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# Green Biological Transformation of Food and Yard Waste

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**Graphical abstract**

**Abstract**

The composting of organic waste is an alternative waste management technique that can be used to control the increase in waste generation. The objective of this study was to identify a type of effective microbes (EMs) that accelerate the composting process. The study also determined the suitability of using a KompostKu rotary composter along with additional materials such as coconut husks and Takakura EMs for composting food waste from the Universiti Kebangsaan Malaysia (UKM), and determines the economic value of the compost. In order to select the most efficient EMs, Takakura and fruit waste EMs were prepared and used during the composting of both food and yard waste using a composter barrel. Four important parameters were examined to ensure the effectiveness of the process, including temperature, moisture content, potential of hydrogen (pH), and carbon to nitrogen (C/N) ratio. The experimental results revealed that Takakura EMs were superior to the fruit waste EMs in accelerating the composting process. The use of coconut husks as an absorbing agent with Takakura EMs also accelerated the composting process, requiring approximately four weeks to fully decompose the food waste. It was estimated that the composting of food and landscape waste at the UKM could annually generate compost products worth over 30,660 Malaysian Ringgit (MYR). The use of Takakura EMs enhanced and accelerated the composting process and provided high-quality compost.

*Keywords*: Takakura EMs; fruit waste EMs; coconut husk; KompostKu rotary composter; composting

**Abstrak**

Pengkomposan sisa pepejal organik merupakan salah satu alternatif dalam teknik pengurusan sisa pepejal yang boleh digunakan untuk mengawal peningkatan jumlah sisa yang terhasil. Objektif kajian ini adalah untuk mengenal pasti jenis mikrob efektif (EMs) yang dapat mempercepatkan proses pengkomposan. Kajian ini juga bertujuan untuk menentukan kesesuaian penggunaan tong kompos berputar KomposKu beserta penambahan bahan-bahan seperti sabut kelapa dan EMs Takakura untuk pengkomposan sisa makanan dari Universiti Kebangsaan Malaysia (UKM), dan menentukan nilai ekonomi kompos. Untuk menentukan EMs yang paling efektif, EMs Takakura dan EMs sisa buah disediakan dan diaplikasikan dalam pengkomposan kedua-dua sisa makanan dan sisa taman dalam tong kompos. Empat penting parameter diuji untuk memastikan keberkesanan proses, termasuk suhu, kandungan kelembapan, potensi Hidrogen (pH), dan nisbah karbon/nitrogen (C/N). Keputusan ujikaji yang diperolehi menunjukkan EMs Takakura adalah lebih efektif berbanding EMs sisa buah dalam mempercepatkan proses pengkomposan. Penggunaan sabut kelapa sebagai agen penyerap bersama EMs Takakura juga telah mempercepatkan proses pengkomposan, di mana hanya 4 minggu diperlukan untuk sisa makanan terurai sepenuhnya. Pengkomposan sisa makanan dan sisa taman di UKM dianggarkan mampu menjana produk kompos yang bernilai lebih dari RM 30,660 setahun. Penggunaan EMs Takakura mampu mempercepatkan proses pengkomposan sekaligus menghasilkan produk kompos yang berkualiti tinggi.

*Kata kunci*: Mikroorganisma efektif takakura; mikroorganisma efektif sisa buah; sabut kelapa; pengkompos berputar kompostku; pengkomposan



## ■1.0 INTRODUCTION

According to the report of the Ninth Malaysia Plan (2006-2010), the population of Malaysia produced 16,200 tons of solid waste per day in 2001, which increased to 19,200 tons per day in 2005. More waste would certainly be generated based on Malaysian population growth estimates of approximately 2.4% or 600,000 people per year since 1994.[1] Over 27,000 metric tons of wastes are currently produced each day in Malaysia, and this amount is expected to increase to 32,000 metric tons by the year 2020 because of the country's increasing population and development;[2] less than 5% of this waste is currently recycled.[3]

The Universiti Kebangsaan Malaysia (UKM) has a population of approximately 30,000, consisting of academic staff, support staff, and students who produce approximately 4.5 tons of solid waste every day.[4] Food waste comprises 54.8% of the total generated solid waste, or approximately 2.5 tons per day. Food waste is suitable for biological treatments such as composting, which assists waste stabilization and thereby reduces waste volume.[5] Approximately 2.36 tons per day of yard waste is generated by the UKM.[6]

Integrated solid waste management is a system consisting of six elements: generation, storage, collection, transportation, biological treatment, and disposal.[7] These elements are important to the concept of sustainable development in public health, economics, engineering, conservation, aesthetics, public awareness, and the environment. Biological treatment is also known as composting, which is a method of recycling organic plant- and animal-based waste to reduce the amount of waste disposed in landfills.[7] The natural process of decomposing organic waste with effective microbes (EMs) produces compost that can be used as organic fertilizer in agricultural operations.[8] Composting is the biological decomposition of organic materials. In this process, microorganisms play an important role in decomposing the organic materials to more stable materials known as compost. The composting process can be classified into two types: aerobic and anaerobic.

An acceptable aerobic composting process occurs when conditions are optimized for the growth of EMs such as bacteria and fungi. These EMs require oxygen, water, and food for the decomposition process. Thus, important parameters such as temperature, moisture content, potential hydrogen (pH), and oxygen demand must be controlled in order to obtain the best quality compost. The optimum moisture content for composting is approximately 50-70% by weight, and the oxygen demand is approximately 15-20% from the air cavity.[9] The required carbon to nitrogen (C/N) ratio is approximately 30/1, and the compost quality is best when the final C/N ratio is between approximately 10/1 and 20/1.[10] Both the carbon and nitrogen contents are important because they supply energy in the form of glucose molecules and nutrients in the form of protein molecules for the EM decomposition process.

Aerobic composting requires the presence of oxygen for EM decomposition.[11] The final products of aerobic composting consist of carbon dioxide ($CO_2$), ammonia ($NH_3$), water, and heat. Equation (1) shows the chemical reaction process of aerobic composting.

$$\text{organic matter} + O_2 + \text{Nutrients} \rightarrow \text{new cells} + \text{semi} - \text{compost organic materials} + CO_2 + H_2O + NH_3 + SO_4^{-2} + \cdots + \text{Heat} \quad (1)$$

Microorganisms such as bacteria, fungi, and actinomycetes exert a major influence on the composting process. These microorganisms are categorized as chemical decomposers because they change the chemical structure of the composted organic waste. A typical EM product is a concentrated brown solution that contains more than 80 microbe strains, primarily lactobacillus, photosynthetic bacteria, yeast, and ray fungi.[9] In addition, EMs contain both aerobic and anaerobic microbes that exist at a pH of 3.5,[12] and they are widely used in agriculture, animal husbandry, aquaculture, wastewater treatment, and solid waste treatment to increase the quantity and quality of the end products and to improve the treatment of certain contaminants.[13]

Selecting the composting process method is one of the most important factors in creating an effective composting system. Good composting methods can accelerate and facilitate the composting process. There are two main stream composting methods: the open method and the mechanical method.[14] Different composting methods such as windrow composting, conventional composter bins, rotary drums, and rotary composters were previously practiced at the UKM.[15] Rrotary composters were shown to be the best composting system for treating organic waste at the UKM.[15]

The objective of this study was to investigate the effectiveness of EMs in accelerating the composting process when using a composter barrel. The study also determined the suitability of using a rotary drum method with additional materials such as coconut husks and EMs for composting food waste from the UKM, and determines the economic value of the compost. The quality of the compost was investigated by measuring important parameters such as temperature, moisture content, pH, and C/N ratio.

## 2.0 EXPERIMENTAL

The methodology of this study was divided into two parts. The first part identified the best and most efficient EMs that enhanced and accelerated the composting process using the barrel composting technique. The composting materials consisted of food and yard waste generated by the UKM. The second part of the methodology addressed the use of the rotary composter for composting the food waste from the UKM Rahim Kajai college cafeteria. The effect of additional materials such as coconut husks and Takakura EMs on the composting process was also investigated.

### 2.1 Effective Microbes preparation

Seed compost (Takakura EMs) was created by mixing fermenting solutions and a fermenting bed. The fermenting solution was prepared from two types of solutions. The first solution consisted of 15 ml of a sugared solution that included fermented foods such as yeast, yogurt, unrefined soy sauce, and fermented soybeans. The second solution consisted of 5 ml of a salted solution that included fresh vegetables such as eggplant, cucumbers, and cabbages along with fruits such as apples, grapes, and oranges. After mixing, the fermenting solutions were left for 3 to 5 days to allow the fermenting microbes to grow before being added to the fermenting bed. The fermenting bed consisted of rice bran and rice husks at a ratio of 1 $m^3$:1 $m^3$. This seed compost was left for 3 to 5 days before being mixed with the compost piles.[16]

The fruit waste EMs consisted of 60% water and 40% fruit waste (fruit peels, fruit seeds, and rotten fruit) by volume. The EMs were left for 3 to 5 days to allow for the growth of microbes before being mixed with the compost piles.

### 2.2 Material preparations and composting process

Yard waste was collected at the UKM and sent to the composting site to be shredded. The waste was shredded using a shredder from the Department of Development Management (JPP) with assistance from workers at the JPP. The food waste used for composting was taken from three cafeterias at the UKM: the Ibrahim Yaakub Residential College cafeteria, the Keris Mas Residential College cafeteria, and the Rahim Kajai Residential College cafeteria. It was a mixture of cooked and uncooked food and vegetables waste (Fig. 1). The waste was collected between 3 pm and 4 pm because the greatest quantity of food waste was produced during that time of day. The food waste was not shredded because the waste was already an acceptable size for composting (approximately 0.1 cm to 1.0 cm) and the excess moisture in the food waste tended to reduce the size much faster during the composting process.

**Figure 1** Food waste sample

A composter barrel technique was used for performing the composting process in order to select the best EMs for accelerating the composting process. The composter barrel contained four compartments, and each compartment contained a unique compost composition with a ratio of 1:1 by volume of yard waste and food waste. Individual quantities of Takakura and fruit waste EMs were added to each compartment in order to study the effect of the EMs on the composting process. Table 1 shows the composition of the compost in the compartments with the distribution of the EMs. The mixtures inside the composter barrel were turned at least two or three times a week to allow aeration inside and outside of the mixtures.

**Table 1** Composition of compost materials in the composter barrel

| Bin | Composition | EM type |
|---|---|---|
| A | 1:1 ratio of yard waste to food waste with EMs | Takakura |
| B | 1:1 ratio of yard waste to food waste with EMs | Takakura |
| C | 1:1 ratio of yard waste to food waste with EMs | fruit waste |
| D | 1:1 ratio of yard waste to food waste with EMs | fruit waste |

### 2.3 Application of rotary composter for food waste composting at UKM

A KompostKu rotary composter Model JK125 (Fig. 2) was used in this study for composting the food waste from the Rahim Kajai college cafeteria. The dimensions of the composter were 95×70×95 cm with a capacity of 125 L. The composter contained two compartments that were covered by an insulation layer. This layer maintained a high temperature during the process that accelerated the decomposition of organic waste.

**Figure 2** KompostKu rotary composter

This type of composting technique (rotary composter) was selected because of its suitable size for the amount of food waste generated and its ease of use in terms of mixing waste (turning) and supplying air through the holes at both sides of the composter.

The food wastes collected from the Rahim Kajai college cafeteria included both uncooked and cooked waste. The collected waste was weighed and mixed with coconut husks at a ratio of 2:1 (food waste to coconut husk) by volume and loaded into the rotary composter daily until each compartment was three-quarters full. The coconut husks act as an absorbing agent for controlling the composting moisture content.[9] The Takakura EMs were added into the process during the first and the second day of the composting process at a ratio of 2:1 (food and coconut husks waste to EMs) by volume. The use of Takakura EMs in the early stage of the process enhanced and accelerated the composting process. Table 2 shows the quantity of the compost materials that were used in the study.

**Table 2** Quantity of compost material

| Rotary composter | Weight (kg) | | | |
|---|---|---|---|---|
| | Food waste | Coconut husk | EM Takakura | Total |
| Compartment 1 | 15.55 | 1.43 | 2.87 | 19.85 |
| Compartment 2 | 13.17 | 1.40 | 2.83 | 17.40 |

### 2.4 Proximate analysis

Laboratory tests were performed to investigate the following parameters involved in the composting process: pH, moisture content, temperature, leachate production, and C/N ratio. The pH value was measured using an electronic pH meter in accordance with Rasapoor et al..[17] The moisture content was measured according to ASTM E989-88 standards. The temperature measurements were taken on site using a thermometer. The volume of leachate production was measured daily using a measuring cylinder in order to determine the effectiveness of the coconut husks and the Takakura EMs during the process. The C/N ratio was tested based on the ASTM E777-87 and E 778-87 standards with a CHNS-O Analyzer. All experimental measurements were taken at least twice, and the average was determined.

## ■3.0 RESULTS AND DISCUSSION

### 3.1 EM Selection

Figure 3a shows that the moisture content of bin D was greater than those of bins A, B, and C because the yard wastes in bins A, B, and C were drier. Thus, the absorption of water from the yard waste reduced the moisture content in bins A, B, and C. The waste was watered to ensure that the waste's optimum moisture content of 40-70% was maintained. Figure 3b shows that the contents of bins A, B, C, and D were acidic in their early mesophilic phases. The pH value subsequently increased to between 8 and 9 during the third week, when the composting process entered its thermophilic phase, and decreased to almost neutral (7-8) during the sixth week, when the compost reached a mature state.

Figure 3c shows the measured temperature inside the composter barrel and indicates that bins A and B reached their highest temperatures (60°C) during the second week of composting. The temperature in bin C began to increase during the third week and reached 50°C. The differences in the times of the temperature increments between bins A and B with bin C show one advantage of using Takakura EMs over fruit waste EMs—the ability of Takakura EMs to accelerate the composting process is superior to that offruit waste EMs. However, bin D only experienced a slight temperature increase due to excess moisture preventing it from reaching an optimal temperature between 40°C and 70°C. The carbon to nitrogen test indicated that the C/N ratio was 17/1 in bin A, 9/1 in bin B, 13/1 in bin C, and 12/1 in bin D. The decrease in C/N ratio in bin B might be referring to the increase in degree of humification of organic matter.[18] The optimal C/N ratio for compost products is less than 20/1.[19] Because these results confirmed that the C/N ratios of all the compost products were lower than 20/1, the compost products were determined to be in mature phases.

## 3.2 Rotary composter with Takakura EMs

Figure 4a shows the moisture content of the compost during the rotary composting process. It can be seen that the moisture content was high at the early stage of the process (79% to 86%) and began to decrease, reaching values between 51 and 53% by the fourth week of the process due to the addition of coconut husks that helped absorb the excess moisture. According to Polprasert,[20] the appropriate moisture content ranges from 50% to 70% and should be maintained during the period of active bacteria. The pH value in the rotary composter was quite high in the early stage, ranging between 7.65 and 8.89 (Fig. 4b). These values decreased during the second and third weeks and became neutral (with readings between 7.02 and 7.35) by the fourth week. For the production of high-quality compost, an optimal pH value range between 7 and 8.[21]

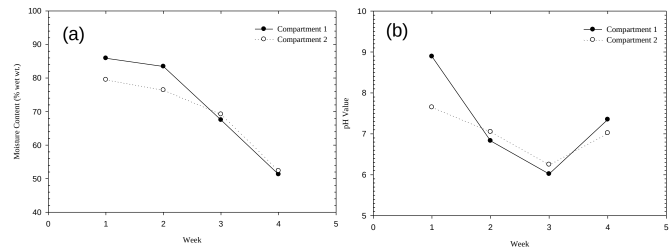


**Figure 4** Rotary composter parameters value: a) moisture content, and b) pH

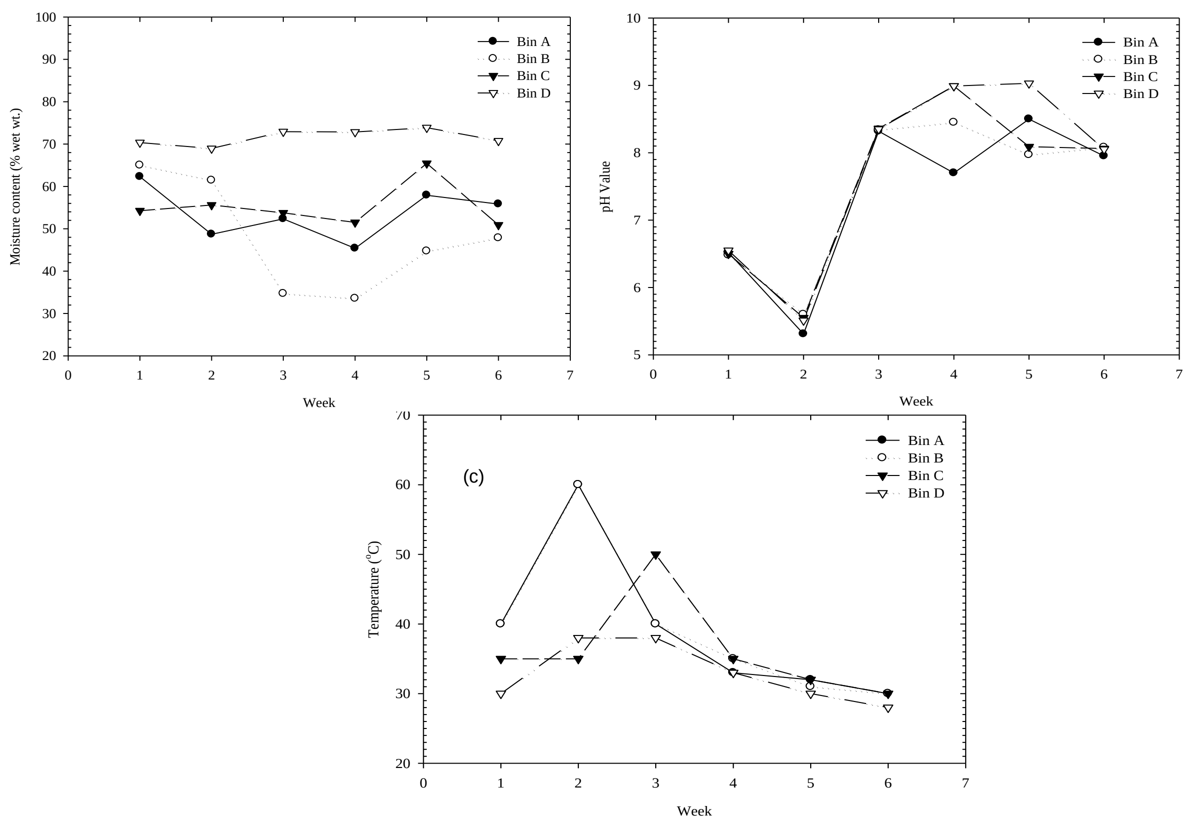


**Figure 3** Composter barrel parameters value: a) moisture content, b) pH, and c) Temperature

A rapid increase in temperature was observed in the composter at the beginning of the process (from 35°C to 73°C) (Fig. 5a). This was due to the addition of the Takakura EMs, which increased the temperature. The temperature subsequently decreased during the following days, reaching 35°C by the end of the process when the food waste was completely decomposed. Figure 5b shows the leachate production during the composting process.

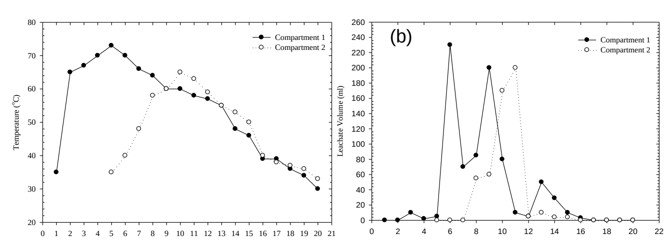


**Figure 5** Rotary composter parameters value: a) temperature (°C), and b) leachate production (ml)

The total leachate production from both compartments was 1,297 ml from a total of 37.3 kg of compost material—an average of 34.8 ml/kg. This is considered low when compared to a previous study conducted by Suriati,[9] who showed an average leachate production of 128.15 ml/kg for compost material. This may be due to the high absorption capacity of the coconut husks used in the process and the high temperature generated from the use of Takakura EMs, which reduced the amount of moisture that was produced.[9] The C/N ratio during the last week of composting process was tested at 12/1 for compartment 1 and 15/1 for compartment 2, indicating that the compost product was at a mature phase.[19]

### 3.3 Compost production and cost benefits

Table 3 shows the initial and final weights of the compost material with the percentage reduction of weight after four weeks of the food composting process using the rotary composter. The compost materials were successfully decomposed after four weeks of the process. This indicated that utilizing Takakura EMs in the composting process enhanced and accelerated the process; a study shown that composting food waste required approximately eight weeks to reach completion without using EMs.[9] Table 3 indicates that an average of 35% compost product resulted from the composting process of food waste. The UKM produces approximately 5 tons/day of organic waste (food and landscape waste);[6, 22] therefore, the use of composting might result in 1.75 ton/day of compost product.

The price for MSW compost on the Malaysian market is approximately between USD 2.5 and 10 per ton, while compost made of agricultural waste sells for a higher value estimated to be USD 15–35 per ton.[23] Assuming that the market value of compost products from mixed organic waste is approximately USD 15 per ton, the conversion of organic waste at the UKM into a compost product could produce revenues of 30,660 Malaysian Ringgit MYR annually (considering that 1 USD equal 3.2 MYR).

**Table 3** Waste reduction of compost material

| Rotary composter compartment | Composting time, week | Food waste reduction | | |
|---|---|---|---|---|
| | | Initial weight of compost material, kg | Final weight of compost product, kg | Percentage of waste reduction |
| Compartment 1 | 4 | 19.85 | 6.35 | 68.0% |
| Compartment 2 | 4 | 17.40 | 6.66 | 61.7% |

## 4.0 CONCLUSION

This study found that the composting process is one of the best methods for treating organic waste generated at the UKM. It was also determined that the use of Takakura EMs was better than the use of fruit waste EMs in the composting process because their addition resulted in a shorter composting process and produced high-quality compost. In addition, the KompostKu rotary composter is the best method of composting and can be used at the UKM in the future because of its ability to enhance and simplify the composting process.

The use of a composting process for food and landscape waste at the UKM can generate compost products worth over 30,660 MYR annually.

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