Windrow Composting of Food and Yard Wastes

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Abstract

Organic waste from public consumption is a problem for waste management. The university campus in Tambol Salaya, Nakorn Prathom Province, a community with a large population, needed to find effective strategies for sustainable waste management. This study aimed to find a proper solution for two major organic wastes, food and yard wastes. Windrow composting was investigated at different conditions including mixing ratios and aerations in the field experiment for 8 weeks. The organic wastes and composted material samples were analyzed for physical and chemical characteristics including moisture content, temperature, pH, organic matter, total nitrogen, total phosphorus and total potassium. Two way ANOVA analysis and LSD post-hoc test were used for statistical analysis. The results showed that food waste had high nitrogen and moisture content while yard waste had high organic carbon. To compost the organic materials without aeration supply conditions revealed significant difference ($p < 0.05$) in higher composting temperature while the higher mixing ratio could significantly increase ($p<0.05$) organic matter. The composting was finished at week 8 and composted materials had a lower temperature and neutral pH. The nutrients, nitrogen and phosphorus were increased whereas potassium was slightly decreased, thus they could match with the organic fertilizer standard. The food yard waste ratio of 1:1, without aeration was a suitable organic composting condition. The findings can also be used as an application criterion for other communities which recycle nutrients back to the environment.

Keywords: food waste, yard waste, compost, nutrient

J Public Health 2017; 47(2): 131-141

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Introduction

Solid waste is a major environmental problem in many cities of Thailand. Urbanization that emphasizes changes in population number and human activities is later related to increased solid waste[1]. As a result, solid waste is produced from various urban activities such as markets, department stores, residents and others. The magnitude of the problem closely relates to the consumption of resources and various packaging materials[2].

Organic waste is a major constituent in most solid wastes[3] and causes a nuisance. The easily decomposing property creates bad odors and encourages a variety of insects and other vectors. It is also a source of food and habitat for them. The high proportion of organic waste mixing in the general solid waste would make more limited conditions for sanitary waste disposal. Therefore, to create a sustainable option, management measures are needed to reduce organic waste production and separate it from the general waste as much as possible. This will not only help better management of solid waste but also conserve natural resources.

Composting is a challenging strategy, which produces organic fertilizer or soil conditioner from organic materials. Composting organic substances over time will then transform it from the original condition to a brown to black powder that can be used for various plantation fields. The Windrow compost pile is a simple pile of material with a more or less triangular cross-section and is an example of a low technology. A windrow should measure less than 3.0 x 1.5 m. (wide x high), and its length will vary depending upon the amount of materials used[4]. Aeration generally occurs naturally or artificially when needed. Materials can be also added as they become available to make a proper sized pile.

Tambol Salaya, Nakorn Prathom Province is a community that has rapidly urbanized because it has a university campus and a variety of business surroundings. Considering only the university campus, it has a day population of more than 25,000 people and a night population of more than 5,000. A huge amount of solid waste, around 4 tons/day, is produced follow increasing population and activities. It creates a waste generation rate of 0.3 kg/person/day[5]. Beside this, food and yard waste are major organic wastes[6] on this campus. Composting these organic wastes in a suitable condition is one option to reduce environmental problems.

The aim of this study was to investigate different compost conditions of food waste mixed with yard waste using windrow composting. The composting factors included mixing ratios and aeration conditions. The findings were expected to be a sustainable management solution for both organic wastes.

It will also create a waste management model for other communities.

Method

Materials

A sample of 366 kg of food waste and 714 kg of yard waste was collected from the university campus area in Tambol Salaya, Nakorn Prathom Province.

Study site

The composting process was conducted at the field workshop of the Physical and Environment Division, Mahidol University, Salaya Campus.

Experimental setup

The organic wastes in the university campus were sampled for study. It was designed as a field experiment using compost piles, 3 mixing ratios; 1:1, 1:2, and 1:3 (vol./vol.) between food waste (FW) and yard waste (YW), and 2 aeration conditions, i.e., with and without aeration. The treatment involved 6 experiments as shown in Table 1. They were analyzed for physical and chemical characteristics including moisture content, temperature, pH, organic matter, total nitrogen, total phosphorus and total potassium from the first day of composting until the end at the 8^{th} week.

Table 1 Experimental Treatment.

Treatment	Mixing ratio (FW : YW)	Condition
A1	1:1	With aeration
A2	1:2	With aeration
A3	1:3	With aeration
A4	1:1	Without aeration
A5	1:2	Without aeration
A6	1:3	Without aeration

Composting

Composted materials were prepared using food waste selecting only small sized (less than 1 inch) constituents and nonbio-degradable materials were removed whereas yard waste was crushed to small pieces, around 1-2 inches or smaller. The studied materials were mixed composted in the windrow piles according to each treatment in Table 1. They maintained the moisture content at around 60-80% during 8 weeks of composting process[7].

Sample collection and analysis

The temperature of each composting pile was measured at the experimental field daily. The other studied physical and chemical characteristics including moisture content, temperature, pH, organic matter, total nitrogen, total phosphorus, and total potassium were measured from the sampled compost materials, before sampling, and sample containers were cleaned by cleaning with tap water. The samples were collected from the compost pile at the beginning of the pile row, middle pile row and the end of the pile row with 30 centimeters depth. Samples were put in a zip lock bag and kept in an ice bucket to transfer to the laboratory. They were analyzed according to standard analytical protocols[8].

Statistical analysis

Descriptive statistics was used to explain the physical and chemical characteristics of food waste mixed with yard waste and composted materials. Inferential statistics, two-way ANOVA and LSD post-hoc test were used to determine the statistical relationship of parameters.

Results and discussion

1. Food and yard waste characteristics

The initial characteristics of food and yard waste were analyzed. They had moisture contents of 77.12% and 24.12%, pH 6.26 and 5.47, organic matter (OM) 21.48% and 42.96%, total nitrogen (T-N) 2.15% and 1.5% and carbon to nitrogen ratio (C/N ratio) 9.99 and 28.64, respectively. These properties were suitable to use as raw materials for the composting process[9].

2. Nutrient mineralization

The moisture content of composting piles was controlled at 60-80%. The compost piles temperatures were measured daily as shown in Figure 1. The other characteristics such as pH, organic matter, total nitrogen, total phosphorus and total potassium at the starting day of composting were determined as shown in Table 2 and Figure 2.

Table 2 Initial Characteristics of Composts.

Parameters	Treatments					
	A1	**A2**	**A3**	**A4**	**A5**	**A6**
pH	5.52	5.48	5.49	5.52	5.48	5.5
OM	48.12	48.58	47.78	50.15	51.12	53.56
T-N	1.23	1.22	1.34	1.08	0.79	1.44
T-P	0.64	1.02	0.61	0.53	0.44	0.66
T-K	0.39	0.56	0.59	0.4	0.53	0.64
C/N ratio	39.12	39.82	35.66	46.44	64.71	37.19

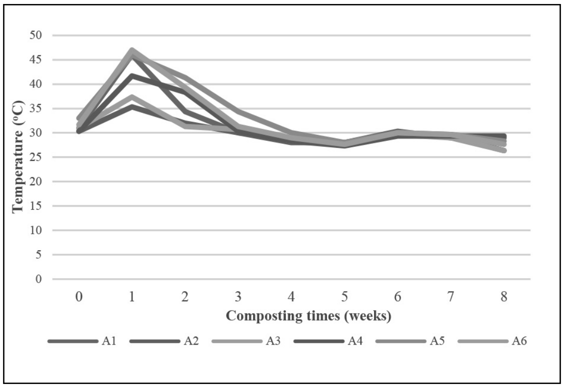

Figure 1 Trend Lines of Temperature Changed

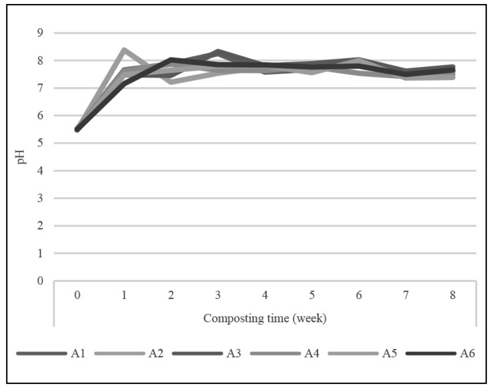

Figure 2 Trend Lines of pH changed

The initial properties of the mixed food and yard wastes obtained at different mixing ratios and conditions of composting are presented in Table 2. The overall characteristics of each compost treatment were quite in the same range. Yard waste was a major contribution of carbon source for the composting material; thus, the C/N ratio of mixtures was increased according to increasing yard waste volume. These C/N ratios were suitable for the composting process[10].

Temperature is considered as one important indicator of the composting process. It directly relates to the microbial activities with the degradation of organic matter[11]. Temperature of all treatments (Table 2) increased on the first day of composting until the 1st week. They ranged between 55-65°C. One report[12] indicated that these temperature ranges are necessary to destroy all pathogens. They were then decreased to near the ambient temperature. On the other hand, the pH trend lines exhibited the opposite change. They were sharply decreased since the early stage of composting. After three weeks, the pH values obtained were in the alkaline range, around 7.54-8.33, until the end of composting process in weeks 8th as shown in Figure 2. The changing pattern of temperature and pH meant the active degradation of organic wastes occurred at the 1st week and ended at the 8th week. It highlighted the fact that the compost pile began to stabilize[13].

The measured nutrients in this study included organic matter (OM), total nitrogen (T-N), total phosphorus (T-P) and total potassium (T-K). The C/N ratio was also determined. Figure 3 shows the trend line of these studied parameters. Organic matter was measured at every 2 weeks from week 0 until weeks 8. Organic matter of all treatments was in the range of 26.82-53.56%. The treatment of A4 presented the highest reduction percentage of organic matter. Two-way ANOVA analysis indicated that a significant difference between mean organic matter of yard waste mixed with food waste treated at different mixing ratios. The LSD post-hoc test also revealed that the mixing ratio could produce a statistically significant mean of organic matter. ($F = 3.856$, $p = 0.033$). This came from the increased ratio of yard waste contributing to the increase of organic carbon content in the composting materials.

Nitrogen was the main nutrient for plants. The requirement of nitrogen and other nutrients depends on many environmental factors[14]. Total nitrogen of all treatments at week 8 was in the range of 1.14-1.85%, in line with that of organic fertilizer standards of the Department of Agriculture[15], except for only treatment A5. It presented a slightly lower amount of total nitrogen than the standard. Two-way ANOVA analysis determined no significant difference between the mean total nitrogen of food waste mixed with yard waste treated at different mixing ratios and aeration conditions. It meant that the increasing ratio of yard waste did not decrease the nitrogen content of the composting materials but the composting reaction could influence the minute increase nitrogen content in all treatments at the end instead.

The amount of total phosphorus found from all treatments at the end of the composting process was in line with the organic fertilizer standard of the Department of Agriculture[16]. However, two-way ANOVA analysis showed no significant difference between the mean total phosphorus of food waste mixed with yard waste treated at different mixing ratios and aeration conditions.

Total potassium of some treatments (A2, A4, and A5) was in line with the organic fertilizer standard of the Department of Agriculture[16]. Two-way ANOVA analysis also found no significant difference between the mean total potassium of yard waste mixed with food waste treated at different mixing ratios and aeration conditions.

That most treatments had the proper nutrients for plants was clearly shown. Only some treatment had total potassium below the standard requirement. It may be necessary to change the composting condition using more specific yard waste to increase the potassium content when the plantation so required.

3. Comparison of composted material

The characteristics of the composted materials of all treatment after finishing the composting process are shown in Table 3 together with the standard criteria of the organic fertilizer standard. It revealed that most had suitable characteristics to be used as organic fertilizer and/or soil conditioner.

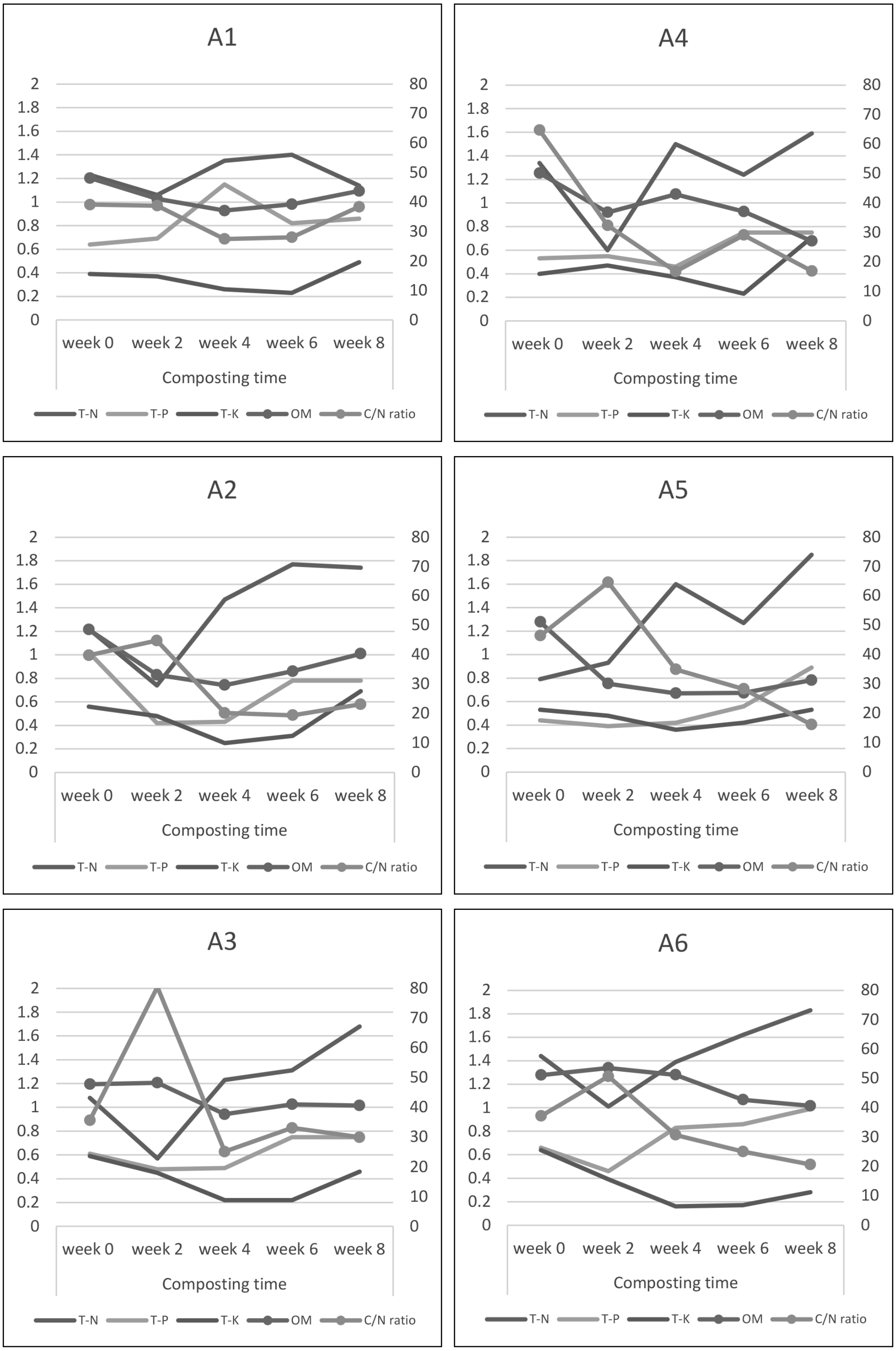

Figure 3 The Trend Lines of Organic Matter and Nutrients Changed.

Table 3 Comparison of Composted Characteristics with the Organic Fertilizer Standard.

Nutrients	Treatments						Organic fertilizer standard
	A1	A2	A3	A4	A5	A6	
pH	7.51	7.37	7.71	7.51	7.53	7.67	5.5-8.5
Organic matter	48.12	48.58	47.78	50.15	51.12	53.56	> 30.0
Total nitrogen	1.23	1.22	1.34	1.08	0.79	1.44	≥ 1.0
Total phosphorus	0.86	0.78	0.75	0.75	0.89	0.99	≥ 0.5
Total potassium	0.49	0.69	0.46	0.71	0.53	0.28	≥ 0.5
C/N ratio	38.38	23.18	29.96	16.13	16.92	20.68	≤ 20:1

Conclusion

The studied organic waste materials had high nutrients and other characteristics suitable for use as composting raw materials. The windrow composting piles were managed for 8 weeks. At the early starting period, the composting process occurred and resulted in increasing pile temperatures and pH levels. After that, the reaction slowed down and finished in the 8^{th} week. Nutrient properties of composted materials in the 8^{th} week revealed that organic matter deceased from 53.56% to 27.1%. However, this amount of organic matter was still quite high and showed good compost characteristics[2]. The C/N ratio was reduced from 64.71 to 16.13, and was also considered to be good compost[17]. Moreover, total nitrogen was higher than 1% in all treatments. The amount of total phosphorus and total potassium were more than 0.5%.

Most treatments had composted characteristics in line with organic fertilizer standards of the Department of Agriculture[16]. Other treatments were also close to this standard requirement. Considering the nutrient contents, waste management, and utilization benefit, mixing food and yard waste in the ratio 1:1, without aeration is a suitable organic composting condition. The findings can also be used as an application criterion for other communities which maximize recycling nutrients to the environment. Furthermore, a further study should focus on the improvement of nutrient contents of the composted material and application effectiveness.

Acknowledgement

This research was partially supported by the Division of Physical Systems and Environment, Mahidol University.

Reference

1. Bunmak S, Sripongpun G, Ratasuk N. Factors Affecting People's Participation in Household Solid Waste Source Sorting in Prong Madua Subdistrict, Muang District, Nakhon Pathom Province. Journal of Public Health. 2016; 46(1):42-56.
2. Sreesai S. Green Organization Development. Journal of Public Health 2014; 44(3): 219-22.
3. Shah KL. Basics of solid and hazardous waste management technology. 1st ed. 2000.
4. Zang L, Sun X. Effects of earthworm casts and zeolite on the two-stage composting of green waste. Waste Management 2015:119-29.
5. Ussawarujijulchai A, Hansuk P, Peerakiat-khajohn P. Zero waste management in Mahidol University Salaya campus. Journal of environmental management 2011; 7: 17-29.
6. Suntararak S. A Quantitative Analysis of Macronutrients in the Mixed of Food Scraps and Agricultural Waste Compost. 2010.
7. Pollution Control Department. Composting. 2009. Available at http://www.pcd.go.th/Public/Publications/print__waste.cfm?task=Composting, accessed April 1, 2017.
8. A.O.A.C. Official Methods of Analysis of the Association of Official Analytical Chemistry. 14, editor. A.O.A.C., Washington, D.C. 1990.
9. Yunmei W, Jingyuan L, Dezhi S, Guotao L, Youcai Z, Takayuki S. Environmental challenges impeding the composting of biodegradable municipal solid waste: A critical review. Conservation and Recycling 2017; 122: 51-65.
10. Kumar M, Ou Y-L, Lin J-G. Co-composting of green waste and food waste at low C/N ratio. Waste Management 2010; 30: 602-9.
11. Wang X, Selvam A, Chan M, Wong JWC. Nitrogen conservation and acidity control during food wastes composting through struvite formation. Bioresource Technology 2013; 147: 17-22.
12. Wathajira L, Ngunkhamkhong K. Windrow Composting of Dry leaves and Vegetable Wastes.: Rajamangala University of Technology Lanna; 2006.
13. Epstein E. Mineral Nutrition of Plants: Principles and Perspectives. New York: John Wiley & Sons, Inc.; 1972. Department of Agriculture. Organic fertilizer standard 2005.
14. Craig C, Bary A, Sullivan D. Fertilizing with yard trimmings. Washington State University Cooperative Extension "Farming West of the Cascades". 2002: 8-13.

15. Makan A. Windrow co-composting of natural casings waste with sheep manure and dead leaves. Waste Management 2015; 42: 17-22.
16. Department of Agriculture Standard. Organic fertilizer standard. 2005.
17. Ilani T, Herrmann I, Karnieli A, Arye G. Characterization of the biosolids composting process by hyperspectral analysis. Waste Management 2016; 48: 106-14

การหมักเศษอาหารและมูลฝอยจากสวนแบบกองแถว

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บทคัดย่อ

มูลฝอยอินทรีย์เป็นปัญหาสำคัญของการจัดการมูลฝอย วิทยาเขตของมหาวิทยาลัยในตำบลศาลายา จังหวัดนครปฐม มีประชากรมาก จำเป็นต้องมีการจัดการมูลฝอยอย่างยั่งยืน ศึกษาการจัดการมูลฝอยอินทรีย์คือ มูลฝอยเศษอาหารและมูลฝอยจากสวนหมักแบบกองแถวในการทดลองภาคสนาม 8 สัปดาห์ สภาวะการหมักมีอัตราผสมและการเติมอากาศแตกต่างกัน วิเคราะห์ลักษณะสมบัติทางกายภาพและเคมี คือ ความชื้น อุณหภูมิ ค่าความเป็นกรด-ด่าง อินทรียสาร ไนโตรเจนทั้งหมด ฟอสฟอรัสทั้งหมด และโปแตสเซียมทั้งหมด ใช้สถิติ Two way ANOVA และ LSD post-hoc ผลการศึกษาพบว่า มูลฝอยเศษอาหารมีไนโตรเจนและความชื้นสูง มูลฝอยจากสวนมีอินทรีย์คาร์บอนสูง สภาวะหมักที่ไม่เติมอากาศทำให้อุณหภูมิแถวกองสูงอย่างมีนัยสำคัญ ($p < 0.05$) ส่วนอัตราการผสมสูงมีนัยสำคัญ ทำให้อินทรียสารสูง ($p < 0.05$) การหมักสิ้นสุดที่สัปดาห์ที่ 8 โดยวัสดุหมักมีอุณหภูมิต่ำลงและมีค่าความเป็นกรด-ด่างที่ปานกลาง ธาตุอาหารที่เป็นไนโตรเจนและฟอสฟอรัสเพิ่มขึ้น แต่มีโปรแตสเซียมลดลงเล็กน้อย มีลักษณะสมบัติตามมาตรฐานปุ๋ยอินทรีย์ แนะนำสภาวะที่เหมาะสำหรับหมักมูลฝอยอินทรีย์ คือ อัตราส่วนมูลฝอยเศษอาหารและมูลฝอยจากสวน 1:1 โดยน้ำหนัก แบบไม่เติมอากาศ ผลการศึกษาสามารถใช้แนะนำให้ชุมชนอื่นซึ่งช่วยนำธาตุอาหารกลับมาใช้ใหม่ในสิ่งแวดล้อม

คำสำคัญ: มูลฝอยเศษอาหาร, มูลฝอยจากสวน, การหมัก, ธาตุอาหาร, การหมักแบบกองแถว

วารสารสาธารณสุขศาสตร์ 2560; 47(2): 131-141

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