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Synthesis of Slow-Release Biofertilizer from Aquaculture Sludge

(Penghasilan Biobaja Pelepasan Perlahan dari Enapcemar Akuakultur)

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ABSTRACT

The development of the aquaculture industry will grow by 37% in 2030 compared to 2016. This development will go hand in hand with the problem of pollution caused by the aquaculture industry. If sludge from aquaculture is not properly treated, pollution problems such as eutrophication in the discharge area. The recovery of nutrients from sludge can be used in the manufacture of slow release biofertilizers. The main objective of this research is to determine the nutrient content in aquaculture sludge, to produce, characterize a slow release biofertilizer synthesized from aquaculture sludge, and to determine the effect of slow release biofertilizer on plant growth. Slow release biofertilizers are produced to reduce the negative impact on the environment compared to conventional fertilizers. The main material that will be used is urea-formaldehyde as a coating and metric for nutrients from sludge. The process that will be carried out is condensation and sublimation. Sludge characterization will be done and the sludge has nutrient concentrations for nitrate (59 mg/g), nitrate (2 mg/g), phosphorus (10290 mg/g), ammonium (440 mg/g), and potassium (397 mg/g). . Therefore, aquaculture sludge is suitable as a slow release biofertilizer due to its high nutrient content. Next, it was found that the rate of nutrient release in the slow release biofertilizer continued to increase until the 15th day for all mediums while conventional fertilizer showed that nutrients had reached a constant rate. Based on the water medium together with slow-release biofertilizers and conventional fertilizers, slow-release biofertilizers have a much lower nutrient release rate than conventional fertilizers, namely potassium (47%), phosphorus (65%), ammonium (32%), nitrate (20%), and nitrite (30%). Nutrient release rates for conventional fertilizers all exceed 95% after day 15. Plant performance in slow release biofertilizers has been observed. Okra trees in slow release biofertilizer showed positive development while conventional and control fertilizers showed a decrease. This is because the plants in the slow release biofertilizer have seven living plants while for the conventional and control fertilizers only 4 and 1 are alive. If viewed in terms of the relative growth rate based on height, biofertilizer release shows a decrease like conventional fertilizer use and control. This is because the plants are mature after the 14th day. The relative rate of growth based on the number of leaves showed an increase starting on the 7th day to the 21st day for all types of medium used while it decreased on the 28th day. Finally, the relative rate of plants based on dry weight showed an increase on day 14 and a decrease on day 28 due to mature plant conditions. In conclusion, the sludge used has a high amount of nutrients and the slow release biofertilizer produced is better than conventional fertilizer in terms of periodic nutrient release.

Keywords: Aquaculture sludge; Slow release biofertilizers; Nutrient recovery; Urea-formaldehyde; Macronutrients and micronutrients

ABSTRAK

Perkembangan industri akuakultur akan berkembang sebanyak 37% pada tahun 2030 berbanding tahun 2016. Perkembangan ini akan berjalan seiring dengan masalah pencemaran yang berpunca daripada industri akuakultur. Jika enapcemar dari akuakultur tidak dirawat dengan baik, masalah pencemaran seperti eutrofikasi di dalam kawasan nyahcas. Pemerolehan semula nutrien daripada enapcemar dapat digunakan dalam pembuatan biobaja pelepasan perlahan. Objektif utama bagi uji kaji ini adalah untuk menentukan kandungan nutrien di dalam enapcemar akuakultur, untuk menghasilkan, mencirikan biobaja pelepasan perlahan yang disintesis daripada enapcemar akuakultur, dan untuk menentukan kesan biobaja pelepasan perlahan terhadap pertumbuhan tumbuhan. Biobaja pelepasan perlahan dihasilkan bagi mengurangkan impak negatif kepada persekitaran berbanding baja konvensional. Bahan utama yang akan digunakan adalah urea-formaldehid sebagai penyalut dan metrik kepada nutrien daripada enapcemar. Proses yang akan dijalankan adalah kondensasi dan pemejalwapan. Pencirian enapcemar akan dilakukan dan enapcemar mempunyai kepekatan *nutrien bagi nitrat (59 mg/g), nitrat (2 mg/g), fosforus (10290 mg/g), ammonium (440 mg/g), dan kalium (397 mg/g). Oleh itu, enapcemar akuakultur sesuai dijadikan sebanyak biobaja pelepasan perlahan kerana kandungan nutriennya yang tinggi. Seterusnya, didapati kadar pelepasan nutrien di dalam biobaja pelepasan perlahan terus meningkat sehingga hari ke-15 bagi semua medium manakala baja konvensional menunjukkan nutrien sudah mencapai kadar tetap. Berdasarkan medium air bersama biobaja pelepasan perlahan dan baja konvensional, biobaja pelepasan perlahan mempunyai kadar pelepasan nutrien yang jauh lebih rendah berbanding baja konvensional iaitu kalium (47%), fosforus (65%), ammonium (32%), nitrat (20%), dan nitrit (30%). Kadar pelepasan nutrien bagi baja konvensional semuanya melebihi 95% selepas hari ke-15.Prestasi tumbuhan didalam biobaja pelepasan perlahan telah diperhatikan. Pokok bendi di dalam biobaja pelepasan perlahan menunjukkan perkembangan yang positif manakala baja konvensional dan kawalan menunjukkan penurunan. Ini kerana tumbuhan di dalam biobaja pelepasan perlahan mempunyai tujuh tumbuhan yang hidup manakala bagi baja konvensional dan kawalan hanya 4 dan 1 sahaja yang hidup. Jika dilihat dari segi kadar relatif pertumbuhan berdasarkan ketinggian, biobaja pelepasan menunjukkan penurunan seperti penggunaan baja konvensional dan kawalan. Ini kerana keadaan tumbuhan yang sudah matang selepas hari ke-14. Kadar relatif pertumbuhan berdasarkan bilangan daun menunjukkan peningkatan bermula pada hari ke-7 hingga hari ke-21 bagi semua jenis medium yang digunakan manakala menurun pada hari ke-28. Akhir sekali, kadar relatif tumbuhan berdasarkan berat kering menunjukkan peningkatan pada hari ke-14 dan penurunan pada hari ke-28 kerana keadaan tumbuhan yang sudah matang. Kesimpulannya, enapcemar yang digunakan mempunya jumlah nutrien yang tinggi dan biobaja pelepasan perlahan yang dihasilkan adalah lebih baik berbanding dengan baja konvensional dari segi pelepasan nutrien secara berkala..*

Kata Kunci: Enapcemar akuakultur; Biobaja pelapasan perlahan; Pemerolehan semula nutrien; Lignin urea-formaldehid; Makronutrien dan mikronutrien

INTRODUCTION

The United Nations Food and Agriculture Organization (FAO) reported in 2018 that the aquaculture sector is expanding more quickly than any other area of food production. The aquaculture industry is a form of agriculture that involves the breeding, cultivation, and marketing of aquatic animals and plants in a controlled environment (Pillay 2004). There are three types of aquaculture systems, namely saltwater aquaculture, freshwater aquaculture, and land-based aquaculture. Based on Pillay (2004), the main types of waste in hatcheries or production farms can be divided into three parts, namely food waste and faecal matter, metabolic products, and biocide and biostat waste. The natural feeding habits of fish species, fish stocking density, total fish biomass, food waste, rate of input feed, water quality, and water management that affect nutrient uptake by fish, as well as water production waste, are the main causes of aquaculture sludge. (Rafiee et al. 2005). The determination of macronutrient and micronutrient content in sludge is important to determine the appropriate technology or process in nutrient recovery. Table 1 shows the nutrient percentage and recovery of nutrients in sludge.

TABLE 1. Nutrient percentage and recovery of nutrients in aquaculture sludge

Types of nutrients	Percentage in sludge (%) (based on dry matter)	Recovery percentage (%)
Nitrogen, N	6	-
Phosphorus, P	18	54.2
Potassium, K	6	26-71
Calcium, Ca	16	64.95
Magnesium, Mg	89	57.29
Ferum, Fe	24	NA
Mangan, Mn	86	13.18
Zink, Zn	47	24.60
Copper, Cu	22	21.79
References	Goddek et al. (2019)	Delaide et al. (2018)

Source: Zhang et al. 2021

There are various methods or technologies that can be used for the sludge nutrient recovery process such as based on biofiltration, physical filtration, and chemical filtration. The fertilizer industry faces a confronts a continuing challenge to improve its products to maximize the effectiveness their use, and to reduce any potential negative effects on the environment. Fertilizer is a chemical or natural substance added to soil or soil to improve its fertility. The main components in fertilizer are nitrogen (N), phosphorus (P), and potassium (K) (Fu et al. 2018). Various types of fertilizers are introduced such as chemical fertilizers, slow-release fertilizers and so on which have their own advantages and disadvantages. To ensure that food supply keeps pace with the growth in global population, a forecast of fertilizer demand is required. (Yahya 2018). Increasing the amount of fertilizer use will have negative effects on the environment such as increasing soil acidity, harmful emissions, causing groundwater pollution, etc. This happens because the release rate per unit time of nutrients is usually much higher than the absorption rate by plants (Pang et al. 2018). Based on Fertahi et al. (2021), only a portion of conventional fertilizers are used by plants and the remainder is lost to the environment. Leaching, mineralization, NH_3 volatilization, gaseous emissions such nitric oxide, soil erosion, and denitrification processes all result in the loss of between 40-70% of the nitrogen content. The goal of using slow-release fertilizers is to ensure that no nutrients should be limited for plant uptake, there should be an increase in nutrient absorption efficiency, and the potential for nutrient leaching should be reduced. Although nutrients are released from slow-release fertilizers (SRFs) more slowly than usual, the pace, pattern, and length of the release are not well controlled. (Trenkel 2010).

METHODOLOGY

Analysis of Macronutrients and Micronutrients in Aquaculture Sludge

Aquaculture sludge will be separated first using the sedimentation method for 3 days. Excess water from the aquaculture sludge sedimentation process will be removed and the sludge will be dried for a week until completely dry. After that, the sludge solids will be crushed using an electric powder grinder until it becomes powder. A ratio of 1:10, sludge (4 g) to deionized water (40 mL) will be used in the process of dissolving sludge in water for sample preparation. The sample will be put through a centrifuge tube and a multi-rotor shaker (DE-2008, China) at 60 rpm for an hour (Hoskins et al. 2009). Next, the centrifuge tube was put into a centrifuge (Centrifuge 5810, Germany) at 4000 rpm for 10 min. Then, the sample will be separated between solid and liquid using a vacuum filter (DOA-P504-BN, Texas). The separated liquid will be put into a 10 mL ion chromatography tube for each sample anion and cation. Samples were analyzed using ion chromatography (Morphy/882 Compact IC Plus).

Synthesis of Slow Release Biofertlizer

50 ml of distilled water was measured and 10 g of urea was weighed and put into a beaker with a capacity of 250 mL. Next, the mixture in the beaker was heated at a temperature of 27 ℃ for 10 min and at a speed of 80 rpm using a magnetic stirrer. Next, 6.5 g of formaldehyde and 50 mL of distilled water were put into a beaker and heated at a temperature of 60℃ for 2 hours and at a speed of 80 rpm. After that, 10 g of aquaculture sludge was mixed in the beaker slowly and heated at a temperature of 27℃ for 10 min and at a speed of 80 rpm. After that, the pH of the sample will be analyzed to ensure it is in the 7-8 range. If the pH is not reached, add a few drops of 4% (m/m) NaOH solution or distilled water into the mixture for 10 min at 80 ℃ and 80 rpm. Finally, the mixture will be dried in an oven at a temperature of 35℃ until an even weight is reached (González-Hurtado et al. 2021; Martínez et al. 2019; Pang et al. 2018).

Characterization of Slow-Release Biofertilizers in Water

15 g of slow release biofertilizer will be soaked in 600 mL of water at room temperature (28℃). The analysis will be carried out for 4 weeks to see the percentage of nutrients released. Samples will be taken every 2 days for 2 weeks. The sample will be sent to the laboratory to determine the content of nitrogen, potassium, and phosphorus. The content of nitrogen, phosphorus, and potassium will be determined using ion chromatography. This step will be repeated using chemical fertilizers by replacing slow-release biofertilizers (Martínez et al. 2019).

Characterization of Slow-Release Biofertilizers in Soil and Sand

15 g of slow release biofertilizer will be mixed with 500 g of soil (under 2 mm diameter) and stored in a 1000 mL beaker covered for 2 weeks at room temperature (28℃). Next, 500 mL of distilled water was added to the beaker. 500 g of soil will be isolated as a control sample. Samples will be taken every 2 days for 2 weeks. The sample will be sent to the laboratory to determine the content of nitrogen, potassium, and phosphorus. The content of nitrogen, phosphorus, and potassium will be determined using ion chromatography. This step will be repeated using chemical fertilizers by

replacing slow release biofertilizers (Martínez et al. 2019). Figure 1 shows experimental arrangement for the characterization of slow-release rates of slow-release biofertilizers and conventional fertilizers.

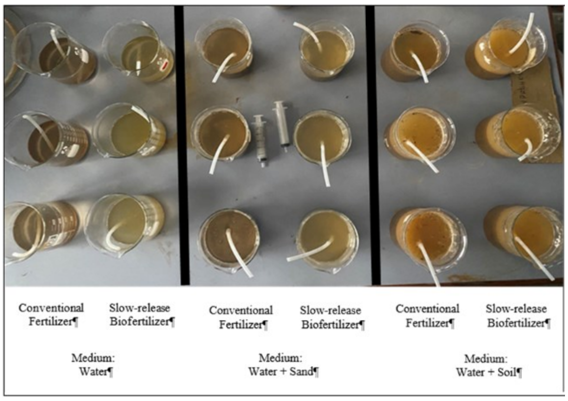


Figure 1 Experimental arrangement for the characterization of release rates of slow-release biofertilizers and conventional fertilizers.

Cultivation of Plants in Slow-Release Biofetrilizers

Determine the relative growth rate of plants based on the type of slow release biofertilizer and conventional fertilizer using soil medium. The field experiment was conducted in the Greenhouse, Universiti Kebangsaan Malaysia (UKM) in 2023 with the experimental period (May to July). The experiment started with a nursery of okra bean seedlings branded Grabbit for a week in cotton mixed with water. After that, the okra seedlings will be transplanted into a nursery containing garden soil with a concentration of 0.50% (w/w) nitrogen, 0.40% (w/w) phosphorus, and 0.50% (w/w) potassium. Garden land was purchased from Kean Beng Lee Indsutries (M) Sdn. Bhd. Figure 2 shows the sown okra seedlings.

Figure 2 Okra seedling nursery

Plants in the Soil Medium

The okra tree from the nursery will be transplanted into a larger site filled with soil from the plant house. This study uses soil medium as a constant enabler. There are nine sites that will be used for manipulators, three for slow release biofertilizer, three for conventional fertilizer, and three for control. The amount of fertilizer nutrients used for slow-release biofertilizer, and conventional fertilizer is the same, which is 10 g of slow-release biofertilizer and 2 g of conventional fertilizer. Each site will have only three trees to ensure that the plants can live healthily and with less competition (Rahman 2016). Observation of the okra tree will be observed every day in the first week and once a week in the following week for a month. Wet and dry weight of trees will be taken five times throughout the trial period for slow release biofertilizer, conventional fertilizer, and control. Okra trees will be taken separately from the three sites provided. Figure 3 shows arrangement of plants in the soil.

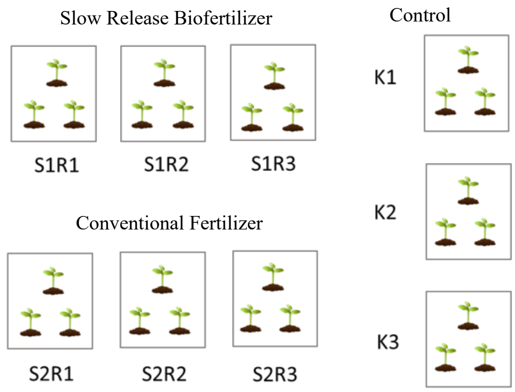


Figure 3 Arrangement of plants for observation and relative rates of plants.
(S1= slow release biofertilizer, S2= conventional fertilizer, K= control)

DATA COLLECTION

Macronutrient and Micronutrient Content

After being analyzed, the amount of nitrogen, phosphorus, and potassium content in the sludge was plotted and compared with urea, conventional fertilizer, slow release biofertilizer, sand, and soil. A graph will be plotted based on the composition of the content against the type of nutrient.

Determination of Slow Release Biofertilizers in Water, Sand, and Soil

The main data are the slow-release rates of nitrite, nitrate, ammonium, phosphorus, and accumulated potassium. Calculation and analysis will be done for slow release biofertilizer and conventional fertilizer for the three replicates prepared. Alternatively, the mean of the data will be calculated and then a graph of the accumulated nutrient release rate against the day will be plotted for both fertilizers. This is done to show the difference between slow release biofertilizers and conventional fertilizers. This step is repeated for soil and sand medium.

Observations on Plant Height

The okra seedling time with the same amount of fertilizer nutrients used will be measured for a period of one month. Observations are done once a week for a month.

Relative Growth Rate (RGR)

Growth analysis is a widely used analytical tool to characterize plant growth. Of the parameters usually calculated, the most important is relative growth. The relative rate of growth will be calculated based on Hoffman et al. 2002 as shown in Formula (1)

$$r = \frac{\ln(W_2) - \ln(W_1)}{t_2 - t_1} \tag{1}$$

where,
r = relative growth rate (g/day)
W1 = plant dry weight (initial) (g)
W2 = plant dry weight (final) (g)
t1 = plant start time (days)
t2 = plant time taken (days)

The RGR will calculate based on the height, number of leaves and dry weight of the plant.

RESULTS AND DISCUSSIONS

Characterization of Aquaculture Sludge

Characterization was done using ion chromatography to identify the presence of nitrite, nitrate, ammonium, phosphorus, and potassium in aquaculture sludge. Figure 4 shows a graph of nutrients in aquaculture sludge.

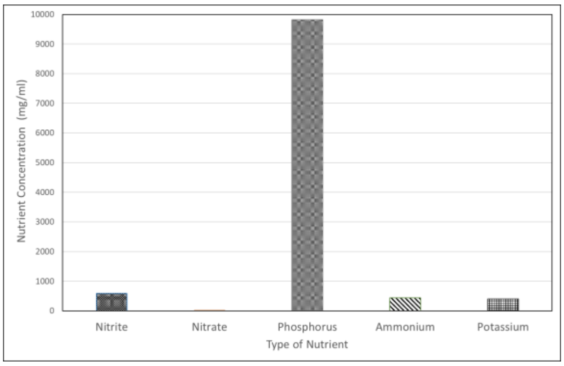


Figure 4 Nutrient concentration in aquaculture sludge.

Based on Figure 4, nitrite, nitrate, and ammonium represent the nitrogen content in the aquaculture slurry. Based on the results obtained, aquaculture sewage has the highest concentration of phosphorus which is 87% compared to others and is followed by Nitrite, ammonium, and potassium of 5%, 4%, and 4%. The concentrations of phosphorus, ammonium, potassium, nitrite, and Nitrate obtained from 4 g of aquaculture sludge were 9820 mg/ml, 592.8 mg/ml, 439.8 mg/ml, 396.7 mg/ml, and 11.4 mg/ml.

Based on Alnawajha et al. (2022) and Zhang et al. (2022), phosphorus has a higher concentration of nutrients compared to others, followed by nitrogen. However (Pillay 2004), shows that nitrogen content is higher compared to phosphorus by 4 times. The concentration of nutrient content in aquaculture is influenced by the type of farm animals, the state of the aquaculture ecosystem, the composition of fish food, and the results of metabolism. For example, the phosphorus content can change from time to time such as in the first week the phosphorus content is 1.7% and the second week becomes <1.0% (Pillay 2004). This shows that using the same resource will also produce different amounts of nutrients.

Nutrient Concentration in Fertilizer

Materials used in slow release biofertilizer production and analysis have been characterized. This is to differentiate the nutrient content of each material used and to prove that nutrients in aquaculture sludge can be used in the production of slow release biofertilizers. Figure 5 shows the difference in nutrient concentration for aquaculture sludge, urea, conventional fertilizer, slow release biofertilizer, sand, and soil.

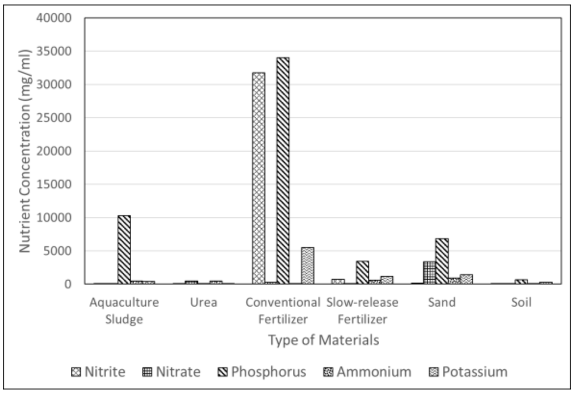


Figure 5 Differences in nutrient concentrations

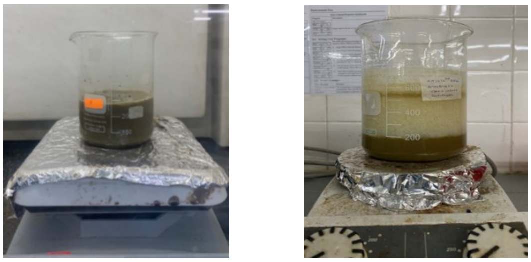
From Figure 5, the nutrient content in conventional fertilizer has the highest compared to other ingredients for nitrite and phosphorus but no nitrate content can be detected. In addition, for nitrate content, sand has the highest concentration of 4 g of characterized samples. Based on the data obtained, it can be seen that the nutrient content of sand exceeds soil. For example, the concentration of phosphorus in sand is 6796 mg/ml but in soil is 657 mg/ml. This happened because the sand was taken from the Greenhouse, Universiti Kebangsaan Malaysia. The Greenhouse is where students do research. There is a possibility that the sand taken has been mixed with other nutrients while being used by other students.

Next, aquaculture sludge has a higher Nitrite concentration than urea, which is 59 mg/g for sludge and 13 mg/ml for urea. Phosphorus concentration is also high in aquaculture sludge which is 10290 mg/ml compared to urea which is 7 mg/ml. Therefore, the production of slow release biofertilizers does not have a significant impact on nutrient use because nutrients in aquaculture sludge are higher than urea.

From Figure 5, conventional fertilizers have the highest concentration of phosphorus and Nitrite among all. If it is seen that there is a decrease in phosphorus when slow release biofertilizer is produced despite using the same amount when characterized. This is because the liquefaction during the slow release biofertilizer production process and the nutrients in the sludge can change based on the type of fish and the day the sludge is taken (Pillay 2004).

Slow Release Biofertilizer Production

Observations are made during the production of slow release biofertilizers. There are two types of slow release biofertilizers that are produced if the parameters used are well controlled. Figure 4.4 and Figure 6 (a) and (b) show homogeneous and non-homogeneous slow release biofertilizer conditions.



(a) (b)

Figure 6 Homogeneous (a) and non-homogeneous (b) slow release biofertilizer conditions

Formulation is the main parameter that controls nutrient release rates. It depends on the component and its compatibility, its hydrophilic or hydrophobic nature, and its concentration (Fertahi et al. 2021). Formulation is the main parameter that controls nutrient release rates. It depends on the component and its compatibility, its hydrophilic or hydrophobic nature, and its concentration (Rivera et al., 2021). The hydrophobic/hydrophilic nature of the formulation used in the preparation of the coating is an important parameter for the nutrient release rate. When the coating material is hydrophobic, the interaction between the coating and water is weak. This lack of interaction prevents the penetration of large quantities of water into the fertilizer core and it reduces dissolution (Fertahi et al., 2021). So, urea-formaldehyde is suitable for use as a coating but parameters such as temperature must be controlled to ensure that the resulting solution is homogeneous.

Nitrite Release Rate

Nitrite release rate was determined based on Nitrate concentration using ion chromatography. Figure 7 shows the nitrite release rate of slow-release biofertilizer and conventional fertilizer for 15 days.

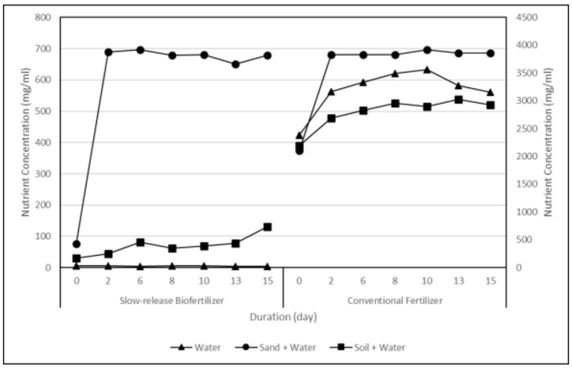


Figure 7 Nitrite release rates for slow release biofertilizers and conventional fertilizers

Based on Figure 7, the nitrate release rate at the beginning of the experiment did not show any high nutrient production in all mediums. For the medium of sand and water, the level of Nitrate released is high compared to other mediums and remains at a constant rate until the 15th day. On the 2nd day, the nutrient content released is called the "burst effect" (Ramli 2019).

Next, for the soil medium with water, an increase in Nitrite can be seen starting from the 6th day and the 15th day. The gradual increase indicates that the slow-release biofertilizer has released its nitrite content periodically. The nutrient release is aided by soil moisture content and also aided by microbial activity. In addition, the release of nitrite in the water medium alone did not show a big change but the concentration of nitrite was increasing day by day. A total of 35% of nitrite was released on the 15th day for the water medium based on the amount of Nitrite used at the beginning of the experiment.

In addition, conventional fertilizers show a rapid and rapid increase in Nitrite release resulting in high initial concentrations. The release of nitrite reached a constant level in the 2nd day for all types of medium and showed a faster release of nitrogenous compounds compared to slow-release fertilizers. The rapid release of nitrite from conventional fertilizers has the potential to cause nutrient leaching and environmental pollution if not promptly absorbed by plants. Based on the water medium, as much as 95% of nitrites are released after the 15th day for conventional fertilizers. This means that the nitrite release rate of conventional fertilizers is higher compared to slow release biofertilizers produced. The total concentration of nitrites in conventional fertilizers is higher compared to slow release biofertilizers produced. Therefore, there will be a difference in nitrite concentration during the determination of nitrite release rate.

Nitrate Release Rate

Nitrate release rate was determined based on nitrate concentration using ion chromatography. Figure 8 shows the nitrate release rate of slow release biofertilizer and conventional fertilizer for 15 days.

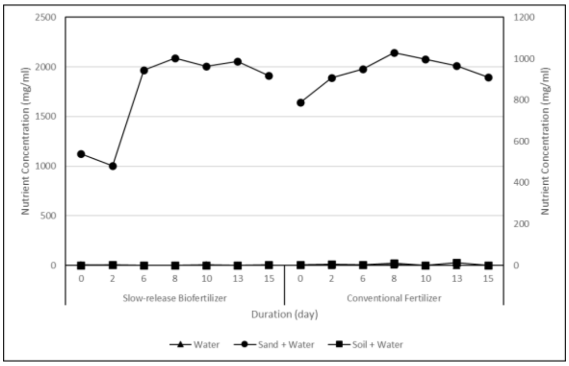


Figure 8 Nitrate release rates for slow release biofertilizers and conventional fertilizers

Based on Figure 8, nitrate emission rates for soil and water medium show small changes and can be considered the same all the time because the concentration is too little. However, for the water medium, the amount of nitrate released is only 20% of the total amount given. This means that there are still many Nitrates that have not been released. In addition, for the sand mixed with water medium, a high rate of nutrient release occurred on the 6th day and remained at a constant rate until the 15th day.

Next, the nitrate content of soil and water medium is the same as the use of slow release biofertilizer where there is no significant change. nitrate release for conventional fertilizer shows that the rate of nutrient release is constant from the first day to the 15th day. This happens because conventional fertilizers do not have any coating to slow down the nutrient release process. In addition, the amount of nitrates in the slow release biofertilizer produced is higher compared to conventional fertilizers. Therefore, nitrate concentration will be higher in slow release biofertilizers.

Phosphorus Release Rate

Phosphorus release rate was determined based on phosphorus concentration using ion chromatography. Figure 9 shows the Nitrate release rate of slow release biofertilizer and conventional fertilizer for 15 days.

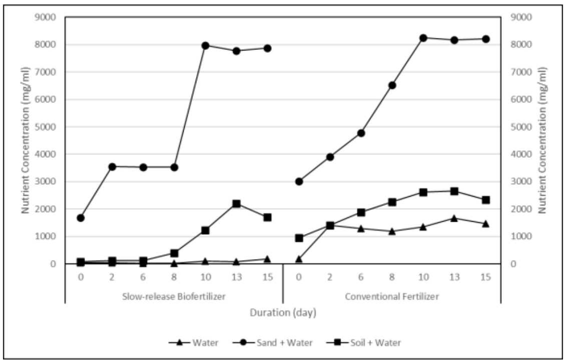


Figure 9 Phosphorus release rates for slow release biofertilizers and conventional fertilizers

Based on Figure 9, the release of phosphorus for the sand mixed with water medium occurs on the 2nd and 10th day. For the medium of soil mixed with water, starting on the 6th day, the proportional release of phosphorus continues until the 13th day. This also happens in water medium with slow release biofertilizer until day 15. This shows the periodic release of phosphorus for the slow release biofertilizer produced. Based on the water medium, the slow release biofertilizer released is as much as 65% of the total amount of phosphorus used.

In addition, for conventional fertilizers, the medium of soil mixed with water and sand mixed with water showed a constant phosphorus release rate on the 10th day but in the water medium it showed a constant phosphorus release on the 2nd day. This is due to the occurrence of microbial activity in the soil and sand medium which increases the concentration of nutrients.

Ammonium Release Rate

Ammonium release rate was determined based on ammonium concentration using ion chromatography. Figure 10 shows the Nitrate release rate of slow release biofertilizer and conventional fertilizer for 15 days.

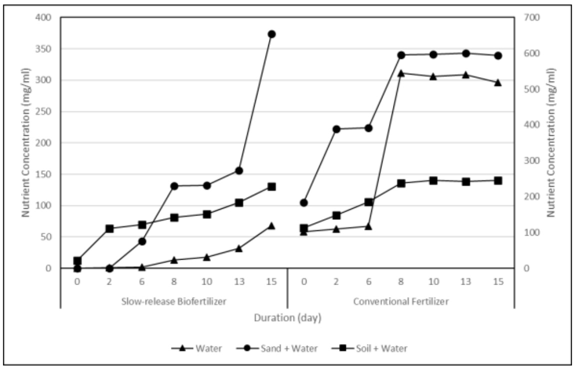


Figure 10 Ammonium release rates for slow release biofertilizers and conventional fertilizers

Based on Figure 10, for the slow release biofertilizer, the soil medium mixed with water showed consistent ammonium release starting from the first day to the 15th day. An increase in the release of ammonium in the water can also be seen from the 6th day to the 15th day. Sand medium with water showed significant improvement on day 8 and day 15. This is because the slow release biofertilizers produced, release nutrients little by little. A significant increase in the sand medium occurs because sand releases nutrients more easily than soil. Only 32% of ammonium was released after the 15th day for the water medium with slow release biofertilizer.

In addition, conventional fertilizer also showed an increase in ammonium but only until the 6th day and a constant rate until the 15th day. This applies to all mediums used. This happens because conventional fertilizers do not have a coating to withstand the gradual release of nutrients. Based on water medium with conventional fertilizers, more than 98% of ammonium is released on the 6th day from the total amount of ammonium supplied.

Potassium Release Rate

Potassium release rate was determined based on potassium concentration using ion chromatography. Figure 11 shows the potassium release rate of slow release biofertilizer and conventional fertilizer for 15 days.

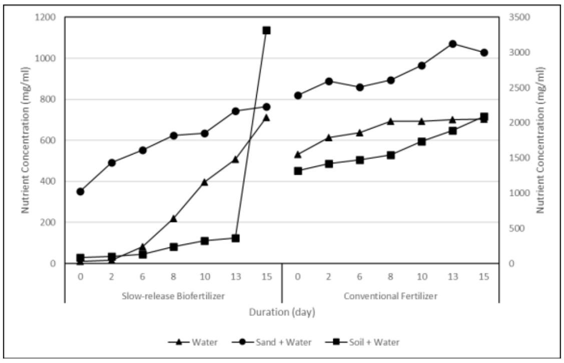


Figure 11 Potassium release rates for slow release biofertilizers and conventional fertilizers

Based on Figure 11, for slow release biofertilizers, the release of potassium for the water medium showed a high increase starting from the 6th to the 15th day. The state of potassium release in the sand medium is directly proportional and consistent from the first day to the 15th day. Next, the potassium release rate showed a gradual increase from the first to the 13th day for the soil medium but on the 15th day a high increase in potassium release occurred. This is caused by the inhomogeneous urea-formaldehyde matrix coating and causes water to easily break the coating and release a lot of nutrient content. Based on water medium and slow release biofertilizer, only 47% of the potassium content is released after the 15th day.

For conventional fertilizers, all three mediums showed a consistent release of potassium because there was not much difference between the days. The concentration of potassium is higher in the medium of water and sand than in soil because the release of potassium in water and sand is easier than in soil. Based on water medium with conventional fertilizers, more than 98% of potassium is released on the 6th day from the total amount of potassium supplied.

Comparison of Nutrient Release rate

Nutrient release rates will be compared with previous studies. Table 2 shows the nutrient release rate for the experiment conducted and previous studies.

TABLE 2. Nutrient release rates using different methods

Types of nutrients	Type of Coating	Nutrient Release Rate	Reference
Aquaculture sludge	Urea-formaldehyde matrix	After 15 days: ▪ Potassium: 47% ▪ Phosphorus: 65% ▪ Ammonium: 32% ▪ Nitrate: 20% ▪ Nitrite: 35%	The experiment conducted
Marine plants: ▪ *Thalassia testudium* (Thr) ▪ *Syringodium filiforme* (Sr)	Urea-formaldehyde matrix	After 30 days: ▪ Potassium: 18-32% ▪ Nitrogen: 18-26% ▪ Phosphorus: 12-20%	Yasnay et al. (2021)
Microalgae: ▪ *Chlorella sp* (CHLO) ▪ *Nannochloropsis sp* (NANNO)	Polymeric Urea-formaldehyde matrix	After 30 days: ▪ Potassium: 46–50% ▪ Nitrogen: 26-48% ▪ Phosphorus: 26-32%	Siverio et al. (2020)
Inorganic compound: Dipotassium phosphate, K_2HPO_4	Urea-formaldehyde matrix with lignin	After 21 days:: ▪ Potassium: 80.64% ▪ Nitrogen: 67.41% ▪ Phosphorus: 85.34%	Pang et al. (2018)

Based on Table 2, the nutrient release rate from the experiment conducted is almost the same as the previous reference although there are some that have different values.

Observation of Plants

Plant observations were observed for each week for a month for slow release biofertilizer, conventional fertilizer, and control without any fertilizer. Table 3 shows observations of plants in the soil.

TABLE 3. Observation of plants

Time Period, days	Type of Fertilizer		
	Slow-release Biofertilizer	Conventional Fertilizer	Control
First day			
Day-7			
Day-14			
Day-21			
Day-28			

Based on Table 3, on the first day after transplanting the plants from the nursery, the plants showed wilting for all types of fertilizers used. This is because the plant is adapting to the new environment. On the 7th day, all the plants using the slow release biofertilizer grew faster compared to the conventional fertilizer and the control. On the 14th day, eight out of nine plants were alive for the slow release biofertilizer while for the conventional fertilizer six out of nine plants were alive. Plants in the control that is without fertilizer only four managed to grow after 14 days. On the 21st day, the plants in the slow release biofertilizer were still the same as on the 14th day, growing healthy. For conventional fertilizers, one out of five living plants wither due to competition for nutrients. Only two plants survived in the control medium. This is due to the lack of nutrients obtained.

On the 28th day, it was found all plants were still alive in the application of slow release biofertilizer. This indicates that nutrients are released slowly to reduce the rate of nutrient loss. For the use of conventional fertilizers, one out of five plants have withered because there is competition for nutrients. The control medium also showed the same thing where one out of two plants had withered because the nutrients in the soil were getting less and less. Therefore, the use of slow release biofertilizer can last for 28 days with only one application of fertilizer while conventional fertilizer can only last until the 14th day when the plant starts to show the wilting process. In addition, three out of six plants that used slow release biofertilizers had young okra seedlings. This happens because the nutrients supplied are sufficient.

Relative Growth Rate of Plant

The relative rate of growth will be based on the height, number of leaves, and dry weight of the plant. Figure 12 shows the relative rate of growth based on height and number of leaves.

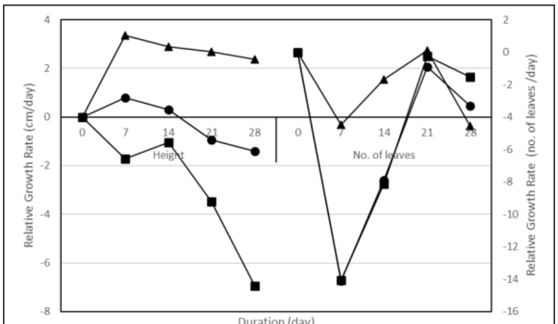


Figure 12 Relative rate of growth based on height and number of leaves

Based on Figure 12, plants that use slow release biofertilizer grow faster in the first seven days. Plants in the control showed a decrease in height because the plants took time to find nutrients in the soil when compared to others where nutrients were supplied. On the 14th day, the plants in the slow release biofertilizer and the conventional fertilizer were not as fast as in the previous week. The plants in the control are already showing positive growth although there are some dead plants. Next, all mediums showed a decrease in the relative growth rate for height on the 21st and 28th day. This is because the plant used is one month after the nursery and in the 6th week, the plant used, which is the okra tree, has started to mature. Therefore, mature plants will cause growth to slow down. However, the relative rate of growth for the use of slow release biofertilizers only showed an insignificant decrease and unlike the use of conventional and control fertilizers.

Next, if seen in the first week the number of leaves for all mediums shows a decrease. The plant has already withered and caused some of its leaves to fall because the plant takes time to adapt to the new environment. On the 14th and 21st day, all plants showed an increase in the number of positive leaves compared to the 7th day. This happens because the plants have started to adapt and get enough nutrients. Next, on day 28, all mediums showed a decrease in the number of leaves. The leaves on the bottom will wither faster than the ones on top because the sunlight does not reach. This is especially true for the use of slow release biofertilizers. It can be seen in Table 12, the slow release biofertilizer has thick leaves at the top causing the leaves below to wither. Conventional and control fertilizers showed a decrease due to the lack of nutrients supplied. Figure 13 shows the relative growth rate based on plant dry weight.

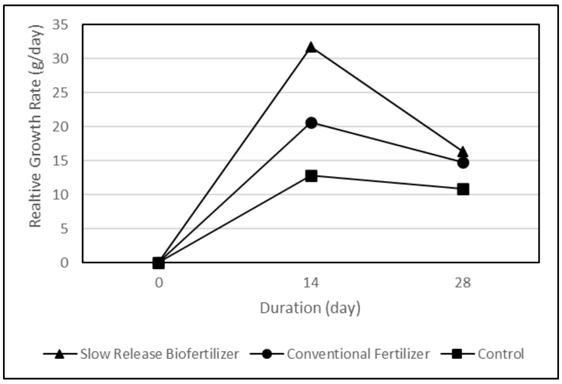


Figure 13 Relative rate of growth based on dry weight

Based on Figure 13, on the 14th day, the relative growth rate showed an increase for all types of medium. The use of slow release biofertilizer showed a rapid increase in growth compared to slow release biofertilizer and the control despite using the same plants. On the 28th day, all mediums show a decrease in the relative growth rate based on dry weight because the plants are mature and the growth process will slow down.

CONCLUSION

Increased production of aquaculture sludge and excessive use of conventional fertilizers can cause pollution to the environment. The use of aquaculture sludge in the production of slow release biofertilizers can solve this problem. The objective of the experiment conducted is to characterize the aquaculture sludge, to determine the nutrient release rate from the slow release biofertilizer produced, and to determine the performance of the plants in the slow release biofertilizer.

The first objective which is the characterization of aquaculture sludge has been characterized using ion chromatography. Sludge has nutrient concentrations of nitrate (59 mg/ml), nitrate (2 mg/ml), phosphorus (10290 mg/ml), ammonium (440 mg/ml), and potassium (397 mg/ml). Therefore, aquaculture sludge is suitable as a slow release biofertilizer due to its high nutrient content.

Determination of nutrient release rate is carried out. A total of three mediums are involved, namely water, sand, and soil. It was found that the rate of nutrient release in the slow release biofertilizer continued to increase until the 15th day for all mediums while the conventional fertilizer showed that nutrients had reached a constant rate. Based on the water medium together with slow release biofertilizer and conventional fertilizer, slow release biofertilizer has a much lower nutrient release rate compared to conventional fertilizer namely potassium (47%), phosphorus (65%), ammonium (32%), nitrate (20%), and nitrite (30%). Nutrient release rates for conventional fertilizers all exceeded 95% after the 15th day.

Plant performance in slow release biofertilizers was observed. Okra trees in slow release biofertilizer showed positive development while conventional and control fertilizers showed a decrease. This is because the plants in the slow release biofertilizer had seven plants alive while for the conventional fertilizer and the control only four and only one lived in the first seven days. If viewed in terms of the relative growth rate based on height, biofertilizer release shows a decrease like conventional fertilizer use and control. This is because the plants are mature after the 14th day. The relative rate of growth based on the number of leaves shows an increase starting from the 7th day to the 21st day for all types of medium used and a decrease on the 28th day because the leaves at the bottom do not get enough sunlight. Finally, the relative rate of plants based on dry weight showed an increase on day 14 and a decrease on day 28 due to mature plant conditions.

Therefore, the sludge used has a high amount of nutrients and the slow release biofertilizer produced is better than conventional fertilizers in terms of periodic nutrient release.

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