The effect of various decomposers on quality of organic fertilizer originated from solid waste of super intensive shrimp pond

H S Suwoyo¹, A Tuwo², Haryati², H Anshary³ and S R H Mulyaningrum¹

¹Research Institute for Coastal Aquaculture and Fisheries Extension, Maros, Indonesia
²Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia

Email: hidayat7676@gmail.com

Abstract. This study aims to evaluate and compare the nutrient content of organic fertilizer originated from shrimp pond waste, which use commercial decomposers and indigenous decomposers. The research was carried out at Research Institute for Coastal Aquaculture and Fisheries Extension (RICAFE), Maros, South Sulawesi, Indonesia. The study used a completely randomized design (CRD) with four treatments and 3 replications. Solid waste of shrimp pond with several types of bio activators used in this study. The treatments were types of bio activators, namely: BIO (A), TR-04 (B), EMs (C) and decomposer bacteria isolated from pond waste ISO (D). The composting time lasted for 30 days. Observed variables were macronutrient content (C-O rganic, N-Total, C/N ratio, P2O5 and K2O) and microelements (Fe, Mn, Zn, Cu) as well as temperature and pH of the composting media. The results showed that different bio activators significantly affected the quality of pond waste organic fertilizer (p <0.01). Nutrient contents (C-O rganic, C/N ratio, P2O5, and K2O, Fe, Mn, Zn, Cu) were not significantly different (p> 0.05), while N-total value was significantly different (p <0.05). The quality of produced compost in all bio activator treatments (BIO, TR, EM, and ISO) met Indonesian National Standard (SNI) 2004 and standard of regulation of the ministry of agriculture republic of Indonesia (PERMENTAN) 2019. This study can be an alternative for treating waste of shrimp culture industry.

1. Introduction

_L. vannamei_ is still to be a strategic commodity for national achievement target of shrimp production. Super-intensive technology cultivation of _vannamei_ is a prospective future aquaculture system with a low-volume high-density concept. Super-intensive pond technology has begun to develop for _L. vannamei_ with a stocking density of 1,250 shrimp/m² and productivity of 12.6 tons /1,000 m² [1]. The high stocking density resulting waste load due to the retention of nitrogen (N) (22.27%) and phosphorus (P) (9.79%) of feed, so that nutrients discharged into waters reached 77.73% of nitrogen and 90.21% of phosphorus respectively [2].

Pond sediment was rich of N, P, K and other macro and micronutrients [3,4]. Pond waste had higher organic matter, total nitrogen, and phosphorus value than soil [5]. Solid waste of shrimp ponds contained 1.92% of organic C, 0.54% of N-total and 1.70% of P2O5 [6]. The pond waste can be used as organic fertilizer through the composting process.
Composting is a biotechnological process in which various microbial communities break down organic matter into simpler nutrients to improve soil quality [7]. Microorganisms (bacteria, actinomycetes, fungi, and soil organisms) play an essential role in the composting process [8]. The composting process is an aerobic biological reforming of unstable organic matter resulting in a more stable form of the final product (compost) [9]. There are four main phases of the composting process, including initial mesophilic phase, thermophilic phase, second mesophilic phase and maturation (stabilization) finally [10]. During composting process, microorganisms use crude organic matter as a food source to produce heat, carbon dioxide, vapor and humus [11].

Composting could run in a faster time with the help of bio activators [12]. The use of bio activators in composting has an effect on the provision of nutrients in it. The types of microorganisms present in the bio activator can affect the chemical content of the compost produced. Several types of commercial bio activators on the market are EM Lestari, Fix-Up Plus, SuperDec, BIOTAN, TR-04, Effective Microorganism (EM), Degrasimba, Orgade, Stardec and Harmony [13]. An organic fertilizer from super-intensive shrimp pond solid waste was made using several types of decomposing agents. This study aims to evaluate and compare the nutrient content of organic fertilizer originated from shrimp pond solid waste, which used commercial decomposers and indigenous decomposers.

2. Materials and method

2.1. Location
The research was carried out at Research Institute for Coastal Aquaculture and Fisheries Extension (RICAFE), Maros, South Sulawesi, Indonesia.

2.2. Equipment and materials
The equipment used included 12 plastic buckets of 80 L volume capacity, which placed in a roofed building, plastic, pH meter, thermometer, shovel, gloves, filters, sacks, scales and basins. Pond solid waste was obtained from a super-intensive shrimp pond in Takalar, South Sulawesi. Pond solid waste was separated from other materials such as plastics, rocks, stones, etc., then weighed and added bio activators.

2.3. Treatments
Different types of activators were used as treatments on composting process of making organic fertilizers, namely:
A: BIOTAN (BIO)
B: TR-04 (TR)
C: EM4 (EM)
D: Indigenous bacteria isolated from pond waste (ISO)
The bio activators were applied on a kg/0.5 tons dose, homogenized by stirring, put in a bucket then covered with a black plastic sheet to keep moisture for 30 days. The stirring of the solid waste pile was done once a week.

2.4. Observed variables
The observed variables were macronutrients content (N-Total, P2O5, K2O, C-Organic), C/N ratio, micronutrients (Fe, Cu, Mn, Zn), temperature and pH of the composting media.

2.5. Data analysis
The data of macronutrients and micronutrients were analyzed statistically using analysis of variant (ANOVA), while data of temperature and pH were analyzed descriptively.
3. Result and discussion

The analysis of macro and micronutrient content, C-organic and C/N ratio of the organic fertilizers produced were presented on Table 1.

Table 1. Macronutrient content, C-organic and C/N ratio of each treatment.

| Variabel         | Treatment | Quality standard *) |
|------------------|-----------|---------------------|
|                  | BIO       | TR                  | EM       | ISO       |
| N Total (%)      | 0.61±0.08<sup>ab</sup> | 0.67±0.04<sup>b</sup> | 0.56±0.01<sup>a</sup> | 0.70±0.01<sup>b</sup> | Minimum 2% |
| P<sub>2</sub>O<sub>5</sub> (%) | 1.42±0.39<sup>a</sup> | 1.50±0.19<sup>a</sup> | 1.35±0.06<sup>a</sup> | 1.59±0.29<sup>a</sup> |
| K<sub>2</sub>O (%) | 0.89±0.09<sup>a</sup> | 0.91±0.00<sup>a</sup> | 0.85±0.03<sup>a</sup> | 0.90±0.02<sup>a</sup> |
| C-Organic (%)    | 9.49±0.96<sup>a</sup> | 10.41±2.30<sup>a</sup> | 9.46±0.63<sup>a</sup> | 10.82±2.62<sup>a</sup> | 9.8-32% |
| C/N Ratio        | 15.30±1.53<sup>a</sup> | 15.67±4.73<sup>a</sup> | 17.00±1.00<sup>a</sup> | 15.30±4.16<sup>a</sup> | ≤ 25 |

Note: *Values with the same superscript within the same row are not significantly different at P < 0.05).

Macronutrients needed by organisms are nitrogen (N), phosphorus (P), and potassium (K). The results showed that the different types of bio activators had a significant effect on the nitrogen content of the pond waste organic fertilizer (P <0.01) (Table 1). The highest average of total nitrogen nutrient content was obtained in ISO bio activator (0.70%), TR and BIO had total nitrogen nutrient content of 0.67% and 0.61% respectively, and the lowest one was EM (0.56 %). Statistical analysis showed that the type of bio activator treatment had a significant effect (P <0.01) on the total nitrogen nutrient content. Compare to EM treatment, the total nitrogen content of BIO, TR, and ISO treatments are not significantly different (P> 0.05), but the TR and ISO treatments are significantly different (P <0.05).

Nitrogen and other compounds were obtained from the breakdown of organic matter during the decomposition process by microorganisms. The carbon content (60%-70%) of the decomposed organic material is evaporated into CO<sub>2</sub> and 30%-40% into nitrogen [14]. The organic matter should first be converted into inorganic to be utilized by microalgae. The biological decomposition of organic matter by decomposer microbes will produce macronutrient, micronutrient, hormone, vitamin and growth agent [15]. The N content increased significantly while C content decreased due to organic matter decomposition [16].

The N total content of pond waste organic fertilizer ranged from 0.56% to 0.70%. The N total value of compost was at least 0.4% [17]. N total content from solid waste fertilizer from the pulp industry was about 0.38-0.85% [18]. The total nitrogen content of household waste organic fertilizers, using 3 different types of bio activators (EM, DS, SD) was ranging from 1.23-1.63% [13]. Nitrogen content of 1.45% and phosphorus of 0.48% from organic fertilizer from vegetable waste and tofu waste using a decomposer agent for the type of bacteria Lactobacillus sp [19].

The results of nutrient content of P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, C-Organic and the ratio of C/N organic fertilizers from solid waste of shrimp ponds in this study are presented in Table 1. The obtained P<sub>2</sub>O<sub>5</sub> nutrient content ranges from 1.35-1.59%, K<sub>2</sub>O 0.85-0.91%, Organic C 9.49-10.82%, and the C/N ratio 15.30-17.00. The results of the analysis of variance (ANOVA) on all of these variables indicate that the types of bio activators were not significantly different (P> 0.05) to the nutrient content of P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, C-Organic and C/N ratio of pond waste organic fertilizer.

Carbon is an important element as a builder of organic matter. One of the factors that influence the rate of the organic fertilizer manufacturing process is the C/N ratio. The C/N ratio is the most important factor in the process of making organic fertilizers. This is because the process depends on microorganisms that require carbon as an energy source and nitrogen to form cells [20]. The C/N ratio obtained during composting reaches 15-17 (Table 1). The C/N ratio is an indication of the maturity of the compost. Changes in the C/N ratio occur during composting due to the use of carbon as an energy source and lost in the form of CO<sub>2</sub> so that the carbon content decreases over time [21]. Range ratio of C/N of 15-20 is ideal for compost that is ready to use [22]. The value of the C/N ratio of compost
ranges from 10-20 [17]. This C/N ratio value has met the quality standard for solid organic fertilizer which is ≤ 25 [23]. That maturity compost had a C/N ratio less than or equal to 25 [24]. Cattle farm waste with a composting time of 28 days. obtained a C/N ratio value of 16-18 [25]. Cow feces and Bionic bio activator for 5-9 weeks resulted in a C/N ratio of 11-14 [26]. C/N ratio ranging from 23.54-26.95 using cow feces and bio-ethanol waste bio activator with 28 days of the composting period [27].

The nutrient content of the shrimp pond solid waste organic fertilizer in this study was not much different from the nutrient content of other organic fertilizers. The nutrient content of compost is P₂O₅ 0.09%, K₂O 0.95%, N total 0.37%, 8.95% organic C, and a C/N ratio of 14%. While bokashi fertilizer contained 0.73% N total, P₂O₅ 6.13%, K₂O 3.25%, organic C 9.39%, C/N ratio 12.9 [28]. The manufacture of organic fertilizer from solid waste from the pulp industry (sludge) plus sawdust charcoal obtained N 1.19-1.29%, P₂O₅ 0.53-0.63%, K₂O 0.63-0.68%, organic C 24.17-28.26%, water content 32.90-39.40%, pH 6.70-6.90, and C/N ratio 18.70-23.70 [29]. Nutrient content of solid waste in giant prawn ponds obtained N total 0.14%, P₂O₅ 5.0%, Organic C 1.38%, C/N ratio 9.9 [30]. The macro and micronutrient content of the pulp industry solid waste fertilizer. namely C-Organic 5.33-7.69%, N total 0.38-0.85%, P₂O₅ 0.47-0.65 %, K₂O 0.09-0.22%, C/N ratio 9-14%, pH 6.75-7.0 [18]. The macronutrient content and C-organic from organic fertilizer from household waste through the composting process uses 3 different types of bio activators (EM, DS, SD), namely N total 1.23-1.63%, P₂O₅ 0.55-0.73%, K₂O ranged from 1.05-1.20%, and C-organic ranged from 11.90-17.0% [13]. The nutrient content of compost from plants is P₂O₅ 0.32%, K₂O 1.70%, N total 1.22%, 12.2% organic C, C/N ratio 10 [31]. The nutrient content of cultivation waste contains 0.44% P₂O₅, K₂O 1.53%, N total 0.49%, 21.9% organic C, and C/N ratio 25.67 [32]. The results of the analysis of market waste composted for 45 days have a P content of 0.22%, K 1.05%, N 1.17%, and 11.46% organic C. Furthermore, it is said that good compost contains a C/N ratio between 15-20 [33]. Macro and micronutrients organic chicken manure added with water hyacinth and using Arbuscular Mycorrhizal Fungi (CMA) decomposer agent. namely C 19.18 %, N 1.05%, P₂O₅ 2.18%, K₂O 0.69%, C/N ratio 18.55, pH 7.64 and moisture content 14% [34].

The macronutrients of cow dung organic fertilizer contain 0.31% P₂O₅, K₂O 0.27%, N total 0.95%, organic C 16.6%, and C/N ratio 17.47. Meanwhile, plant waste contains 0.32% P₂O₅, K₂O 0.51%, N total 1.13%, 20.93% organic C, and a C/N ratio of 18.52 [35]. The solid waste of the vannamei shrimp pond contains P₂O₅ 1.70%, Organic C is 1.92%, N total is 0.14%, and C/N ratio is 3.55 [36]. The nutrient content of pond waste with vermicompost. namely P₂O₅ 0.24%, K₂O 0.45%, N total 0.99%, organic C 16.3%, and C/N ratio 16.46 [37]. Nutrient content of compost organic fertilizer P₂O₅ 1.43%; K₂O 0.58%, total nitrogen 0.60%, organic C 7.90% and C/N ratio of 13.93 [38]. Nutrient content of mushroom compost, namely total Nitrogen 0.98%. P₂O₅ 0.80%; K₂O 0.28%, organic C 14.7% and C/N ratio 15.0 [39]. Nutrient content of livestock waste fertilizers, namely total nitrogen 4.0%, P₂O₅ 0.50%, K₂O 0.40%, 20.82% organic C, and a C/N ratio of 5.21 [40].

Micronutrient elements needed by plants include plankton in small amounts, including iron (Fe), manganese (Mn), zinc (Zn), copper (Cu). The results of an analysis of micronutrient content of pond waste organic fertilizer are presented in Figure 1. Based on the figure, it can be seen that the levels of Fe obtained range from 7707-9022 ppm, Mn ranges from 667-791 ppm, Zn is 57.01-73.43 ppm, Cu ranges from 19.93-29.16 ppm. The levels of these microelements have met the quality standards for solid organic fertilizers following regulation of the Ministry of Agriculture Republic of Indonesia, namely a maximum Fe content of 15.000 ppm, a maximum of Zn of 5.000 ppm, a maximum of 5.000 ppm of Mn and a maximum of 5.000 ppm of Cu.
Bacteria in the anaerobic process require micro-nutrient and metal elements such as nitrogen, phosphorus, sulfur, potassium, calcium, magnesium, iron, nickel, cobalt, zinc, manganese, and copper for optimal growth performance [41]. Although these elements are required in deficient concentrations, a deficiency of these nutrients will harm microbial growth and performance [42]. Micronutrient content of solid waste from aquaculture activities, namely 3.81% Fe, 0.06% Mn, 168 ppm Cu and 250 ppm Zn. The micronutrient contents of rice straw were 0.08% Fe, 0.05% Mn, 5.33 ppm Cu and 178 ppm Zn respectively. Meanwhile, the micronutrient contents of vermicompost solid waste from cultivation activities were 3.64% Fe, 0.55% Mn, 19 ppm Cu, and 266 ppm Zn [32]. Micronutrient content of fertilizers from biogas processing (slurry), namely Co 2.35 ppm, Cd 0.11 ppm, Zn 295 ppm, and Cu 36.3 ppm. Meanwhile, the nutrient content of compost. Co is 1.19 ppm, Cd 0.24 ppm, Zn 195 ppm and Cu 20.4 ppm [43]. Micronutrients from solid waste oil palm sludge (POME), namely Fe 1.09%, Zn 151 ppm, Cu 70.40 ppm, Mn 495.24 ppm [44]. Micronutrient levels from treated palm oil waste, namely Fe 2.24%, Zn 130 ppm, Cu 45.05 ppm, Mn 422.56 ppm, At the same time, the WHO / FAO standards for microelements are Zn 140 ppm, Cu 75.0 ppm, Mn 500 ppm [42]. The results of observing the temperature and pH of the composting media during the study are shown in Table 2.

| Variable       | BIO     | TR      | EM      | ISO     |
|----------------|---------|---------|---------|---------|
| Temperature (°C) | 27.13-31.60 | 27.20-31.56 | 27.30-31.90 | 27.17-33.10 |
| pH             | 6.64-7.06 | 6.25-7.14 | 6.44-7.14 | 6.44-7.14 |

The temperature ranges of each type of bio activator during the composting process were BIO = 27.13-31.60 °C; TR=27.20-31.56 °C; EM= 27.30-31.90 °C and ISO= 27.17-33.10 °C (Table 2). This temperature is classified into the mesophilic composting temperature. During the composting process, the raw organic material undergoes a renovation process by microorganisms in the form of fungi and bacteria. The temperature in the compost pile will increase with the decomposition activity. So the

![Figure 1. Micro nutrient content of different bio activators.](image-url)
total carbon content will decrease while the nitrogen content will increase. At the end of composting, where ripe compost has been formed, the temperature will decrease [28]. Temperature is one of the most important parameters in the composting process. The rise and fall of temperature during the composting process can be caused by the growth rate, metabolism, and the types of organisms in the compost [45,46]. The temperature of composting organic waste from cattle farms using bioethanol waste decomposer for 28 days of 29.40°C- 29.63°C [27]. Composting phase is categorized into four temperature ranges: mesophilic, thermophilic, cooling (second mesophilic stage), and maturation stage [47]. Composting from organic waste occurs in three temperature ranges known as psychrophilic (0-20 °C), mesophilic (20-40 °C) and thermophilic (more than 45 °C), although the mesophilic temperature is an effective composting [48].

The composting media pH values of all treatments are presented in the Table 2. The range of pH values for each type of bio activator during the composting process were BIO = 6.64-7.06, TR = 6.25-7.14, EM = 6.44-7.14 and ISO = 6.44-7.14, with an average pH value for the whole treatment of 6.79. The optimum pH value for the composting process ranges from 6.5 to 8.0 [49,50]. During the composting process, organic material is utilized by microorganisms which causes a decrease in the pH value in the first week. After that, the pH value increases significantly at the decomposition stage. This increase was caused by an increase in ammonia [51,52], breakdown of organic matter, degradation of acid compounds, and mineralization of organic compounds such as proteins, amino acids, ammonia, and peptides [53,54]. Changes in pH have been found to occur during the composting period and are considered an indicator of biological activity [8]. The pH value range suitable for bacterial development is 6.0-7.5, whereas mushrooms prefer a pH range of 5.5-8.0 [55].

The quality of organic fertilizers produced in this study provides an overview of the ability of each decomposer agent to decompose organic matter in solid waste from shrimp ponds. The nutrient quality of organic fertilizers from the four bio activator treatments (EM, BIO, TR, and ISO) was not significantly different, meaning that although the composition and abundance of species in each bio activator were different, the environmental conditions that occurred in the process were quite optimum for the growth of microorganisms so that the four treatments had the same effectiveness in decomposing organic matter.

4. Conclusion
The quality of organic fertilizers with different type of bio activator treatment (BIO, TR, EM, and ISO) has met the quality standard of organic fertilizer based on Indonesian National Standard (SNI) 2004 and standard of regulation of the ministry of agriculture republic of Indonesia (PERMENTAN) 2019. The use of bacteria isolated from pond waste as bio activator on fertilizer composting had the same quality as commercial bio activators (BIO, TR, EM), therefore this technology can be an alternative for treating waste in the shrimp pond culture industry.

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