Organic Waste Management by BiobiN Compostor: Case Study of Warinchamrap Municipality

Rungnapa Tubnonghee, Sompop Sanongraj, and Wipada Sanongraj

Abstract**—***The objective of this research is to study organic waste management by composting using BiobiN compostor. Approximately 850 kilograms/cycle of organic waste was collected in Warinchamrap municipality and then sent to compost in the BiobiN compostor. The amount of 1,700 kilograms of compost was obtained for each cycle. The results showed that compost reached stability after the 65th day of composting. Physical characteristics of compost were observed. It has soil-like smell with dark-brown to black color. Also, there were no fungi-like and white powders in the compost.The elevated temperature at above 55°C was observed in the period of the 6th-15th day of composting. The pH varied from 5.5 to 6.9 for the whole period of composting. In conclusions, all physical, chemical, and biological characteristics of compost meet the standards and criterion issued by the Department of Agriculture (DOA) after 65 days of composting. The numbers of microorganism and pathogenic bacteria were reduced and destroyed as compared to standard of DOA. However, the composting temperature above 60°C for a period of over 3 weeks was required for a safety concern and needed to be futher investigated.*

Keywords— Compost, Composting, Organic waste, BiobiN Compostor, Warinchamrap Municipality.

1. INTRODUCTION

Municipal solid waste (MSW) is all of the wastes arising from human activities [1]. The population of Warinchamrap municipality area has around 30,000. The total amount of generated MSW is about 30 tons each day. The MSW compositions can be mainly divided into two parts: burnable and non-burnable. The burnable solid wastes are organic wastes 38.5%, papers 5.5%, plastic bottles 5.5%, plastic bags 12.6%, wood-soils 9.0%, leather-rubbers 4.0%, foam boxes 2.0%, and others 2.0%, respectively. The non-burnable solid wastes are glass bottles 13.0% and aluminums cans 1.0%. Organic solid wastes are major component of the MSW stream and suitable composting substrates. Therefore, composting is selected to handle organic solid wastes for decreasing expenditure of the sanitary landfill of Warinchamrap municipality. Conceptually, organic solid waste is separated at major sources including household, canteen, food shop, restaurant, and market [2]. Project of Organic waste composting (OWC) was set up in 2005 by the helping education and cooperation from Japan Bank international Cooperation (JBIC), Saga University and Chulalungkorn University. This project studied about change of composts in physical, chemical, and biological characteristics in a laboratory scale. The organic waste compost was prepared with Hachigama's formula from Mr.Toshiaki Fukuda concept. Results of this project found that, the 100th organic waste compost had good characteristic and met the standard and criterion issued by the Department of Agriculture (2005) [3]. However, the composting could not control temperature above 60°C for 3 weeks in order to significantly destroy and reduce number of microorganism and pathogenic bacteria [4, 5]. In principal, the requirement of compost for safe application in soil is its degree of stability or maturity, which implies stable organic matter content, and the absence of phytotoxic compounds and plant or animal pathogen [6, 7, 8]. Recently, MSW management involves advanced technologies that offer more protection to the environment and human health [9].

In 2008, Warinchamrap municipality launched a program to separate food waste, or food swill at source to compost in BiobiN [10]. BiobiN is reactor for composting (7 cubic meter container type equipped with air blower). The composting in BiobiN was controlled conditions for stability and maturity compost. The organic waste compost was observed to meet the standard and criterion issued by the Department of Agriculture (2005) after 100 days of composting. It reached to stability after the 45th day of composting. As following the previous work [10], this study provide the monitoring and investigation of organic waste compost for practically use in a local area.

2. METERIAL AND METHODS

2.1 Composting of organic wastes and experimental details.

The composting mixtures were prepared in the following proportions. The organic wastes composts (OWC) were consisted of food wastes (30% by wt), shredded yard wastes (20% by wt), the local raw materials (40% by wt) and soil inoculums from a local forest (10% by wt). The Local raw materials were mixed from sawdust (20 % by wt), rice husk (10 % by wt), and rice brian (10 % by wt). The OWC had total weight 1,700 kilograms (100 % by wt. on wet basis). The OWC was uniformly mixed and put in BiobiN reactor. BiobiN had approximately 2.0x3.5x2.0 meters (WxLxH). It was

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2.2 Physical and Chemical Analysis

The compost was observed odor and color, measured temperature and pH in 5 points of the reactor in everyday for 65 days. The pH was measured in a 1:1 (compost:water) aqueous extract by Twin pH meter : Model B-212 and Glass electrode method. Temperature in compost pile was measured by CUSTOM thermometer. (range -50°C to + 250°C and probe 25 centremeter). The compost was determined by physical and chemical analysis including %moisture, %total organic carbon (%C), %total organic nitrogen (%N), C/N Ratio, and electric conductivity (EC). The compost sample was collected in the 65th day about 1.0 kilogram. The moisture content was determined on a wet basis (dry in an oven at 77 ºC for 24 hrs.). The EC was measured by the electric conductivity meter followed the electrode method. The compost sample was analyzed for the total organic carbon by dry combustion [11] and the total nitrogen by Kjedahl method [12].

2.3 Biological Analysis

The compost was investigated for microorganism and pathogenic bacteria by dilute plate methods of pathogenic bacterial counts such as Total E.Coli, Total Salmonella, Total Shigella, and Chromocult coliform. Unit of count was Colony Form Unit per weight by dry matter (CFU/g dry matter). Unit of Total coliform bacteria count was Most Probable Number (MPN/g dry matters) [13]. The biological analysis was conducted by the Environmental Protection Center (EPC) under the department of Chemical Engineering at Ubonratchatani University, Thailand. The details about laboratory procedure please see at Rungnapa *et. al.* [5, 10].

3. RESULTS AND DISCUSSION

In the reactor had degradation both aerobic and anaerobic composting. The odor had severe ammonia smell on the 3rd day and had more on the 5th day. Then its smell decreased and could not get odor on the 8th day. After the 14th day, the compost had soft soil-smell and got stronger smell until the 65th day. The color had dominant yellow color from sawdust and food swill on the 3rd day. Since sawdust was slower degradable than other organic wastes. It also had the high C/N ratio of 225. The texture of compost had tough and indicated each one-piece of components. Then on the 6th-10th the compost color changed to dark-yellow, had fiber fungi-like and white powders distributed on the top surface compost pile. The texture of compost had homogeneous components. After the 24th day, the color changed from dark-brown to black on the 30th day throughout the 65th day. The Physical characteristics reached to stability on 45th day [14].

Table 1 shows physical and chemical characteristics of organic waste compost. The initial moisture content has 50.25 %. Decomposition of organic matter depends on the presence of moisture to support microbial activity. General ranges of moisture content found suitable for various waste, such as municipal waste was 55-65% [1]. At the end of this study, the moisture content has dropped to 23.06%. The compost was black and dry. This may be due to an evaporation of water from the compost by-product of aerobic and anaerobic degradation. At the beginning, the content of total organic carbon starts at 36.26% and it decreases as the decomposition proceeds [15]. Typically, organic waste contains 15-17% degradable organic carbon [16]. Therefore, an aerobic degradation of organic compounds results in the storage of a small amount of carbon that does not degradate to CO_2, but it is tranformed into slowly decomposable components. The EPA reported a lower bound of approximately 0.03 tons of carbon equivalent (CE) per ton of composted waste [17]. At the 65th day, the total organic carbon and the total organic nitrogen reached 21.72% and 4.15%, respectively. The C/N Ratio was calculated to be 2.23. A value of C/N Ratio is assigned by DOA at a lower than 20:1. A suggestion of a C/N Ratio should be start at 30 : 1 to 15 : 1, because the amount of nitrogen has not effect to restrict a digestion rate and it is a part of necessary photosynthesis elements, $C_5H_7O_2N$ as shown in Eq. (1) [18].

$$5CO_2 + 2H_2O + NH_3 + \text{energy} \longrightarrow C_5H_7O_2N \qquad (1)$$

In addition, the EC was 216 µs/cm at the 65th day. The EC is the ability of a material to transmit or conduct an electrical current. The EC was measured or estimated in physical and chemical properties of salinity, including water content, clay content, cation exchange capacity (CEC), exchangeable Ca and Mg, soil organic matter, and herbicide behavior in soil or compost.

Biological characteristic of the compost was determined at the beginning and at the 65th day. The result showed that total viable bacterial counts decreased from 3.40×10^7 to 4.30×10^3 cell /g dry matter. Total viable fungal and actinomycete counts changed from 0 to 2.3×10^2 and 0 to 5.8×10^5 cell/g dry matter, respectively. The pathogenic bacteria, including total E.Coli, total Salmonella, total Shigella, and total coliform, was determined by the dilute plate method. It was found that the amount of pathogenic bacterials decreased from the beginning to the end of composting. Total E.Coli and total Salmonella changed from 5.20×10^6 to 3 CFU/g dry matter and 2.60×10^4 to 0 CFU/g dry matter, respectively. Total Shigella and total coliform decreased from 1.89×10^4 to 1.3×10^1 CFU/g dry matter and 9.20×10^8 to 2.30×10^5 MPN/g dry matter, respectively. The destruction of pathogenic organisms is an important design element in a compost process. Most of pathogenic organisms will be destroyed rapidly when all parts of the compost pile are subjected to a temperature of about 55ºC. Only a few can survive at a temperature up to 67ºC for a short time period. Elimination of all pathogenic organisms can be accomplished by allowing the composting waste to reach a temperature of 70ºC for 1-2 hours [14, 18, 19, 22]. The amount of the bacterial pathogen issued by the Department of Agriculture (DOA) is not more than 1,000 CFU/g dry matter)

The temperature profile of the compost for the whole

Table 1. Physical, Chemical, and Biological characteristic of organic waste compost

Physical and Chemical characteristic	Organic waste compost 0 Day	Organic waste compost (65th Days)
%Moisture	50.25 %	23.06 %
%Total organic carbon	36.26 %	21.72%
%Total organic nitrogen	2.13 %	4.15 %
C/N Ratio	17.02	2.23
Electric Conductivity (EC)	74.58 µs/cm	216 µs/cm
Biological characteristic	Organic waste compost 0 Day	Organic waste compost (65th Days)
Total viable bacterial counts (cell /g dry matter)	3.40×10^{7}	4.30×10^{3}
Total viable fungal counts (cell /g dry matter)	0	2.30×10^{2}
Total viable actinomycete counts (cell /g dry matter)	0	5.8×10^{5}
Total E.Coli counts (CFU/g dry matter)	5.20×10^{6}	3
Total Salmonella counts (CFU/g dry matter)	2.60×10^{4}	0
Total Shigella (CFU/g dry matter)	1.89×10^{4}	1.30×10^{1}
Total coliform (MPN/g dry matter)	9.20×10^{8}	2.30×10^{5}

The second period of the high temperature on the 4th to 9th day is called the thermophilic microorganism digestion. The periods of the constant temperature is called curing phase [14, 18, 19, 20]. Biological digestion by microorganism metabolism is exothermic reaction that rises over 70 ºC temperature in a compost pile. The organic substants is easy breaked out to simple form [21]. In the last of period , the organic substants are mostly digested and the temperature is decresed. The Compost reaches to cured and stabilized condition [18].

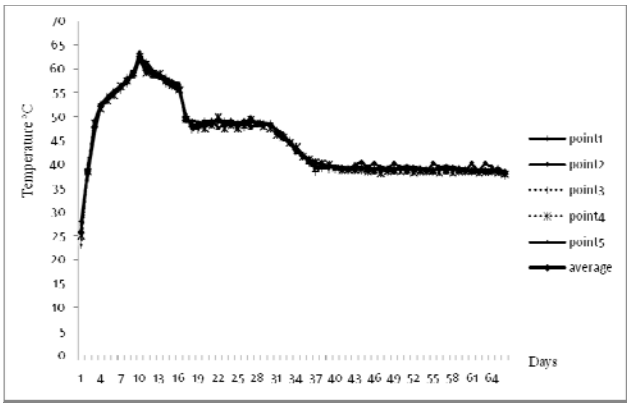

Fig.1. Temperature Profile of the Compost

The pH profile of the compost for the whole period of composting is shown in Fig.2. When all components of the compost were mixed, the measured pH of the sample was 6.1. The pH of the compost decreased from 6.1 to 5.44 on the 2rd day. Then, the pH raised and varied from 5.5 to 6.9 for the whole period of composting.

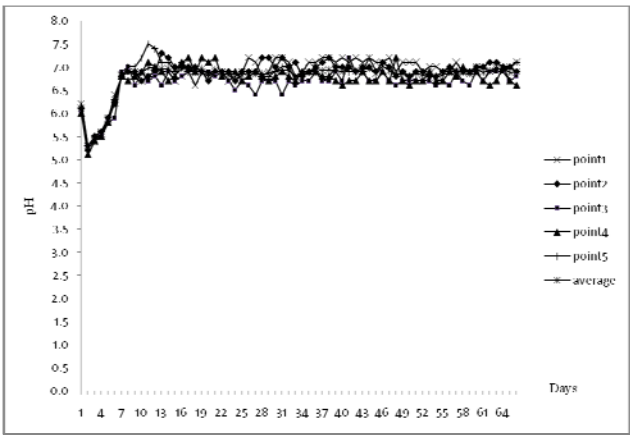

Fig.2. pH Profile of the Compost

4. CONCLUSION

For this case study, all physical, chemical, and biological characteristics of the compost obtained from the BiobiN compostor meet the standards and criterion issued by the Department of Agriculture (DOA) after 65 days of composting. The numbers of microorganism and pathogenic bacteria were reduced and destroyed as compared to standard of DOA.

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REFERENCES

[1] Roger, T. Haug. 1993. The Practical Handbook of Compost Engineering. Florida: CRC Lewis Publishers.

[2] Warinchamrap Municipality. 2005. Organic waste management of Warinchamrap Municipality.(Report Paper)

[3] Ministry of Agriculture and Cooperatives, Department of Agriculture .2005. Announment from Department of Agriculture, Criterion of Organic Fertilizer in 2005. Royal Thai Gazette No. 122. Special section 109 ng, September 30th, 2005.

[4] Tubnonghee, R.; Srihanon, P.; Piapukiew, J.; and Sanongraj, S. 2006. Variation of Physical, Chemical and Biological Characteristics during Composting of Organic Waste. In Proceedings of the 1st Research Conference of Ubonratchathani University. pp 85-86. Ubonrachatani.

[5] Tubnonghee, R.; Srihanon, P.; Piapukiew, J.; and Sanongraj, S. 2008. Temperature Changes During OrganicWaste Decomposition Caused by Adding Different Sources of Microorganisms. Thai Environmental Engineering Journal. 22:3: 49-59.

[6] Bernal, M.P., Paredes, C., Sanchez-Monedero, M. A., Cegarra, J., 1998. Maturity and Stability parameters of compost prepare with a wide range of organic wastes. Bioresource Technology. 63: 91-99.

[7] Matsuda, J., Hyakumachi, M., Shimizu, Himoto. J., 1996. The compost of soil and agricultural wastes and its sterilizing, suppressing and fertilizing effects. Int. Congress Exhibit. 2: 153-154.

[8] Gomez, A., 1998. The evaluation of compost quality. Trends Analysis Chemical. 10: 310-314

[9] Diaz, R., and Warith, M., 2005. Life-cycle assessment of municipal solid wastes: Development of the WASTED model. Waste management xxx(2005)xxx. “to be published”. Accepted 3 May 2005.

[10] Tubnonghee, R.; Srihanon, P.; Piapukiew, J.; and Sanongraj, S. 2008. Variation of Temperature in Organic Waste Composting With and Without Operating Air Blower in BiobiN. In Proceedings of the 7th Research Conference of Environmental Engineering Association of Thailand.

[11] Nelson, D. W., and Sommer, L. E., 1982. Total carbon, organic carbon and organic matter. In: Page A. L. (Ed), Method of Soil Analysis Part II: American Society of Agronomers, Madison, pp. 539-579.

[12] Bremner, J. M., and Mulvaney, C. S., 1982. Nitrogen total. In: Page, A.L., Miller, R. H., Keeney, D. R., (Eds), Method of Soil Analysis Part II: American Society of Agronomers, Madison, pp. 371-378.

[13] Pepper, L. I., Gerba, P. C. and Brendecke, W. J. 1995. A Laboratory Manual Environmental Microbiology. Academic Press Publishers, California.

[14] Vesilind, P. A., Worrell, W. and Reinhart, D. 2002. Solid Waste Engineering. BROOKS/COLE. The United States of America.

[15] Sneh, Goyal., S, K. Dhull. and K, K. Kapoor. 2005. Chemical and biological changes during composting of different organic wastes and assessment of compost maturity. Bioresource Technology. 96: 1584-1591.

[16] IPCC. (International Panel on Climate change), 1986. Revised 1996 IPCC Guidelines for national greenhouse Gas Inventories: Workbook. International Panel on Climate change.

[17] EPA. (Environmental Protection Agency) 2002. Solid waste management and greenhouse gases. A Life-cycle assessment of Emissions and Sinks, 2nd ed. Contract EPA530-R-02-006, US Environmental Protection Agency Washington, DC.

[18] Tchobanoglous, G., Theisen, H., and Vigil, S. A.,1993. Integrated Solid Waste Management: Engineering principle and management issue. International Edition. McGraw-Hill. Singapore.

[19] Gerard, K., 1997. Environmental Engineering. McGraw-Hill. New York.

[20] Baby, R. E., and other. 2005. Evolution of Thermophilic period in biosolids composting analyzed with an electronic nose. Sensors and Actuators B 106 (2005): 44-51.

[21] M, De Bertoldi., G, Vallini. And A, Pera. 1983. The biology of composting. Waste Management & Research. Vol 1, Issues 2, 157-176.

[22] Hassen, A., and other. 2001. Microbial characterization during composting of municipal solid waste. Bioresource Technology. 80: 217-225.