Interdisciplinary
Research Review
Volume 18, Number 5, Pages 1 – 8

Prototype of household compost bin turns food waste into compost for residents in a personnel condominium of Yala Rajabhat University

Piyaruk Pradabphetrat[1*], Saudee Maprasit [2], Montakarn Pimsen [3], Warin Narawit[4] and Sidthipong Sathawong[5]

[1] Program in Public Health, Faculty of Science Technology and Agriculture, Yala Rajabhat University, Yala 95000, Thailand
[2] Program in Environmental Science, Faculty of Science Technology and Agriculture, Yala Rajabhat University, Yala 95000, Thailand
[3] Program in Applied Biology, Faculty of Science and Technology, Princess of Naradhiwas University, Narathiwat 96000, Thailand
[4] 4Program in Information Technology, Faculty of Science and Technology, Princess of Naradhiwas University, Narathiwat 96000, Thailand
[5] Program in Food Science and Technology, Faculty of Science Technology and Agriculture, Yala Rajabhat University, Yala 95000, Thailand

Abstract

This research was to study the design guidelines for a prototype of the household compost bin for the residents of the personnel condominium of Yala Rajabhat University and to analyze the macronutrient contents of compost from the household compost bin. The questionnaire was used to interview residents in the personnel condominium to explore information about the type, quantity, and management of solid waste and to study the feasibility of developing a prototype of the household bin to turn food waste into compost. The results revealed that most households in the personnel condominium collected the solid waste without sorting or disposing of the waste in the same container. The amount of organic waste that needs to be disposed of is about 0.5-1 kg per day, including food scraps, e.g., rice scraps, snack scraps, vegetable scraps, and fruit peels. The residents opined that sorting food scraps before throwing them out is not a burden. They agreed that the household compost bin was available for use in the area of the personnel condominium. Therefore, the researchers have designed a household compost bin made from a 200-liter HDPE polypropylene plastic tank, placed it vertically on a steel stand, and installed stirrers inside the tank. After that, household organic waste was composted to make fertilizer with organic waste materials, consisting of rice husks, coconut coir dust, and small dry leaves. Then, the Super LDD 1 microbial activator of the Land Development Department was added to assess the efficiency of the household compost bin. The composting of household organic waste in the compost bin for 30 days revealed that the compost is soft, crumbly, easily torn, smells like soil, and the color of fermented material is dark brown. The composts obtained from the 3 different fermented materials demonstrated that the amount of moisture, pH value, electrical conductivity, amount of organic matter, organic carbon, C/N ratio, total nitrogen content, total phosphorus, and total potassium met the organic fertilizer standard of the Department of Agriculture, Thailand. Consequently, quality compost can be used as a soil amendment.

Keywords: food waste, compost, household compose bin

Article history: Received 13 January 2023, Revised 14 April 2023, Accepted 03 May 2023

1. Introduction

Currently, the problem of community solid waste in Thailand is urgent. It is an issue that needs to be properly addressed due to the production of large volumes of solid waste, which tends to increase every year while the areas of waste disposal sites are limited and local government organizations responsible for the management of solid waste have limited budgets and personnel. Thus, all of the solid waste cannot be properly disposed of according to sanitation principles and may cause environmental pollution problems, sources of disease vectors, nuisances, impacts on the economy of the country, and public health problems. Therefore, solid waste management guidelines should focus on reducing the amount of solid waste at the source by promoting and supporting the reuse of solid waste before disposing of it at the waste disposal site [1]. More than 50 percent of solid waste is food waste, vegetables, and fruits, which are often not managed properly and become breeding grounds for germs, emitting bad odor, and generating methane, causing environmental problems, including being one of the major causes of global warming [2].

The sorting and utilizing organic waste are ways to reduce solid waste, such as organic composting, bio-fermented water for soil nourishment in agriculture, biogas production to replace fuel energy, and animal feed. The solid waste that can be composted is food waste, vegetables, fruits, leaves, twigs, animal manure, sludge from wastewater treatment systems, sawdust, etc. [3]. Composting is a waste management op-

*Corresponding author; email: piyaruk.p@yru.ac.th

tion suitable for limited resources in developing countries. It is also an environmentally friendly approach that avoids all pollution problems. One of the benefits of compost comes from the use of microorganisms to decompose organic waste into nutrients and produce organic fertilizers [4]. Compost is a soil conditioner because adding compost to the soil improves soil structure, chemical composition, and biological properties that make soil conditions suitable for plant growth, such as increasing soil aeration and water retention capacity, and providing a source of micronutrients necessary for plant growth [3]. Yala Rajabhat University attaches great importance to the environment according to the policy of university development toward a green university (Green YRU) since 2018. The implementation of the Green YRU project showed that the amount of solid waste in the university has increased, which affected the environment and created bad smell and negative images and scenery of the university. Also, the solid waste problem lacks systematic action for collecting, sorting, potential waste recycling, and disposing of solid waste. The university has taken the first step to solve this problem by providing adequate waste bins inside and outside the building. In addition, there was a campaign for students and staff to realize the importance of separating and disposing of solid waste into different containers provided and segregating solid waste for proper management and further use, such as compost to nourish the soil and trees in the university. This can reduce the use of chemicals or chemical fertilizers, be cost-saving, increase the value of solid waste, and help to preserve the environment in the university. This led to the concept of a study to survey the situation of solid waste in the personnel condominium of Yala Rajabhat University in order to know the basic information about the type, quantity, and management of solid waste by using a questionnaire to collect data from the relevant target groups who live in the personnel condominium. These data were used to study the feasibility of developing a prototype of a household compost bin to convert food waste into fertilizer. Consequently, the main aim of this study was to study the design guidelines for a prototype of the household compost bin for the residents of the personnel condominium of Yala Rajabhat University. It also analyzes the macronutrient contents of compost from the household compost bin. Moreover, this study provides rich information for studying and designing a prototype of the household compost bin to produce compost from compostable raw materials that add nutrients to the soil and help improve soil quality. Furthermore, the use of waste organic materials provides an alternative for communities and industries to produce environmentally friendly compost.

2. Materials and methods

2.1 The design guidelines for a prototype of the household compost bin for the residents in the personnel condominium of Yala Rajabhat University

2.1.1 A survey of the type, quantity, and management of solid waste in the personnel condominium of Yala Rajabhat University

This is a situational survey study about the type, quantity, and management of solid waste in the area of the personnel condominium of Yala Rajabhat University. The population in this study was the residents of the personnel condominium of Yala Rajabhat University, consisting of 44 studio-type rooms and 53 unit-type rooms. In this study, the whole population was used as a sample group for data collection. The questionnaire was used to interview relevant target groups, which are the residents of the personnel condominium. Data were used for a feasibility study in the preparation of a prototype of the household compost bin that turns food waste into compost. The collected data were analyzed using descriptive statistics, e.g., frequency and percentage. The content analysis was also used to describe other suggestions or comments from the target groups.

2.1.2 Prototype design of the household compost bin for residents in the personnel condominium of Yala Rajabhat University

From the results of the preliminary questionnaire study, the relevant target groups are the residents of the personnel condominium. Thus, the prototype of the household compost bin was designed by referring to the household composter [5], which can be used in houses with about 4-5 residents. In this study, aerobic compositing was selected to produce organic material that is useful for plants, called humus. Organic waste or household biodegradable waste, e.g., food scraps and fruit and vegetable scraps were fermented with residual organic materials that can be obtained locally (i.e., rice husks, coconut coir dust, and small dry leaves) at a ratio of 60:40 by weight, and 10 grams of the Super LDD 1 Microbial Activator of the Land Development Department were added. The 3 treatments consisted of 1) organic waste + rice husks + LDD 1, 2) organic waste + coconut coir dust + LDD 1, and 3) organic waste + small dry leaves + LDD 1. The initial humidity of the fermented material was controlled to be in the range of 50-60%. Physical and chemical changes, including temperature inside the tank, the amount of moisture, and pH value, were measured every two days during the study to evaluate the efficiency of the household compost bin.

2.2 Analysis of the macronutrient contents of compost from the household compost bin

This experiment studied the organic waste composting. At the end of the 30-day fermentation period, the compost was removed from the compost bin. The samples were analyzed for physical and chemical properties, including the macronutrient quantity in the laboratory. The samples of compost from 3 treatments were analyzed to evaluate the suitable quality of household compost for recycling as fertilizer, including temperature, moisture content, pH value, electrical conductivity (EC), organic matter (OM), organic carbon (OC), C/N ratio, total nitrogen content (N), total phosphorus (P), and total potassium (K).

3. Results and discussion

3.1 The design guidelines for a prototype of the household compost bin for the residents in the personnel condominium of Yala Rajabhat University

3.1.1 A survey of the type, quantity, and management of solid waste in the personnel condominium of Yala Rajabhat University

The results of a survey of preliminary information about the type, quantity, and management of solid waste by residents in the personnel condominium of Yala Rajabhat University indicated that most of the respondents throw all types of waste directly into the household bins. Most of the households had an amount of organic waste that had to be disposed of each day about 0.5-1 kilogram. The types of organic waste that occur in the household on a daily basis are food waste, rice or snack scraps, vegetable scraps or fruit peels, meat scraps, e.g., pork, fish, shrimp, crab shells, fishbones, chickens, eggshells, leaves or branches, and others. The majority of the respondents commented that sorting food waste before discarding was not a burden because it was easy to do. They agreed that there was a dedicated and readily available household compost bin in the personnel condominium. Consequently, the researchers have designed a household compost bin that is suitable for the residents of the personnel condominium of Yala Rajabhat University.

According to the results of this study, some residents in the personnel condominium have sorted and reused the solid waste in various ways, causing less household waste to be disposed of. The operant conditioning theory of Skinner [6] stated that the relationship between behavior and the environment (the stimuli that cause the behavior and the result of that behavior) may be due to multiple environments not conducive to the separation of solid waste, such as a lack of containers for separating solid waste, improper segregation of solid waste, ignorance of the benefits of waste segregation. Moreover, some people think that it is not their duty to separate solid waste. Nonetheless, these behaviors can be changed by promoting or educating people about the benefits and harms of solid waste to create awareness of the problem or incentives for the public to provide more garbage containers. As a result, people can separate more solid waste through the recycling waste bank project. Good awareness can be created by giving people knowledge about solid waste reduction and segregation and appreciation of solid waste value in generating income for people in the community, resulting in awareness and participation in environmental stewardship [6]. Hence, Yala Rajabhat University should continuously organize activities or take action on solid waste management by raising conscience or awareness about solid waste management in all sectors. Moreover, there are guidelines for managing solid waste from the beginning to the end by using the 3R principles (reduce, reuse, and recycle).

3.1.2 Prototype design of the household compost bin for residents in the personnel condominium of Yala Rajabhat University

The household compost was made from a 200-liter HDPE polypropylene plastic tank of 45 cm in diameter and 100 cm in height and placed vertically on a steel stand. The 7-layer pitched-blade turbine was installed inside the tank with a rotating handle, and the blades have a tilt angle of 30 degrees. Around the compost bin, the holes were drilled about 0.3 cm in diameter to allow outside air to flow into the compost bin at all times, which maintains an aerobic composting environment. Two holes were drilled in the top lid of the tank, approximately 15 x 40 cm, for filling the fermentation materials into the tank. The bottom part of the tank was drilled to an opening-closing size of 20 x 45 cm for removing compost from the compost bin. This tank was designed to operate in a semi-continuous system. At the end of the fermentation period, the pre-fed fermented materials were removed first, and the next fermented materials were replaced.

Physical and chemical analysis results of compost from the compost bin, which is obtained from waste organic material used as a composting medium for three types of fertilizers (rice husks, coconut coir dust, and small dry leaves). The results of the fermentation materials from the bottom layer of the compost bin are shown as follows:

Temperature: The temperature changes in the compost bin were measured every 2 days throughout the experimental period. The results demonstrated that the temperature was affected during the fermentation process in all three experiments (Figure 1), showing an increase in temperature during the 2-7 days of fermentation. The initial temperature increase was due to microbial metabolism and growth in the early stage of fermentation, which caused more microbial degradation [7, 8, 9]. Moreover, there is an exothermic process from decomposing organic matter [10], resulting in heat accumulation inside the compost. Over time the temperature of the compost gradually decreases due to some microorganisms beginning to die. Therefore, the amount of organic matter is completely decomposed, causing the decrease of temperature. The temperature is stabilized when complete decomposition has occurred. The composting period was approximately 30 days, after that the temperature of the compost was stable and close to room temperature [8]. In addition, it seemed that the temperature in the compost bin was not higher than 60°C, which is the range of temperature that can destroy pathogens in the compost [11]. This is because the compost bin was designed with a pitched-blade turbine for inverting the fermented material and for ventilating the heat accumulated from microbial degradation activities while the blades are rotating, resulting in a higher rate of biodegradation of organic waste [12]. Moreover, continuous fermentation feeding allows partial mixing of new and old fermented materials, causing the transfer of heat from decomposition to the environment. Nevertheless, the change in temperature of the fermented materials in the compost bin still tends to increase and decrease according to general composting [5].

Moisture content: The fermentation in this compost bin was continuously added to the fermented materials daily, with the initial moisture content controlled to be in the range of 50-60%. Water was not added throughout the experiment. The moisture content in the compost bin is within the range that can be composted by the liquid produced by the degradation activity of the continuously fed fermentation materials, and the ventilation in the bin is not excessive to the extent that it loses moisture. The change in moisture content of the fermented material was measured every 2 days throughout the experimental period (Figure 2). On the first day of the 3 treatments, the moisture content of the fermentation material was in the range of 55-75%. It is because the fermented materials used in the experiment were food scraps, fruits, and vegetables, which were organic materials with high moisture content. The bottom of the compost bin had to be waterlogged and when sampled for analysis, it looked muddy. The high moisture content in the compost bin could lead to anaerobic conditions and a longer composting process [11, 13]. The fermentation process increases the moisture content of the compost bin because the fermented material is dehydrated by the decomposition reaction. It can be seen that the dehydration rate is high during days of high temperatures in the compost bin or days of high degradation activity. Thereafter, the moisture content gradually decreases, whereas the decrease in moisture content during fermentation is one of the indexes indicating degradation activity due to the heat generated by decomposition leading to the evaporation of water in the fermentation material and the use by microorganisms [5, 14]. Proper moisture content is essential for microbial growth and is an important factor in fermentation for microbial degradation and nutrient transfer in chemical reactions. In cases where the moisture content of the compost is too high (¿70%), it will hinder the airflow inside the compost bin (blocking the oxygen from entering the gaps in the fermentation material), which can lead to nutrient oxygen depletion and anaerobic fermentation with low degradation reactions. On the other hand, if the moisture content is too low (¡30%), the airflow rate is insufficient for the biochemical degradation reaction to carry out thoroughly because microorganisms lack water. Consequently, microbial activity decreases and goes into a dormant state, causing the microorganisms to be unable to propagate species [5, 14, 15, 16]. The most preferable moisture content for composting ranges from 40 to 60% [17, 18].

pH value: It is an important factor affecting the degradation of materials in the composting process, depending on the environment, so that the microorganisms involved are active within specific ranges of pH [14, 19, 20]. The measurement of the pH of the composted material every 2 days throughout the experimental period (Figure 3) showed that the pH during the composting process of organic waste with rice husks, coconut coir dust, and small dry leaves as the medium in the compost bin was lower in the initial stage of composting and was favored by a slightly acid pH. This is because the microbial degradation activity of carbohydrate-type organic compounds produces organic acids. After that, the pH tends to increase towards neutral when organic acids are converted to carbon dioxide by the action of microorganisms and ammonia is released from the protein degradation process [5, 7]. The neutral pH of the compost indicated that the compost has matured [14], and the pH has subsequently increased [7]. The result showed that all 3 treatments had pH values in the range of 5.5-8.5, which is in the organic fertilizer standard B.E. 2548 [21].

3.2 Analysis of the macronutrient contents of compost from the household compost bin

At the end of the fermentation process, compost material samples were taken to analyze the physical and chemical properties of the compost material and compared the quality of the fermented product with the organic fertilizer standard (Table 1). All 3 treatments had moisture content, pH level, salinity level (in terms of electrical conductivity), amount of organic matter, organic carbon, carbon/nitrogen ratio, total nitrogen content, total phosphorus content, and total potassium content, which followed the organic fertilizer standard of the Department of Agriculture [21]. Accordingly, these composts can be used as soil amendments.

The results from the chemical analysis of the samples from 3 treatments of rice husks, coconut coir dust, and small dry leaves as composting mediums (Table 1) showed that the treatment with coconut coir dust as the medium had a higher moisture content than the others. Due to coconut coir dust being lightweight, a fiber, and able to absorb and hold water well, this may lead to less drainage and ventilation [22]. The pH

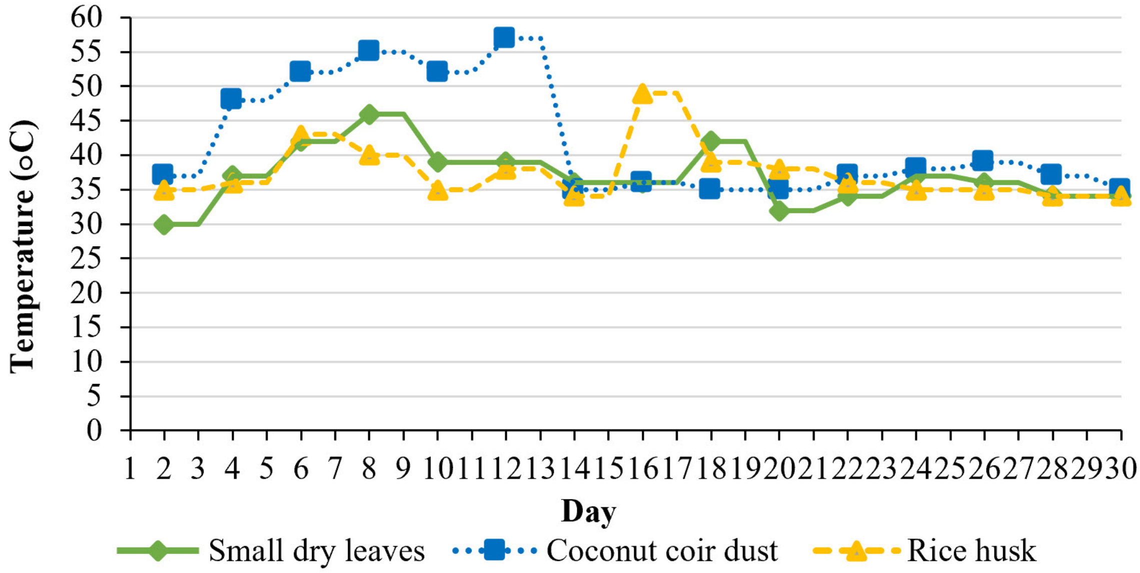

Figure 1: Temperature change during composting in the compost bin.

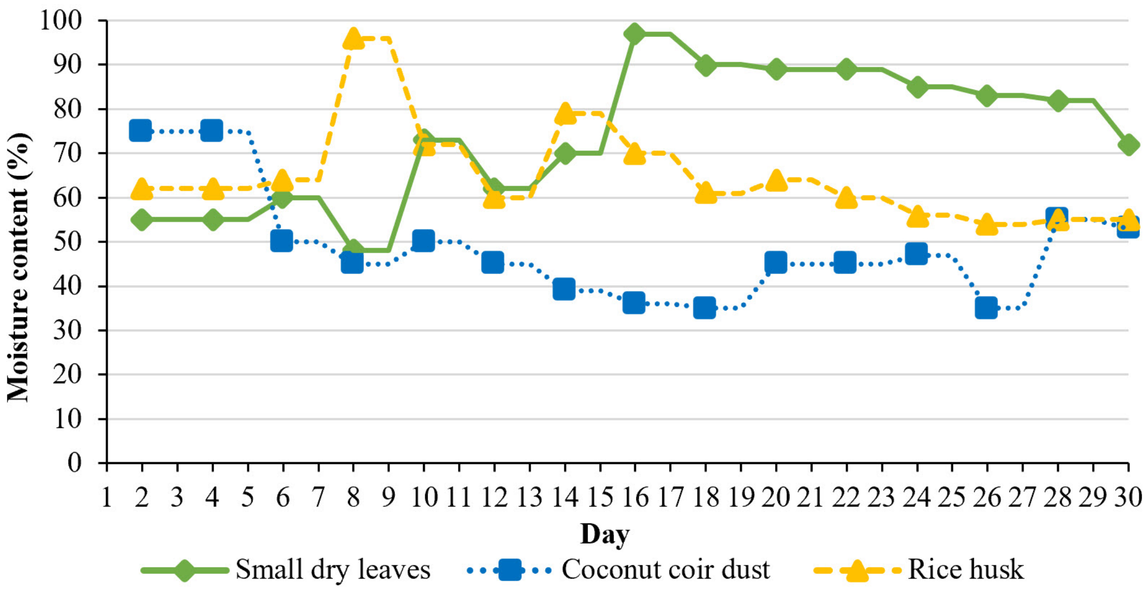

Figure 2: Moisture content change during composting in the compost bin.

affects the activity of microorganisms, thereby affecting the decomposition of organic materials. In general, the decomposition of organic materials at neutral pH (pH = 7) occurs faster in the acidic or overly alkaline range (below 4.5 or above 9.0) [14]. This is because the pH of compost depends on the raw materials used for composting [8]. Coconut coir dust has a pH value of 5.43, and rice husks have a pH value of 5.93 [23]. Thus, it may result in the treatment with coconut coir dust as the medium having a lower pH than other treatments. The electrical conductivity is the value that indicates the salinity or soluble salt in the fertilizer. pH does not directly affect the electrical conductivity, but it may indirectly affect the salt solubility and moisture content of the fertilizer. It can be seen that the treatment with coconut coir dust as the medium had higher electrical conductivity than the treatment with rice husks and small dry leaves as the medium because compost has a low pH level. Moreover, they had a high soluble salt content and high electrical conductivity [24]. Organic carbon is an important component of organic matter and is used to assess the process by which organic matter is degraded by microorganisms. The carbon content of organic matter is important for the composting process because microorganisms decompose organic matter to

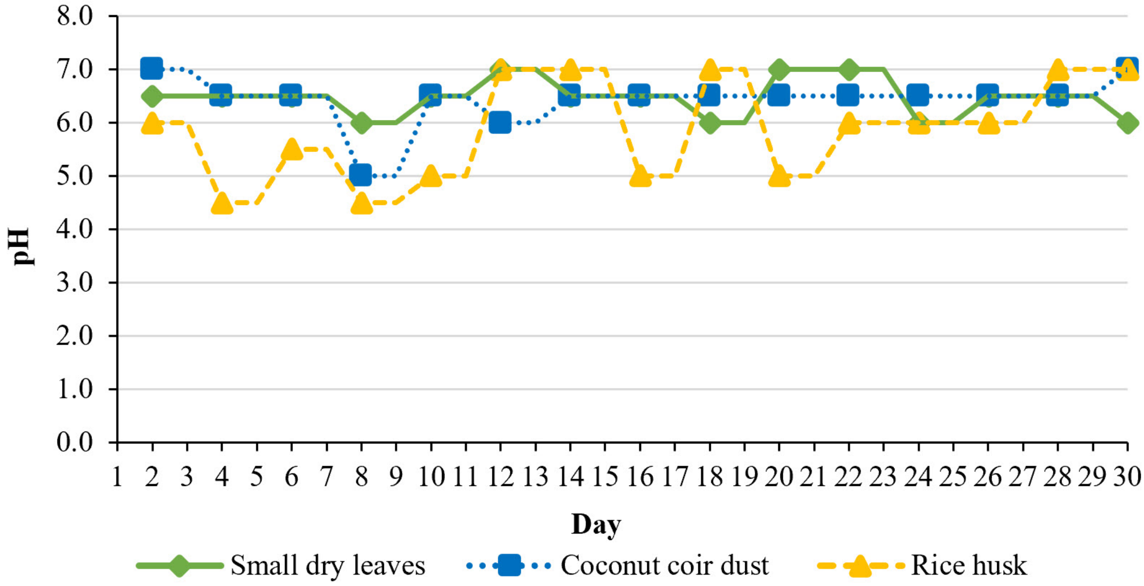

Figure 3: pH level change during composting in the compost bin.

Table 1. The quality of the compost material at the end of composting compared to the organic fertilizer standard

The quality of the compost material	Organic material as a composting medium			Criteria1
	Rice husks	Coconut coir dust	Small dry leaves	
Moisture content	12.95	17.93	12.20	<35%
pH level	7.60	7.36	7.68	5.5-8.5
Electrical conductivity (EC)	0.009	0.015	0.014	<6 dS/m
Organic matter (OM)	49.80	42.35	39.17	>30%
Organic carbon (OC)	28.96	24.62	22.77	-
Total nitrogen content	1.73	2.22	2.33	>1%
Total phosphorus content	0.69	0.74	1.18	>0.5%
Total potassium content	1.10	1.99	1.86	>0.5%
C/N ratio	16.74	11.09	9.77	<20:1

Notation
1/Announcement of the Department of Agriculture: Organic Fertilizer Standard B.E. 2548 [21]

use carbon to create cell components for growth [25]. In addition, organic matter is very important for cultivation as a source of plant nutrients (especially nitrogen). Most plants obtain phosphorus and sulfur from the decay of organic matter. Thus, the amount of organic matter allows for the assessment of soil fertility [20]. From the study, it can be seen that the treatment with small dry leaves as the medium has a large percentage of organic carbon and organic matter, which is lower than other treatments. This may be because microorganisms have a greater decomposition process than other treatments. The compost with rice husks as the medium contains the highest amount of organic matter, which means that this type of compost can affect the growth of the cultivated plants very well. As a result, the quality of cultivation and the productivity of farmers are high. Organic carbon is an important component of organic matter that is used to assess microbial degradation processes occurring in organic matter. The amount of carbon contained in organic matter is important for microorganisms, as they decompose organic matter to use carbon to make cell components for growth [25]. The decomposition of organic matter is caused by microorganisms that use carbon as their energy source and nitrogen as their nitrogen source to build cell structures, so their demand for carbon is greater than that for nitrogen. If excess carbon is excessive, decomposition dwindles when nitrogen is exhausted and some organisms die. The stored nitrogen is used by other organisms to create new cell materials, and more carbon is used in the process. Accordingly, the carbon content is reduced to a more optimal level while nitrogen is recycled [7]. If the compost contains a mixture containing carbon and nitrogen below the optimal value, high nitrogen content results in excessive nitrogen consumption by microorganisms, and nitrogen is lost in the form of ammonia gas. Especially under conditions of high temperature and pH, ammonia gas and foul odor will be produced, and the resulting fertilizer will make the soil acidic (NH4)2SO4 because each organic material has a different carbon/nitrogen ratio. Therefore, in the production of compost, materials with an appropriate carbon/nitrogen ratio [14, 15] should be used to make compost that is produced from good-quality organic waste and can be used effectively in the future [26].

Nitrogen is a nutrient that microorganisms need in large quantities for their growth because most of the components of the microbial cell are proteins and nucleic acids, of which nitrogen is an important constituent [25]. It can be seen that the treatment with small dry leaves as the medium had a higher percentage of total nitrogen than other treatments. Most of the small dry leaves are Samanea saman, which is a perennial plant with cotyledons and is in the same family as legumes. The leaves have a high nitrogen content due to the presence of the bacteria Bradyrhizobium in the root node, which helps fix nitrogen and is a good source of nitrogen for plants and animals. It is often planted to add nitrogen to the soil or to improve the soil, used to make fertilizer, and made into animal feed. The leaves of Samanea saman contain nitrogen up to 3.25%, which is higher than other leaves that are not legumes [27, 28]. Phosphorus in organic compounds is essential for the fermentation process, as is nitrogen. Phosphorus is the number of nutrients that microorganisms use in the fermentation process, which is used for the growth of microorganisms. The phosphorus content of compost is in the form of P2O5 [25]. It can be seen that the compost with small dry leaves as the medium had a higher percentage of total phosphorus than the other treatments because microorganisms decompose organic matter by using phosphorus as a nutrient to aid growth. The results showed that the compost with coconut coir dust as the medium had the highest percentage of total potassium, which is a lightweight planting material with the ability to hold water, good ventilation, and low nitrogen and phosphorus content. Nonetheless, coconut coir dust has a potassium content that is quite high compared to other waste organic materials [29]. The change in the C/N ratio of compost indicates the degradation effect of organic matter and is an index used to describe the maturity and quality of fermentation products [5].

4. Conclusions

Based on the study and survey of preliminary information on the type, quantity, and management of solid waste, especially organic waste, it was found that at present, most households in the personnel condominium of Yala Rajabhat University disposed of solid waste in the same container without sorting. The type of organic waste in the household each day is food waste, e.g., rice scraps, snack scraps, vegetable scraps, and fruit peels. Most of the residents in the personnel condominium opined that sorting food scraps before throwing them out is not a burden because it is easy to do. They agreed that there were household compost bins available for use in the area of the personnel condominium. Hence, the prototype of the household compost bin was made from a 200-liter HDPE polypropylene plastic tank, placed vertically on a steel stand with stirrers inside the tank. Subsequently, the organic waste or biodegradable waste in the household, e.g., food scraps, vegetable scraps, and fruit scraps, was composted together to make fertilizer with residual organic materials including rice husks, coconut coir dust, and small dry leaves. Then, the Super LDD 1 Microbial Activator of the Land Development Department was added to assess the efficiency of the household compost bin through the aerobic decomposition process. According to the experiments, it was observed that the composted household organic waste in the compost bin for 30 days was soft, crumbly, easily torn, and soil-like smell, and the color of the fermented material was dark brown. However, during the composting process, there is a foul or rotten egg smell in the early stages. At the end of the fermentation process, the compost material samples were taken from the compost bin, and the physical and chemical properties of the compost material were analyzed, and compared the quality of the fermented product with the organic fertilizer standard. All the 3 different fermented materials clearly show the amount of moisture content, pH level, salinity level (in terms of electrical conductivity), amount of organic matter, organic carbon, carbon/nitrogen ratio, total nitrogen content, total phosphorus content, and total potassium content following the Organic Fertilizer Standard B.E. 2548 (2005) of the Department of Agriculture, Thailand. Thereby, this showed that these composts can be used as a soil improvement material. This research presents one of the alternative ways to manage household organic waste that is more environmentally friendly. Likewise, the farmer's cultivation area may contain other agricultural waste that may be beneficial to the crops. Consequently, it is suggestible to study and compare composting with other natural materials in the agricultural area to determine which fermentation methods provide the most effective nutrient content for plants.

Acknowledgments

This study was funded by the Faculty of Science Technology and Agriculture, Yala Rajabhat University (grant number 022/2564).

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