Pumakkal compost formula for degrading shrimp pond sediment (As a learning source of Biology subject)

Euis Ariyani¹, Agus Sutanto¹, Agus Sujarwanta¹, Hening Widowati¹, Achyani¹

¹Biology Education Postgraduate Program, Muhammadiyah Metro University

*Corresponding author: sutanto11@gmail.com

Abstract. Research used completely randomized design (CRD) 5 treatments of C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria) 5 replications. Compost quality is measured activated carbon, Nitrogen (N), C / N ratio, levels of phosphorus (P), calcium (Ca) and potassium (K). A total of 30 samples weighing 300 g each after 30 days of fermentation was analyzed in the Chemistry Laboratory of the University of Muhammadiyah Malang. The results showed that the five treatments were significantly different. Pumakkal Pineapple Liquid Waste Bioremediator is able to degrade shrimp pond sediments into Shrimp pond sediment compost (KSTU), from the parameters of organic carbon, C / N ratio, nitrogen, phosphorus, potassium and the degree of acidity (pH). The most effective treatment is Konsorsia C15 (15 isolates) with the best average yield. Treatment of C15 consortia (15 bacteria) obtained 25% C-organic yield, for a C/N ratio of 24; Nitrogen (N) 3.4%, Pospor 2.3%, from Potassium 2.1%, Calcium (Ca) content 20% and pH 7.2

Keywords: Nutrient content, pumakkal indigen bacteria, shrimp pond sediment.

1. Introduction
The problem of shrimp ponds is the accumulation of leftover feed, shrimp feces, and microorganisms so that sediment or sludge is formed, which can reduce water quality and ultimately disrupt the life process of vannamei shrimp. This waste is dumped at the edge of the pond and produces solid waste that is useless. Sedimentation in the ponds occurs due to the deposition of organic matter particles both originating from leftover feed, shrimp feces, plankton or other dead organisms and sludge particles carried by the flow of water supply from the sea [1]. Pond sediment solid waste has a fairly high nutrient content (nutrients) such as total N 0.67%, P2O5 4.78%, K2O 1%, C-organic 17.87%, pH 6.25, and moisture content 15, 60% so that it has the potential to be used as organic fertilizer. The quality of compost depends on fermentation by microbes to break down organic matter. Microbes in shrimp pond sediments are expected to have the ability to decompose organic substances ie the ammonia content in water. In the last experiment done by Ambarsari (2017), it is necessary to add microbiological fertilizer in the form of Effective Microorganisms 4 (EM4) as a media optimization step to the microorganism consortium of shrimp pond sediment [2]. Consortium is a mixture of bacterial populations in the form of communities that have the potential to be used in the waste treatment process. The waste processing process will be easier with the activity of microorganisms which will break down the substances in the waste into simpler ones. The consortium of bacteria used in this research is the consortium of pineapple liquid waste indigenous bacteria (LCN). Pineapple Liquid Waste (PLW) is a waste that has acidity
characteristics and contains organic matter including 4.41% protein, which can be used as a substrate for bacterial growth [3]. The starter of pineapple liquid waste indigenous bacteria with a combination of K1 consortia (1: 1) and a volume of 1% - 5% (v/v) and the effective time to neutralize pH is 6 days [4].

Pineapple Liquid Waste (LCN) indigenus bacteria are bacteria that have the potential to act as decomposers and can be used as a starter in waste recovery. The use of Liquid Pineapple Waste (LCN) has been researched before. Adding cow manure and waste compost pineapple liquid can significantly increase the number of phosphate solvent microbes were compared with controls at 30 and 60 days after incubation [5]. Variation treatment of consortia LCN bacteria which have 15 kinds of bacteria are grouped into five: C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria). C3 and C6 have five types of potential bacteria, namely Bacillus cereus and Bacillus subtilis. C9 and C12 have ten types of bacteria, namely Bacillus cereus, Acinetobacter baumannii, and Bacillus subtilis. C15 has 15 types of potential bacteria, namely Bacillus cereus, Acinetobacter baumannii, Bacillus subtilis, and Pseudomonas pseudomallei. Bacillus cereus bacteria, Acinetobacter baumannii have the ability to degrade organic acids, then Bacillus subtilis bacteria, and Pseudomonas pseudomallei have the ability to degrade other than organic acids [6]. The aim of this research is to find out how the Pumakkal Pineapple Liquid waste bioremediator can degrade the sediments of shrimp ponds. Is the bioremediation result of shrimp pond sediment suitable for compost?

2. Methods

This Research is quantitative experimental research by using experimental methods from the variation of LCN bacterial consortia in making sediment compost in white shrimp ponds. experimental research is research that is carried out on variables for which data do not exist so that it needs to be done manipulation process through giving specific treatment to the subject the impact of research was observed / measured (forthcoming data) [7]. The research design used a completely randomized design (CRD) with five treatments, one control and five repetitions. LCN bacteria consortia used dC3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria). Compost is fermented for one month then analyzed the content of carbon (C), C/N ratio, levels of phosphorus (P), calcium (Ca) and potassium (K), pH at the Chemical Laboratory of the Muhammadiyah University of Malang. The data were analyzed quantitatively using the Kruskal Wallis Non-Parametric Anava test.

3. Results and Discussion

The results of the analysis of the ability of the Pumakkal bioremediation to degrade shrimp pond sediments into Shrimp pond sediment compost (KSTU), from the parameters of organic carbon, C/N ratio, nitrogen, phosphorus, potassium and the degree of acidity (pH) are described as follows.

3.1 Level C Organic

The results of testing the levels of C-organic in Shrimp Pond Sediment Compost (KSTU) in five treatments, namely control (KO), C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria) after fermentation is presented in Figure 1.
Figure 1 shows that the five treatments were significantly different (p < 0.05) with the lowest levels of C-organic found in the compost of shrimp pond sediment treatment C15, namely 25% and according to the standard [8]. The low levels of C-organic are due to the use of Pumakkal as a starter for decomposer microorganisms, among other bacillus cereus and able Bacillus subtilis break down organic compounds such as carbohydrates and proteins during the fermentation process into simpler compounds that can be utilized by plants [9]. These microorganisms use carbon as an energy source in decomposing organic matter during the fermentation process [6]. According to Yulipriyatno [10] During the fermentation or composting process, organic materials undergo severe decomposition by heterotrophic microorganisms, namely bacteria, fungi, actinomycetes and protozoa where carbon is a source of energy for microorganisms and can be seen from the following reactions:

$$\text{Organic Ingredient} + \text{O}_2 \xrightarrow{\text{Microbial Aerobic}} \text{H}_2\text{O} + \text{CO}_2 + \text{Nutrients} + \text{Humus} + E$$

Then followed by an anaerobic process which takes place gradually. The first stage, several types of facultative bacteria will break down organic material into fatty acids. He was then followed by the second stage, where another group of microbes will convert fatty acids into ammonia, methane, carbon dioxide and hydrogen. The heat generated in the anaerobic process is lower than that of aerobes. The following is a reaction that occurs under anaerobic conditions. With the following reaction:

$$\text{Organic Ingredients} \xrightarrow{\text{Anaerobic Microbial}} \text{CH}_4 + \text{Nutrients} + \text{Humus}$$

Based on [11], C-organic is at least 6%, so the carbon content in all treatments in this study meets the standards.

### 3.2 C/N ratio

The results of the calculation of C/N ratio in a compost of shrimp pond waste in five treatments, namely control (KO), C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria), after fermentation, is presented in Figure 2.

![Figure 2. Graph of Average C/N of Shrimp Pond Sediment Compost.](image)

The C/N ratio is the ratio of the mass of carbon to the mass of nitrogen in a substance. Organic material that is still new has a higher C/N ratio than the C/N ratio after the composting process. This means that composting is an effort to reduce the C/N ratio of organic matter so that it has a C/N ratio that can be absorbed by plants. Each organic material has a different C/N ratio. The higher the C/N ratio of a material, the longer its decomposition time will be. Organic matter that can be absorbed by plants is the organic matter with a C/N ratio close to the C/N ratio of the soil, which is around 12-15 and the temperature is almost the same as the ambient temperature. Too high a C/N value causes the composting process to take a long time because the development of microorganisms is slow, whereas if the C/N value is too low, nitrogen will be released into the air to become ammonia [12]. C/N ratio contained in the compost of shrimp pond sediments with the Pumakkal starter treatment. Treatment C15 ranges from 8-10, has met the standards in [16] which is less or equal to 25. One of the bacteria at C15 is Pseudomonas are bacteria that are important in balance in nature, globally active in aerobic
decomposition and biodegradation because they play an important key in the carbon cycle. In natural ecosystems, most nutrients such as N, P, and S are bound in organic molecules and are therefore minimally bioavailable for plants. To access these nutrients, plants are dependent on the growth of soil microbes such as bacteria and fungi, which possess the metabolic machinery to depolymerize and mineralize organic forms of N, P, and S [13].

3.3 Nitrogen (N) Levels
The results of testing nitrogen levels in compost from shrimp pond waste there are five treatments, namely control (KO), C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria) after fermentation is presented in Figure 2.

Figure 3 shows that nitrogen levels in the C3 to C15 treatment experienced an increase and was significantly different (p <0.05). This is thought to be due to the use of Pumakkal and the waste of protein-rich shrimp ponds. From these data, it can be seen that the highest nitrogen content is in the C15 treatment, which is 3.4%. The increase in nitrogen levels is thought to be caused by the breakdown of organic matter by bacteria *Acinetobacter baumannii* as nitrifying bacteria which convert ammonia to nitrate at the end of the fermentation process. In addition, microorganisms also contribute a number of single-cell proteins which are obtained during the fermentation process. After the decomposition process is complete, nitrogen will be released again as one of the components contained in the compost. The various types of nutrients, especially N as a result of the description, will be bound in the microorganism's body and will return after the microorganisms have died. Following is the nitrogen formation reaction, according to:

\[
\text{Organic Ingredients} \xrightarrow{\text{Amination Reaction}} \text{Protein} \xrightarrow{\text{Ammonification Reaction}} \text{Amino Acid} \xrightarrow{\text{Ammonification Reaction}} \text{Amonia (NH}_3\text{)} \text{and Ammonium (NH}_4^+\text{)}
\]

Nitrogen is an element needed by plants in vegetative growth and protein formation, and if the plant is deficient in nitrogen it will cause the plant to become stunted, leaves turn yellow and fall, and limited root growth. The nitrogen content contained in the compost of shrimp pond sediments with the Pumakkal starter treatment has met internal standards [16] that is, at least 2%.

3.4 Content of Phosphor (P)
The results of research on phosphorus content (P) in a compost of shrimp pond waste there are five treatments, namely control (KO), C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria) after fermentation is presented in Figure 4.
Figure 4. shows that the compost of shrimp pond sediment waste in the five treatments had an increase in phosphorus and was significantly different. Standard [16] that is, at least 2%, the treatment is C15 (15 bacteria). Although the fermentation process has been running optimally due to the presence of the Pumakkal starter, the C3 to C12 treatment is still low, because the phosphorus content contained in the sediments of the shrimp ponds is relatively low, the results obtained do not show sufficient phosphorus content. Phosphate organic waste in sediments can be dissolved back in the water. Due to physical, chemical and hydrodynamic factors such as turbulence, the nutrients accumulated in the sediment could be released in water bodies. The release of N and P nutrients from sediments into water bodies is the cause of water pollution and eutrophication so that the concentration of N and P in the waters continues to receive serious attention [14]. Plants use phosphorus to accelerate root growth, accelerate flower formation and accelerate fruit ripening and increase grain production.

3.5 Content of Calcium (Ca)

The results of research on the content of calcium (Ca) in a compost of shrimp pond waste there are five treatments, namely control (KO), C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria) after fermentation is presented in Figure 5.

Figure 5 shows that the compost of shrimp pond sediment in the treatments C0, C3, C6, C9, C12 and C15 were significantly different (p <0.05). According to[15], the maximum calcium content is 25.50 (%). The results of all research meet these criteria, and the highest in treatment C12 is 24%. Giving starter C15 with 15 isolates resulted in the best degradation due to the potential microbial content to break down the organic matter of shrimp pond sediment. Microbes that play a role in dissolving phosphate and calcium are bacteria, fungi and actinomycetes. Among the bacteria groups: Bacillus firmus, B. subtilis, B. cereus, B. licheniformis, B. polymixin, B. megathermium, Arthrobacter, Pseudomonas, Achromobacter, Flavobacterium, Micrococcus and Mycobacterium. Pseudomonas is a genus of the Pseudomonadaceae family. These bacteria are chemo-organotrophic aerobic bacteria, in the form of straight or curved rods, the size of each bacterial cell is 0.5-0.1 μm x 1.5- 4.0 μm, does not form spores and react negatively to Gram stain. In the soil, the amount is 3-15% of the bacterial population. Pseudomonas is divided into groups, among which are the sub-group fluorescent (Fluorescent) which can secrete the pigment phenazine. The ability to produce phenazine pigments was also found in a group of non-fluorescent species known as Pseudomonas multivorans species. In
connection with that, there are four species in the fluorescent group, namely *Pseudomonas aeruginosa*, *P. fluorescent*, *P. putida*, and *P. multivorans* [16].

3.6 Potassium (K) Content
The results of the research on the content of potassium (K) in compost from shrimp pond waste there are five treatments, namely control (KO), C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria) after fermentation is presented in Figure 6.

![Graph of Average Potassium (K) Content of Shrimp Pond Sediment Compost.](image)

The results of testing for potassium levels in the sediments of shrimp ponds were significantly different (p <0.05). The highest average potassium levels were in treatment C9 and C15. The change in potassium levels was due to the decomposition process carried out by decomposer microorganisms from Pumakkal. Potassium is needed by plants to regulate the mechanism of photosynthesis, protein synthesis, and the opening of stomata and the supply of carbon dioxide. If there is a lack of potassium in the plant, it can cause the leaf segments to shorten, the edges of the leaves are brown, and the plant cannot grow [17]. This was confirmed by [19]. There is an increase in several types of nutrients by microorganisms, especially nitrogen, phosphorus, and potassium. These nutrients can be returned through weathering the remains of living things when these microorganisms die.

Organic material remover consists of primary remover and secondary remover. Peros. Primer is mesofauna of organic matter remover, such as *Collembola, Acarina*, which functions to break down organic matter/litter into smaller sizes. Earthworms eat the remains of the crumbs which are then excreted as faeces after going through digestion in the worm's body. Secondary remodelers are microorganisms that break down organic matter such as *Trichoderma reesei*, *T. harzianum*, *T. koningii*, *Phanerochaeta crysosporium*, *Cellulomonas*, *Pseudomonas*, *Thermospora*, *Aspergillus niger*, *A. terreus*, *Penicillium*, and *Streptomyces*. The existence of soil fauna activity makes it easier for microorganisms to utilize organic matter so that the mineralization process runs faster and the supply of nutrients for plants is better [18]. Result analysis of the potassium has been done obtained a potassium content of 0.58%. The results obtained have met the standards based on [15] amounting to at least 0.20%. The presence of potassium in the compost is because a lot of potassium comes from organic matter. Organic materials can increase the cation exchange capacity, and this is related to the negative charges that come from the group-COOH and OH which dissociate to form COO- and H + and O- + H +. This negative charge is the potential for Humus to adsorb cations such as Ca, Mg and K, which are bonded with medium strength so that they are easily exchanged or undergo a cation exchange process [20].

3.7 Degree of Acidity (pH)
The results of research on the degree of acidity (pH) in a compost of shrimp pond waste there are five treatments, namely control (KO), C3 (3 bacteria), C6 (6 bacteria), C9 (9 bacteria), C12 (12 bacteria) and C15 (15 bacteria) after fermentation is presented in Figure 6.
Figure 7 shows that shrimp Pond Sediment Compost those processed using the Pumakkal bioremediation experienced an increase in pH, the highest was in the C12 D and C15 treatments, namely pH 7.2. The results obtained have met the standards based on [19], which is equal to 6.80-7.49. The change in pH to neutral is due to an acid-base reaction that is formed between the Pumakkal bio activator when it decays during the fermentation process with the following reaction:

\[ H_2O \rightarrow H^+ + OH^- \]

The Pumakkal bio activator contains bacteria *Acinetobacter baumannii* and *Pseudomonas pseudmallei*, which has the ability to decompose organic acids in waste [18]. The effect on pH in fertilizers is very important in determining the absorption of nutrient ions by plants. Generally, nutrients will be easily absorbed by plants at a pH of 6-7, because at that pH most of the nutrients will dissolve easily in water [13]. After the harvesting and drying period of the ponds, shrimp droppings, shrimps and shrimp feed remains that rot as debris at the bottom of the pond. The residue will dry out and can be used for shrimp biosolids. These biosolids are considered waste and are usually disposed of in landfills. These biosolids or shrimp pond residues are a valuable source of N, P, K and a variety of other useful plant nutrients. The highest content of these biosolids is nitrogen [20]. The environmental impact of shrimp pond activities is closely related to the management of wastewater and sediment pond sludge. The sludge from pond ponds has the potential to be reused and can also be used as organic fertilizer in the presence of high levels of nutrients and organic matter [21]. The dominant indigenic bacteria in pineapple wastewater that have the potential to neutralize pH are *Bacillus cereus*, *Acinetobacter baumannii* [22]. Shrimp pond solid residue cannot be used alone as a complete fertilizer but must be used together with commercial fertilizers. The solid pond residue has very high organic matter, and it is expected that soil minerals with low organic matter will be raised infertility which may contribute to successive crops being planted in the same location [20]. Pumakkal as a bio activator is able to decompose shrimp pond sediment into compost that meets the criteria of the content of C, N, C/N, P, Ca, K and pH.

### 3.8 Biology Learning Resources

Real learning sources in nature (contextual), which are able to prepare students in cognitive, affective, and psychomotoric domains, and which are able to support environmental care character, are rare to develop [23]. Teaching and learning process Science emphasizes more on approach process skills, so that students can discover facts, build concepts, theories and students’ scientific attitudes itself that can ultimately take effect positive on the quality of the educational process as well as educational products [24]. Based on the results of the validation questionnaire analysis of the two aspects, namely the material aspect and the media aspect, the results are suitable for use. From the research results, practicum guides that have been designed as a learning resource can be used in learning because they can improve students’ competencies, namely cognitive, psychomotor and affective competencies. In the practicum guide, there are observations about temperature, humidity, and pH. The activities carried out in the observation add knowledge to students about things that need to be considered in the process of making organic fertilizers such as humidity, good temperature and what is the right pH in the composting...
process. In addition, the texture of compost such as colour, shape, aroma and texture of the finished compost can also improve the cognitive competence of students.

In addition to knowledge, there are several processes in composting that involve psychomotor aspects such as measuring humidity, temperature and pH, which require the skills of students to get the right results. The process of weighing materials in making organic fertilizer for each treatment is also a psychomotor aspect because this activity is carried out by students during the process of making fertilizer.

At the time of observing humidity, temperature, and pH also need guidance in carrying out scientific work. Some of the scientific attitudes taken at the time of observation are curiosity, honesty, objectivity, discipline, thoroughness and responsibility. This scientific attitude is included in the affective competence of students. Cognitive, psychomotor and affective competencies are carried out by students in the process of making fertilizer with the implementation instructions contained in the practicum guide, which has been designed as a learning resource.

In the world of education, the learning process will run better if the teacher uses learning resources as a tool to make it easier for students to transfer knowledge. That is the reason a teacher is required to have the ability to design learning resources [25]. Learning resources are anything that is used by someone to learn something. Learning resources include messages, people, materials, tools, techniques, and settings. Learning resources can be divided into designed learning resources and used learning resources.

Some learning resources can be designed to create interesting, innovative and creative learning so that learning becomes more active [16]. Learning experiences in class can be obtained by interacting between students and learning objects and resources in accordance with the formulated description of the learning material. The form can be in the form of a book review, study of research results, conducting experiments in the laboratory, measuring the length of cells using a ruler through a microscope, group presentations after conducting experiments and others.

The practicum guide is one of the choices of learning resources used by science teachers in the learning process. The practicum guide is a guideline in carrying out practicum so that it helps students because the purpose of the practicum is to increase scientific knowledge, teach experimental skills, develop "scientific attitudes" such as open-mindedness, being objective, and willingness, delaying assessment, can develop expertise and be able to provide assessments and motivate students, with an interesting simulation in the learning process.

4. Conclusion
The research conclusions are: Pumakkal Pineapple Liquid Waste Bioremediator is able to degrade shrimp pond sediments from the parameters of activated carbon, C/N ratio, nitrogen, calcium, potassium and degree of acidity (pH). The most effective treatment was Konsorsia C15 (15 isolates) with the best average yield. The C15 Consortia treatment obtained 25% C-organic yield, for a C/N ratio of 24; Nitrogen (N) 3.4%, Pospor 2.3%, kaof Potassium 2.1%, levels of Calcium (Ca) 20% and pH 7.2. Practical guidelines are suitable for learning media in schools.

REFERENCE
[1] Suwoyo H S, Tahe S dan Fahrur M 2015 Karakterisasi Limbah Sedimen Tambak Udang Vaname (Litopenaeus vannamei) 901 901–913
[2] Ambarsari H Dan Harahap M R 2017 Performance Optimization of Microbes from Shrimp Pond Sediment by Adding EM4 In Nitrification Process for the Treatment of Wastewater Containing High Ammonia Concentration Microbiol. Indones. 11 94–102
[3] Sidik B R, Achyani, Sutanto A, Zen S dan Noor R 2020 Application pineapple liquid waste to increase fruit weight and vitamin c pineapple as biological learning resources J. Phys. Conf. Ser. 1567
[4] Direktorat Jenderal Kekayaan Intelektual 2013 DJKI | E-Status
[5] Ramadhani W S, Handayanto E, Nuraiini Y dan Rahmat A 2020 Aplikasi Limbah Cair Nanas Dan
Kompos Kotoran Sapi Meningkatkan Populasi Mikroorganisme Pelarut Fosfat Di Ultisol, Lampung Tengah J. Tek. Pertan. Lampung (Journal Agric. Eng. 9 78

[6] Sutanto A, Achyani M S dan Zen S Limbah Cair Nanas UM Metro Press Metro

[7] Jaedun A 2011 Oleh : Amat Jaedun Metodol. Penelit. Eksperimen 0–12

[8] Suwoyoh S, Fahrur M, Makmur M dan Syah R 2017 Pemanfaatan Limbah Tambak Udang Super-Intensif Sebagai Pupuk Organik Untuk Pertumbuhan Biomassa Kelekap Dan Nener Bandeng Media Akuakultur 11 97–110

[9] Sutantoa A, Zena S dan Nora R 2016 The formulation of pineapple liquid waste (PLW) as liquid organic fertilizer for agricultural crops Sci. Eng. 3 176–181

[10] Yulipriyanto H 2010 Biologi tanah dan strategi pengelolaannya (Graha Ilmu)

[11] Indonesia K P R 2011 Peraturan Menteri Pertanian: Nomor 70/Permentan/SR (140/10/2011 Tentang Pupuk Organik, Pupuk Hayati, Dan Pembenah Tanah)

[12] Dalzell H W, Dalzell H E, Biddlestone A J, Gray K R dan Thurairajan K 1987 Soil management: compost production and use in tropical and subtropical environments (Food & Agriculture Org.)

[13] Jacoby R, Peukert M, Succurro A, Koprivova A dan Kopriva S 2017 The role of soil microorganisms in plant mineral nutrition—current knowledge and future directions Front. Plant Sci. 8 1–19

[14] Zhu M, Zhu G, Li W, Zhang Y, Zhao L dan Gu Z 2013 Estimation of the algal-available phosphorus pool in sediments of a large, shallow eutrophic lake (Taihu, China) using profiled SMT fractional analysis Environ. Pollut. 173 216–223

[15] Nasional B S 2004 SNI 19-7030-2004 tentang Spesifikasi Kompos dari Sampah Organik Domestik Jakarta Badan Standar Nas. Indone.

[16] Madjid A 2009 Dasar-Dasar Ilmu Tanah. Bahan Ajar Online. Fakultas Pertanian Unsri & Program Studi Ilmu Tanaman, Program Magister, Universitas Sriwijaya, Palembang. Propinsi Sumatera Selatan. Indonesia

[17] Sundari I, Ma’ruf W F dan Dewi E N 2014 Pengaruh Penggunaan Bioaktivator Em4 Dan Penambahan Tepung Ikan Terhadap Spesifikasi Pupuk Organik Cair Rumpit Laut Gracilaria SP. J. Pengolah. dan Bioteknol. Has. Perikan. 3 88–94

[18] Eriksson K-E L, Blanchette R A dan Ander P 2012 Microbial and enzymatic degradation of wood and wood components (Springer Science & Business Media)

[19] Smolders A J P, Lamers L P M, Lucassen E C H E T, Van Der Velde G dan Roelofs J G M 2006 Internal eutrophication: How it works and what to do about it—a review Chem. Ecol. 22 93–111

[20] Dufault R J, Korkmaz A dan Ward B 2001 Potential of Biosolids from Shrimp Aquaculture as a Fertilizer for Broccoli Production Compost Sci. Util. 9 107–114

[21] Rahaman S M B, Sarder L, Rahaman M S, Ghosh A K, Biswas S K, Siraj S M S, Huq K A, Hasanuzzaman A F M dan Islam S S 2013 Nutrient dynamics in the Sundarbans mangrove estuarine system of Bangladesh under different weather and tidal cycles Ecol. Process. 2

[22] Direktorat Jenderal Kekayaan Intelektual 2013 DJKI | E-Status

[23] Muhfahroyn M dan Oka A A 2017 Improving Post-graduate Students Learning Activities through Lesson Study in Learning Forest-Prototype Biosaintifikasi J. Biol. Biol. Educ. 9 311

[24] Rosniati dan Lufri L 2020 The Development of Guided Inquiry-Oriented Guides for Plant Morphology Biology Education Practicum Students of IPTS Padangsidimpuan 10 292

[25] Mularsih H 2017 Belajar dan Pembelajaran Serta Pemanfaatan Sumber Belajar Rajawali Press Depok