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Article

Vermicompost from Chula Zero Waste Cup and Rain Tree *(Samanea Saman)* Leaves

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Abstract. To recycle waste including paper-cup waste and rain tree leaves, the objective of this study was to determine the appropriate ratio of paper-cup waste (Chula Zero Waste Cup) and rain tree leaves in a vermicomposting process that uses the earthworm species *Eudrillus eageniae* and combines cow dung and coffee grounds as bulking agents. The vermicomposting in this study was conducted for 60 days. From the analysis of physical and chemical properties, it was found that all treatments (T1 to T5) on the final vermicomposting had the values of pH, EC and C/N ratio in the range of 8.16–8.41, 1.24–1.55 dS/m and 2.36–2.71 respectively. The total organic carbon content and total organic matter content had the highest value in treatment: 4 (T4) was 33.47 ± 0.56% and 57.56 ± 0.96%, respectively, while the lowest value in treatment 3 (T3) was 32.09 ± 0.61% and 55.20 ± 1.06%, respectively. For the primary macronutrients, including total Kjeldahl nitrogen content available, phosphorus and exchangeable potassium content, the study found that the total Kjeldahl nitrogen content had the highest in treatment 4 (T4) and the lowest in treatment 1 (T1), with the value of 14.17 ± 0.46% and 12.24 ± 0.48%, respectively. Available phosphorus content had the highest in treatment 1 (T1) and the lowest in treatment 5 (T5), with the value of 1,418.08 ± 305.45 ppm and 472.69 ± 57.98 ppm, respectively. Exchangeable potassium content had the highest in treatment 1 (T1) and the lowest in treatment 3 (T3), with the value of 8,146.81 ± 739.40 ppm and 3,861.98 ± 1,024.56 ppm, respectively. In addition, the seed germination test found that the highest value in treatment 1 (T1) was 45.00 ± 10.00%, while the lowest value in treatment 2 (T2) was 31.67 ± 23.63%. In comparing these results to the compost quality standards of the Department of Agriculture (2005), we conclude that T1 to T5 can help improve the physical properties of the soil as an alternative method for waste utilization by vermicomposting.

Keywords: Vermicompost, paper cup waste, rain tree *(Samanea Saman)*.

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1. Introduction

Municipal solid waste (MSW) management poses a major environmental challenge in Thailand. In 2017, the amount of MSW was 27.4 million tons or 75,046 tons of MSW per day, 8.25 million tons of waste were recycled, representing 31% of total MSW, leaving about 5.34 million tons of residue to be disposed of [1]. Waste utilization represents a viable way to reduce that discarded residue.

Cognizant of the solid waste management issues at both national and international levels, Chulalongkorn University established the Chula Zero Waste Project, a five-year plan to guide sustainable waste management within the university. In July 2018, Chula Zero Waste launched a closed-loop bioplastic management project to reduce waste from plastic glasses and straws by using paper cups. The Chula Zero Waste Cups are coated with polylactic acid (PLA), a bioplastic that degrades in six months. Seven canteens at Chulalongkorn University reported the consumption of 690 kg of paper cups, or 63,600 cups, per month. The relatively high volume of cups means a longer degrading time [2].

The rain trees (*Samanea saman*) in Chulalongkorn University's campus, which are over 25 meters high and can live for more than 100 years, produce large quantities of waste all year long, due to their leaves and branches shedding [3]. Suntararak (2014) reported that mixing food scraps and rain tree leaves in compost provided a better alternative to chemical fertilizer (considering the amount of grain produced). This mixed compost soil contained 1.25% nitrogen, 0.15% phosphorus and 0.38% exchangeable potassium, whereas soil without fertilizer has 0.05%, 0.01%, and 0.02% of nitrogen, phosphorus, and potassium, respectively [4].

Composting, especially vermicomposting, is one of the best ways to manage compostable waste. Vermicomposting is a natural technology that involves the biological decomposition and stabilization of organic matter through the interaction of earthworms and microorganisms. They transform physicochemical and biochemical properties of organic matter at a faster rate than composting alone [5]. According to Arumugam et al. (2018), vermicomposting can degrade paper cup waste and change it to high quality vermicompost with high nitrogen, phosphorus and potassium content [6]. Bulking agents play an important role in controlling the various factors of composting, such as moisture content, biodegradation, and the composting or vermicomposting processing time. There are several bulking agents used in the composting or vermicomposting process. Cow dung is a popular bulking agent for its wide availability around the world, especially in agricultural countries like Thailand. Furthermore, as a bulking agent, it can control moisture, bulk density, and C/N ratio [7]. Moreover, Thailand has seen an increased coffee ground waste. According to the Department of Business Development (2017), the expansion of Thailand's coffee business has seen the market value of roasted coffee and instant coffee increase by 7.3% annually in the last five years, resulting in both an increased domestic coffee consumption and a resulting waste [8]. To reduce the amount of waste taken to landfills, coffee grounds can be used to supplement cow dung as another composting material [9].

This research uses vermicomposting to manage waste from rain tree leaves and paper cups generated at Chulalongkorn University, using a combination of cow dung and coffee grounds as a bulking agent.

2. Materials and Methods

2.1. Materials

The paper cup waste was collected from the Chula Zero Waste Project, Chulalongkorn University, and then cleaned with water and cut into 2-cm-long pieces. The rain tree leaves were collected from the Chulalongkorn University campus. Both raw materials were dried in the oven at 70°C to a constant weight [10]. The vermicompost requires bulking agents to enhance the degradation process. Bulking agents have many important functions in composting and vermicomposting processes, such as controlling the pH, moisture content, bulk density, carbon-to-nitrogen ratio, and aeration [7]. Cow dung was brought in from Thunhikorn shop, while the coffee grounds were obtained from Terracotta, a Chulalongkorn University coffee shop. The bulking agents were dried under sunlight for a week [11]. All raw materials and bulking agents were given a physical-chemical analysis before experimentation (Table 1).

The adult epigeic earthworm (*Eudrillus eugeinea*) was obtained from Baan Sai Duean Farm, Bangkok, Thailand. Epigeic earthworms are the most suitable earthworm group to use in the vermicomposting process because they have the most degradation efficiency, are distributed throughout the world, and tolerate a wide array of environments [11].

Table 1. Analytical methods for physical-chemical properties.

Parameters	Instrument/Method
C/N Ratio	Using results from TOC and TKN analysis
pH	pH meter (UB-10 Denver)
EC(ds/m)	Conductivity meter (Hach Senion156)
TKN (%)	Kjeldahl method (Kjelflex k-360)
Available P (ppm)	Ascorbic acid sulfomolybdo-phosphate blue color method (Spectrophotometer, Spectro sc)
Exchangeable K (ppm)	Atomic Absorption Spectrophotometry (Agilent, 240AA)
TOC (%)	Total organic carbon analyzer with Solid Analyzer (SHIMADZU, TOCVCPH)
TOM (%)	Using results from TOC

2.2. Experimental Design

To study the appropriate ratios of paper cup waste and rain tree leaves, this study used earthworm and microbial activators (PD1) to activate the vermicomposting process, with a cow dung and coffee ground mixture as a bulking agent. There are five treatments and three replicates of each treatment using Completely Randomized Design (CRD). The composition of vermicomposting materials was tested with different ratios, as shown in Table 2.

Table 2. Composition of vermicomposting materials in different treatments.

Treatment	Composition (g)				C/N** Ratio
	Paper cup waste	Rain tree leaves	Cow dung*	Coffee ground*	
T1	1000	0	200	450	30
T2	950	50	200	450	30
T3	900	100	200	450	30
T4	850	150	200	450	30
T5	800	200	200	450	30

*Proper ratio of cow dung and coffee grounds as bulking agent used in composting or vermicomposting [9].
**C/N ratio of raw materials; Total Kjeldahl nitrogen.

The process for all of the raw materials in each replicate was carried out in 20-liter plastic containers (29.5 cm in diameter and 38.2 cm in height). After mixing all raw materials, the carbon-to-nitrogen ratio in the initial vermicomposting was adjusted to 30/1 by adding urea fertilizer of 22.83 g, 20.91 g, 19.00 g, 17.01 g, and 15.20 g to T1, T2, T3, T4, and T5 respectively. In addition, microbial activator named PD1, one of the commercial microbial products often used to enhance the composting process in the compost mixture consisting of 2 strains of bacteria in Genus *Bacillus* sp., 2 strains of Actinomyces in Genus *Streptomyces* sp., and 4 strains of fungi that include *Scopulariopsis* sp., *Helicomyces* sp., *Chaetomium* sp., and *Trichoderma* sp. [12-13], was added to initiate the vermicomposting process in PD1/compost mixture with the ratio of 10 ml /500 g. They were then left for 17 days or until the temperature in the vermicompost pile decreased for equilibration and gas elimination (turned over every day). Then, 30 g of adult worms of the same size were released to each treatment. All treatments were placed on wood pallets in the trail area for 60 days and covered with a container lid.

During the vermicomposting, various factors need to be controlled:

1) Moisture content should be maintained in the range of 40%–65%. If moisture content is lower than 40%, the treatment must include the spraying of water. If moisture content is higher than 65%, the vermicompost will need to be turned over, to allow for the water in the treatment to evaporate.
2) pH should be in the range of 5.5-9 throughout the vermicomposting period. Generally, vermicomposting will see a slight decrease in pH. If the value is lower than 5.5, lime ($CaCO_3$) will need to be added, to bring the pH up to the appropriate range.
3) Vermicomposting is an aerobic degradation process that helps microorganisms completely decompose. If there is not enough oxygen, it will cause an anaerobic digestion process that may cause odor problems. To add oxygen to the treatments, the vermicompost will need to be turned over every day [14]. Furthermore, turning over the vermicompost can help eliminate volatile gases that are toxic to earthworms [9].

2.3. Sampling

All vermicomposting samples were collected on days 15, 30, 45 and 60. The samples were mixed and then picked out with a sieve to separate the earthworms. Afterwards, the samples without earthworms were air-dried overnight and placed on top of stainless-steel 2-mm and 0.5-mm sieves. The air-dried samples are then put through a physical-chemical analysis.

2.4. Physical and Chemical Analysis

The vermicompost's physical and chemical characteristics were tested, following the operation manual guidelines for analyzing plants, fertilizer and soil improvement from Land Development Department of Thailand, as shown in Table 1.

2.5. Seed Germination Test

The phytotoxicity of the final vermicompost was assessed with a seed germination test that uses aqueous extracts from vermicompost. Samples from each treatment (15 replicates) were mixed with distilled water at a ratio of 1:5 (w/w) and were shaken for one hour, then filtered by 0.22-μm-filter membrane. The 2 mL extract was dropped onto a 90-mm diameter sterilized filter paper in a sterile Petri dish; 20 maize seeds were also put into the dish. The seeds were incubated at 25°C under dark conditions for 48 hours. As a control, the test was done using the same method but with deionized water instead of vermicompost extract. After 48 hours, the number of seeds in each dish was determined [9].

The percentage of seed germination (SG) was calculated using the following equation [15]:

$$\%SG = \frac{\text{Number of germinated seeds}}{\text{Number of total seeds}} \times 100$$

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2.6. Statistical Analysis

The data were analyzed using a one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Tests (DMRT) for the comparison of the means at the significance level of 0.05.

The vermicomposting processes are shown in Fig. 1.

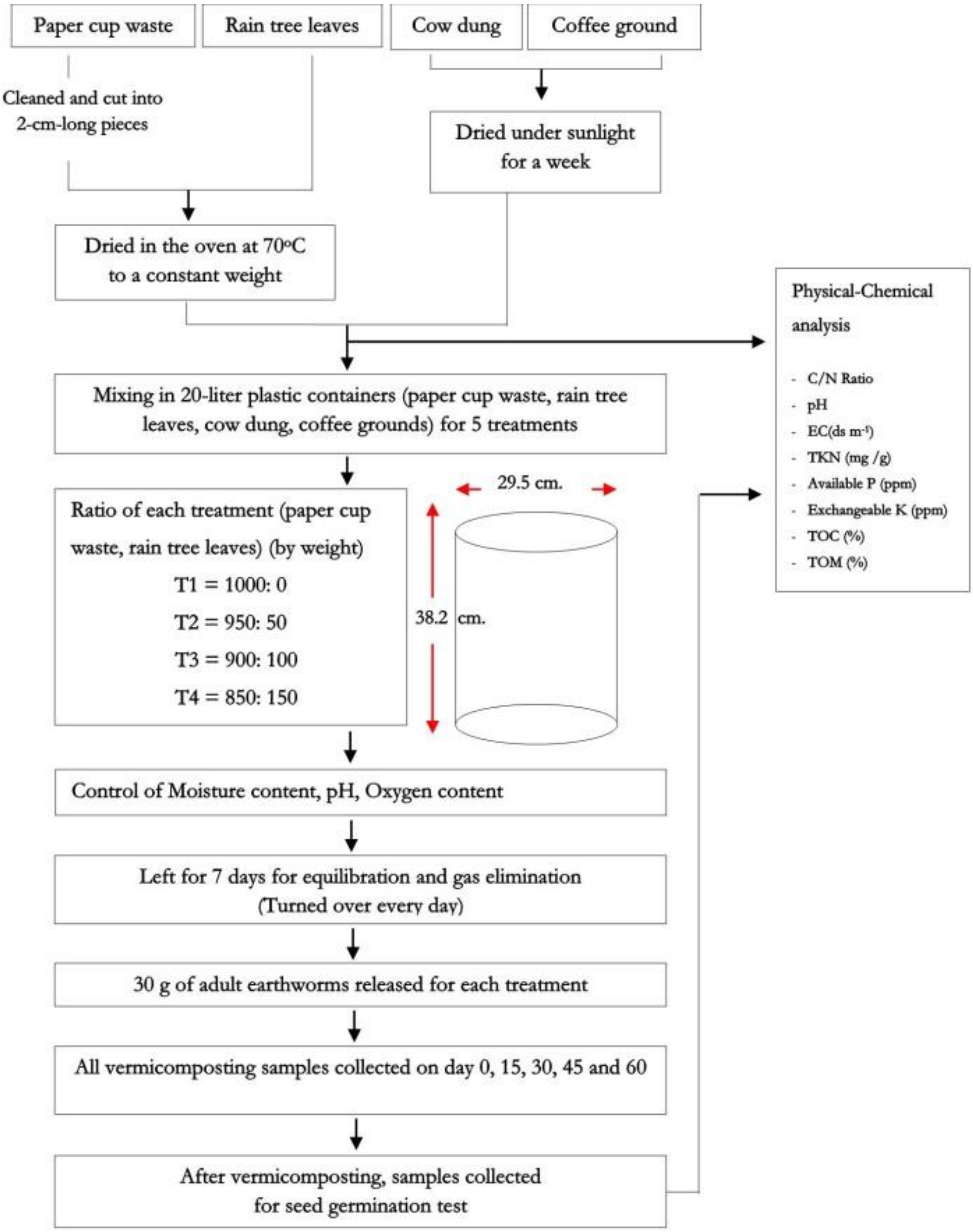

Fig. 1. Flowchart of the vermicomposting processes.

3. Results and Discussion

3.1. Chemical Properties of Raw Materials

Based on the chemical analysis of the raw material before vermicomposting, as shown in Table 3, the paper cup waste has the highest carbon-to-nitrogen ratio (C/N ratio) of 1,763.74, indicating that it is a slowly degraded material. Therefore, the used of paper cup waste as the raw material for vermicomposting is necessary to use other raw materials together in order to produce faster degradation with the initial carbon-to-nitrogen ratio of 25:1 which is suitable for composting [16]. Coffee ground, rain tree leaves, and cow dung have the lower in carbon-to-nitrogen ratio, respectively. Rain tree leaves have the highest amount of total kjeldahl nitrogen, total organic carbon, and total organic matter is 2.62±0.066, 45.54±1.72 and 78.33±2.96, respectively. Cow dung has the most amount of available phosphorus and exchangeable potassium is 2,854.99±143.97 and 27,465.68±1,714.87 ppm, respectively. As shown in Table 3.

Table 3. Chemical properties of raw materials used for vermicomposting.

Parameters	Raw materials			
	Paper Cup Waste (PCW)	Rain Tree Leaves (RTL)	Cow dung (CD)	Coffee Ground (CG)
C/N ratio	1763.74	17.39	15.37	17.58
%TKN*	0.0213±0.001	2.62±0.01	1.38±0.04	1.81±0.01
Available P (ppm)	201.51±33.10	376.65±70.19	2,854.99 ±143.97	410.55±23.52
Exchangeable K (ppm)	12.003 ±2.66	6,385.81 ±916.26	27,465.68 ±1,714.87	3,777.78 ±173.61
%TOC	37.49±0.71	45.54±1.72	21.28±1.58	31.82±0.56
%TOM	64.49±1.22	78.33±2.96	36.60±2.72	54.73±0.97

* Total Kjeldahl nitrogen (TKN) content of raw materials.

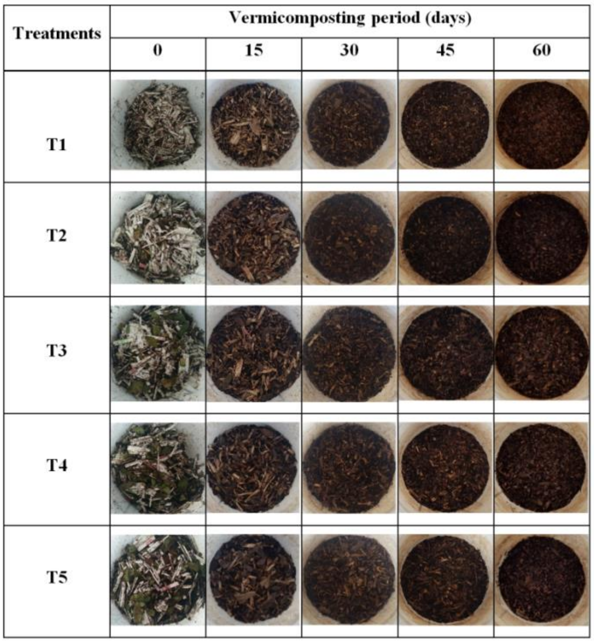

Fig. 2. Physical characteristics of vermicompost in treatments T1 to T5 on days 0, 15, 30, 45 and 60.

3.2. Physical Characteristics of Vermicompost

The study looked at the physical characteristics of the raw material used during vermicomposting. All treatments were observed at the initial vermicomposting on day 0 and continued into day 30; the vermicompost had heterogeneous characteristics because it could be separated into pieces of raw materials used in vermicomposting, those raw materials being paper cup waste and rain tree leaves. But, when vermicomposted from day 45 to day 60, the texture of vermicompost became homogeneous, which cannot be separated as raw materials. Therefore, the texture of T1 to T5, composted within a 60-day period, was similar to dark brown organic matter, as shown in Fig. 2.

3.3. Chemical Characteristics of Raw Materials During Vermicomposting from Chula Zero Waste Cups and Rain Tree *(Samanea Saman)* Leaves

3.3.1. Temperature

In the initial vermicomposting, the temperature in the vermicompost piles increased rapidly, a result of the heat generated by microbial degradation. The temperature subsequently decreased, at a gradual rate, to eventually reach the mesophilic phase of composting, which is primarily caused by the degradation of mesophilic bacteria (bacteria that grow well in a 25°–45°C temperature range). The temperature in the vermicompost pile did not rise above 45 °C [17] and it remained the same until the maturation of vermicomposting, which is akin to traditional composting.

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3.3.2. pH

The variation of pH value was affected by the organic compound decomposition during vermicomposting [16]. The vermicomposting pH values on days 15, 30 and 45 tended to increase in all treatments, with values in the range of 7.25–8.18, which the value that in the range (pH value is 7–9) with high degradation rate [17]. The final vermicomposting pH values of all treatments were not significantly different ($p > 0.05$) (Fig. 3), with values in the range of 8.16–8.41. These adhere to the Thai Agricultural Standard TAS9503-2005 for compost [18], which state that the appropriate pH value must fall in the range of 5.5–8.5.

Moreover, in the initial vermicomposting, the pH value may have decreased due to easily degraded organic materials rapidly decomposing and producing CO_2, ammonium ions, NO_3, and volatile organic acids in the system [19-20]. Subsequently, the pH values increased rapidly until entering an alkaline state with values in the range of 8–9, caused by organic acid generated from the decomposition process of the microorganisms. Being a source of carbon, their ammonium ions increased the pH values in the system, resulting in reduced acidity [17].

In addition, a pH value higher than 8 helps to promote the degradation process and reduces forms of nitrogen compounds that can dissolve and become ammonium compounds. This can affect the pH value of the system, adding alkalinity. When raw materials decompose and begin to stabilize, their pH value measures in the range of 7–8 and remains at that level until the final vermicomposting.

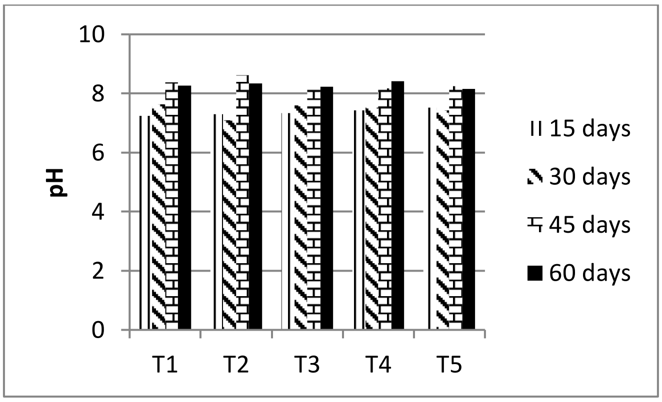

Fig. 3. Comparison of pH value of all treatments on the final vermicompost.

3.3.3. Electrical conductivity (EC)

From the initiation to final vermicomposting (on days 15, 30, 45 and 60) EC values tend to increase in all treatments, with values in the range of 1.13–1.55 dS/m. In the final vermicomposting, the EC values of all treatments were not significantly different ($p > 0.05$) (Fig. 4), with values in the range of 1.24–1.55 dS/m, which adhere to the Thai Agricultural Standard TAS9503-2005 for compost [18]. However, the appropriate EC value must not be greater than 6 dS/m due to higher value of EC will cause phytotoxicity. EC was the value of soluble salt effecting to roots more difficult to absorb water causing dehydration in plants [21]. The increase in EC values could be explained by the generation of mineral ions from the earthworms' ingestion and excretions, and the release of minerals from the decomposition of organic matter, in cation form, during vermicomposting [6, 22].

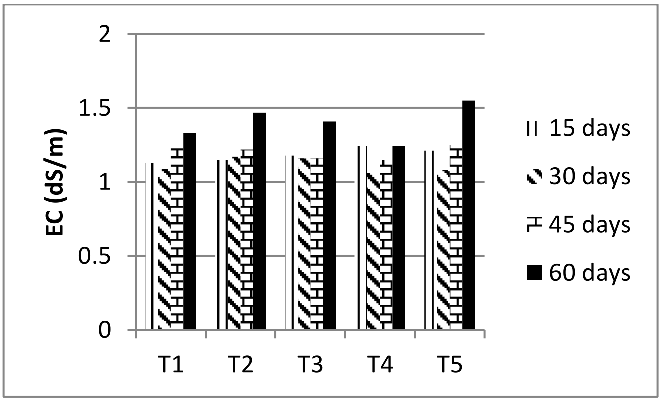

Fig. 4. Comparison of electrical conductivity values of all treatments on the final vermicompost.

3.3.4. Total organic carbon (TOC)

Total organic carbon content gradually declined from initial to final vermicomposting in all treatments (on days 15, 30, 45 and 60). In the final vermicomposting, T4 had the highest total organic carbon content by weight of 33.47±0.56 %, followed by T1 (33.16±0.25%), T5 (32.91±0.41%), T2 (32.44±0.78%) and T3 (32.09±0.61%), respectively. However, the total organic carbon content of all treatments was not significantly different ($p > 0.05$) (Fig. 5). The reduction of total organic carbon content could be attributed to the decomposition of organic matter, including carbon loss from microbial respiration and the carbon needed to create microbial cell elements [21]. Moreover, Zhi-wei et al., (2019) reported that the earthworm has the ability to use organic waste as a carbon/energy source and convert it into their biomass [23].

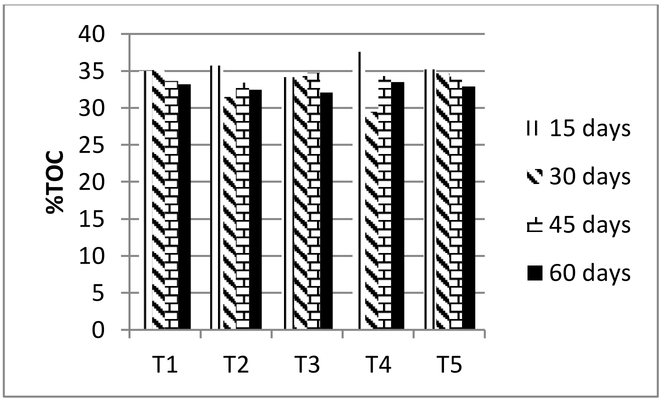

Fig. 5. Comparison of total organic carbon values of all treatments on the final vermicompost.

3.3.5. Total organic matter (TOM)

Total organic matter content gradually declined from initial to final vermicomposting (on days 15, 30, 45 and 60) in all treatments. In the final vermicomposting, T4 had the highest total organic matter content of 57.56±0.96 % by weight, followed by T1 (57.04±0.42%), T5 (56.61±0.71%), T2 (55.79±1.35%) and T3 (55.20±1.06%), respectively, which present the same tendency compared to the total organic carbon content. However, the total organic carbon content of all treatments was not significantly different ($p > 0.05$) (Fig. 6), which adhere to the Thai Agricultural Standard TAS9503-2005 for compost [18], which states that total organic carbon content must make up at least 30% of total weight. The reduction of total organic matter content has the same cause as the reduction of the total organic carbon content (in 3.3.4).

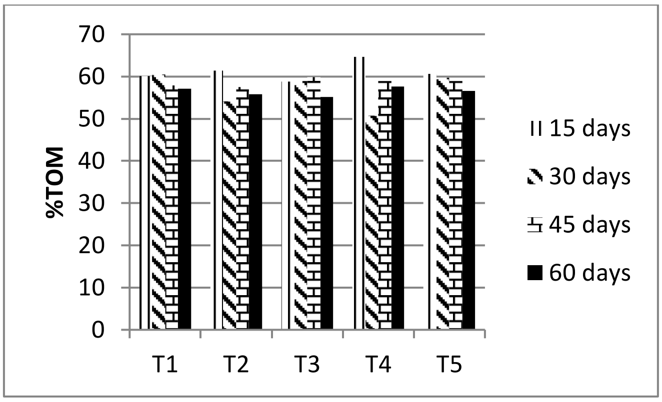

Fig. 6. Comparison of total organic matter values of all treatments on the final vermicompost.

3.3.6. Total Kjeldahl nitrogen

The total Kjeldahl nitrogen content of all treatments tends to increase from the initial to final vermicomposting (on days 15, 30, 45 and 60). In the final vermicomposting, total nitrogen content of all treatments was significantly different ($p < 0.05$) (Fig. 7). T4 had the highest total Kjeldahl nitrogen content of 14.17±0.46%, followed by T3 (13.59±0.82%), T5 (13.52±0.32%), T2 (13.23±0.82%) and T1 (12.24±0.48%), respectively. However, total nitrogen content of all treatments adheres to the Thai Agricultural Standard TAS9503-2005 for compost [18], with total nitrogen content required to make up at least 1.0 % of the total weight. Negi et al. (2018) presented nitrogen immobilization in compost as the cause of the increase in total Kjeldahl nitrogen content [24]. The mineralization of organic nitrogen through ammonification, ammonium volatilization and CO_2 emission increased nitrogen content in the final vermicompost.

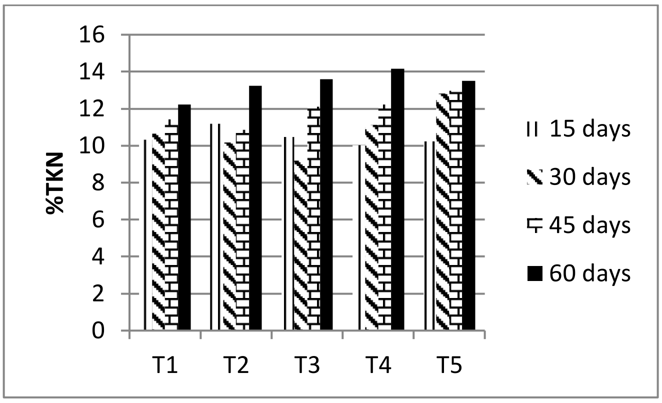

Fig. 7. Comparison of total Kjeldahl nitrogen values of all treatments on the final vermicompost.

3.3.7. Available phosphorus

In the final vermicomposting, available phosphorus content of all treatments including T1 (707.81±83.07 ppm), T2 (502.83±114.26 ppm), T3 (728.81±257.48 ppm), T4 (589.45±81.55 ppm) and T5 (472.69±57.98 ppm) was not significantly different ($p > 0.05$) (Fig. 8). The available phosphorus content in all treatments did not adhere to the Thai Agricultural Standard TAS9503-2005 for compost [18], which determines that the value must make up at least 0.5% of total weight or 5,000 ppm.

The increase in available P can be witnessed by the activity of microbes and earthworms. When microorganisms decompose organic matter, they produce acid, an important mechanism for solubilization of insoluble phosphorus [20]. Those organic acids that are important to phosphorus solubilization are carbonic, nitric, and sulfuric [22]. The microflora in the gut and cast of earthworms, along with secreted mucus, plays an important role in increasing phosphorus content in vermicomposting [19]. Furthermore, all treatments have mixed cow dung. Based on an analysis of chemical properties, there were 2,854.99±143.97 ppm of phosphorus content detected, making it possible that the increase of available phosphorus in vermicompost cause this, as well [6]. The reduction of available phosphorus content is caused by the use of phosphorus as an energy source by microorganisms [24].

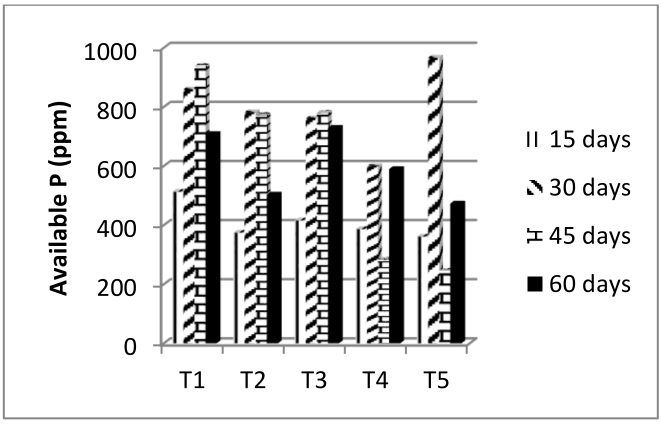

Fig. 8. Comparison of available phosphorus values of all treatments on the final vermicompost.

3.3.8. Exchangeable potassium

In the final vermicomposting, exchangeable potassium content of T5 had the highest exchangeable potassium content of 5,505.15±360.32 ppm and was significantly different ($p < 0.05$) from T1 (4,239.32±184.38 ppm), T4 (4,089.58±385.16 ppm), T2 (4,143.41±384.22 ppm) and T3 (3,861.98±1,024.56 ppm) as shown in Fig. 9. The exchangeable potassium content in T5 adhere to the Thai Agricultural Standard TAS9503-2005 for compost [18], which determines that the value must be at least 0.5% of total weight or 5,000 ppm. Khatua et al., (2018) reported that the microflora in the gut and cast of earthworms, along with secreted mucus, plays an important role in increasing potassium content in vermicompost, as well as increasing the potassium content [19]. As shown in Table 3, rain tree leaves contain high amount of exchangeable potassium. Therefore, adding more rain tree leaves in the treatments will help to increase exchangeable potassium in vermicompost.

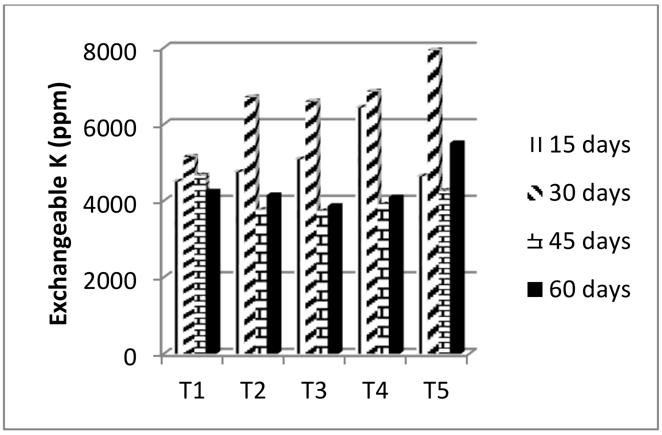

Fig. 9. Comparison of exchangeable potassium values of all treatments on the final vermicompost.

3.3.9. C/N ratio

The C/N ratio of all treatment tends to decrease gradually from the initial to final vermicomposting (on days 15, 30, 45 and 60) with values in the range of 2.36–3.44. In the final vermicomposting, T1 had the highest of C/N ratio of 2.71% because T1 was the ratio with the most amount of paper cup waste. The chemical properties analysis of paper cup waste found that the initial high C/N ratio affected the final vermicomposting and was a high C/N ratio. This was followed by T2 (2.46), T5 (2.44), T3 (2.37), and T4 (2.36), respectively. However, the C/N ratio of all treatments was not significantly different ($p > 0.05$) (Fig. 10), adhering to the Thai Agricultural Standard TAS9503-2005 for compost [18], which determines that the appropriate C/N ratio must not be greater than 20/1.

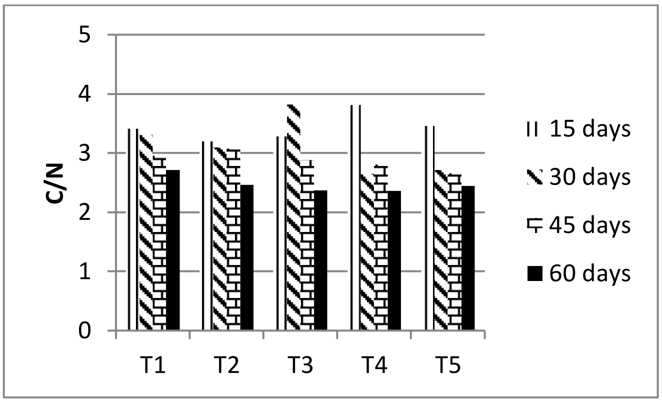

Fig. 10. Comparison of C/N ratio values of all treatments on the final vermicompost.

3.4. Seed Germination Test

From the study of the seed germination test, which act as biological parameters for assessing phytotoxicity, it was found that T1 had the highest percentage of seed germination of 45.00±10.00%, followed by T3 (41.67±24.66%), T4 (35.00±22.91%), T5 (33.33±24.66%) and T2 (31.67±23.63%), respectively. However, the percentage of seed germination for all treatments was not significantly different ($p > 0.05$), as shown in Table 4.

Table 4. Seed germination (SG) of maize seeds in each treatment of vermicompost.

Treatment	SG (%)
deionized water	15.00
T1	45.00
T2	31.67
T3	41.67
T4	35.00
T5	33.33

4. Conclusions

This study focuses on the use of organic waste as raw materials for vermicomposting at Chulalongkorn University. The objective of this study was to investigate the appropriate ratio of paper cup waste to rain tree leaves in vermicomposting. There were five treatments (T1 to T5), with each treatment using paper cup waste and rain tree leaves in different ratios, mixed with bulking agents of cow dung and coffee grounds. The result from physical and chemical property analysis of all treatments on the final vermicompost found that the vermicomposting process T1 to T5 in a 60-day period can be used to decompose waste from paper cups and rain tree leaves.

For physical properties, the vermicompost texture of all treatments was similar to dark brown organic matter, while the EC values were not significantly different ($p \geq 0.05$). Chemical properties, the values of pH, total organic carbon, total organic matter, C/N ratio, and available phosphorus were not significantly different ($p \geq 0.05$), while the primary macronutrients (total Kjeldahl nitrogen, and exchangeable potassium) were significantly different ($p \leq 0.05$).

The comparison with the compost quality standards of the Thai Agricultural Standard appeared to show that T5 was the most appropriate ratio due to T5 was the only ratio that had the exchangeable potassium content adhere to the Thai Agricultural Standard. However, T1 to T5 can help improve the physical properties of the soil but required the addition of nutrients (nitrogen, phosphorus and potassium), which should be used alongside chemical fertilizers. The use of organic waste in vermicomposting proves to be a viable alternative for managing waste at Chulalongkorn University. It helps to recycle waste and reduce disposal costs.

Further studies to enhance the number of primary macronutrients (total Kjeldahl nitrogen, available phosphorus, and exchangeable potassium), in an effort to improve the chemical properties of the soil, should be conducted, while a life-cycle assessment and economic feasibility study should be conducted to understand its sustainable development value.

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