Study of traditional market waste bioremediation in lowland city as materials for making compost and prospects of development

I R Rahim¹, T Harianto² and M Ihsan³

¹Environmental Engineering Department, Universitas Hasanuddin, Makassar, Indonesia
²Civil Engineering Department, Universitas Hasanuddin, Makassar, Indonesia
³Civil Engineering Department, Sekolah Tinggi Teknik Baramuli, Pinrang, Indonesia

E-mail: irwanrr@yahoo.com

Abstract. Compost is organic materials that have decomposed and is used as a plant fertilizer and soil conditioner. The principle technique of composting is to convert organic materials considered as waste to process such a way so that compatible to be used as media which functioning to loose soil and fertilizer plants. The study was conducted on a laboratory scale, composting the market’s garbage in Makassar city using cow manure as the additional material and the addition of an effective microorganism (EM4) as an activator by using Takakura composter. This study seeks the effect of certain variables in strictly controlled conditions. The results show that the addition of effective EM4 affects the quality of the final compost which is relatively better than natural composting. Additional material variation is very influential to the quality of finished compost. The best quality compost contained in variation P2 containing vegetable waste and cow manure with C-organic of 20.39 %, N-total of 1.2 %, C/N ratio of 17:05, P-total of 1.98 % and K-total of 1:09 %. This composting method provides an opportunity to develop as a business, economic value generator and help the government in reducing waste generation. Keywords: compost bioremediation, market’s garbage, effective microorganism (EM4), development prospect

1. Introduction

Rapid development in Indonesia, particularly in urban areas, is followed by urbanization to pursue a better life. This tremendously affects the increase of urban population which is also proportioned to the generated waste. However, this is not followed by adequate provision of facilities and infrastructure for waste management. As a result, the existing services are not optimum and leading to the degradation of environmental quality.

Makassar is one of the cities experiencing staggering problems in managing waste, particularly fresh market waste with volumes of market waste reaching 686.62 m³/day in 2013 [1]. One of the largest wastes in terms of volume produced due to the extensive market activities is an organic waste. Undeniably, an appropriate waste management system is certainly necessary.

One of the waste management methods is the composting method, which aims to reduce the volume of waste by transforming organic compounds into useful products. Waste processing can be done directly at the source, at specially designed places, at Temporary Disposal Sites, or at Final Disposal Sites [2]. Microorganisms are sometimes used to degrade market waste as the main
ingredient for composting in a process called bioremediation. Composting is considered as a sustainable technology because it aims for environmental conservation, human safety, and economic value generation. The use of compost helps to conserve the environment by reducing the use of chemical fertilizers that can cause soil degradation. Composting also indirectly helps human safety by preventing organic waste disposal. Many researchers have investigated the potentials of composting as well as the improvement methods including amendments component, controlling moisture, temperature and other elements [3-5].

2. Research methods
This study uses an experimental-laboratory approach which aims to investigate the influence of certain variables under tightly controlled conditions [6]. The research was carried out on a laboratory scale where compost was produced from fresh market waste with the addition of cow manure as well as the effective microorganism activator (EM4) using Takakura composter. The main ingredient of compost is vegetable waste collected from Terong Fresh Market, one of the largest fresh markets in Makassar.

3. Results and discussion

3.1 Characteristics of compost material
After the composting process takes place, each compost treatment variation is carried out to test the content of the compost variation (initial test). This preliminary test aims to determine the characteristics of each compost variation. The compost variations are P0 (vegetable waste) as control, P1 (vegetable waste + EM4), P2 (vegetable waste + cow manure), P3 (vegetable waste + cow manure + EM4).

| No | Treatment                                      | Water Content | pH   | C-organic | N-total | C/N   |
|----|-----------------------------------------------|---------------|------|-----------|---------|-------|
| 1  | Vegetable waste (P0)                          | 89.71         | 6.88 | 29.37     | 0.59    | 49.95 |
| 2  | Vegetable waste + EM4 (P1)                    | 91.15         | 9.47 | 33.45     | 1.05    | 32.44 |
| 3  | Vegetable waste + cow manure (P2)             | 81.92         | 9.6  | 34.87     | 1.11    | 31.58 |
| 4  | Vegetable waste + cow manure + EM4 (P3)       | 81.72         | 9.49 | 31.14     | 1.13    | 28.04 |

Table 1. Test results for the characteristics of compost material.

As shown in table 1, it was found that the C/N ratio of P0 variation was 49.95 where compost material was composed only by vegetable waste with high C-organic values and low N-total. It was then contributing to a higher ratio of C/N than that of other variations. In principle, organic matter with pH values between 3 and 11 can be composted with optimum pH ranging between 5.5 and 8.0 [7]. Therefore, the pH value of each variation meets the requirements. The water content in each compost variation is at a considerably high percentage. This is due to the composition of compost which is vegetable waste which has a significantly high moisture content of 81.72% - 91.15%.

3.2 Effect of EM4 and additional variations on compost quality
Compost fertilizer is not a new invention. It has traditionally been used in agriculture for a long time regardless of its decreasing popularity due to the lengthy process. The recent development of the composting process has achieved acceleration to 14-30 days using bio-activators. In this study, the addition of EM4 is used as a bio-activator for several compost variations.
The C/N ratio is used as an assessment of the nutritional needs of microorganisms to carry out their activities in substrate remodeling. Cow manure with a low C/N ratio is used in this study as an additional for variations.

3.2.1 Water content
Testing the water content is carried out at the beginning and end of composting which aims to determine changes in water content in each compost material [8].

| No. | Treatment | Water content (%) | Initial | Final | Difference |
|-----|-----------|-------------------|---------|-------|------------|
| 1   | P0        |                   | 89.71   | 20.99 | 68.72      |
| 2   | P1        |                   | 91.15   | 12.00 | 79.15      |
| 3   | P2        |                   | 81.92   | 6.67  | 75.25      |
| 4   | P3        |                   | 81.72   | 6.87  | 74.50      |

From table 1, it can be seen that the initial moisture content of composting at each variation is very high. This is due to the high water content in vegetable waste. Therefore there is no watering for all variations until the water content is close to the standard in compost mature. It is also shown that significant decreases in water content are found in the variation P1 with EM4 bio-activator and variation P2 with additional cow manure which results in a faster composting process which is 30 days of composting.

3.2.2 Changes in temperature
Temperature measurements are carried out every 2 days to find out the changes that occur during the composting process and to measure the temperature using a soil thermometer. From each variation of activator addition to temperature change, it can be seen that the effect of adding EM4 activator and additional variation of cow manure is not significantly different [9]. The results of observations of temperature during the composting process indicate a gradual increase in temperature. Temperature rise at the beginning of the process indicates that the composting process is going as expected. Temperature fluctuation is as indicated in figure 1.

![Temperature measurement](image_url)

**Figure 1.** Changes in compost temperature.

The temperature increase due to the addition of bio-activators with the highest concentration induced the increase of bacterial population causing the decomposition process of organic matter to run fast and the increasing temperature in the compost stack.
At the start of composting, temperatures of the four variations moved up rapidly and reached peak temperatures. The peak temperature achieved for each variation was 51.9°C, 57.1°C, 55.1°C and 50.9°C. The peak temperature in variation P0 occurred on the second day, whereas in variation P1 and P3, the ultimate temperature occurred on the fourth day. In variation P2, the highest temperature occurred on the sixth day. This happens because the variation of P0 has the highest C/N ratio of 49.95. Nitrogen is needed by microorganisms as a food source for the formation of body cells and carbon as a source of energy for microorganisms to breed well and be able to produce higher heat.

On figure 1, it can also be seen that for the variation P1 and P3, temperatures increase faster on the fourth day compared to the variation in P2. This is due to the addition of EM-4 on variations in P1 and P3 so that the activity of microorganisms is faster in decomposing the compost material, causing shrinkage of the stack.

3.2.3 Changes in pH
Temperature measurements are carried out every 2 days to find out the changes that occur during the composting process and to measure the temperature using a soil thermometer. From each variation of activator addition to temperature change, it can be seen that the effect of adding EM4 activator and additional variation of cow manure is not significantly different during the composting period, the pH is measured periodically every ten days. In principle, organic matter with pH values between 3 and 11 can be composted, optimum pH ranges between 5.5 and 8 [10]. Based on the initial pH, materials that will be composted still qualify the optimum range, as shown in table 3.

| No. | Treatment | pH (day)    |
|-----|-----------|-------------|
|     |           | 0 | 10 | 20 | 30 | 40 | 50 |
| 1   | P0        | 6.88 | 6.3 | 6.5 | 7.53 | 7.8 | 7.73 |
| 2   | P1        | 9.47 | 7.79 | 7.85 | 9.05 | - | - |
| 3   | P2        | 9.6 | 8.73 | 9.18 | 8.72 | - | - |
| 4   | P3        | 9.49 | 9.17 | 9.41 | 8.54 | 9.46 | - |

Figure 2. Changes in pH of compost.

From figure 2 above, it can be seen that variations other than P0 experience alkaline pH. The variation P0 experiences a neutral pH at the beginning of the composting process. The running time of the composting pH decreases. This is due to the activity of microorganisms that break down organic matter into simple organic acids. Variations of P1 and P3 use vegetable waste compost material plus EM4 activator and cow manure with high nitrogen concentration so that it has the potential to contain ammonia produced during composting. Ammonia increases pH because of its alkaline nature. A very high alkaline pH can inhibit the growth of plants and soil microorganisms [11].
3.2.4 Changes in odor, color and physical form of compost

Observations on the odor of compost are as follows:

**Table 4. Results of observation of the odor of compost.**

| No. | Treatment                              | Odor indication          |
|-----|----------------------------------------|--------------------------|
| 1   | Vegetable waste (P0)                   | No Odor                  |
| 2   | Vegetable waste + EM4 (P1)             | No Odor                  |
| 3   | Vegetable waste + cow manure (P2)      | Soil-like odor           |
| 4   | Vegetable waste + cow manure + EM4 (P3)| Soil-like odor           |

The odor of compost formed according to SNI standards is a soil-like odor. This condition is found in variations P2 and P3 as shown in table 4. Observations on the color of compost are as shown in table 5.

**Table 5. Observations of compost color.**

| No. | Treatment                              | Color         |
|-----|----------------------------------------|---------------|
| 1   | Vegetable waste (P0)                   | Dark brown    |
| 2   | Vegetable waste + EM4 (P1)             | Dark brown    |
| 3   | Vegetable waste + cow manure (P2)      | Dark brown    |
| 4   | Vegetable waste + cow manure + EM4 (P3)| Dark brown    |

Good color of compost resembles the color of the soil. In this study, all test objects for all treatments resemble the color of the soil which is dark brown and considered fulfilling Indonesian National Standard (SNI). Observations on the physical form of compost are as shown in table 6.

**Table 6. Observations of the physical form of compost.**

| No. | Treatment                              | Physical form |
|-----|----------------------------------------|---------------|
| 1   | Vegetable waste (P0)                   | Dry           |
| 2   | Vegetable waste + EM4 (P1)             | Dry           |
| 3   | Vegetable waste + cow manure (P2)      | Fine          |
| 4   | Vegetable waste + cow manure + EM4 (P3)| Fine          |

The physical form of compost that resembles soil (fine consistency) is only formed in P2 and P3 treatment. For treatment P0 (control) and P1, the consistencies tend to be dry, wherein the second stage of the composting process both were wetter and experienced no watering. However, for the final yield of composting based on shrinkage, P0 and P1 were dry. So that only variations in P2 and P3 physical forms meet SNI specification for consistency.

3.2.5 C-Organic

Carbon forms carbohydrates, fats, and proteins for plant growth. In addition, cellulose cell walls that strengthen plant parts are also formed due to the presence of carbon elements [12]. The test of C-organic content is carried out at the beginning and end of composting. It aims to determine the differences in percentage in C-organic content during the composting process.
Table 7. C-Organic content.

| No. | Treatment | C-Organic (%) | Initial | Final | Decrease |
|-----|-----------|---------------|---------|-------|----------|
| 1   | P0        |               | 29.37   | 19.48 | 9.89     |
| 2   | P1        |               | 33.45   | 21.98 | 11.47    |
| 3   | P2        |               | 34.87   | 20.39 | 14.48    |

Table 7 shows that C-organic has decreased from the initial phase of composting to the final phase of composting. This is because C-organic functions as a source of energy for microbes. This is consistent with the principle that C-organic in materials is useful as a source of energy for microorganisms for their metabolic activity and decomposes in the form of CO2.

3.2.6 N-Total
Nitrogen is a source of energy for microorganisms in the soil which plays an important role in the process of decaying or decomposition of organic matter. Nitrogen is needed in the photosynthesis process. The lack of nitrogen elements can cause the growth of leaves and plants to become stunted. On the contrary, the excess effect of nitrogen elements is including the stems to be easily broken and easily invested by diseases and infections.

Table 8. N-Total content.

| No. | Treatment | N-Total (%) | Initial | Final | Increase |
|-----|-----------|-------------|---------|-------|----------|
| 1   | P0        |             | 0.59    | 0.94  | 0.35     |
| 2   | P1        |             | 1.05    | 1.16  | 0.11     |
| 3   | P2        |             | 1.11    | 1.2   | 0.09     |
| 4   | P3        |             | 1.13    | 1.15  | 0.02     |

It is notable in table 8 that the highest N-total increase is in the variation P0 with a value of 0.35%. Material composition variation P0 is only vegetable waste (control), where the decreased value of C-organic content is lower than other compost variations and the initial value of nitrogen is lower than other compost variations. Despite the significant increase in nitrogen in the P0 variation, the final nitrogen value remained low at 0.94%. The lowest increase was in the P3 variation of 0.02%. The material composition of P3 variation, which is composed of vegetable waste, cow manure, and EM4 bio-activator, has a high N-total value of 1.13% which means the increase in N-total value is relatively low. This is also experienced in other compost variations due to high N-total values.

3.2.7 C/N ratio
The C/N ratio is a ratio of carbon and nitrogen elements. The C/N ratio is used to meet the nutritional needs of microorganisms to carry out their activities in substrate decomposition. The C/N ratio content test is carried out at the beginning and end of composting.
Figure 3. Changes in C/N ratio.

Figure 3 shows that the C/N ratio has decreased during the composting process. This is due to the process of decomposition by microbes in which carbon decomposition is used by microbes as a source of energy and growth whereas nitrogen is used by microbes for protein synthesis and the formation of body cells. So that the amount of C-organic content is low and the Nitrogen content is high, the C/N ratio is low.

The C/N ratio for P0 variations is higher than other variations. Variation of P0 slightly exceeds the threshold of 20.76 where the value of C/N ratio according to SNI is 10-20. This is due to the variation of compost P0 is vegetable waste which does not contain cow manure and EM4 bio-activator whereas variation P1, P2, and P3 contain cow manure and EM4 bio-activator. This is in accordance with Mulyono (2014) stating that at a high C/N ratio microorganisms do not develop optimally due to nitrogen deficiency. The variation of P0 only contains a small portion of nitrogen which is 0.59% and creating a high value of C/N ratio.

3.2.8 \( P_2O_5 \) and \( K_2O \)

Tests of \( P_2O_5 \) and \( K_2O \) content are carried out after composting ends. This is conducted to determine the \( P_2O_5 \) and \( K_2O \) content in the mature compost from the best compost variations. The phosphorus element (\( P_2O_5 \)) for plants plays a role in accelerating the growth of roots in seedlings, as well as strengthening and accelerating growth in mature plants. In addition, the phosphorus element (\( P_2O_5 \)) is useful to add quality to grain crops and affect the formation of cell nuclei. From the results of the previous compost examination, it was found that P2 variation was the best variation among other compost variations with each organic C content = 20.39; N-total = 1.2% and C/N ratio = 17.05.

Table 9. P-total and K-total content.

| No. | Treatment | \( P_2O_5 \) (%) | \( K_2O \) |
|-----|-----------|------------------|------------|
| 1   | P2        | 1.98             | 1.09       |

As depicted in Table 9, the \( P_2O_5 \) content of variation P2 is equal to 1.98% while its \( K_2O \) content is equal to 1.09%. Comparing the results to the standard quality of mature compost according to SNI 19-7030-2004 where minimum \( P_2O_5 \) content is 0.10% and minimum \( K_2O \) content is 0.20%, the content of \( P_2O_5 \) compost is mature and \( K_2O \) has met the standards [13].

3.3 Duration of composting

The duration of composting time in this analysis is determined based on the weight loss of the waste and takes into account the physical standards of compost such as texture that resembles soil. In table 10, the highest initial weight composting result is P3 variation which is 4200 g where the composition...
of P3 variation is vegetable waste added cow manure and EM4 bio-activator with higher density than that of other variations while the lowest weight is in the P0 variation with 3000 g.

### Table 10. The average initial weight of composting.

| No. | Variation | The initial weight of composting | Average initial weight (gram) |
|-----|-----------|----------------------------------|------------------------------|
|     | I         | II                               | III                          |
| 1   | P0        | 3000                             | 3000                         |
| 2   | P1        | 3590                             | 3600                         | 3596 |
| 3   | P2        | 3900                             | 3900                         | 3900 |
| 4   | P3        | 4200                             | 4200                         | 4200 |

Weight of the composted material experiences shrinkage which means that the compost has matured. Material shrinkage values are as shown in table 11.

### Table 11. The average final weight of composting.

| No. | Variation | The final weight of composting | Average final weight (gram) |
|-----|-----------|--------------------------------|------------------------------|
|     | I         | II                             | III                          |
| 1   | P0        | 566.23                         | 563.87                       | 566.43 | 565.51 |
| 2   | P1        | 536.07                         | 536.15                       | 539.70 | 537.31 |
| 3   | P2        | 1500                           | 1500                         | 1500   |
| 4   | P3        | 950                            | 900                          | 950    | 933.33 |

From table 11, it can be seen that the weight of mature compost in P2 and P3 variations is 1500 g and 933.33 g, due to the material composition of variation P2, which is composed of vegetable waste with additional cow manure, and additional EM4 bio-activator in variation P3, making the material decompose by microorganisms that produce ammonia and nitrogen trapped in a compost stack because the pores of the compost pile are so minuscule that ammonia and nitrogen are released into the air in small amounts. The lowest weight of compost in variation P1 and P0 is equal to 537.31 g and 565.51 g. Compost shrinkage from each variation of compost is as shown in table 13. The highest shrinkage value is on variation P1 that is equal to 85.14% and the lowest is variation P2 that is equal to 61.53%.

### Table 12. Compost shrinkage.

| No. | Variation | Average initial weight (gram) | Average final weight | Shrinkage (%) |
|-----|-----------|-------------------------------|----------------------|---------------|
| 1   | P0        | 3000                          | 565.51               | 81.14         |
| 2   | P1        | 3596                          | 537.31               | 85.05         |
| 3   | P2        | 3900                          | 1500                 | 61.53         |
| 4   | P3        | 4200                          | 933.33               | 77.77         |

The longest duration of composting is of variation P0 which reaches 50 days of composting while the shortest duration of composting is of variation P1 and variation P2 with 30 days of composting time. While based on the physical form of compost, the texture of variation P1 and P0 is dry which
does not meet the SNI standard. This is caused by the basic ingredients of variation P1 and P0 used are vegetable waste without cow manure, so that the gases produced by the decomposed microbes into the air, such as ammonia and water vapor cause the weight of the final material to decrease and become dry.

### Table 13. Recapitulation of the results of compost quality.

| No. | Parameter       | Unit | Composting standard | Variation of compost |
|-----|-----------------|------|----------------------|----------------------|
| 1   | Water content   | %    | max 50               | 15-25                |
|     |                 |      |                      | 20,99                |
|     |                 |      |                      | 12                   |
|     |                 |      |                      | 6,67                 |
|     |                 |      |                      | 6,87                 |
| 2   | C-organic       | %    | 9.80 - 32            | min. 15              |
|     |                 |      |                      | 19,48                |
|     |                 |      |                      | 21,98                |
|     |                 |      |                      | 20,39                |
|     |                 |      |                      | 20,59                |
| 3   | N-total         | %    | min. 0.40            | min. 4               |
|     |                 |      |                      | 0.94                 |
|     |                 |      |                      | 1.16                 |
|     |                 |      |                      | 1.2                  |
|     |                 |      |                      | 1.15                 |
| 4   | C/N-ratio       |      | 10 - 20              | 15 - 25              |
|     |                 |      |                      | 20,76                |
|     |                 |      |                      | 19,05                |
|     |                 |      |                      | 17,05                |
|     |                 |      |                      | 18,01                |
| 5   | K2O             | %    | min. 0.20            | min. 4               |
|     |                 |      |                      | -                    |
|     |                 |      |                      | -                    |
|     |                 |      |                      | 1.09                 |
| 6   | P2O5            | %    | min. 0.10            | min. 4               |
|     |                 |      |                      | -                    |
|     |                 |      |                      | -                    |
|     |                 |      |                      | 1.98                 |
| 7   | pH              |      | 6.80 – 7.49          | 4 – 9                |
|     |                 |      |                      | 7.73                 |
|     |                 |      |                      | 9.05                 |
|     |                 |      |                      | 8.72                 |
|     |                 |      |                      | 9.46                 |
| 8   | Odor            | Soil-like | - | No-odor |
|     |                 |      |                      | No-odor              |
|     |                 |      |                      | No-odor              |
|     |                 |      |                      | No-odor              |
| 9   | color           | Dark brown | - | Dark brown |
|     |                 |      |                      | Dark brown           |
|     |                 |      |                      | Dark brown           |
|     |                 |      |                      | Dark brown           |
| 10  | Duration of composting | Day | - | 50 |
|     |                 |      |                      | 30                   |
|     |                 |      |                      | 30                   |
|     |                 |      |                      | 40                   |

### 3.4 Prospect of development of market waste as compost material

Based on data in 2017, the total volume of Makassar municipal solid waste generation was 4,188.26 cu.m/day. The market volume of the Makassar city market reaches 686.62 cu.m/day. Based on measurements made in a market in the city of Makassar, it is known that the total organic waste is 89% or 415.54 m3/day which can be decomposed and 11% or 51.36 m3/day of organic waste that cannot be decomposed. The composition of organic waste that can be decomposed is shown in table 14.

### Table 14. The daily volume of organic waste production.

| Type of waste                | Percentage (%) | Volume (cu.m/day) |
|------------------------------|----------------|-------------------|
| Vegetable waste              | 45.31          | 188.28            |
| Fruit waste (including fruit peel) | 35.12    | 145.94            |
| Dry leaf waste               | 19.57          | 81.32             |

From the measurement results obtained, daily vegetable waste production is 188.28 cu.m/day and capable of producing 16394.98 kg/day or approximately 16 tons/day. As much as 188.28 cu.m/day or as much as 65.89 tons/day of vegetable waste can be recycled as compost material.
4. Conclusions

Based on the results and discussion, some conclusion can be drawn:

- The addition of effective microorganism (EM4) affects the quality of mature compost which is relatively better than natural composting.
- The variation of additional ingredients in compost significantly affects the quality of mature compost where the best quality of compost is found in variation P2, composed of vegetable waste and cow manure with 20.39% C-organic compost quality, 1.2% N-Total, C / N ratio 17.05, P-Total 1.98%, K-Total 1.09%. Variation P0 (control) and variation P1 (vegetable waste and EM4) cannot be used as compost because the final physical form of compost tends to be dry whereas for variation P3 (vegetable waste with additional cow manure and EM4), macronutrient content and physical form meets compost quality standards but the pH value exceeds the threshold of 9.46 and tends to be alkaline.
- The duration of composting is based on shrinkage of compost material and the physical form of mature compost found that variation P2 has the fastest composting duration of 30 days.

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