* sp. and snakehead fish, including biomass gain, specific growth rate (SGR), absolute weight gain, absolute length gain, and survival rate, were analyzed using one-way analysis of variance (ANOVA). Significant treatment effects (P<0.05). When significant differences were observed, the Student–Newman–Keuls (SNK) multiple comparison test was applied to distinguish differences among treatment means and identify the most effective LOF dosage¹⁹.

3. RESULT AND DISCUSSION
Water Quality

The water quality parameters measured in this study included total organic matter (TOM), phosphate, nitrate, carbon dioxide (CO₂), dissolved oxygen (DO), temperature, and pH. The results of water quality measurements throughout the experimental period are presented in Table 1.

Table 1. Range of average water quality measurement

Parameters	Result					Reference
	P0	P1	P2	P3	P4	
BOT (mg/L)	7,58-37,10	12,64-41,11	13,90-45,86	15,17-49,14	16,43-55,72	>40 ⁵
Nitrate (mg/L)	0,0604-1,2729	0,0813-2,1063	0,0729-2,3875	0,0979-4,0958	0,1813-10,0229	1-10 ²⁰
Phosphate (mg/L)	0,0310-2,3451	0,1150-2,3960	0,2434-3,9668	0,6372-4,0398	0,6991-5,1416	4-22 ²¹
CO ₂ (mg/L)	3-10	3-11	4-13	4-16	5-18	<20 ²²
DO (mg/L)	4,87-5,52	4,91-5,59	4,71-5,31	4,42-5,29	4,10-5,21	3,70- 5,70 ²³
pH	6,7-7,6	6,6-7,6	6,5-7,6	6,5-7,6	6,2-7,4	6,5-8,5
Temperature(°C)	27-29,1	27-29	26,9-29,2	27-29,1	27,1-28,9	25,5-32,7

Description: P0 (control, no goat manure liquid organic fertilizer), P1 (0.5 mL/L), P2 (1.0 mL/L), P3 (1.5 mL/L), and P4 (2.0 mL/L).

The data presented in Table 1, P4 (2.0 mL/L) maintained water quality within

ranges suitable for the growth of snakehead fish and *Lemna* sp. Under this treatment,

total organic matter ranged from 16.43 to 55.72 mg/L, phosphate from 0.6991 to 5.1416 mg/L, nitrate from 0.1813 to 10.0229 mg/L, carbon dioxide (CO₂) from 5 to 18 mg/L, dissolved oxygen (DO) from 4.10 to 5.21 mg/L, pH from 6.2 to 7.4, and temperature from 27.1 to 28.9°C. Optimal water quality can support fish growth²⁴. The ability of *Lemna* sp. to assimilate dissolved nutrients, coupled with nutrient inputs from goat manure LOF, likely contributed to maintaining a stable aquatic environment that supported both plant and fish growth.

Total organic matter (TOM) concentrations increased in all treatments (P0–P4) throughout the culture period, ranging from 7.58–16.43 mg/L at the beginning of the experiment, 16.54–30.13 mg/L on day 15, and 37.10–55.72 mg/L on day 30. The highest TOM concentration was recorded in P4, while the lowest was observed in P0. The increase in TOM was likely caused by the accumulation of organic matter derived from goat manure LOF, uneaten feed, fish metabolic wastes, and decomposing *Lemna* sp. biomass. Boyd & Tucker²⁵ reported that increasing organic matter in aquaculture systems is generally associated with the accumulation of dissolved and suspended organic materials originating from culture activities. Similarly, Boyd & Lichtkoppler²⁶ stated that feed residues, fish excretion, organic fertilizers, and decomposing aquatic organisms are major sources of organic matter in culture waters. Furthermore, the continuous increase in *Lemna* sp. biomass without harvesting may have contributed to TOM accumulation²⁷.

Nitrate (NO₃⁻) is the primary form of nitrogen in natural waters and serves as a key nutrient for the growth of plants and algae²⁸. Nitrate concentrations increased in all treatments throughout the culture period. At the beginning of the experiment, nitrate concentrations were relatively low, ranging from 0.0604 to 0.1813 mg/L, with the lowest value recorded in P0 and the highest in P4. These concentrations were below the optimal range for *Lemna* sp. growth (1–10

mg/L) reported by Ming et al.²⁰. The low nitrate levels at the initial stage were likely due to the limited accumulation of nutrients from goat manure LOF and the low activity of nitrifying microorganisms. Similarly, Ahmad et al.²⁹ reported that nitrate concentrations are generally low during the early culture period because nitrogen remains predominantly in the form of ammonia.

From day 15 to day 30, nitrate concentrations increased markedly, particularly in P4, which consistently showed higher values than the other treatments. This increase was likely associated with greater nitrogen availability from goat manure LOF, which stimulated nitrification by *Nitrosomonas* and *Nitrobacter* bacteria. According to Fadillah et al.³⁰, elevated organic matter and dissolved nitrogen concentrations can accelerate nitrification under favorable environmental conditions. At the end of the study, nitrate concentrations increased in line with the increasing doses of liquid organic fertilizer (LOF) applied. This finding suggests that nitrification occurred effectively, converting toxic ammonia into nitrate, a less harmful form of nitrogen for aquatic organisms³¹.

Phosphate concentrations increased with culture duration and increasing doses of goat manure liquid organic fertilizer (LOF). At the beginning of the experiment, phosphate concentrations ranged from 0.0310 to 0.6991 mg/L, increasing to 1.8208 – 3.3031 mg/L on day 15 and 2.3451–5.1416 mg/L on day 30. The highest phosphate concentration was recorded in P4 (5.1416 mg/L), while the lowest was observed in the control treatment (2.3451 mg/L). This increase was likely associated with the decomposition of goat manure LOF, uneaten feed, and fish metabolic wastes.

According to Boyd & Lichtkoppler²⁶, phosphate accumulation in aquaculture systems commonly originates from feed residues and fish excretion. Despite the increase, phosphate concentrations remained within the range suitable for *Lemna* sp.

growth, which is reported to be 4–22 mg/L²¹. The availability of phosphate likely supported *Lemna* sp. growth, while nutrient uptake by the plant contributed to maintaining water quality through phytoremediation processes³². The availability of phosphate in aquatic environments is an indicator of water fertility; however, excessive phosphate levels can be harmful to cultured fish³³.

CO₂ concentrations increased with culture duration and increasing doses of goat manure liquid organic fertilizer (LOF). At the beginning of the experiment, CO₂ concentrations were relatively low, ranging from 3 to 5 mg/L, likely due to limited organic matter accumulation and low decomposition activity. According to Boyd & Lichtkoppler²⁶, CO₂ in aquaculture systems primarily originates from organism respiration and organic matter decomposition.

By day 15, CO₂ concentrations increased to 7–15 mg/L, with the highest value recorded in P4. This increase was likely associated with fish and microbial respiration as well as the decomposition of feed residues, fish feces, and organic fertilizer. The elevated biological activity resulting from LOF application may have contributed to higher CO₂ production. Dissolved CO₂ serves as an important carbon source for aquatic plants, including *Lemna* sp., supporting photosynthesis and biomass production³⁴.

At the end of the experiment, CO₂ concentrations ranged from 10 to 18 mg/L, with P4 exhibiting the highest value. The higher CO₂ concentration in P4 likely reflected greater organic matter accumulation from fish metabolism, uneaten feed, and decomposing fertilizer residues. This finding is consistent with Robinson et al.³⁵, who reported that respiration and microbial activity are major contributors to dissolved CO₂ accumulation in aquatic systems. *Lemna* sp. can utilize dissolved CO₂ concentrations below 50 mg/L for photosynthesis³⁶. Furthermore, all treatments remained within a tolerable range

for snakehead fish, indicating no adverse effects on fish survival. Nevertheless, excessive CO₂ should be avoided because it may reduce pH and dissolved oxygen levels, thereby affecting water quality³⁴.

Dissolved oxygen (DO) concentrations showed a generally decreasing trend throughout the culture period across all treatments. Insufficient oxygen availability in the culture water can impede the survival and physiological activities of cultured organisms³⁷. On day 1, DO values ranged from 5.21 to 5.52 mg/L, with the highest value recorded in P0 and the lowest in P4. The relatively high DO concentrations at the beginning of the experiment indicate that organic matter accumulation was still limited and microbial respiration activity remained low. According to Sari et al.³⁸, oxygen is consumed during the decomposition of organic matter by microorganisms. Therefore, the low organic matter content at the initial stage resulted in lower oxygen demand and higher DO concentrations.

From day 15 to day 30, DO concentrations declined in all treatments, likely due to increased decomposition of organic matter derived from uneaten feed, fish feces, and senescent *Lemna* sp. biomass. This process requires oxygen and consequently reduces DO levels. Similarly, Simarmata et al.³⁹ reported that increasing organic matter concentrations in aquatic environments can lower dissolved oxygen levels because oxygen is utilized during microbial decomposition. Despite this decline, DO concentrations remained within the optimal range for snakehead fish culture (3.70–5.70 mg/L) reported by Rahman et al.²³, indicating that the culture conditions were still suitable for fish growth and survival.

pH is an important parameter that determines water acidity and directly affects the stability of aquatic ecosystems, particularly by regulating nutrient availability and the solubility of chemical compounds. pH measured at the beginning,

midpoint, and end of the experiment for each treatment are presented in Figure 1.

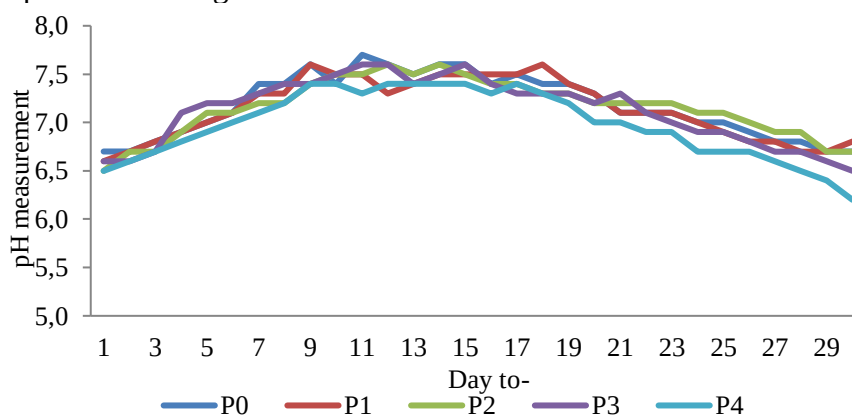


Figure 1. pH

The pH values increased from day 1 to day 8 and remained within the optimal range for the culture of snakehead fish and *Lemna* sp. From day 10 to day 18, pH values were relatively stable across treatments, ranging from 7.3 to 7.6. This stability was likely due to a balance between CO₂ produced through fish respiration and organic matter decomposition and CO₂ utilized by *Lemna* sp. during photosynthesis. In addition to supporting biomass growth, *Lemna* sp. assimilates nitrogen and phosphorus derived from fish metabolism and feed residues, thereby contributing to water quality maintenance. This finding is consistent with Ansari & Khan⁴⁰, who reported that *Lemna minor* effectively absorbs nutrients and improves water quality.

From day 19 to day 30, pH values gradually declined in all treatments, with the lowest value recorded in P4 (6.2), although still within the acceptable range for snakehead fish and *Lemna* sp. culture. Too low or too high pH conditions can affect the biological activities of aquatic organisms, including respiration, growth, and fish resilience. The decrease in pH was likely associated with increasing dissolved CO₂ concentrations observed during the experiment.

According to Suhartawan et al.³⁴, dissolved CO₂ reacts with water to form carbonic acid (H₂CO₃), which subsequently dissociates into hydrogen ions (H⁺) and

bicarbonate ions (HCO₃⁻), thereby lowering pH. These results indicate that *Lemna* sp. not only functions as a nutrient-removing phytoremediation agent but also contributes to maintaining pH stability through its influence on carbon dynamics in the culture system.

Water temperature remained similar among treatments throughout the experiment. Although daily fluctuations were observed, temperatures remained within the optimal range for the culture of *Lemna* sp. and snakehead fish (25–32.7°C). According to Tumembouw et al.⁴¹, daily temperature fluctuations are common in aquaculture systems and generally do not adversely affect aquatic organisms as long as temperatures remain within their optimal range.

Temperature is an important physicochemical factor influencing the metabolic activities of aquatic organisms. Faizah⁴² reported that water temperature directly regulates biochemical reactions, enzymatic activity, and physiological processes. Under optimal temperatures, photosynthetic activity and biomass production of *Lemna* sp. can be enhanced, while suitable temperatures also promote metabolism, feed utilization, and growth in snakehead fish. In addition, temperature affects other water quality parameters, including dissolved oxygen availability and microbial activity. Fadillah et al.³⁰ stated that

temperature influences oxygen solubility and the activity of microorganisms, particularly nitrifying bacteria. Therefore, the relatively stable temperature observed in this study likely supported a balanced aquatic environment without causing thermal stress to either *Lemna* sp. or snakehead fish.

Biomass Increment and Specific Growth Rate of *Lemna* sp

Observation data on biomass increase and specific growth rate of *Lemna* sp. during the study are presented in Table 2. The biomass gain and specific growth rate (SGR) of *Lemna* sp. differed among treatments. The

highest biomass gain was recorded in P4 (2.0 mL/L goat manure LOF), reaching 362.58 g/m², whereas the lowest was observed in the control (P0) at 182.05 g/m². Similarly, the highest SGR was obtained in P4 (6.56%/day), while the lowest was recorded in P0 (4.69%/day). The superior growth performance observed in P4 was likely associated with greater nutrient availability resulting from the higher LOF dosage. This finding is consistent with Zenir et al.⁴³, who reported that the growth of *Lemna* sp. is strongly influenced by nutrient availability, and nutrient deficiencies may limit plant development

Table 2. Biomass increment and specific growth rate of *Lemna* sp

Treatment levels	Biomass (g)	SGR (%/day)
P0 (control)	182,05 ± 10,21 ^a	4,69 ± 0,146 ^a
P1 (0,5 mL/L)	232,42 ± 9,86 ^b	5,33 ± 0,113 ^b
P2 (1mL/L)	232,95 ± 8,36 ^b	5,33 ± 0,092 ^b
P3 (1,5 mL/L)	284,92 ± 18,16 ^c	5,88 ± 0,175 ^c
P4 (2 mL/L)	362,58 ± 6,95 ^d	6,56 ± 0,055 ^d

The highest SGR obtained in this study (6.56%/day). This difference may be attributed to variations in nutrient composition, particularly nitrogen, phosphorus, and potassium concentrations, between the goat manure LOF and the dairy wastewater used in their study. According to Schmidt & Goldbach³⁶, the growth of *Lemna* sp. is largely determined by nutrient availability and favorable environmental conditions. These results indicate that goat manure LOF effectively enhanced the growth of *Lemna* sp. in the snakehead fish culture system. The following is Figure 2, a graph of the increase in biomass of *Lemna* sp.

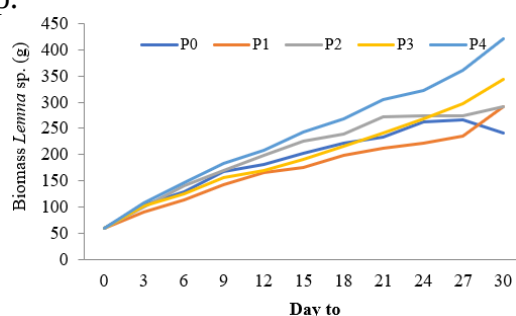


Figure 2. Biomass *Lemna* sp.

The biomass of *Lemna* sp. increased throughout the 30-day culture period in all treatments, indicating its ability to adapt and grow under the experimental conditions. However, biomass accumulation was greater in P4 than in P0, suggesting that goat manure liquid organic fertilizer (LOF) enhanced *Lemna* sp. growth. This result is consistent with Ullah et al.⁴⁴, who reported that the growth of *Lemna* sp. is strongly influenced by nutrient availability, particularly nitrogen and phosphorus, as well as environmental factors such as light intensity and pH.

Environmental factors, such as sunlight intensity during the rearing period, also influence the growth of *Lemna* sp.⁴⁵. No harvesting of *Lemna* sp. was conducted during the experiment to maintain its function as a phytoremediation agent capable of absorbing nitrogen, phosphorus, and organic matter from the snakehead fish culture medium. According to Ardiansyah & Fotedar²⁷, retaining *Lemna* sp biomass for longer periods can enhance biofiltration

performance and improve nitrogen removal efficiency in aquaculture systems.

Growth Performance Snakehead (*C. striata*)

The data on absolute weight gain, absolute length gain, and specific growth rate (SGR) of snakehead fish (during the experimental period are presented in Table 3. The highest absolute weight gain of snakehead fish was observed in P4 (2.0 mL/L), reaching 3.20 g. This result was

likely associated with the effectiveness of goat manure liquid organic fertilizer (LOF) in promoting *Lemna* sp. growth, thereby enhancing its capacity to absorb nitrogen and phosphorus from the culture medium and maintain favorable water quality conditions. Similarly, Budiman et al.⁴⁶ reported that improved *Lemna* sp. growth under nutrient-enriched conditions contributes to water quality enhancement through more efficient utilization of dissolved nutrients.

Table 3. Growth performance snakehead fish (*C. striata*)

Treatment levels	Absolute Weight (g/ind.)	SGR (%/Day)	Absolute Length (cm)
P0 (control)	1,19 ± 0,098 ^a	1,22 ± 0,083 ^a	2,92 ± 0,175 ^a
P1 (0,5 mL/L)	1,86 ± 0,155 ^b	1,70 ± 0,231 ^b	3,13 ± 0,080 ^{ab}
P2 (1 mL/L)	2,10 ± 0,155 ^b	1,85 ± 0,123 ^b	3,38 ± 0,257 ^{bc}
P3 (1,5 mL/L)	2,72 ± 0,196 ^c	2,42 ± 0,069 ^c	3,54 ± 0,141 ^c
P4 (2 mL/L)	3,20 ± 0,087 ^d	2,60 ± 0,162 ^c	3,88 ± 0,092 ^d

The highest specific growth rate (SGR) was also recorded in P4 (2.60%/day), whereas the lowest was observed in the control treatment (1.22%/day). The superior growth performance observed in the present study was likely related to improved water quality resulting from nutrient uptake by *Lemna* sp., which may have reduced the accumulation of potentially harmful compounds, minimized fish stress, and enhanced energy allocation for growth.

The highest absolute length gain was likewise obtained in P4, reaching 3.88 cm. The improved length growth was likely associated with the higher nutrient availability provided by goat manure LOF, which stimulated *Lemna* sp. development and enhanced its ecological functions within the culture system. According to Saputra & Samsudin⁴⁷, *Lemna* sp. and other aquatic macrophytes can function as biofilters and provide shelter for snakehead fish, thereby creating a more favorable environment for growth and survival.

Survival Rate of Snakehead Fish (*C. striata*)

Survival rate of snakehead fish during the experimental period are presented in Table 4.

Table 4. Survival rate snakehead fish

Treatment levels	Survival Rate (%)
P0 (control)	98 ± 98,33 ^a
P1 (0,5 mL/L)	98 ± 98,33 ^a
P2 (1 mL/L)	98 ± 98,33 ^a
P3 (1,5 mL/L)	100 ± 0,00 ^a
P4 (2 mL/L)	98 ± 98,33 ^a

As shown in Table 4, the survival rate observed in P3 (1.5 mL/L) indicates that this treatment provided the most favorable environmental conditions for snakehead fish. According to Anjarkasi et al.⁴⁸, high fish survival rates reflect optimal culture conditions. The absence of mortality in P3 suggests that snakehead fish were able to adapt well to the environmental conditions established under this treatment.

This result was likely associated with the balance between the applied goat manure liquid organic fertilizer (LOF) dosage and the capacity of the culture system to regulate organic matter and dissolved nutrients. Adi⁴⁹ reported that stable water quality, particularly in terms of dissolved oxygen and organic matter accumulation, is a key factor influencing fish survival. At a dosage of 1.5 mL/L, the LOF likely promoted the growth of *Lemna* sp. as a phytoremediation

agent without causing deterioration of water quality that could adversely affect fish health.

Furthermore, the presence of *Lemna* sp. contributed to maintaining water quality stability through the uptake of dissolved nutrients and organic matter. Astuti & Indriatmoko¹⁴ reported that aquatic plants can improve water quality and reduce fluctuations in environmental parameters, thereby supporting the survival of aquatic organisms. These findings suggest that P3 provided the most suitable culture environment for snakehead fish

4. CONCLUSION

The results of this study demonstrated that the application of goat manure liquid organic fertilizer (LOF) significantly

enhanced the biomass production of *Lemna* sp. in a snakehead fish culture system. The best performance was obtained in treatment P4 (2.0 mL/L), which produced the highest *Lemna* sp. biomass gain (362.58 g/m²) and specific growth rate (6.56%/day). In addition, goat manure LOF supported snakehead fish growth, resulting in an absolute weight gain of 3.20 g/individual, an absolute length gain of 3.88 cm, a specific growth rate of 2.60%/day, and a survival rate of 98%. Water quality parameters remained within acceptable ranges throughout the experimental period, indicating that the integration of *Lemna* sp. and goat manure LOF can improve nutrient utilization while maintaining a suitable culture environment for snakehead fish production.

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