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Development of Organic Fertilizer from Food Waste by Composting in UTHM Campus Pagoh

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Abstract: In Malaysia, most of the food waste is sent to landfill and produce methane gas which causes greenhouse effect. Hence, the aim of this research is to reduce the food waste at landfill by composting using designed compost bin. The objectives of this research is to reduce the amount of food waste in UTHM Pagoh; develop a composting process for managing food waste and improves its quality for possible use in the growth of plants as well as develop a composter for composting process. Food wastes were collected and put into the designed rotary composter with the consideration of all the parameters that is related to aerobic composting. At the end of the composting process, the temperature of the compost was at ambient temperature and had a pH of 7.5. Results of this study showed that the compost produced consists 0.9% of Total Nitrogen as N, 0.8% Total Phosphorus as P_2O_5 and 0.4% Total Potassium as K_2O which are all in the accepted range of mature organic fertilizer. In conclusion, the composting of basic food waste in campus can produce an acceptable organic fertilizer for plant use will greatly reduce the amount of generated food waste to the landfill.

Keywords: aerobic composting, organic fertilizer, food waste

1. Introduction

From year 2000 to 2017, the global urban population has increased from 2.9 billion to 4.1 billion and by 2030, it is expected to reach 5.1 billion out of 8.6 billion of global population [1]. The explosion of population and increment of urbanization with changing lifestyles create more and more wastes being generated in many cities and townships. This ever-rising shift of the world population is already evident and will produce even more remarkable amounts of urban food waste, which in turn will add pressure to the already overloaded municipal solid waste transportation system and landfill sites [2]. According to the study conducted by SWCorp showed that Malaysians generated 38,000 tonnes of solid waste daily in 2016, of which 15,000 tonnes was food waste. It found that 20%, or 3,000 tonnes, of this food waste was avoidable [3].

Most food waste has been land filled together with other wastes, resulting in various problems such as emanating odor, attracting vermin, emitting toxic gases, contaminating groundwater by the leachate and wasting landfill capacity [4]. Methane (CH4) and carbon dioxide (CO2) emitted as a result of microbial activity under uncontrolled anaerobic conditions at dumping sites are released into the atmosphere and contribute to global warming [5].

Composting is a good idea to reduce the amount of solid waste in the landfill. Composting is a controlled decomposition where natural breakdown process occurs. Composting is the transformations of raw organic materials into biologically stable, humic substances suitable for a variety of soils and plant uses [6]. Organic fertilizers are the end product of composting. Organic fertilizers are natural fertilizer which made up from vegetables, fruits, animals and many more. Organic fertilizers are crucial in agricultural sector because they have positive effect on soil without damaging ground water and plants [7].

2. Related Work

2.1 Composting

Composting involves the conversion of organic residues of plant and animal origin into manure. The main product of composting is the compost which is rich in humus and plant nutrients and the by-products are carbon dioxide, water, and heat. It needs oxygen to carry out the composting process which is called as aerobic composting.

2.1.1 The Biology of Composting

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Aerobic microorganisms use organic matter such as food waste, agriculture waste as a substrate. The microorganisms decompose the substrate, breaking it down from complex to intermediate and lastly to simpler compounds. The mixture contains carbon and nitrogen. During composting, they are transformed through successive activities of different microbes to more stable organic matter, which chemically and biologically resembles humic substances. The rate and extent of the transformations depend on available substrates and the parameter used to control composting [8].

There are a few steps to reduce the composting time. The first one is taking care of the Carbon to Nitrogen (C/N) ratio properly and the temperatures at desirable levels. Besides, make sure that the particle size of the greens and browns are small and do not add too hard items such as bones, or oily and greasy items such as cheese [9].

2.1.2 **Factors Affecting Food Waste Composting Process**

In order to produce a good quality of organic fertilizer from organic waste, there are some parameters which will affect the food waste composting process. All the factors have their optimum level to produce good quality compost. The factors are moisture content, temperature, pH, Carbon to Nitrogen ratio and aeration. By controlling all these parameters at optimum level, the rate of composting can be increased and the nutrients in the compost will be better.

2.1.3**Bulking Agents**

Bulking agent is important in composting. The main function of bulking agent is to provide sufficient dry matter to give a porous structure to the compost mixture and to absorb the moisture produced by the decomposing process of food waste [2].

In food waste composting, bulking agents are often added to adjust moisture content, pH, C/N ratio and enlarge free air spaces. Chopped wheat straw, saw-dust, rice bran, cornstalks and some other materials were used as bulking agents, in order to deal with the variation of food waste production rate and substrate nature arising from seasonal change, to speed up the reaction in composting process [13]. By adding bulking agents, it could reduce or even avoid leachate production, and also lead to the release of much less CH_4 and N_2O than compost with kitchen waste alone [19].

2.1.4**Sources That Enhance Production of Organic Fertilizer**

Composting is a time consuming process. There are some tips to speed up the process. Regular mixing and stirring the pile loosens the material and maintains proper aeration is one of the ways. Sprinkling some sugar or gur water, and sour butter milk can speed up the process as well.

2.2 **The Composting Process**

In the completion of the composting food waste by using compost bin, there are three sections of procedure to complete the compost. Materials selection is the first section which lists out what is needed for the composting process. The next step is the design of compost bin which will be used for composting. The third section of the research is the composting process which includes the analysis of the content in the compost. All the materials selected will be put into the composter. Attention will be given to the whole composting process. Aeration, moisture content, temperature need to be constantly supervised. The content of the compost is then being analyzed in laboratory.

2.2.1**Material Selection**

The material selected is the food waste from the cafeteria. The food waste such as vegetables, fruits peels, coffee ground, egg shells and tea leaves are used as the materials for the composting process. Besides dry leaves, soil, shredded paper and newspaper are added into the compost as well to reduce the excess moisture. They are the materials that can absorb water due to their ability of absorption.

In addition, the compost should not include cooked food, meat, or fish as they contain pathogen, which may contaminate the compost. Hard items such as bones or oily and greasy items such as cheese also should not be put into the composting process.

2.2.2**Carbon and Nitrogen Sources**

In composting process, greens and browns are needed as the basic source as the composting materials. They are used to be called as Carbon and Nitrogen source. By greens we mean the kitchen waste, while browns mean dry leaves, sawdust, shredded paper and soil. Table 2.1 shows the source of Carbon and Nitrogen to be put into the composting process.

Table 2.1: List of Carbon and Nitrogen source

Greens (High in Nitrogen- N)	Browns (High in Carbon- C)
Discarded vegetables or vegetable peels	Dry leaves
Fruit peels	Soil
Coffee and tea grounds	Shredded paper and newspaper

2.2.3**Carbon and Nitrogen Ration (C/N Ratio)**

Different material have different C/N ratio. After referring many previous researches, the optimum C/N ratio for composting is 25-30:1 [8][9]. The C/N ratio is calculated based on the weight percentages of the component wastes in the mixture. The C/N ratio chosen is 30:1 in this research. Table 3.3 shows the C/N ratio of each composting materials that is used in the compost.

Table 2.2: List of Carbon to Nitrogen ratio of each material

Materials	C/N ratio	Reference
Discarded vegetables or vegetable peels	24:1	Adhikari, Barrington, Martinez, & King, (2009)
Fruit peels	35:1	Rim Toumi, (2017)
Coffee and tea grounds	20:1	Angima, (2005)
Dry leaves	60:1	Rim Toumi, (2017)
Soil	10:1	Batjes, (2014)
Shredded paper	170:1	Rim Toumi, (2017)
Shredded newspaper	170:1	Batjes, (2014)

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3. Methodology

3.1 Design of the Compost Bin

A plastic container has been chosen. There are a few holes pierced on the lid of the container in order to provide the compost with air. As mentioned previously, bacteria need oxygen to keep up the respiration process that happens within aerobic systems. Additionally, putting the compost in a closed container is better. The bin will cover the compost from the rain and will help to retain the temperature inside. Closed container is also used to avoid bad smell or odour and prevent other animals from disturbing the process.

The container will be placed horizontally on a four-wheeled base so that it can be rotated like a rotating tumbler. As the waste mixture is tumbled in its passage down the length of the drum, the material is gradually broken down and is well mixed with oxygen and water. The consequent increase in granularity causes increasingly intense biological activity leading to a well-established decomposition process.

The composter is made to allow a healthy composting process. Therefore, its design takes some factors into consideration. Aeration and temperature are the parameters that relate to the design of the composter. In this research, the designed composter will be pierced with some holes and will be rotated for ventilation in order to improve the aeration for the composting process. Besides, the compost temperature may vary from 25°C to 70°C. Therefore, the composter has to retain heat by not easily lose heat to the surrounding. Figure 3.1 shows the design of the rotary compost bin.

Figure 3.1: The design of rotary compost bin

3.2 Equipment Used During Composting

Thermometer is the basic equipment which is used to monitor the performance of the compost. In this research, a 4in1 tester which can test pH, moisture, thermometer and light intensity is used. pH and moisture content of the compost need to be monitored during the composting process as well. Temperature of composting needs to be checked every day. During composting, temperature above 65°C should be prevented because sensitive microorganisms may be killed and the decomposition process may slow down. Composting will essentially take place within two temperature ranges known as mesophilic (25 to 40°C) and thermophilic (over 40°C). Although mesophilic temperatures allow effective composting, however experts suggest maintaining of thermophilic temperature ranging up to 60°C, is essential to destroy pathogens, weed seeds and fly larvae in the compost [14].

3.3 Composting Process

The composting process included the method of composting by considering the characteristic of the materials chosen. The end product of composting is tested in laboratory to obtain the content of the compost.

3.3.1 Composting Method

The composting was basically done layer by layer. The browns and greens were layered alternatively until it reaches half of the container. Then, it was rotated for mixing and breaking down of the size of the materials.

Step 1: The bottom of the compost bin was filled with a thick layer of browns such as soil and shredded newspapers. These help to soak up excess moisture and improve aeration.

Step 2: The prepared greens was added into the composter. They should form a layer above the browns that were added in step 1.

Step 3: A few handful of compost starters were added into the composter. Then, they were mixed with the greens that are added in the previous step.

Step 4: Another layer of shredded browns was added into the composter. About the same amount of browns was added as greens from step 2. Then, this new layer was mixed with the greens and compost starters from the previous step. This introduces air spaces into the compost pile, ensuring an aerobic situation and effective composting process. It also prevents the compost pile from smells and pests.

Figure 3.2: The layered materials in composter

After layering all the materials, a handful of water was sprinkled into the composter and some turmeric powder was added to avoid ants. The composter was placed at a warm place. This helps the microorganisms in the compost work more efficiently, as they thrive in warmer temperatures. A dry layer at the top also functions as a first line of defense against flies that are seeking moist places to lay their eggs on.

The composter was put under partial sun exposure to keep the compost pile warm. The composter was avoided from direct sunlight as extreme temperatures would kill the beneficial microorganisms [7]. The composter was then being rotated every day for mixing and aeration purpose.

3.4 Analysis of Content in the Compost

When the compost is mature, it has a nice soil-like smell and dark brown in colour. Since the compost is the organic fertilizer for plants, it must contain the nutrients that a plant requires. The nutrients that plants require in large amount are called macronutrients such as Nitrogen, Phosphorus, Potassium,Calcium, Magnesium, and Sulfur. The compost is then sent to the laboratory to test the nutrients in it.

The compost was sent to Lotus Laboratory Services (M) Sdn Bhd in Johor Bahru to determine the content of the organic fertilizer. The elements which can be tested are Nitrogen, Phosphorus, Potassium, Calcium and Magnesium and etc. The analysis method was done by following Association of Official Analytic Chemists (AOAC) 17th Edition by Helrich, 1990.

Nitrogen (N), Phosphorus (P) and Potassium (K) are the primary nutrients required by the microorganisms involved in composting. They are also the primary nutrients for plants, so nutrient concentrations also influence the value of the compost. Many organic materials contain enough quantities of nutrients for composting. Excessive or insufficient carbon or nitrogen will affect the process. Carbon provides microorganisms with both energy and growth; nitrogen is essential for protein and reproduction [16].

4. Results and Discussion

4.1 Temperature profile

The temperature has been widely recognized as one of the most important parameters in the composting process. Figure 4.1 shows the temperature profile throughout the composting process. Initially, the temperature of the compost pile was 32°C. Due to the breakdown of the available organic matter and nitrogenous compounds by the microbial activities, the temperature of the pile increased to the thermophilic phase [17]. The thermophilic phase lasted for 4 days corresponding to the maximum temperature at 42°C, 41°C and 40°C on day 2, 3, 4 and 5. When the temperature reached around 40°C, the mesophilic bacteria will begin to die and leave the floor to the thermophilic bacteria who will take over. The temperature will stabilize during this stage, which will last no longer than 3 days due to the small size of the compost and the regular turning [11].

During the cooling phase, the microbial activities and organic matter decomposition rate slowed down and the temperature of the compost pile gradually decreased. The compost pile decreased to ambient temperature on day 27 which is considered to have entered the maturation phase.

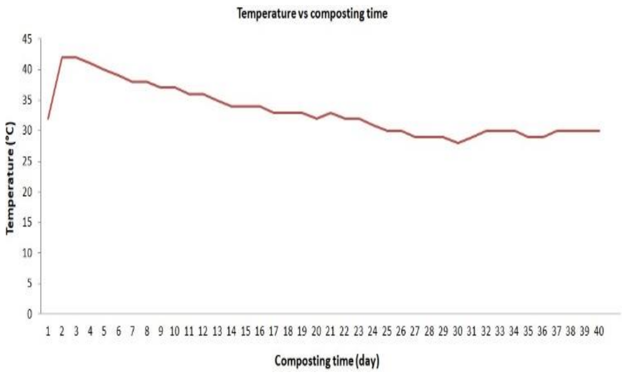

Figure 4.1: Change of temperature during composting process

4.2 Evolution of pH

Throughout the whole composting process, the pH value varied from acid to neutral. At the beginning, the pH value was 2. The compost pile was at acidic stage. The pH that reflects the acid concentration is a function of the accumulated acid production and the decomposition of acids to produce CO_2 and heat [18]. The microbial decomposition of organic matter and production of organic acids would be reason of the acidic situation.

The acidic phase varied from pH 2.0 to 6.5 until day 24. On the 25th day, the pH value rose to 7.0 and maintain in neutral stage until the end of the composting process at pH 7.5. The pH rose after a period of time because the acids were consumed. The pH rise also can be explained by the generation of ammonia from ammonification and mineralization of organic nitrogen through microbial activities [19]. The process being mineralization of nitrogen such as nitrates, nitrites and other organic acids, the At the end of composting, the pH value was in the range of satisfactory value of pH 7 to 8.5 [20].

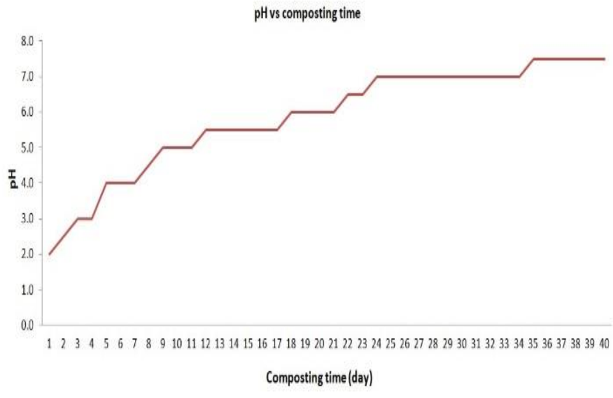

Figure 4.2: pH values during composting process

4.3 Nutrients content of the compost

For this research, the contents that were concerned were only Nitrogen, Phosphorus and Potassium. In this study, the organic fertilizer from food waste composting is considered mature and in the acceptable range because all the percentage of the nutrients is over the minimum value of mature compost. The percentage of total Nitrogen, total Phosphorus and total Potassium are 0.9%, 0.8% and 0.4% respectively. Hence, it means that a simple aerobic composting of food wastes can produce organic fertilizer that can be used for plants. The materials used for composting are all organic substances such as vegetable waste, fruits waste, coffee grounds, soil and dry leaves. All these materials are available in UTHM Pagoh.

In UTHM Pagoh, chemical fertilizer was used for the plants in order to improve the landscape around the campus. The ratio of the total Nitrogen to total Phosphorus and total potassium is 16:16:16. It is a high nutrient fertilizer. This kind of fertilizer is used for the rehabilitation of plants.

Due to concerning the environment, organic fertilizer is currently being applied in UTHM Pagoh. The nutrients percentage is much lower than the previous chemical fertilizer but it can still help with the growth of the plants. The nutrients of the organic fertilizer are as shown in Table 4.1.

Table 4.1: Comparison between the content of different fertilizers

Nutrient in fertilizer	Suggested range [21]	Food waste composting	Organic fertilizer used in UTHM (MAS Hitam)	Chemical Fertilizer used in UTHM (Yara Mila)
Total N (%)	> 0.6	0.9	2.3	16
Total P (%)	> 0.22	0.8	2.4	16
Total K (%)	> 0.25	0.4	2.3	16

4.3.1 **Nitrogen (N)**

Nitrogen is the most commonly used mineral nutrient. It is important for protein production. It plays a pivotal role in many critical functions such as photosynthesis in the plant and it is a major component of amino acids, the critical element constituent component of proteins. These amino acids are then used in forming protoplasm, the site of cell division and plant growth. Nitrogen is necessary for enzymatic reactions in plants since all plant enzymes are proteins. If there is lacking of Nitrogen and chlorophyll means the plant will not utilize sunlight as an energy source to carry on essential functions such as nutrient uptake.

For organic composting, the mature phase is which the organic materials continue to decompose and are converted to biologically stable humic substance. The increase in the Nitrogen value at the end of the composting period might occur due to the usage of Nitrogen by microorganism to build up cells, thus reducing the Nitrogen, and some of the organisms will eventually die, which is recycled as Nitrogen and thus contribute to increase.

In this study, the Nitrogen content is 0.9% which is in the suggested range which is more than 0.6% [10]. 0.6% of Nitrogen is the minimum percentage of mature compost.

4.3.2 **Phosphorus (P_2O_5)**

Phosphorus is the other primary nutrients for plant. It is essential for plant growth and a plant must access it to complete its normal production cycle. With efficient Phosphorus, it can stimulate root development, increase stalk and stem strength and improve flower and seed production. In this study, the total Phosphorus content is 0.8% as P_2O_5. It is also in the acceptable range of mature organic fertilizer which is 0.22% [10].

4.3.3 **Potassium (K_2O)**

Potassium is vital to photosynthesis, protein synthesis and many other functions in plants. It enhances many enzyme actions aiding in photosynthesis and food formation. It builds cellulose and helps translocation of sugars and starches. Potassium is known as the "quality nutrient" because of its important effects on factors such as size, shape, color, taste, shelf life, fiber and other quality-related measurements. Other than that, Potassium can increase root growth and improves drought tolerance.

After conducting the composting process for about 2 months, the Potassium percentage is 0.4% as K_2O. The final compost is considered as mature as the minimum range for Potassium is at 0.25% [10].

5. **Conclusion**

The objectives of this research was to reduce the amount of food waste in UTHM Pagoh, develop a composting process for managing food waste and improve its quality for possible use in the growth of plants as well as develop a composter for composting process. This research is considered a success as the organic compost from food waste composting can be used as the fertilizer because the content of it is in the acceptable range for mature fertilizer. The percentage of total Nitrogen, total Phosphorus and total Potassium is 0.9%, 0.8% and 0.4% respectively. The final product has soil-like smell and dark brown in colour which means it is matured enough to be used.

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