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Research paper

The Discovery of Physical Properties of Food Waste in Composting Process

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Abstract

Composting as a method of solid waste management should be given attention. It gives means of producing a valuable end product, by treating of organic wastes in an environmentally friendly method which does not release any hazardous chemical which can affect human health without causing a major disruption to the surrounding ecosystem. Nevertheless, the issue of time-consuming arises and this correspond to the sink of market demand. The optimized pre-composting process was done through drying, grinding and controlled aeration resulted in the fast-compost formation and cost-effective. This study aimed to discover the physical properties of food waste in composting process. The controlled parameter of the composting which is aeration time where pre-composting processes applied was drying and grinding. The manipulated parameter of composting process happened within two durations: rotation and rest. Each container has been rotated for 15 minutes yet different resting time was applied which are 15, 25, 50, 150 minutes namely A, B, C and D. The data collection has been done in hourly basis for the total of 72 hours. Based on the statistical analysis, results show that mass reduction of samples (A=38.6%, B=32.6%, C=24.6%, D=22.6%). The compost temperature ranged between (23°C - 39°C) while the compost pH was (5.12 – 5.85). Peak level of surrounding temperature was (35.7°C) while surrounding relative humidity (53%) in normal condition. Among the highest moisture content was (52.63%) while the lowest discovered in sample D (24.81%) respectively. Results show that with the longer the aeration time, the better physical properties of compost formed. The obtained data will provide evidence on its significances application to the agencies, the public and the industrial player to cope up with this major environmental threat. This study found a significant relationship between physical factors and compost formation which contribute to better analysis, especially to food waste management.

Keywords: *Food Waste; Composting; Physical Properties; Aeration*

1 Introduction

Ecological diversity on earth make balanced system in which organic waste has been produced and recycled at the same time as such some organisms use it as their source of nutrient and energy where with this it can be seen that recycling organic waste act as functional integration towards any ecosystem. The process of natural degradation in organic waste happen with the ability of organisms to recycle organic waste known as composting, as humans utilize the process for their benefits, they started to see the process can be precisely control in order to perform an efficient process that produce high quality compost.

For over the decade, various procedure with preference targets on solid waste management in Malaysia were proposed such as recycling, composting, incineration and others (ordinary dumping) yet low level of accomplishment showed up until today specifically on composting rate is zero to only 1% from the year 2002 to 2006. In the year 2020, the government planned to reduce the landfilling to 50%, by increasing composting to (1) as supported by other study stating biological utilization in degrading organic waste was more proper solution method compared to other treatments such as landfill and incineration in dealing with the organic waste(2).

The two largest problems faced by the composting process are odour and leachate where the both of them often correlate with the deficiency of process management. Nevertheless, an improved process management and control must be implement in which requires more precise knowledge of the process. Recently, major research effort has been done in order to encounter knowledge limitation upon the composting process. For an example, a major finding was found through a start-up in batch composting where the composting process inhibited by low pH in combination with temperatures above 40 °C(3). Although, results from research in a pilot-scale composting are not directly transferable to large-scale processes, but this issue was the starting point for any work reported as will included in this thesis.

In Malaysia, common issue such as scarcity of information where outdated data were used by most researchers and government officials for the estimation of future trends in regards to the solid waste compositions(4) However, the optimization of formula in composting process was convenient in order to perform efficient process as well as high quality of composting other than encountering the slow composting process. Hence, the overall aim of the research is to study physicochemical properties of food waste at the composting process. High frequency of stirring cause more introduction of oxygen towards compost pile significantly provide more resources for bacteria degradation in organic waste which consequently produce better physical quality of compost. The main objective of this study is to utilize the food waste of the solid waste generated in selected residential areas from Kuantan, Pahang, Malaysia to produce organic fertilizer/compost. The specific objectives are as follows to conduct an enhanced composting process for food waste and to determine the physical parameter properties (such as odor, color, texture, pH, temperature, moisture content and mass reduction) of the food waste during the composting process.

2. Literature Review

2.1. Introduction

Wastes are being generated daily from different institutions such as industries, agricultural farm, house and kitchen through their everyday activities where almost majority of the generated wastes will end-up in landfill whether with or without treatment. Among these, food waste was well known for its major contribution in total waste generation. Its management implies the selection and application of suitable techniques, technologies and management to achieve specific objectives such as waste minimization, re-use and recycling. The waste, if not efficiently treated, poses great problem to human health and environment especially given rise to global warming. The affects are follows:

(i) Generation of uncontrollable quantity of food waste by booming of population resulted formidable problems pertaining to proper management and disposal.
(ii) Growing concern about high rate of live expense of waste management due to immense growing budget for landfill management, food waste disposal and their management.
(iii) Conventional disposal of food waste in landfill that develop leakage of toxic leachate into soil and groundwater that expose great risk for humans and environment(5).

Having these understood, it is therefore a great necessity to design a most acceptable, economically sustainable, environmentally friendly and safe technique for ultimate disposal and re-use of food wastes. Thorough research on their waste characterization and qualities based on their physical, chemical, and biological properties in comparison between their sources of generation revenue are indeed crucial to complete the necessity of design treatment.

2.2. Rate of Food Waste Generation

In the 21st century, the development and globalization caused more presence of supermarkets and fast food chains which make the new generation of this developed world very different from their ancestors and even the people of developing nations. The process of urbanization caused also varieties of food waste produced whereby the community could easily access the food source. Not only do we have much better access to food nowadays, but a high provision of wealth where people afford to waste more food. Nearly 1.3 billion tonnes of foods including fresh vegetables, fruits, meat, bakery and dairy products are lost along the food supply chain(6). "Food waste" refers to food that is of good quality and fit for human consumption but that does not get consumed because it is discarded either before or after it spoils(6). The food waste classified into pre-consumer and post-consumer. The amount of FW has been projected to increase in next 25 years due to economic and population growth, mainly in Asian countries. For example, the annual amount of urban FW in Asian countries could rise from 278 to 416 million tonnes from 2005 to 2025(7) and Malaysia specifically contributes 3.36 Million tonnes(8).

2.4. Composting

Composting can be defined as the biological degradation of organic substances by microorganisms(9). It is a natural s as the fugitive emission of GHG(10).

Composting of food and food-related items is one method of waste diversion that individuals can do to make an effective contribution to waste diversion to landfill. Reduction of organic waste that ends up in landfills will reduce the amount of methane and leachate formulation. In addition, composting has the potential to reduce greenhouse gas emissions(11), help to mitigate climate change while reduce the pressure on existing Landfills. The composting process has always occurred in nature.

2.6. Factors That Affect Composting Process

Currently, substantial research efforts have been carried out to evaluate the impacts of various parameters on composting performance and microbial community composition(12). The state-of-the-art environmental assessment of waste management systems has relied on the data for the physicochemical composition of individual material fractions comprising the specific waste(13).

Thus, it is a prerequisite for collection program managers to have detail information about the nature and quantity of solid waste generated in order to set appropriate management systems which in this paper will be focused on composting. The two most significant issues in a compost process, strictly linked, are original matrix physicochemical composition and existing microorganism populations. Performance of composting correlates with proper decision on their controlling parameter whether correspond to physical and chemical properties of organic wastes in order to control in situ processes to be identifiable and reliable for management(14).

2.7. Physical Parameter

Without data for the physicochemical composition of these individual material fractions, the environmental consequences of such management initiatives cannot be systematically estimated and evaluated, and emissions from the waste treatment processes cannot be tracked back to individual waste material fractions(15). This supported by the study which stated that the principal factors that contribute to making an optimum environment for the microbial processes in composting are oxygen, temperature, moisture, Carbon/Nitrogen ratio and pH(16).

Another study had proved that temperature during the composting process is among factors that contribute to ammonia emissions along with C/N ratio of the initial composting mixture, by the temperature reached during the process and by the aeration(17).

2.8. Aeration and Particle Size

Composting is the decomposition of organic wastes in the presence of oxygen (air); products from this process include CO_2, NH_3, water and heat. Commonly, sewage sludge and food waste provide oxygen depletion or moisture loss and nitrogen would slow microbial activity and lead to ‘‘premature’’ pile cooling(18) while excessive application of high aeration rates during composting provide a significant cooling effect towards compost that lead to slower microbial activity(19). Different operational condition also had been studied by authors such as ventilation and turning, to know their relationship in microbial activity(20).

2.9. Hydrogen Ion Level (pH)

Recent studies have proof that emission of odors from values of pH(21) The optimum pH of potting media would be different for different plants, but usually the desirable range was between 5.0 and 6.5(22). This pH range of 5.1 to 6.0 was seen in the optimum range for growing media(23) who stated that the optimal range is from 5.2 to 7.3.

2.10. Moisture Content (MC) and Relative Humidity

MC of the composting mixture is an important factor as it provides a medium for the transport of dissolved nutrients required for the metabolic and physiological activities of microorganisms. Another crucial parameter for composting process is MC of materials because it provides a medium for transport of dissolved nutrients require for metabolic and physiological activities of microorganisms(5).

Early dehydration during composting usually comes from extreme low values of MC where it will stop the biological process, thus giving physically stable but biologically unstable composts(24). Several researchers also reported that optimum MC (55–60 %), C/N ratio (25–30) and pH are the important factors for stabilization(25) and maturation of compost(21). Recent studies have shown that the municipal solid wastes generated in Malaysia contained a high percentage of organics (45-60%) with a MC of about 55% (26).

2.11. Pile Temperature and Ambient Temperature

The compost temperature determines crucial background on the type and boundary of microbial activity established in which microbial biodegradation established through positive feedback mechanism gives impact on the temperature of the compost system itself. Fluctuation of pile temperature had been shown their significances in several studies as their relation with the development of microbial metabolism and biomass were highlighted(27). The pile temperature influenced the microbial metabolism while microbial cleavage of carbon bonds in organic matter was known in generation of heat during composting process. Energy released during these exothermic reactions dissipates heats approximate to 50% whereby the rest being used by the biomass for metabolism and growth(28). Temperature provides an important indicator of composting process efficiency in which it resembles its strong relationship of temperature with decomposition rate(29). In most cases, pile temperature was superior parameter in their strength of influenced towards composting process but other researcher found that temperature, moisture and odor are main monitoring pile factor that ensured the optimum pile decomposition.

3. Methodology/Materials

3.1 Equipment

Equipment and apparatus used in this study are listed in Table 1.

Table 1: List of Equipment

Apparatus and Equipment	Company
Analytical Balance Digital Scale	Perkin Elmer
pH Reader	Mettler Toledo
Universal Drying Oven Stainless Steel	Memmert
Humidity and Temperature chart recorder	Extech Instrument
Mechanical Weighing Scale	Camry
Digital Thermometer	Greisinger

3.2. Introduction

The initial levels of the physical parameters in food waste can be altered in order to create waste mixtures that biodegrade at higher rates. This section examines the ways in which pre-composting process and the measurement of all the parameters were done in order to analyzed their interactions within 3 days of food waste composting. The study is both field based experiment and laboratory based experiment as indicated in Figure 3.1. Three experiments were conducted for achieving the whole objectives of the project from enhanced Pre-Composting Process for food waste which are, (i) observation of changes in color, odor and texture, (ii) investigation of hydrogen ion level (pH values) and pile and surrounding (ambient) temperature in hourly basis, (iii) determination of moisture content and mass of the food waste during and after composting process.

3.3. Model Research Framework

The overall model research framework as shown in Figure 1 was created for this project. The empty bin with labelled 'food waste only' had been sent to Ana Ikan Bakar Petai Restaurant for the step of FW collection. The FW was brought to IRS for composting process. The pre-composting process of this project, the FW firstly was separated from the remaining non-FW. After that, the FW was spread out on canvas under sunlight for 2 hours to dry the excess water within the FW. Then, the FW had been undergone grinding process by using a heavy-duty commercial blender and collected in one large bin. In this project, the composting process had been done as such that the dried FW was being divided into 5 kg in each composting bin whereby the waste had been stirred for 5 minutes within different frequency per hour. The time used to stir the food waste is the aeration time whereby the balanced non-aerated time is the resting time. The resting time was set differently within the sample which are 25, 55 and 115 minutes. The result collected had shown the value of temperature, pH, and MC in hourly basis.

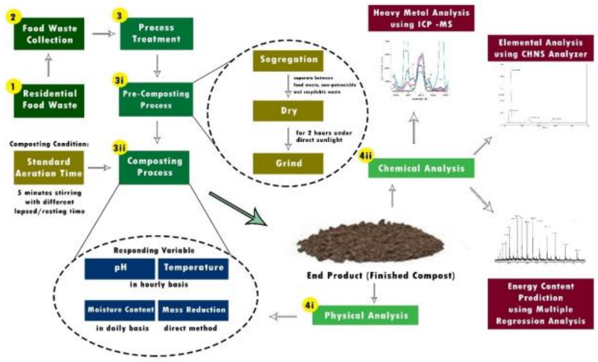

Fig. 1: Model Quick-Composting Research Framework

3.4. Enhanced Composting Process for Food Waste

The design and operation of composting systems to minimize the cost of producing compost remain a major goal where the evaluation of how system design affects: (i) acceptable compost stability and (ii) suitable compost maturity is critical to optimize the process. In particular, this study optimized the composting process in all three stages such as sampling collection (described in section 3.5), pre-composting process (described in section 3.6) and composting process (described in section 3.7). Optimization of sampling collection was accomplished, (i) by its segregation from sources, and (ii) by its primary content of staple food whereby pre-composting and composting process was achieved, by enhancing its natural capability of compost formation.

3.5. Sampling Collection: Feedstock

The sampling project aims in utilizing food waste collection from residential areas. The FW feedstock used in this study was collected from Ana Ikan Bakar Petai Restaurant (Figure 2) situated in 3°47'52.17"N; 103°20'23.441"E Tanjung Lumpur, Kuantan, Pahang, Malaysia.

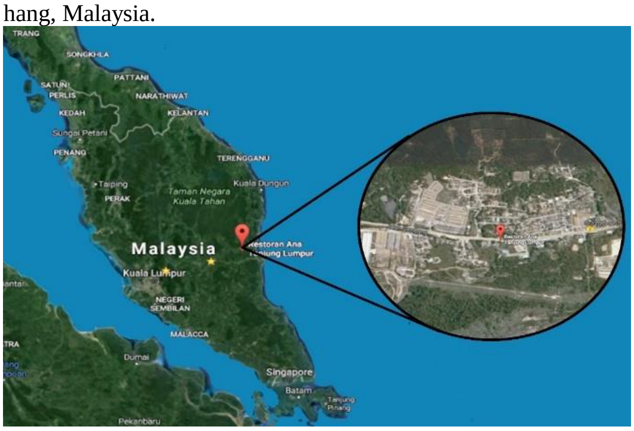

Fig. 2: Location of the sampling sites in Tanjung Lumpur

The samples of FW were taken from the pre-consumer which consist of kitchen waste use for cooking due to overproduction, spoilage, expiration, and trim waste whereby post-consumer FW which consist table scrap food refuse due to behaviors, portion sizes, self-service. Three extra trashcans were put on the collection site with the relevant authority permission and the kitchen staff was asked to support the segregation process between the FW and non-FW.

Three bins were labelled in order to support this first step of segregation of FW. The FW was filled after a night and the filled-trashcan was being placed in IRS for further process. The sample collection site had been chosen for the sampling sources because a large amount of food waste can be collected in one day time compared to another site as well as it contains various kinds of food wastes. The feedstock composition comprises of the main staple food which found in the residential areas such as rice, bones (chickens and fish), vegetables (include peel skin) and other component such as seafood, egg shell and meat are also present in the feedstock.

3.6. Enhanced Composting Process

Part of the pre-composting process was conducted at Kuliyyah of Science and IRS. The process was optimized under three phases such as drying, segregating and grinding. Drying was accomplished, by placing it into a canvas while spreading the FW using a shovel and let it expose under direct sunlight. Segregation of non-putrescible (tissue, paper, wood stick, straw, plastic and wrapper) was done manually by hand from the feedstock. Next, grinding of FW was done using Heavy-Duty Professional Blender where it takes 5 hours for a full ground of FW. This was done to increase the total surface area and porosity of potting media. After finished grinding, the FW that could not be ground such as big size bones will be removed from the overall sample. The mix were prepared, thoroughly mixed manually until a homogeneous mixture was produced. The sample was placed in one container before separating into three containers in order to achieved same saturation between all samples.

The composting bin that had been used for all samples as the container is a container with 400 grams' weight, a height of 24 cm, a width of 44 cm and a length of 58 cm. The controlled parameter of this composting process was aeration time which is 5 minutes whereas the manipulated parameter was the rest duration. With the aim of maintaining aerobic conditions during the process, the pile was turned manually every 5 minutes with different applied resting time into compost pile which are 25, 50, 115 minutes where the sample had been named A_{25}, B_{50}, and C_{115}. which lasted for sixty days. Subsequently, the samples were taken systematically per hour before composting (T_0), after 1 hour of composting (T_1), and at T_2, T_3, T_4, T_5, T_6 until the last hour which is T_{72}. The stirred had been done evenly between all sample within the same timeline using different mixing tools in order to avoid any inaccuracy reading. The data collection has been done in hourly basis for the total of 72 hours. Each parameter had been measured every 1 hour except for MC which is 24 hours. After that, each parameter had been analyzed for further reference. The overall flow of the composting process was shown in Figure 3 consist of several steps which are step 1 already (described in section 3.7), step 2 (described in section 3.8), step 3 (described in section 3.9) and step 4-5 (explained in 3.10-3.12).

Fig. 3: Overall flow of this composting project

3.7. Determination of Physical Properties

The analysis of the composting, with the aim of improved system design, requires consideration of the system parameters. Selection of physical parameter for this project was based on the effect: (i) composting process, and (ii) compost quality. Other authors identified list of parameters to include system layout and sizing parameters up to 36 controllable factors(30). A partial of the significant parameters of the process was done in this study where the test was done, (i) on-site and (ii) in the laboratory. The pH, compost temperature, ambient temperature, relative humidity, MC (%) and mass reduction (%). were measured as the physical properties in this experiment. The details of these procedures used for each parameter are described in section 3.8 until 3.12.

3.8. Hydrogen Ion Level (pH)

The pH readings were measured with pH meter (Mettler Toledo S2210-Kit, Switzerland in hourly basis. This new pH meter has the ISM® (Intelligent Sensor Management) technology where the meter automatically recognizes the sensor and transfers the latest set of calibration data from the sensor chip to the meter. The last five calibrations, as well as the initial calibration certificate, are also stored on the sensor chip. The pH of the sample was determined by a sample/deionized water ratio of 1:5. Therefore, 10 g of sample was diluted in 50 ml of deïonised water (ratio: 1:5). The electrode probe was first placed in calibration buffer and "Cal" button was pressed. Next, the probe was dipped into compost mix in deionized water with 1:5 ratio sample/deionised water for all sample. Then, sample measurement was done by pressing the button "Read" until there is sound from the sensor. The data displayed on the main screen of the pH meter was recorded within the acidic pH range 1-6.99 for further analysis.

3.9. Compost Temperature (°C)

Compost pile temperature depends on how the heat produced by microorganisms is offset by the heat lost through aeration or surface cooling. Compost temperature (°C) recordings were taken per hour by inserting the probe of the digital thermometer (GMH 1150) at a depth of 1 inch's depth inside the pile. Temperatures were recorded after 1 minutes of inserting the thermometer because temperature and pH are excellent composting process indicators. In a raining day, the compost temperature was recorded under the tent that had been set-up in the research station.

3.10. Moisture Content

The MC had been taken for every 24 hours. The estimation MC was measured in the lab using standard oven-drying techniques(31) where it has undergone few procedures were which starts from weighing of the aluminium dish. Next, the dish with FW sample was filled with 50 grams of sample and re-weigh. After that, the FW with the dish was dried by placing in an oven for at least 24 hrs at 105°C. Then, the dish was removed from the oven and allowed to cool in a desiccator. The total weight of dry FW and dish was weighed and recorded. This step continues for the next 2 days of the composting process for each sample.

3.11. Mass Reduction of Compost (Initial and Final reading)

In this study, the weight of the sample was measured using commercial mechanical weighing Scale with the capacity of 50 kg/110 lbs (Camry, CMBP) where the reading scale is 0.1 kg. The pin scale of the weighing balance was adjusted to 0 kg by screwing clockwise on the top nut before any weighing measurement is done. The sample weight was measured for two times which are (i) before running the composting process (initial) where it happens after the pre-composting process and (ii) after the composting process runs completely (final).

3.12. Ambient Temperature and Relative Humidity

Humidity and temperature chart recorder (RH 520A), detachable probe with cable by Extech Instruments had been used to record the surrounding temperature and Relative Humidity (RH) values. The chart recorder was set up and operate where it shows simultaneous numerical and graphical display of humidity and temperature readings, plus time and date. The large graphical LCD screen offers adjustable vertical and horizontal TAC resolution, which enabled monitoring both temperature and humidity within a specified range. The RH520A has a temperature range of -20 degrees to 140 degrees F and a humidity range of 10 to 95 percent relative humidity (RH). The recorder had been set up 50 cm from the ground. The reading had been recorded for hourly basis.

4. Results and Findings

4.1. Scope of Data

Successful composting requires a balance between several key parameters. The greatest cause for failure in composting operations was the odor, due to improper operation. Foul odours can cause issues with neighbours; they are also an indicator of improper treatment. Other composting failures can include failure to deactivate pathogenic microorganisms. By maintaining proper operating parameters, odours are contained and composting success is assured. The characterization of food waste can be categorizes based on their feedstock and region: the feedstock such as animal-derived food waste, general food waste and plant food waste whereby site sources are commercial, residential and agricultural. In this study, the food waste categorizes general residential food waste. Knowledge of waste generation and composition is useful for facilitating the preparation of an effective and economical long-term plan for waste management. Waste generation data and waste composition data will determine the potency of waste for composting. The enhanced composting process was achieved in 3 days which is much quicker than the recent composting process. The compost was form in 3 days' times shown that the physical structure plays crucial role here. When FW is shredded, nutrient accessibility to microbes increases due to increased surface/volume ratio; therefore, degradation accelerates and all the easily biodegradable substrate (OM) is depleted(32).

4.2. Determination of Physical Parameter Properties

The effects of compost on the physical properties of the soil on-station are shown previously in Table 4. After composting, there was significant difference in temperatures, MC, mass reduction but only slight significant differences in compost pH was observed between the different compost treatments. Total data recorded during sampling is 72 data in 3 days. Figure 4 shows the graph of overall compost temperature versus time whereby the graph shows a fluctuating line. The highest compost temperature recorded is 35°C while the lowest is 19°C. pH for compost shows the highest at 5.85 and the lowest at 5.12. For surrounding temperature and RH, the highest is 36.7°C and 92%, while the lowest is 23.6°C and 65%, respective. No statistical analysis was done as the sample was tested once using different set of condition without any duplication. Based on the graph as shown in Figure 4.1, the temperature for composting are slightly higher than the ambient temperature (surrounding temperature). As for relative humidity (%), an increasing value indicated that ambient temperature was decreasing while decreasing value indicated that ambient temperature was increasing. The sample that was aerated after every 25 minutes' rest was labelled as sample A, 55 minutes' rest for sample B and 115 minutes for sample C.

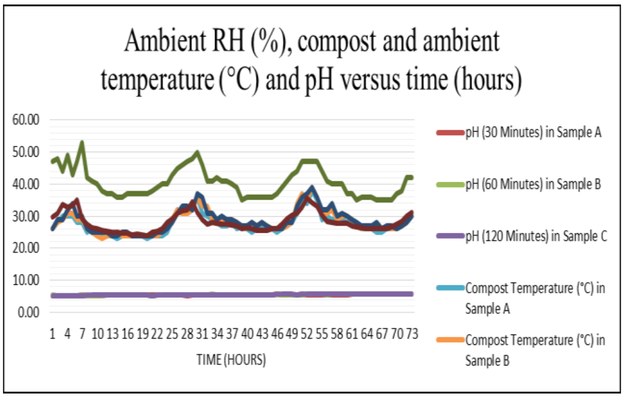

Fig. 4: Graph trend of Ambient RH (%), Compost and Ambient Temperature (°C) and pH presented in overall sample during the 3 days of composting process

4.3. Color, Texture and Odor

The Figure 5 shows the sample after manual separation from non-food waste and size reduction process. Size reduction facilitates handling and reduces bulky items to particles in which sizes that are compatible with the processing equipment. Based on the Figure 5 and 6, there were changes in their (i) colours and texture and (ii) odour and appearances detected during the process of composting treatment. Based on the Figure 5, the colour of the pile resembles dark brown soil and earthy smell can be detected as the composting process was done properly, there were none developed malodors detected nor any rodent infestation and offensive odours were not noted in any of the composting trials. The compost product tended to have the uniform dark crumbly appearance (dark brown to black) with little or non-recognizable pieces/components of used waste such fish bones, soil-like or earthy smell without obnoxious odour or with no distinctive smells to suggest instability. The sample A tended to have dark brown colour with aggregates and moist, B tended to have dark brown colour with aggregates and moist, but with a lighter brown colour than A, C tended to have fewer aggregates than B and C, including with a lighter colour for both B and C. Yet, all sample displayed the same soil-like texture.

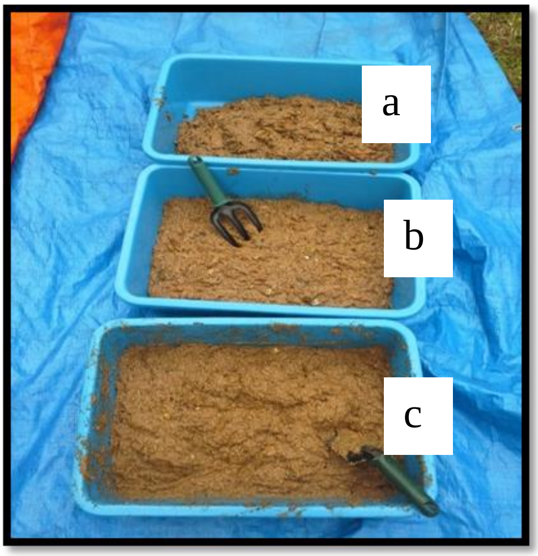

Fig. 5: Colour differences between the sample before composting process recorded as T_0 hours (a-c). starting from left sample A, sample B and sample C

(a)

(b)

(c)

Fig. 6: Colour differences between mature compost that had undergone T_{72} hours composting process (a-c). starting from left sample A, sample B and sample C

The physical properties of compost sample in this study can be considered as mature. As other studies also found that compost with odorless, a fine texture and dark colour is matured compost(33). This study also found that short period formation of compost compared to traditional method was due to the pre-composting process applied during the first period of the study in which the minimization process from grinding caused the large particles into smaller pieces. We understood that particle size enhanced O_2 movement into and within the heap, as well as microbial and enzymatic access to the substrate. Thus, exchange of particle size support fastens the period of the composting process.

4.4. Hydrogen Ion Level (pH)

In overall sample during composting process, the pH gradually increased to a maximum 5.85 for sample C at 69th hours followed to a minimum 5.12 for sample A at the 1st hour. The highest pH value of all compost sample was observed at pH 5.85 and followed by 5.80 which means the compost is a weak acid. The pH level generally covers a fairly narrow range where the pH level drops during the first 6 hours down to 5.1 because of the volatilization of ammoniacal nitrogen and the H^+ release resulting from microbial nitrification process. After that, the pH begins to rise and reached levels as high as 5.85 due to the production of ammonia during ammonification and mineralization of organic nitrogen. In a number of experiments, the pH of the system reduced from 6 or so to 4 or 5 during the initial stage of composting, which is likely due to the production of organic acids. That the decomposition of organic acids was followed by a rapid in-crease of pH caused by the transformation of organic nitrogen into ammonium nitrogen(34). For all sample, the maximum pH value that was observed at 69th hours where sample A, B, C were 5.77, 5.83 and 5.85 (Table 1). The lowest pH values that were observed from sample A at 1st hour 5.12, sample B at 4th hour was 5.19 and sample C in 4th hour was 5.16. Relatively increased trend values of these parameters were recorded to depth nearly neutral values at the end of the composting process (Figure 7). The optimum pH of compost observed was different for different aeration time per hour but usually range 5.1 and 6.0 which was acidic. This pH range is in the optimum range for growing media(23) who stated that the optimal range is from 5.2 to 7.3 as well that stated the desirable range for plant media was between 5.0 and 6.5. These increment towards an alkaline value are attributed to proton consumption during decomposition of volatile fatty acids (abundant in the initial mesophilic phase) and to organic-N mineralization to NH_4-N. Next, Sample B and C was shown fluctuate at higher rates compared to Sample A. The rate of pH value increased as the aeration time during composting process increased.

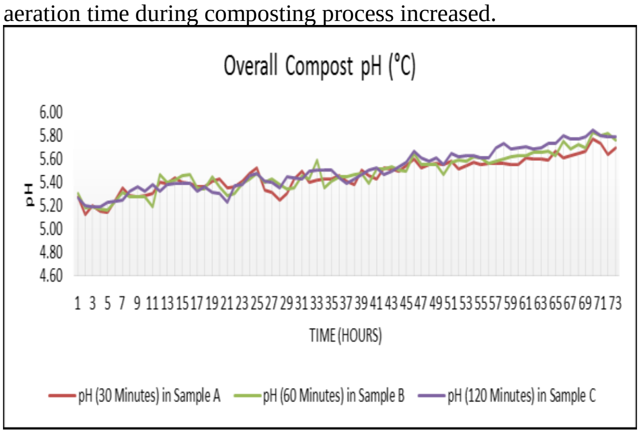

Fig. 7: Variation of pH of compost matrix with time in overall sample

The thermophilic stage during the composting process in this food waste could not be seen referring the traditional composting process as the traditional composting process the thermophilic stage happen when the pH rises up to 9 whereby NH_3 will be release and the maturation stage when pH will drop to neutral. The decline of pH was observed during the first initial process as shown in Figure 4.4 could be explained in bacterial action whereby the bacteria synthesis of organic acids and hydrolysis of acetate groups on hemicelluloses which is the source of acetic acid(35). However, the utilization of acids by microbial community causes the pH rises. Thus, we could see differences between the composting process (a-c) whereby more aeration rates cause faster synthesis of organic acids.

4.5. Temperature Between Ambient and Compost

Almost similar temperature profiles trends were observed in all samples. The temperature gradually increased and reached the first peak level at around 29 – 31 days of composting treatment. After that, it decreased gradually around 15 hours and again increased as the second highest temperature at second peak level at 51 – 53 days of composting treatment. Higher temperatures were recorded for sample C (115 minutes resting time). The optimum temperature of compost observed was different for different aeration time per hour but usually range 25 °C and 32 °C. Next, Sample A was illustrated fluctuate at higher rates compared to Sample B and C. The rate of compost temperature value increased as the aeration time during composting process increased. Hourly compost temperature was recorded in between 23.0 - 36.0 °C while ambient temperature in between 24.1-35.2 °C. Three types of compost temperature had reached its first peak during the six hours, where for Sample A was 30°C, Sample B was 31 °C, whereas for Sample C were 34°C. The second peak had been reached during the 29th hours, where for Sample A and B was 36°C and Sample C was 37 °C. The third peak had reached during 52nd hours, where Sample A was 38°C and Sample B and C was 39°C. The temperatures during composting ranged between (23°C till 38°C), (23°C till 39°C) and (24°C till 39°C) for A, B and C mixtures respectively and as seen in Figure 4.3.2.8, temperature mostly stayed below ambient temperature within below 40°C in all the experiments from the 3 corresponding days as shown in Figure 8. There were slight increases in pile temperatures until it reached peak temperature immediately after temperature drop for A at hour 22-29 from (24°C to 36°C) and hour 46-52 from (26°C to 38°C), for B at hour 21-29 from (24°C to 36°C) and hour 46-52 from (26 °C to 52°C), for C during hour 20-29 from (24°C to 37°C) and hour 46-52 from (26°C to 39 °C). The temperature of treatments with lower aeration rate rose more slowly. This difference is because the lowest AR leads to a lower organic degradation rate and lower losses of moisture and heat. Then, the pile temperature appeared reached lower than the ambient level at three-points which are first 24 hours of composting process, at 46 into 49 hours and after 70 hours and between the duration stated the pile temperature decreased gradually to the ambient level. Although MC is not in optimum range but it still supports the biodegradation. Thus, during the first 3 to 5 hours of microbial activity, small quantities of heat energy are released and the rate of temperature rise is accordingly slow increases during this temperature processes. The pile temperature had reached 38 °C as it highest but several authors study that the minimum pile temperature requirement for a proper disinfection of waste materials from animal and plant pathogens is 55 °C(36).

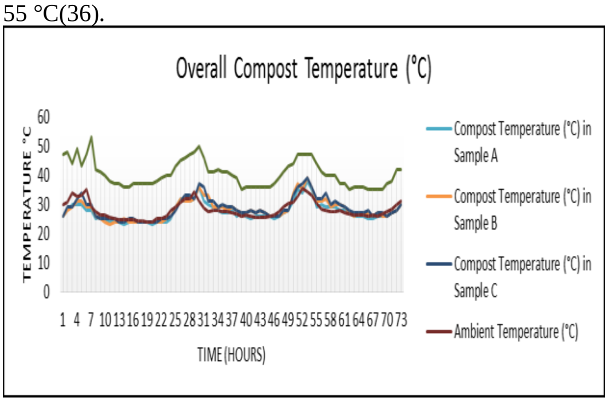

Fig. 8: Variation of overall Temperature of compost matrix with time

Thus, we considered the disinfection of waste materials are weak and the compost formation is may probably of exposed towards pathogens. Though, the short period maintain thermophilic condition was may be due to the less volume of waste and high surface area for heat loss in small systems as this was agreed(37). Furthermore, the result shown that it had undergone mesophilic bacteria was active during the composting process(38) where it is known to be effective for breakdown of biomaterial and the rise of temperature higher than ambient temperature shows that bacteria work on oxidizable materials in the mixture of compost(39). However, we could saw that there are differences between the compost pile temperature and ambient temperature that this explains that the aerobic process happens. The process of aerobic degradation on organic wastes happen where heat is released in the oxygen-consuming microbial metabolism, resulting in an increase in temperature.

Moreover, the composting materials had not gone through the three typical degradation phases: mesophilic, thermophilic and curing when referring to Chinese national standard (GB 7989-87) as the thermophilic phase standard set by the standard has more than 50 °C. This is because there are differences in duration of composting process in which their method was that all treatments were left intermittent with 25 minutes of aeration time followed by 5 minutes without aeration over the whole composting period. The compost piles were turned on days 3, 7, 15 and 24. However, there are still discussion on temperature as the main of the indicator towards stabilization and maturation of composting process.

4.6. Moisture Content

The MC increased with increasing period of aeration per hour (Figure 9). For MC, result in Table 4.3 shows that every 24 hours, the highest percentage of MC recorded is the initial MC which is 53.63°C while the lowest is 4.35°C in sample A. The starting MC is 53.63 where single data was collected due to their same sources as first. The data signifies their differences in MC of the standard food waste which range between 75-85%. The percentage of MC is decreased. For the first day of sampling day, compost from Sample A and C contained 0.41% more MC compared to Sample C but 1.47% less compared to Sample B, where the 2nd day was 2.59% less MC from Sample C but 2.9% less compared to sample B and 3rd day was 0.53% more MC from Sample C but 4.09% less compared to sample B. This indicated that aeration plays an important role to lower the percentage of MC in shorter time. The longer rotation time; lower the MC of the compost. Therefore, the addition of aeration of time per hour of composting process created an increased in the MC in one-hour limit which is the MC increased 4% compared aeration time for every 25 minutes (sample A) and every 55 minutes (sample C).

Increase rate of MC in compost depends on the aeration time of composting process in the limit of one hour. As the composting process goes on, the MC reached lower than optimal range (45-50%) for bacterial and fungal species activity(40) starting the 2nd days of composting process for all samples. Thus, there was decreased in bacterial and fungal species activity in all samples after 2nd days whereby the samples that applied with higher aeration time (sample A) shown has lesser bacterial and fungal species in context of MC but surely that there are many other factors affecting bacterial and fungal species activity as the result of color for sample A shown the best quality.

Furthermore, this will provide a thin layer of moisture around the organic material, while still allowing free air movement. Water is produced during the compost process by the micro-organisms and is lost by evaporation. The least final MC observed in sample C was expected due to evaporation process. In the tropics, temperatures are high and compost can quickly dry out. Therefore, farmers need to ensure an adequate MC content at all times by wetting the mixture initially and if necessary during the process(41). The optimum MC for the compost process is 50 to 60% as water will interfere with O_2 accessibility, slowing the rate of composting. Inadequate amounts of water will hinder diffusion of soluble molecules and microbial activity(42-44).

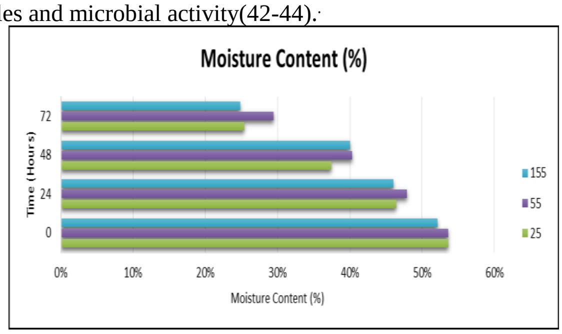

Fig. 9: Graph of Moisture Content (%) versus Time in Sample (in hour)

The result also gives significant fact that there is a reduction of water content within the waste where the problems of recent management relate towards the formation of leachate in waste. Thus, composting process showed that the process has the potential to reduce the amount of leachate produces.

4.7. Mass reduction of the food waste

For mass reduction, result in Figure 10 shows that the percentage of sample mass is decreased between sample A until sample C. Compost from Sample A contained 0.8g less total wet mass and 16% more total mass reduction compared to Sample D where it is 0.7 g less total wet mass and 14% more from Sample B and 0.3g less than total wet mass and 6% more from Sample C. Sample D had the lowest total mass reduction of approximately 22.6% because of the low level of microbial activity obtained during the active composting phase, as indicated by the low temperature regimes. This indicated that aeration plays an important role to higher the percentage of mass reduction in degrading more compost. The longer rotation time; higher the mass reduction of the compost. Another indication is that the permeability (hydraulic conductivity) of compacted solid waste depend on pore size distribution, surface area and porosity. Thus, decreasing mass reduction signifies a decrease in surface area. Hence, this important physical property shows that smaller surface area causes easier process of governing the movement of liquids and gases in a landfill. Therefore, the addition of aeration of time per hour of composting process created an increase in the mass reduction which is the total mass reduction increased 16% compared aeration time for every 15 minutes and every 120 minutes. Increase rate of mass reduction in compost depends on the aeration time of the composting process.

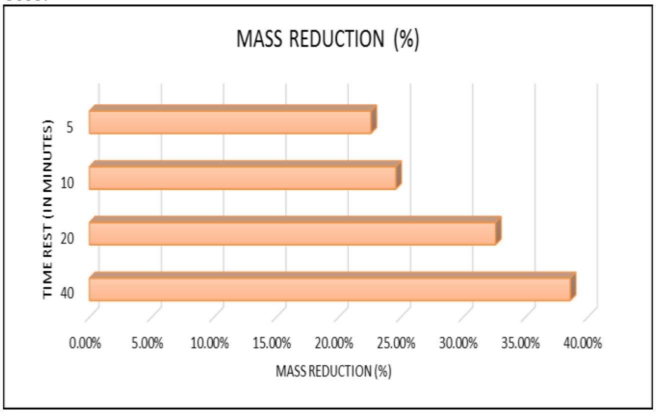

Fig. 10: Mass Reduction versus Resting Time in overall sample

Moreover, the result also present important facts that composting process could reduce the amount of waste which correlates with the usage of land. As the composting process could reduce the amount of waste, the landfill will need lesser utilization of space for disposal.

5. Conclusion

In this study, the physicochemical parameters were monitored over a 3-day period where different set of aeration time within the duration of 2 hours of the composting process was applied towards food waste in order to evaluate their effect and interactions upon the physical and chemical properties during the composting process. Different aeration times were found to have significant impact to physical and chemical properties during the composting process except on the generation of energy where the aeration time was seen to have an intermediate effect. Furthermore, pH and temperature during food waste composting had reached the ranged of the agricultural a strong significant potential on the waste reduction in waste management while MC had a significant reduction in which this solves the problem of leakage from leachate formation. As AT was involved in all associations with O_2 uptake and interactions with physicochemical parameters, indicating its broad and connected role in food waste biodegradation. Moreover, strong correlations were found between different AT application which related with different stages of O_2 uptake over the 3-day treatment. The temperature was not seen to achieve the strong thermophilic level while pH achieved the standard appropriate level for soil amendment. After that, regression analysis produces predictive models for energy content as a potential biomass for energy generation. The models illustrate the importance of establishing optimum physical parameters in an inclusive manner.

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