Effect of Passive Aeration on Conventional Composting of UTP Organic Wastes for Value-added Products

by

Stephen Liew Chee Seng

14921

Dissertation submitted in partial fulfillment of
of the requirements for the
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(Chemical)

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CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr Rashid Shamsuddin)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

STEPHEN LIEW CHEE SENG

ABSTRACT

Composting is a method of converting organic waste into value-added products. The outcomes are usually nutritious fertilizers and this method has been practiced for decades especially by farmers. Universiti Teknologi PETRONAS (UTP) is generating wastes at a high volume daily. There is a significant potential of carrying composting for UTP's waste to reduce operation cost in handling of waste and gardening works. The study aims to take a scientific approach to investigate the parameters that will affect the composting activity. While it is shown that passive aeration might be able to help speed up the rate of composting, further study needs to be done to establish the fact. Literature review shows that composting is expected to complete in the period of about 60 days. Temperature and pH profile indicates composting in this study took 65 days to complete, 5 days longer than expectation. Average mass yield percentage was recorded at 20% for the recipe of applying carbon to nitrogen ratio of 25. Organic carbon content analysis shows that the compost possesses carbon weigh percent in the range of 1.4% to 2.5%. Meanwhile test results have shown that nitrogen content in the final product is in the range of 1.1% to 2.8% weight percent. Both the carbon and nitrogen properties are comparable to that of the commercial compost studied in this research. The comparison suggests that the quality of the compost generated using UTP organic wastes is as good as commercially available compost. Feasibility studies determined that there is a potential of up to RM3,300 of saving per month if UTP recycles organic wastes collected in campus into compost. The reduction of cost in terms of transportation and purchase of fertilizers outweighs the additional labor cost to handle the composting project. There is also generation of excess compost monthly that could be considered for commercialization to generate additional revenue. This study provides the basis for further study into framing a sustainable business model for the composting project in UTP.

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The preparation of this interim report, “Effect of Passive Aeration on Conventional Composting of UTP Organic Wastes for Value-added Products”, would not have been possible without the valuable contribution and assistance of Chemical Engineering Department of Universiti Teknologi PETRONAS (UTP) Malaysia, Labs and Facilities Technical Assistants, Postgraduates of Civil Wastewater Department and Chemical Engineering Final Year undergraduates.

I would like to express my deepest gratitude and appreciation to my Final Year Project supervisor, Dr Rashid Shamsuddin for his continuous guidance throughout the preliminary research work on developing a strong foundation of knowledge in the field of composting. Dr Rashid’s advice and comments on the work has also been embedded in the report. I wish to acknowledge the effort of Final Year Project Coordinators for Chemical Engineering Department, Dr Sintayehu Mekuria Hailegiorgis and Dr Asna binti Mohd Zain, for their initiatives in coordinating every stages of the project. I would also like to take this opportunity to express thankfulness to Mr Fazli Zainal and Mr Khairul Anuar for the assistance in handling laboratories equipment. My heartfelt thank you also goes out to Mr Azizi Wahab of Property Management & Maintenance and Mr Wan Tarmizi of Residential College for providing critical information on the feasibility study of composting project in UTP.

Personally, I would hope that this report will provide a clear insight into the future work that needs to be carried out. The knowledge gained and methods devised will be applied to ensure the success of the study. I am grateful for the opportunity to carry out this meaningful research work with UTP and given a chance to transform people’s perspective toward what has traditionally been considered as waste.

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CHAPTER 1. INTRODUCTION

1.1 Background

Composting is the natural way of recycling organic wastes. The product of composting, known as compost, is decayed organic matters that can be rich in nutrients. Imbeah (1998) stated that “For many centuries, composting has been used as a way of recycling organic matter back into the soil to improve soil structure and fertility”. Conventional farming has utilized compost as one of the main fertilizers. Composting has been a popular practice due to minimal cost and effort involved while being able to reap maximum benefits as composts are good conditioner for soil.

The fundamental of the process is to pile the waste together in a heap and wait for it to break down over a period of time. In modern time, various methodologies have been experimented to increase the efficiency of composting. Besides reducing composting time which could take up years, new methods have also been proven to be able to increase the yield of compost. Composting is now being practiced on an industrial scale (Deng et al., 2004). Fan et al. (2001) has proven through their cost analysis studies that the future of composting looks promising since the cost of production is low. It is such that multi steps process with close monitoring on the scientific parameters of composting is continuously being investigated. There are also studies on methods utilizing organisms such as the fly larvae method and vermicompost method using worms. Domínguez et al. (2008) mentioned that earthworms are able to achieve a higher extent of degrading activities when compared to conventional composting.

Furthermore, another added benefit of composting is the effective way of handling waste. Conventional waste handling systems requires large area of land which will limit handling capacity. Fan et al. (2001) mentioned in their report that small and medium scale municipal waste treatment plant running on composting systems helps reduce usage of landfill meant for waste.

1.2 Problem Statement

Universiti Teknologi PETRONAS (UTP) campus which currently sits on 400 hectares of land has an enrollment number of about 7000 students. There are currently 8 fully operating food courts in the campus. Given such set up, UTP is bound to produce large amount of organic waste in forms of food scraps, paper wastes, leaves, and grass clippings daily. Currently, the method of handling such waste is to dispose it off campus. Wastes are gathered daily before being picked up by assigned contractors to be transported to landfills. Such operation incurs extra cost and manpower. Looking from another perspective, these organics are potentially precursors for value-added products such as nutrient fertilizers. While it reduces the cost and effort of disposing the waste, the process also minimizes the need to purchase retail fertilizers.

1.3 Objective and Scope of Study

This study on composting of UTP organic waste aims to:

1) Study the process of composting through scientific methods of evaluation which include investigating the pre-determinant parameters of the process such as temperature, and pH as well as assessing the quality of the product by its organic content.

2) Study the effect of passive aeration on composting activity.

3) Look into the feasibility of introducing a green-cycle method of handling UTP's daily organic wastes in the form of composting.

Extra emphasis needs to be placed on the composting time, costs and manpower needed throughout the whole process. Composting on a campus scale has to prove to be more practical and beneficial than current method of handling waste to be considered feasible. Literature review will be conducted to help build the framework of the study. Besides, the logistical aspect of composting, the scope of study extends to the scientific background of the process.

The four main components of successful compost are carbon, nitrogen, oxygen and water. These will be monitored closely. Data collection of organic matter content, pH values, and temperature will be done periodically. In order to further prove the nutrient content of the composts, leachate from the composts will be used to study the effect on seedling growths of chili plants. One of the main criteria to judge the outcome of the process is to measure the mass percentage of composting to determine the product yield. Time period taken for compost to fully degrade is another major consideration. Analysis will also be conducted on the temperature plot of compost to determine the degree of degrading activity. Four composts will be prepared with varying parameters in terms of aeration as this study will attempt to investigate the effect of aeration on the magnitude of degradation.

CHAPTER 2. LITERATURE REVIEW

Composting can be as simple as piling up waste or it can be studied scientifically to improve the process. Studies have consistently been carried out to speed up the maturation of compost. Li et al. (1996) stated that mature compost improves soil properties for better crop production while Fang et al. (1999) affirmed the fact that application of immature compost may retard plant growth. These studies show the importance of scientific analysis on the process of composting. Additional considerations on factors such as compost content and operating parameters are needed in order to produce high quality composts.

According to Epstein (1997); temperature, aeration, moisture and nutrients are the variables that need proper controlling in order to achieve compost maturity. Indeed, good compost should have carbon, nitrogen, oxygen and water components. Some studies have shown the importance in controlling the carbon to nitrogen ratio. As Huang et al. (2004) adequately puts it, "Co-composting of pig manure with sawdust at an initial C/N of 30 resulted in the compost reaching maturity after 49 days of composting." In the same report, Huang et al. (2004) proved the importance of the ratio as they claimed, "… at low initial C/N can reduce the amount of sawdust used, but it would require a composting period of more than 63 days." However, Zhu (2007) proposed that lower carbon to nitrogen ratio has higher economic advantages for the composting of swine manure. Carbon to nitrogen ratio should be kept close to the value of 30 as it has been proven to be able to produce good maturity period compost.

As for moisture content, Deng et al. (2004) suggested the range of 45-60% moisture throughout composting period. Cayuela et al. (2008) has also supported the notion by mentioning that water is constantly being added to maintain the compost's moisture level at 40-60%. Considering that this study will be conducted in high humidity climate, keeping the moisture level at about 50% would be sufficient. Looking onto an extreme low case, Bueno et al. (2008) concluded that 40% moisture content is suitable to produce compost with satisfying chemical properties.

Nutrients of compost are highly attributable to the content of nitrogen. It indicates the presence of nitrate, the major component of fertilizer. Therefore, composting environment needs to be conducive to retain nitrogen content. Bernal et al. (2001) confirmed through their report that pH and temperature are the main factors determining the loss of nitrogen through the volatilization of ammonia. Highest intensity of ammonia release takes place during the active decomposition of organic matters (Fukumoto et al., 2004). Jeong and Kim (2001), deduced a new method of conserving nitrogen, "It was demonstrated that struvite crystals could be formed in aerobic composting, when sufficient Mg and P were added. This crystallization process resulted in a substantial reduction of ammonia loss." Bueno et al. (2008) conducted their experiments and found that pH value of compost in the range of 7-8 is optimum for nitrogen conservation.

Oxygen is another principal factor affecting composting as it is required for anaerobic activities. Tam and Tiquia (1998) showed through their studies that forced aeration produces compost as efficiently as compost that is turned periodically. This shows that composting can be done with pre-installed aeration mode. Hence, manual or power supported effort to turn the pile during composting can be ignored. Deng et al. (2004) added on, "The forced aeration system is the most effective mode to provide oxygen for the pile because of its characteristic of easy-to-operate. A passive aeration mode was suitable for a small scale swine farm; however, a forced aeration mode should be considered to apply in a middle and large scale swine farm for its high extent of industrialization." These points are worth taking note as this study aims to reduce manpower and energy consumption during composting.

In evaluating the optimum mixture ratio, Külcü and Yaldiz (2014) analyzed the change in temperature, organic content, dry materials contents and carbon dioxide values. Measurement of temperature has been established as a suitable yardstick to estimate the level of anaerobic activity taking place in the compost. During the decomposition phase, microorganisms release heat and energy by breaking down organic materials. Therefore it contributes to the rise of temperature in the compost. Külcü and Yaldiz (2014) also aptly mentioned, "The depletion of the oxygen within the pile by microorganisms leads to the formation of anaerobic conditions, which, in turn, will decrease the decomposition rate, lower the temperature and contribute to the formation odor.” With that said, temperature profile of compost is a good representation of the maturity process throughout the composting period.

Besides temperature, there were also attempts to apply other parameters as a measurement of the level of activity in the compost. Castaldi et al. (2008) concluded in their studies that evolution of enzymatic activities along with water soluble fractions have indicated to be a suitable criterion to judge the state of organic matter. Enzymatic activities have been proven to be at maximum during the initial phase of composting. This coincides with the temperature profile established by other researchers which proved that rampant decomposition activities take place during that period. Bhattacharyya et al. (2008) have further supported these findings by stating, “It is evidenced from the results that the degradation of labile substrates contained in organic materials was quick in case of rapid composting than normal composting. This was apparent through the studies on microbial dynamics and enzyme activities.” While this could be a parameter to analyze the extent of composting activity at the microorganism level, it requires a more biological approach to examine the samples. Hence, plotting temperature profile serves as a more suitable mean.

In some efforts, the organic content of the compost pile is being measured from time to time to determine the degree of degradation. Discrepancies between initial and final organic content shows how much of decomposition has taken place. Külcü and Yaldiz (2014) applied the method of placing sample into oven to dry at 105°C until it reaches constant weight before burning the same sample at 550°C for 4 hours. Mass after the final drying will be used to determine the moisture content while the mass of remaining sample with ashes after burning can be calculated to obtain the organic content figure. Meanwhile, Zhu (2007) practiced another similar approach by drying the sample at 105°C for 24 hours to determine the moisture content before burning it at 550°C for 8 hours. While the approach is the same, the parameters used in both experiments differ.

CHAPTER 3. METHODOLOGY

3.1 Experimental Set Up

Composting activity will be conducted in the Environment Research Laboratory of Civil Department in UTP Campus located opposite Village 2. The four composts will be prepared in four different containers of same sizes. Containers will eventually be stacked above each other for housekeeping purposes. In between each container will be another layer of retainer to collect the leachate. Holes will be drilled on the corners of the containers to allow leachate accumulation in the retainer. Two of the four containers will be fitted with pre-drilled PVC pipes penetrating the inner part of compost to allow passive aeration. These containers will be placed in the backyard compound of the laboratory to allow easy access to water. Refer to **Figure 1, Figure 2,** and **Figure 3** for compost bin set up.

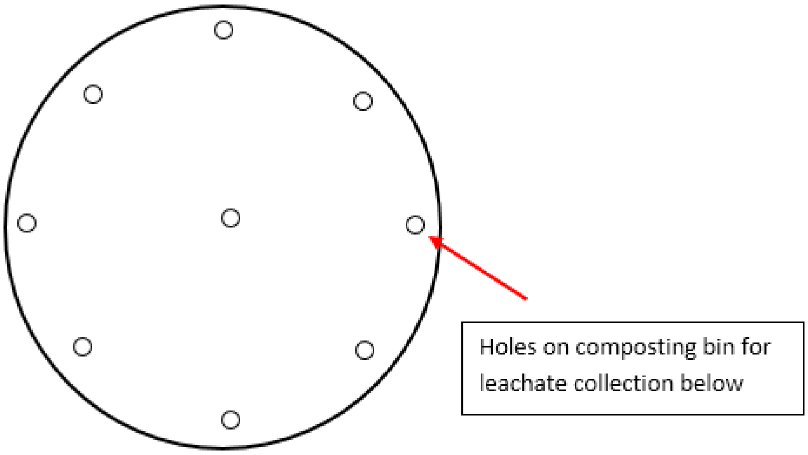

Figure 1: A Single Unit Composting Bin.

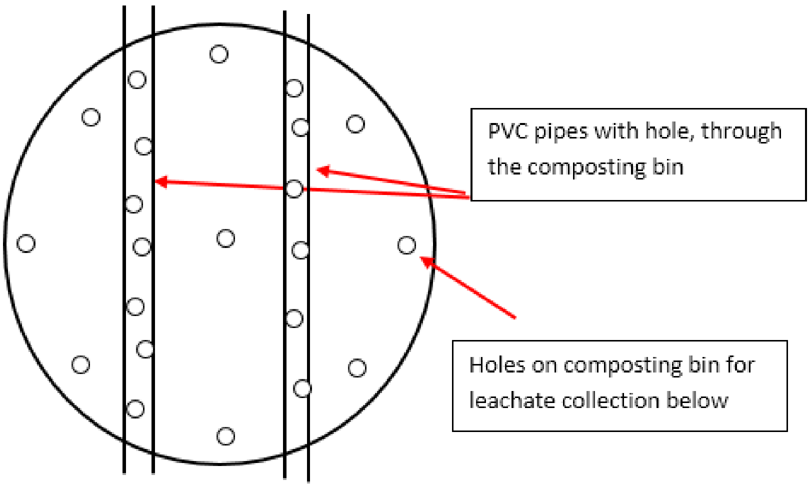

Figure 2: A Single Unit Composting Bin with PVC Pipes.

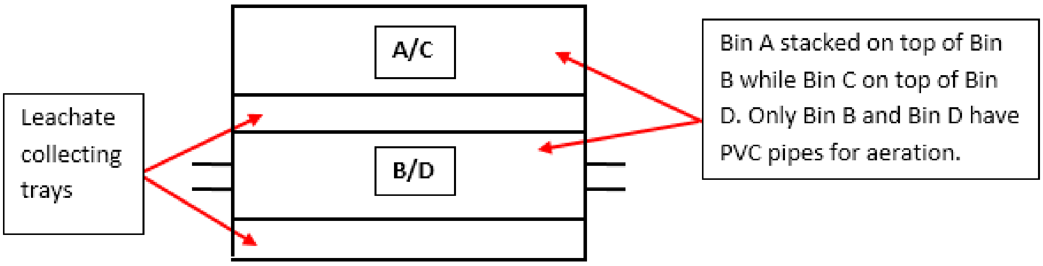

Figure 3: Front View of Composting Bin Stacks.

List of laboratory equipment and raw materials needed is as listed in **Table 1.**

Table 1: Equipment and Raw Materials Required

Equipments	Raw Material
Composting bins	Fruit waste
Aerated PVC pipes	Food waste (garbage)
Leachate collection trays	Grass clippings
Balance	Leaves
Furnace oven	Paper waste
Portable pH and temperature probe	Initial compost material (to provide bacteria)
Glassware	Water

Camera

Initial organic waste composition will be made up of food scraps, paper wastes, leaves and grass clippings collected in UTP. Each preparation will weigh up to 10 kilograms. The amount of each component will be determined based on its carbon to nitrogen ratio. In order to achieve adequate temperature for optimum composting, compost will be prepared according to 25:1 carbon to nitrogen ratio. **Table 2** shows the typical range of the ratio in waste according to On-Farm Composting Handbook, Cornell Composting (1996).

Table 2: Typical Range of C:N Ratio.

Material	Carbon : Nitrogen ratio
Fruit waste	25
Food waste (Garbage)	15
Grass clippings	20
Leaves	50
Paper Waste	128

In order to achieve particle size reduction to speed up the process, final mixture will be blended. At the same time, water will be added into the compost to maintain moisture content of 50% for aerobic activities to take place. In order to achieve that level of moisture, the amount of water to be added into the compost should be half the initial mass of the compost.

3.2 Consumables

Firstly, the mass to be used for each raw materials need to be determined. Carbon to nitrogen content of the initial compost has been set to 25. Mass of each material has to be balanced accordingly in the recipe in order to achieve that ratio. From the recipe, the study would know the set amount of preparation for the same recipe to achieve a minimum initial compost weight of 40kg. This is important as the parameter set is to have a 10kg per initial compost and this study comprises of 4 setups. The following recipe listed in **Table 3** has been formulated according to the carbon to nitrogen ratio value obtained through literature.

Table 3: Recipe for the Initial Compost.

Material	Carbon : Nitrogen ratio	Mass (kg)
Fruit waste	25	5.25
Food waste (Garbage)	15	4
Grass clippings	20	0.2
Leaves	50	0.2
Paper waste	128	0.35
	TOTAL	**10**

Validity of this recipe can be proven through the following calculation:

$$\frac{Sum\ of\ [(Material\ Mass)\ x\ (C\!:\!N\ Ratio)]}{Total\ mass} = C\!:\!N\ Ratio \qquad \textbf{(1)}$$

$$\frac{(5.25)(25)+(4)(15)+(0.2)(20)+(0.2)(50)+(0.35)(128)}{(5.25+4+0.2+0.2+0.35)} = \mathbf{25}$$

Sources of raw materials have been identified. Food and fruit wastes will be obtained from Village 5 and Village 3 cafeteria operators in Universiti Teknologi PETRONAS. In the event of lack of food waste, additional waste can be collected from other operating cafes such as those in Village 4, Village 2 and Village 1. As for leaves and grass clippings, these can be obtained from the third party operators who are contracted to perform landscaping work in the university. Paper waste will be collected from academic blocks of Block 4 and Block 5. Water is easily accessible in the Environmental Research Lab where the practical work will be based at. In order to enhance composting, bacterial starter will be applied by introducing a ready-made compost in the market into the initial compost mixture.

These can be obtained from the nurseries in the nearby town, Bandar Seri Iskandar.

3.3 Compost Preparation

Compost preparation began with the collection of waste one week before the first day of composting. Organic wastes collected include fruits, food waste, leaves, grass clippings and shredded paper. Matured compost which will provide the initial bacteria for composting activity was purchased from a nursery in Ipoh, Cheah Sung Enterprise. The composting bin was also prepared a day earlier. The following figures show sample of wastes and the composting bins to be used in this study. **Figure 4** to **Figure 9** shows the ingredients of the compost. Meanwhile, **Figure 10** shows the build of composting bin with 2 PVC pipes inserted through the middle which is supposed to provide passive aeration.

Figure 4: Fruit Wastes.

Figure 5: Food Wastes.

Figure 6: Dry leaves.

Figure 7: Grass Clippings.

Figure 8: Shredded Paper.

Figure 9: Mature and Processed Compost.

Figure 10: Top View of the Finished Composting Bin.

Composting was done on the 16th of January 2015 and will this date will be marked as Day 1. Wastes collected were blended and mixed together. Each composting bin was then filled with compost according to the pre-set composition. The set up was placed at the back of UTP's Environment Research Laboratory to avoid creating discomfort in the laboratory as compost releases unpleasant odor. The following figures show the ready compost and the set up.

Figure 11: Blended and Mixed Compost.

Figure 12: Set Up of Composting Bins.

Figure 11 shows the condition of the ingredients after being blended and mixed together while **Figure 12** shows the final set up of the composting bins with compost placed in them. Each bin is labelled as A, B, C and D respectively. A separating board is placed on top of the bin before the stacking of the next bin to prevent compost from getting in contact. The manipulated variable among all 4 bins is the method of aeration. **Table 4** shows the different configuration for each bin. Passive aeration is provided by the PVC pipes passing through the middle of the bins.

Table 4: Method of Aeration for Each Composting Bin.

Compost	Manual Turning	Passive Aeration
A	Yes	No
B	Yes	Yes
C	No	No
D	No	Yes

3.4 Collection of Data

Mass of each composting bin will be recorded before the preparation of compost. This is to account for the weight of bin during the measuring of mass of total compost throughout the process. During composting, measurement of mass will be taken once a week for all compost to keep track of the loss in mass. Temperature and pH values of the compost will be recorded once a week on a constant basis. Small samples will be collected from the compost to be tested before being placed back into the pile. Value of pH is to be maintained in the range of 6-8. Temperature and pH values will be plotted on graph to produce the temperature profile for analysis purposes at the end of composting. In order to obtain representative data of the compost as a whole, the probe will be placed in 6 different spots spread across the compost, for an average value of temperature and pH.

For any properties determination such as moisture content, sample will be collected from 6 different points in the compost to obtain an average value. The mass of the compost will be measured before being placed in the oven. Oven will operate at 105°C for 3 hours. Water content is removed by the end of heating. In order to validate the parameters used are enough to completely dry the sample, drying hours will be varied at the initial stage. During the first sample collection, drying will be done at 1, 3 and 5 hours to compare the efficiency of drying. Once the optimum drying time is established, it will be applied throughout the study. Final mass needs to be measured and compared with initial mass to determine the moisture content according to the following formula:

$$Moisture\ content = \frac{Mass_{\ sample} - Mass_{\ dried}}{Mass_{\ sample}}\ x\ 100\% \qquad \textbf{(2)}$$

Moisture content is to be maintained at 50%. As for organic matter content, the study is only interested in the initial and final value throughout the composting process. Samples for organic content will only be taken twice, during the preparation and end stages of composting. Total Organic Carbon (TOC) test method will be applied to analyze the organic carbon content in the sample. Samples mixed with nitric acid will be burned at 200°C for an hour to completely digest the solid sample into liquid form. The liquid sample will then be placed into the TOC equipment for pyrolysis process in determining the amount of total carbon and amount of ionic carbon. Nitrate content at the end of composting will also be determined using the Kjeldahl method (TKN). Sample collected will be heated with sulfuric acid. Potassium sulfate will be added once the organic sample has decomposed. The solution formed will be distilled with small amount of sodium hydroxide before undergoing back titration.

Physical observation of compost will be captured weekly with the aid of a camera. Concurrently, leachate collected from compost will be used to water chili seedlings. The effectiveness of leachate produced will be examined on the growth of chili seedlings in later part of the study. Physical observation of the chili seedlings growth will also be recorded.

3.5 Analysis of Data

Data collected over the composting period will be analyzed after the completion of composting. These analysis methods will determine the characteristics of the compost. Through these, the study will be able to investigate the success of the composting experiment carried out. Comparing the results of 4 composts will also show the effect of passive aeration on composting activity.

3.5.1 Temperature and pH Profiling

Temperature and pH data will be collected with a handheld portable solid probe. Temperature data collected will be plotted on the graph with temperature of compost versus time. From the graph, the study will be able to determine the peak period of composting activity within all compost. Maturation time of compost can be determined using the temperature profile as at the end of the process, the temperature reading should plot a flat line considering there is no longer any decomposing activity. The rate of change in temperature shows the speed of organic degradation. Calculating the area under the graph will also provide a representation of activity level throughout the composting period. **Figure 13** shows a sample of temperature profiling done by Külcü and Yaldiz (2014). This study is expected to produce similar profile trend.

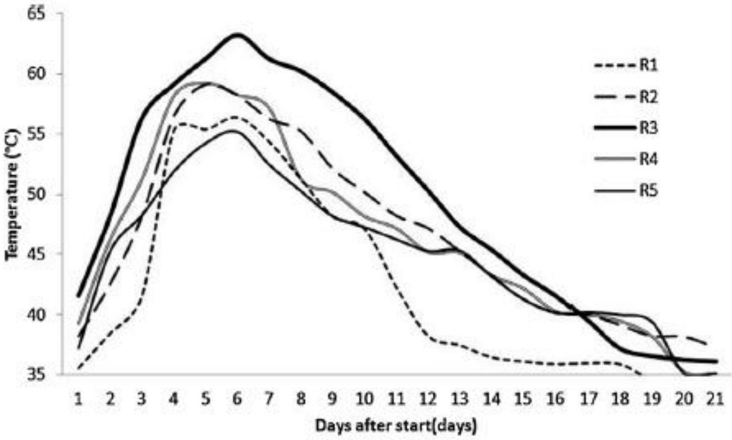

Figure 13: Temperature Profiling by Külcü and Yaldiz (2014).

Profiling of pH values also indicate level of activity in the compost. As compost tend to self-regulate and maintain a pH of about 7 for healthy microorganism activities, any breach in the pH of 6-8 might represent the reduction in degradation activity. Such condition inhibits further composting and needs to be rectified once noticed.

3.5.2 Mass Balance

Mass of the compost will be determined using the mass balance available in laboratory. Final and initial mass of the compost will be compared to determine the overall yield of it. Besides the speed, the yield in mass is also important as an evaluation factor. Mass yield can be calculated as follows:

$$Mass\ Yield\ (\%) = \frac{Mass_{final}}{Mass_{\ initial}}\ x\ 100\% \tag{3}$$

$$Average\ Yield\ (\%) = \frac{Sum\ of\ Mass\ Yield\ Percentage}{4} \tag{4}$$

3.5.3 Organic Content

Besides considering the speed and yield of the compost, another important consideration of good compost is the final organic content. This is the main nutrient measures in fertilizers that reflect product quality. After undergoing digestion in nitric acid and the pyrolysis process, organic matter in sample can be determined by the following formula:

$$Organic\ Carbon\ = Total\ Carbon -\ Ionic\ Carbon \tag{5}$$

Determination of organic matter will only be conducted twice, at the beginning and at the completion of composting. The value obtained in terms of part per million will be converted into weigh percent of the total sample.

3.5.4 Nitrogen Content

Nitrogen content is another important nutrient measures for compost to determine its quality level. In this study, the method used to study the nitrogen content is Total Kjeldahl Nitrogen (TKN). Solid compost sample will first be diluted into liquid with potassium sulfate and sodium hydroxide solution. The liquid mixture will be analyzed using the TKN equipment.

3.5.5 Physical Observation

While physical observation should not be considered the absolute measurement of compost maturity, it is a qualitative method of assessment. Physical changes of the compost will be captured periodically and compared. Compost can be considered as mature when it is no longer possible to identify the individual initial components that make up the compost. When physical observation could not differentiate the materials used in the compost, there is a high chance that the composting has completed.

3.6 Key Milestones

Key milestones of this project is set based on the requirements for completion for both FYP1 and FYP2. It is shown in **Table 5**. Considerations are also given on the duration of composting while drafting the key milestones.

Table 5: Key Milestones of FYP1 and FYP2.

Step	Period	Key Milestones
1	FYP 1	Submission of Extended Proposal
2		Proposal Defence
3		Fabrication of Reactor
4		Organic Waste Collection
5		Composting Activity
6		Collection of Data (pH, temperature, moisture content & organic content)
7		Submission of Interim Report
8	FYP 2	Calculation and Analysis of Data
9		Submission of Progress Report
10		Pre-SEDEX
11		Submission of Dissertation (soft bound)
12		Submission of Technical Paper
13		Viva
14		Submission of Dissertation (hard bound)

3.7 Gantt Chart

Gantt Chart details the progress of the composting study throughout Final Year Project 1 and 2. It is drafted according to the key milestones set for the project. Please refer to **Figure 41** and **Figure 42** in **Appendices** for the Gantt Chart.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Physical Properties

The physical changes of all four compost have been recorded and as displayed from **Figure 14 – Figure 17**. By Day 8 it is noticeable that all compost has been infected with maggots. Presence of maggots is indication of decomposition of the fruit and food wastes. These maggots continue to exist up till about Day 32. At the same time, the presence of flies and unidentified black worms in high amount is observed. There is also growth of seedlings and moss scattered across the surface of compost. Black worms are estimated to live up till Day 62. By Day 62, it is noticeable that all black worms are dead in the compost. This could indirectly point to the fact that most materials have been decomposed by that time and there is no food left for the worms to survive on.

Since the compost is fresh on Day 1, the fragrance of fruit waste still lingers on. However, a strong unpleasant odor is noticeable by Day 8. This strong unpleasant odor continues to persist up till at least Day 32. From Day 32 onwards, the strange odor still exist but on a lower intensity. This coincides with the disappearance of maggots from the compost on Day 32. The presence of the odor is still noticeable up till the last day of observation which is Day 83.

It is also observable with the naked eye that the content of the compost have been reduced significantly by Day 27. Almost 50% of the entire volume of every composting bin is void. Each compost undergo further volume reduction in the following days up till Day 62. It is estimated that only about 25% of the original volume is left by then. From here onwards, compost A and compost B undergo different changes compared to compost C and compost D. From Day 62 to Day 75, it is noticeable that the leaves in compost A and compost B have greatly reduced in terms of size. The leaves have been broken up to smaller parts. Meanwhile contents of compost C and compost D remained about the same from Day 62 till the end of composting. One of the possibilities contributing to this is that the manual turning of compost A and compost B helped fasten the rate of decomposition.

Figure 14: Progress of Compost A.

**(Top, from left to right: Day 1, Day 8, and Day 27
Bottom, from left to right: Day 46, Day 62 and Day 75).**

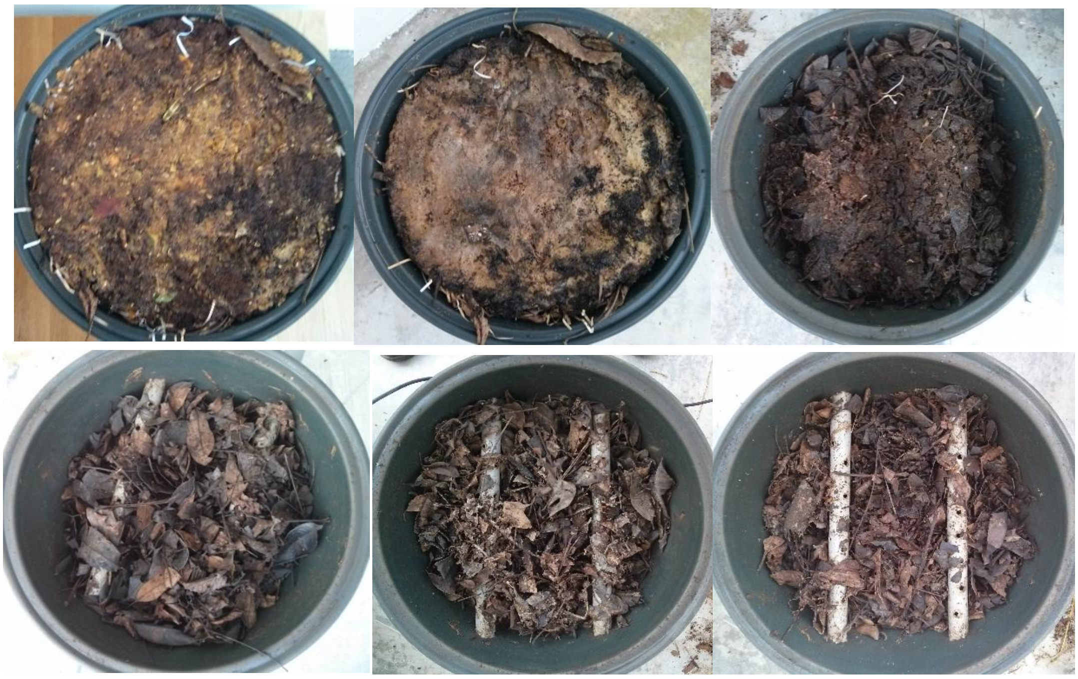

Figure 15: Progress of Compost B.

**(Top, from left to right: Day 1, Day 8, and Day 27
Bottom, from left to right: Day 46, Day 62 and Day 75).**

Figure 16: Progress of Compost C.

(Top, from left to right: Day 1, Day 8, and Day 27
Bottom, from left to right: Day 46, Day 62 and Day 75).

Figure 17: Progress of Compost D.

(Top, from left to right: Day 1, Day 8, and Day 27
Bottom, from left to right: Day 46, Day 62 and Day 75).

4.2 Mass Yield

Comparing data collected from Day 75 and Day 83, it is determined that all compost have fully completed composting. Temperature and pH profiles suggest that at this point, decomposition activities have ceased, while physical observation remains the same over that period. The temperature and pH profiles will be further discussed in the next section.

After determining the completion of composting, analysis on the mass yield was carried out. Initial mass of the composting bin without compost was weighed on Day 1 during the preparation. On Day 83, each bin with its compost content was weighed. By deducting the mass of the composting bin, the final mass of compost was obtained. **Table 6** shows the final mass of each compost.

Table 6: Final Mass of Compost.

Compost	Mass of Bin (kg)	Final Mass of Compost + Bin (kg)	Final Mass of Compost (kg)
A	0.43	2.50	2.07
B	0.45	2.47	2.02
C	0.43	2.44	2.01
D	0.45	2.35	1.90

Applying **Equation (3)**, the mass yield percentage can be calculated. The initial mass for each compost is 10kg. Mass yield percentage of each compost is as shown in **Table 7**. Compost A has the highest yield percentage at 20.7% while compost D is the lowest at 19.0%. The difference in yield for each compost does not differ much. This is because the recipe of each set up is the same. Results obtained proved that the recipe used in this research is capable to generating an average of 20% yield of compost from the organic wastes used. It also shows that method of aeration does not affect the final yield or total amount of content decomposed at the end of decomposition.

Table 7: Mass Yield Percentage.

Compost	Initial Mass (kg)	Final Mass (kg)	Mass Yield Percentage (%)
A	10.00	2.07	20.7
B	10.00	2.02	20.2
C	10.00	2.01	20.1
D	10.00	1.90	19.0

$$Average\ Yield\ (\%) = \frac{20.7\% + 20.2\% + 20.1\% + 19.0\%}{4}$$

$$Average\ Yield\ (\%) = 20.0\%$$

4.3 pH Profile

pH data are collected on Day 1, Day 11, Day 27, Day 32, Day 39, Day 46, Day 54, Day 62, Day 68, Day 75 and Day 83. Data for each set up is as displayed in **Table 8** to **Table 11** in the **Appendices**.

Recording method on Day 1 and Day 11 are different from the rest as the portable probe is unavailable at that time. Instead, a bench top temperature plus pH meter was used. Six samples were collected from different spot on the compost and mixed together. A small sample was retrieved from this new mixture to be used to obtain the temperature and pH. This is done to obtain a representative and average reading. As for the other days, a portable probe for solid and soil was used to record the data. Data are also collected from six different points and averaged out. **Figure 18** shows the comparison of pH profile of all four composts. Individual pH profile for each compost are included in the Appendices as **Figure 21** to **Figure 24**. Each plot has a total of 11 data points. The method of plotting the graph is by using Excel’s smoothed line estimation connecting two adjacent data points.

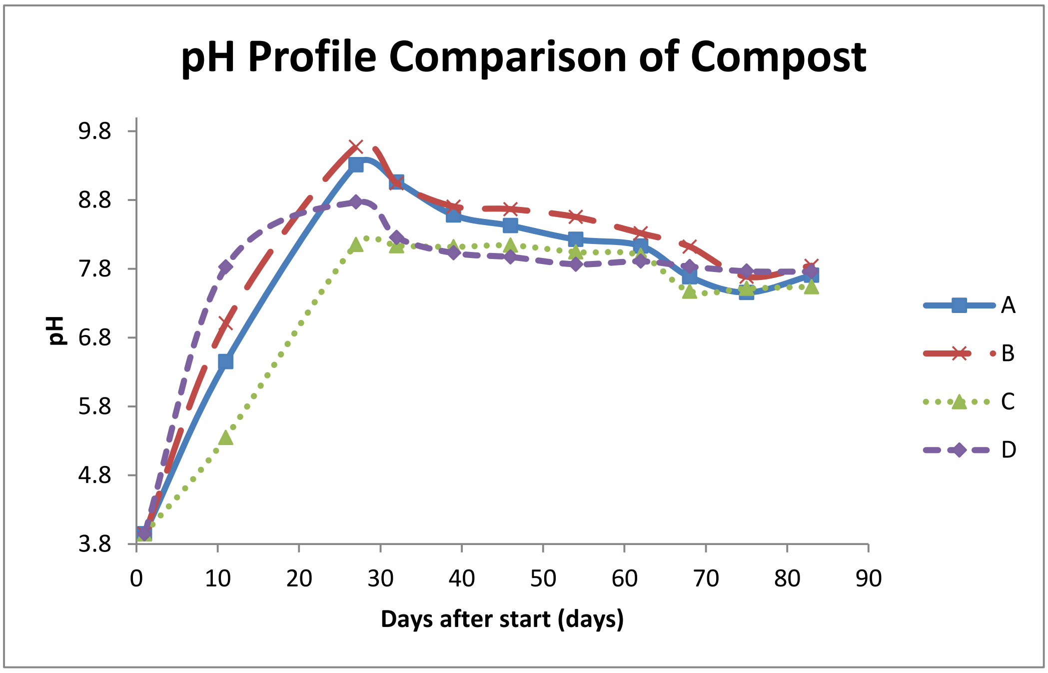

Figure 18: pH Profile Comparison of Compost.

As expected, the pH begins to rise immediately from Day 1. It was expected that each compost will regulate itself to maintain a pH value of about 7 for healthy composting. During the initial phase of this self-regulating process, the pH values overshoot into the range of 8 to 9. The highest peak recorded was of Compost B, reaching about 9.8, which means that the content is basic. At about Day 28 to Day 30, it is observed that the compost pH value began to drop. As a result, a pattern of fluctuation can be observed. The compost are self-regulating to reach pH value of about 7.

All four trends suggest that composting activity have reached its peak at about Day 24 – Day 30. The pH values drop immediately after that. As expected, the pH begins to flat out towards Day 65 and eventually towards the end. Aerobic decomposition produces organic acid that lowers the overall pH value. The trend suggests that the production of organic acid continuously reduces the pH until a point where it starts to remain steady in the same range. This is because the production of organic acid stops when there is no longer any decomposing activity. These behavior strongly suggests the end of composting activity.

4.4 Temperature Profile

Temperature data are collected on Day 1, Day 11, Day 27, Day 32, Day 39, Day 46, Day 54, Day 62, Day 68, Day 75 and Day 83. Data for each set up is as displayed in **Table 12** to **Table 15** in the Appendix.

As of the method of data collection for pH, it is the same for temperature. Recording method on Day 1 and Day 11 are different from the rest. Data are always collected from six different points of the compost to be averaged out. **Figure 19** shows the comparison of temperature profile of all four composts. Individual temperature profile for each compost are included in the Appendices as **Figure 25** to **Figure 28**. Plotting method is also the same, applying Excel's smoothed line estimation connecting two adjacent data points.

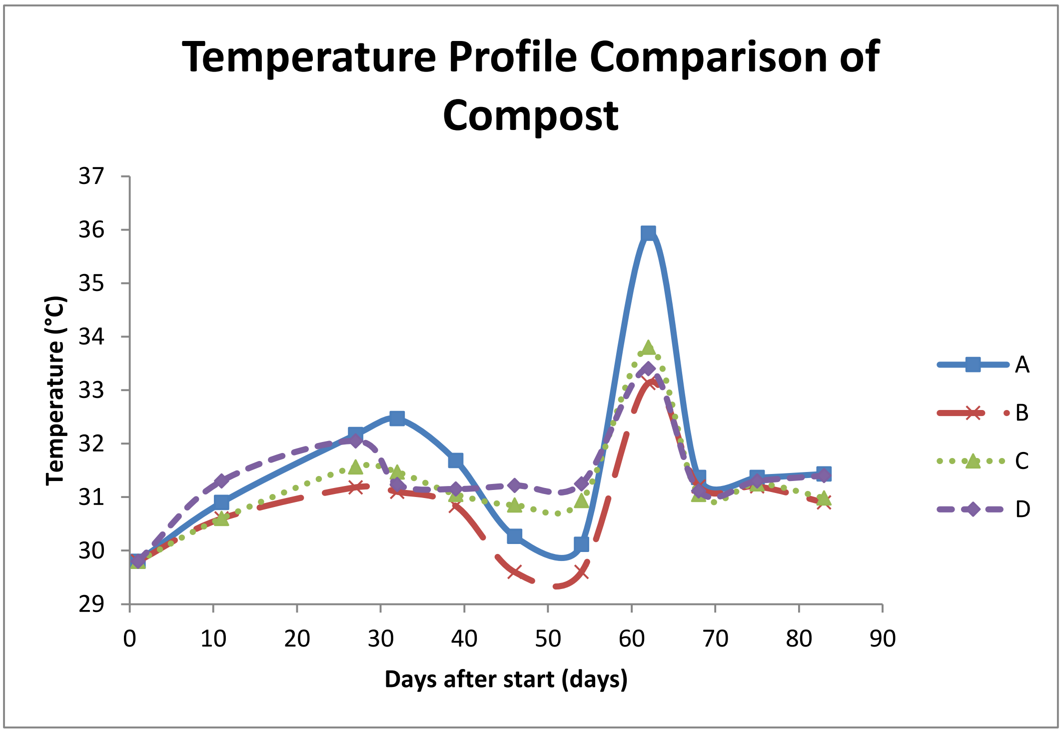

Figure 19: Temperature Profile Comparison of Compost.

From the trend, it is observed that there is a sudden temperature spike on Day 62. It is worth to take note on the average surrounding temperature of the day from about Day 60 till the end, Day 83, is higher than the initial period of composting. Higher surrounding temperature might have affected the temperature of compost through conduction and convection of heat. As such, data collected on Day 62 is excluded from the temperature profile in order to obtain a better representation of the composting activity. A new graph is plotted and **Figure 20** shows the temperature comparison after adjustment.

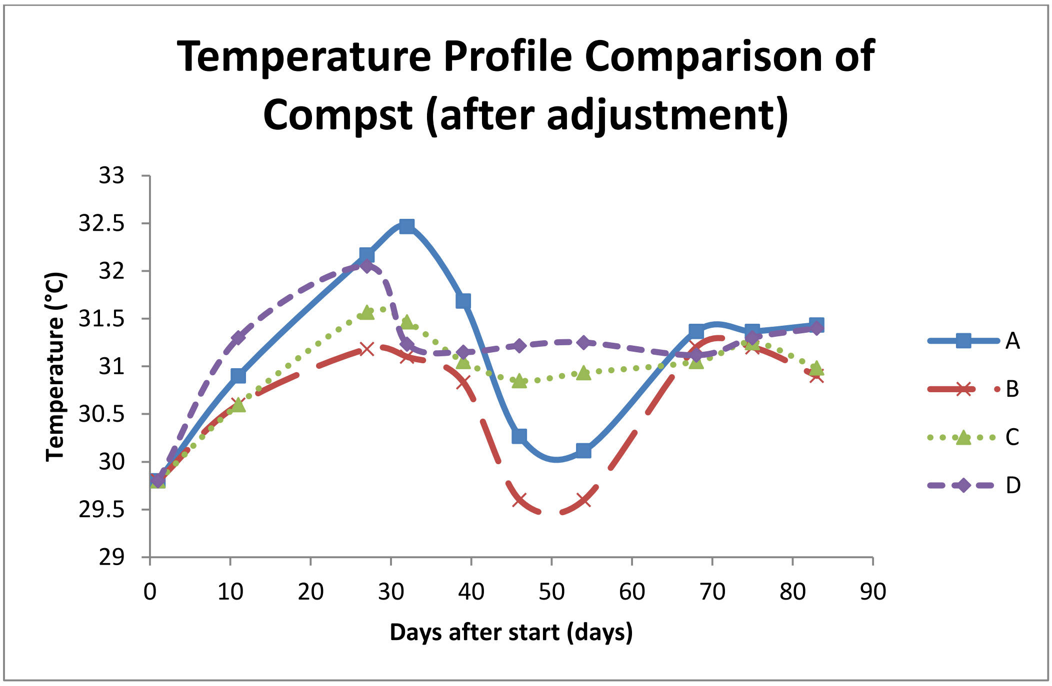

Figure 20: Temperature Profile Comparison of Compost (after adjustment).

In general, the temperature profile of all compost behaves as expected. The rise of temperature from Day 1 up till about Day 20 – Day 35 suggests an increase in decomposing activities. Compost B, Compost C and Compost D reach their peak the fastest by about Day 28. This coincides with the pH profile of the composts. Compost A took longer time to reach its peak which is on Day 32. It is noticeable that the temperature for all compost began to drop after hitting the peak which highly suggest the reduction in the level of composting activity. General expectation would be for the temperature profile to flat out as the composting progresses. A sudden increase in temperature again after about Day 50 for all compost could again be attributable to the rise in surrounding temperature. This inference has valid support as the temperature trends did reach a steady state immediately after the rise. It could be said that the temperature for all compost fluctuate at about the same value from Day 65 onwards till the end of composting. It coincides with the pH profile as well as physical observation. There is no physically observable compost degradation after Day 62.

In comparison, Compost B is expected to decompose at a faster rate compared to Compost A since it has passive aeration and is being manually mixed weekly. The comparison supports this hypothesis as Compost B reaches its peak faster than Compost A. Meanwhile Compost D should also record a higher activity of decomposing compared to Compost C due to the availability of passive aeration for Compost D. The higher peak recorded for Compost D does support this statement. Passive aeration does not seem to affect the rate of decomposing between Compost D and Compost C.

Manual mixing does not show any positive impact through the temperature profile. Compost A shows a slower rate of decomposing while Compost B shows a lower peak of decomposing activity. Physical observations have showed otherwise as Compost A and Compost B manage to breakdown the leaves to smaller particles. This contradiction could be caused by the loss of internal heat of Compost A and Compost B during the manual mixing process.

From the temperature profiles comparison, it cannot be determined that passive aeration has helped speed up the composting period as all trends marks the end of composting at about the same time. One possible inference could be the method of passive aeration introduced in this study is not effective.

4.5 Organic Content and Nitrogen Content

Organic content and nitrogen content analysis is conducted on all 4 compost samples as well as sample from the initial compost material before the start of composting. Another sample is taken from the commercial compost as this will provide the control factor for comparison. Comparing the final product of this study against the commercial compost helps to evaluate the quality of the product.

Total Organic Content (TOC) is obtained through the reduction of ionic carbon from the total carbon in the sample according to **Equation 5**. Value obtained from the equipment is in the unit of parts per million or equivalent to miligram per liter. Sample with a total weight of 3grams is digested in 30mililiters of nitric acid and 70 mililiters of distilled water. Results from the test is displayed in graphs as show from **Figure 29** to **Figure 34** in the **Appendices**. Amount of carbon detected is represented by the area under the graph. The total organic carbon in ppm and weight percentage is as shown in **Table 8** and **Table 9**.

Table 8: Total Organic Carbon of Samples.

Compost	Total Carbon (ppm)	Ionic Carbon (ppm)	Total Organic Carbon, TOC (ppm)
A	765.7	0.8	764.8
B	643.8	2.9	640.8
C	509.4	4.3	505.0
D	438.2	2.5	435.6
Initial	802.9	1.6	801.3
Commercial	697.4	1.5	695.8

Table 9: Weight Percent of Carbon.

Compost	Total Organic Carbon, TOC (mg/L)	Total Organic Carbon, TOC (mg/100ml)	Weight Percent (%)
A	764.8	76.48	2.549
B	640.8	64.08	2.136
C	505.0	50.50	1.683
D	435.6	43.56	1.461
Initial	801.3	80.13	2.671
Commercial	695.8	69.58	2.319

As the results show, there are reduction of carbon in the compost compared to the initial amount of carbon content. Compost D experienced the greatest carbon loss, losing about 350ppm compared to Compost A which have loss only about 35ppm. The analysis on the final product does not show any direct correlation to the effect of passive aeration.

By plain comparison, the weigh percentage of organic carbon in the final product is comparable to that of the commercial compost. An indirect conclusion that can be drawn is that the quality of all 4 composts matches the expectation of commercial grade compost.

Nitrogen content in the compost is evaluated using the Total Kjeldahl Nitrogen (TKN) method. In this method, ammonia gas is liberated through the heating of sample in sulfuric acid. Eventually, only the nitrate will be left in the sample. Therefore amount of nitrogen detected are the nutrient of the compost. Results from the test are as displayed from **Figure 35** to **Figure 40** in the **Appendices**. Amount of nitrogen is represented by the area under the curve. Table 10 below shows the total Kjeldahl nitrogen detected and nitrogen's weight percent in each sample.

Table 10: Total Kjeldahl Nitrogen and Weight Percent of Nitrogen.

Compost	Total Kjeldahl Nitrogen, TKN (mg/L)	Total Kjeldahl Nitrogen, TKN (mg/100ml)	Weight Percent (%)
A	286.2	28.62	2.862
B	126.2	12.62	1.262
C	116.4	11.64	1.164
D	221.4	22.14	2.214
Initial	331.1	33.11	3.311
Commercial	463.4	46.34	4.634

The result is consistent with the analysis of organic carbon. Results of all 4 compost show comparable weight percent to that of the commercial compost. The weight percent falls in the range of expected result where anything in the range of

0.5% to 2.75% weight percent of nitrogen in compost would represent a good quality compost. Compost C experienced the greatest loss in nitrogen by dropping from the initial 3.31% to 1.16%. Meanwhile Compost A retained the highest amount of nitrogen at the end of composting, standing at 2.86% weight percent. Again, these results have no direct correlation to the set up of passive aeration. It is also not consistent with the organic content as Compost D has the lowest organic content while Compost C has the lowest nitrogen content. The only conclusion to be drawn from both results are that the compost produced in this study are as good as the commercial compost.

4.6 Feasibility of Composting UTP Organic Wastes into Value-added Products

It is determined that the quality of compost produced from the organic wastes generated in UTP possesses characteristics of those of commercial compost. It would then be possible to replace the current usage of fertilizers in UTP with the self generated compost from daily organic wastes collected in the campus. Further study is carried out to look at the potential saving in terms of cost for the project. Assumptions made in this study is that the period of study is conducted based on a 30 days per month basis and the minimum wage of the current employers at RM900 is applied.

As recorded during the study, it is estimated that 2 persons and 4 man hours each will be required to manage the process of grinding, blending, mixing and preparing the compost daily. That will be a total of 8 man hours spent daily. This will amount to a total of 240 man hours per month. A total of 4 one tonne lorry are hired daily to transport wastes collected around the campus to the municipal waste collection centre in Batu Gajah. Each of them costs RM30. If the compost project is conducted in UTP this will remove the cost of transporting wastes. As for fertilizers, UTP currently uses a total of 200kg fertilizers per month at RM150 per 50 kg. With the self generated compost, UTP will no longer have to purchase additional fertilizers.

Amount of wastes generated in the campus is estimated to be at 2,000kg per day. Mainly are domestic wastes from the residential colleges and leaves collected around the campus. Of the total wastes, 50% are assumed to be organic waste. UTP is capable to generate the following amount of organic wastes per month:

$$Organic\ Wastes\,\frac{kg}{month} = Total\ Wastes\,\frac{kg}{day}\ \ x\ 0.5\ x\ 30\,\frac{days}{month} \tag{6}$$

$$Organic\ Wastes\ \frac{kg}{month} = 2000\,\frac{kg}{day}\ x\ 0.5\ x\ 30\,\frac{days}{month}$$

$$Organic\ Wastes\ \frac{kg}{month} = 30000\,\frac{kg}{month}$$

Out of the 30,000kg of organic wastes generated per month only 20% will be successfully be converted to compost as suggested by the result of average mass yield percentage. The capacity of compost generation per month is:

$$Compost\ \frac{kg}{month} = Organic\ Wastes\,\frac{kg}{month}\ \ x\ Mass\ Yield\ Percentage \tag{7}$$

$$Compost\ \frac{kg}{month} = 30000\,\frac{kg}{month}\ \ x\ 0.2$$

$$Compost\ \frac{kg}{month} = 6000\,\frac{kg}{month}$$

UTP will be capable of generating 6,000 kg of good quality compost per month. This amount is enough to replace the current usage of 200kg fertilizers per month. Excess of compost can also be considered for commercialization purposes. **Table 11** details the potential cost saving of converting UTP generated organic waste into compost.

Table 11: Potential Saving of Composting UTP Organic Wastes.

Item	Unit	Cost per Unit (RM)	Cost per Month (RM)
Transportation	4	30	3,600
Fertilizer	4	50	600
Labor Cost for Handling Compost	240	-3.75	-900
		TOTAL	3,300

According to the information provided and assumptions made, UTP will be able to make a saving of RM3,300 per month if organic wastes collected in campus is converted into compost. This calculation excludes the excess compost which could potential be commercialized for additional revenue. The result of this study provides a basis to conduct further studies which could potentially frame a sustainable business model for this project.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

The problem statement provides the opportunity to study the effect of passive aeration on the activity of composting as well as converting UTP's organic waste into valuable products. Recycling organic waste helps tackle the issue increasing use of landfills while present UTP an opportunity to generate its own fertilizers for landscaping purposes. Conclusive literature review on previous attempts of composting investigation served as guide to develop the methodologies for this study It includes the experimental set up and methods of data collection along with analysis.

While pH and temperature profiles show that the composting activity took about 65 days to complete. Physical observation shows that Compost A and Compost B can further break down the leaves components up till Day 75 while leaves in Compost C and Compost remained the same from Day 63 till the end of study on Day 83. This suggests that manual mixing helps to redistribute the compost evenly for easier decomposing as outer materials are harder to decompose.

As suggested in the literature review, a lower C:N ratio would help speed up the composting speed. However a ratio too low will stifle the process. Composting took 65 days to complete, 5 days more than the expected 60 days. Future research can study a lower C:N ratio to determine if the period of composting can be further shorten.

The study does not strongly suggest that passive aeration helps speed up the composting process. The only indication is that Compost B, with passive aeration, reaches its peak activity level faster compared to Compost A. Further studies need to be done in order to support this indication. Method of passive aeration applied in this study might not be effective.

Average mass yield percentage recorded is at 20% with the highest at 20.7%. Organic content is in the range of 1.4% to 2.5% weight percent while nitrogen content of the compost is in the range of 1.1% to 2.8% weight percent. The result is comparable to the properties of commercial compost. It suggests that the final product is as good as the quality of commercially available compost. Feasibility studies have also shown that there is a potential of RM3,300 of saving per month if UTP recycles its own organic wastes instead of disposing it daily. Excess amount of compost generated from the project could also be commercialized for additional revenue.

5.1 Recommendations

Some of the recommendations for future studies and improvements:

1. Design method of passive aeration that could allow higher rate of air flow.
2. Study the effect of manual aeration on composting activity.
3. Reduce particle size of ingredient of compost for faster composting rate.
4. Use a lower C:N ratio. This could lead to a shorter composting period.
5. Include organic content study as one of the criteria in determining the level of composting activity. Total organic content will remain the same at the end of composting. This study only analyze the organic content at the beginning and end of composting, therefore it does not indicate the completion of composting.

Some of the recommendations for implementing the composting project in UTP:

1. Design composting bin that allows easier manual mixing, active aeration or passive aeration.
2. Construct C:N ratio for compost according to the availability of organic wastes generated in UTP.

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CHAPTER 7. APPENDICES

Table 12: pH Readings of Compost A.

Day	Date	Reading						Average
		1	2	3	4	5	6	
1	16-Jan	-						3.95
11	26-Jan	-						6.45
27	11-Feb	9.76	9.56	9.16	9.20	9.00	9.21	9.32
32	16-Feb	8.79	9.41	9.40	9.22	8.86	8.70	9.06
39	23-Feb	8.23	9.14	7.94	8.82	8.30	9.06	8.58
46	2-Mar	7.77	8.46	8.71	8.56	9.01	8.05	8.43
54	10-Mar	8.64	7.65	8.31	7.99	8.85	7.93	8.23
62	18-Mar	7.96	8.03	8.45	8.82	7.94	7.60	8.13
68	24-Mar	8.15	7.42	7.30	7.51	7.71	8.02	7.69
75	31-Mar	7.83	7.49	7.58	6.92	7.35	7.57	7.46
83	8-Apr	7.98	7.04	8.21	7.45	7.66	7.90	7.71

Table 13: pH Readings of Compost B.

Day	Date	Reading						Average
		1	2	3	4	5	6	
1	16-Jan	-						3.95
11	26-Jan	-						7.01
27	11-Feb	9.33	9.62	9.71	9.84	9.73	9.21	9.57
32	16-Feb	8.43	9.06	9.71	8.86	8.44	9.75	9.04
39	23-Feb	8.56	8.86	9.54	9.15	8.23	7.89	8.71
46	2-Mar	9.01	8.51	8.27	8.85	8.76	8.60	8.67
54	10-Mar	8.87	9.04	8.22	7.97	8.43	8.79	8.55
62	18-Mar	8.05	9.06	7.04	9.11	7.97	8.67	8.32
68	24-Mar	8.67	8.10	7.68	7.79	8.05	8.44	8.12
75	31-Mar	8.73	7.80	7.49	7.36	7.08	7.65	7.69
83	8-Apr	7.56	7.91	7.90	8.24	7.63	7.83	7.85

Table 14: pH Readings of Compost C.

Day	Date	Reading						Average
		1	2	3	4	5	6	
1	16-Jan	-						3.95
11	26-Jan	-						5.35
27	11-Feb	7.82	7.82	8.56	8.24	8.33	8.17	8.16
32	16-Feb	8.12	7.78	8.14	7.99	8.08	8.71	8.14
39	23-Feb	8.32	8.12	8.30	8.08	7.90	8.01	8.12
46	2-Mar	7.48	8.27	7.96	8.59	8.30	8.26	8.14
54	10-Mar	8.41	8.37	7.73	7.15	8.68	7.94	8.05
62	18-Mar	7.73	8.24	8.41	7.08	8.07	8.44	8.00
68	24-Mar	6.89	7.88	7.08	7.68	7.39	7.94	7.48
75	31-Mar	7.72	7.57	6.83	7.22	7.84	7.92	7.52
83	8-Apr	6.81	7.54	7.80	7.83	7.36	7.91	7.54

Table 15: pH Readings of Compost D.

Day	Date	Reading						Average
		1	2	3	4	5	6	
1	16-Jan	-						3.95
11	26-Jan	-						7.83
27	11-Feb	8.82	8.84	9.77	9.11	7.44	8.65	8.77
32	16-Feb	8.08	8.18	8.16	8.28	8.40	8.45	8.26
39	23-Feb	7.87	7.90	8.12	8.05	8.65	7.60	8.03
46	2-Mar	8.09	8.20	7.67	7.47	8.47	7.94	7.97
54	10-Mar	7.65	8.22	7.49	7.88	7.92	8.05	7.87
62	18-Mar	8.23	8.04	7.21	7.89	8.32	7.78	7.91
68	24-Mar	8.08	7.50	7.96	7.69	7.73	8.05	7.84
75	31-Mar	8.72	6.87	8.37	7.87	6.87	7.90	7.77
83	8-Apr	8.11	7.56	7.62	7.90	8.07	7.31	7.76

Table 16: Temperature Readings of Compost A.

Day	Date	Reading (°C)						Average
		1	2	3	4	5	6	
1	16-Jan	-						29.8
11	26-Jan	-						30.9
27	11-Feb	33.10	32.20	32.20	31.40	32.70	31.40	32.17
32	16-Feb	33.90	32.60	31.70	31.60	32.90	32.10	32.47
39	23-Feb	32.80	32.10	31.50	31.20	32.00	30.50	31.68
46	2-Mar	29.80	30.80	31.00	30.40	30.00	29.60	30.27
54	10-Mar	29.70	30.50	31.10	30.80	30.00	28.60	30.12
62	18-Mar	36.60	36.10	35.20	35.50	36.10	36.10	35.93
68	24-Mar	30.60	32.40	31.60	31.20	30.80	31.60	31.37
75	31-Mar	32.20	32.60	31.00	31.00	31.10	30.30	31.37
83	8-Apr	31.80	31.00	30.80	32.20	31.70	31.10	31.43

Table 17: Temperature Readings of Compost B.

Day	Date	Reading (°C)						Average
		1	2	3	4	5	6	
1	16-Jan	-						29.8
11	26-Jan	-						30.6
27	11-Feb	33.00	30.10	31.60	31.60	30.00	30.80	31.18
32	16-Feb	32.00	29.90	31.70	30.60	31.70	30.70	31.10
39	23-Feb	31.50	31.00	29.80	31.90	30.50	30.30	30.83
46	2-Mar	29.30	29.50	30.40	29.60	29.70	29.10	29.60
54	10-Mar	30.10	29.50	29.60	30.00	29.20	29.20	29.60
62	18-Mar	33.60	33.40	33.00	33.20	33.10	32.50	33.13
68	24-Mar	30.80	31.20	31.40	31.20	31.70	30.90	31.20
75	31-Mar	30.60	31.40	32.10	31.60	31.80	29.70	31.20
83	8-Apr	31.20	30.70	30.50	31.00	30.90	31.10	30.90

Table 18: Temperature Readings of Compost C.

Day	Date	Reading (°C)						Average
		1	2	3	4	5	6	
1	16-Jan	-						29.8
11	26-Jan	-						30.6
27	11-Feb	31.80	31.80	31.40	31.50	31.40	31.50	31.57
32	16-Feb	32.10	31.40	31.60	31.60	31.50	30.60	31.47
39	23-Feb	30.10	31.50	31.00	30.70	31.20	31.80	31.05
46	2-Mar	31.50	30.80	30.60	30.80	30.80	30.60	30.85
54	10-Mar	30.50	30.70	31.40	31.00	30.50	31.50	30.93
62	18-Mar	33.90	33.70	33.90	34.00	33.80	33.50	33.80
68	24-Mar	31.00	29.90	31.50	30.90	31.20	31.80	31.05
75	31-Mar	31.10	32.40	30.80	31.40	30.60	31.20	31.25
83	8-Apr	29.80	30.70	30.60	31.50	31.80	31.50	30.98

Table 19: Temperature Readings of Compost D.

Day	Date	Reading (°C)						Average
		1	2	3	4	5	6	
1	16-Jan	-						29.8
11	26-Jan	-						31.3
27	11-Feb	32.10	34.90	30.70	31.30	31.20	32.10	32.05
32	16-Feb	32.60	31.00	30.30	30.90	31.40	31.20	31.23
39	23-Feb	31.00	31.40	30.70	31.50	31.70	30.60	31.15
46	2-Mar	31.00	31.90	31.50	31.00	31.00	30.90	31.22
54	10-Mar	31.20	30.80	31.40	31.40	30.90	31.80	31.25
62	18-Mar	33.70	33.10	33.10	34.00	33.60	32.90	33.40
68	24-Mar	30.80	30.50	30.90	31.60	31.20	31.70	31.12
75	31-Mar	32.10	31.60	31.40	31.20	31.60	29.90	31.30
83	8-Apr	32.00	31.20	31.60	30.60	31.50	31.50	31.40

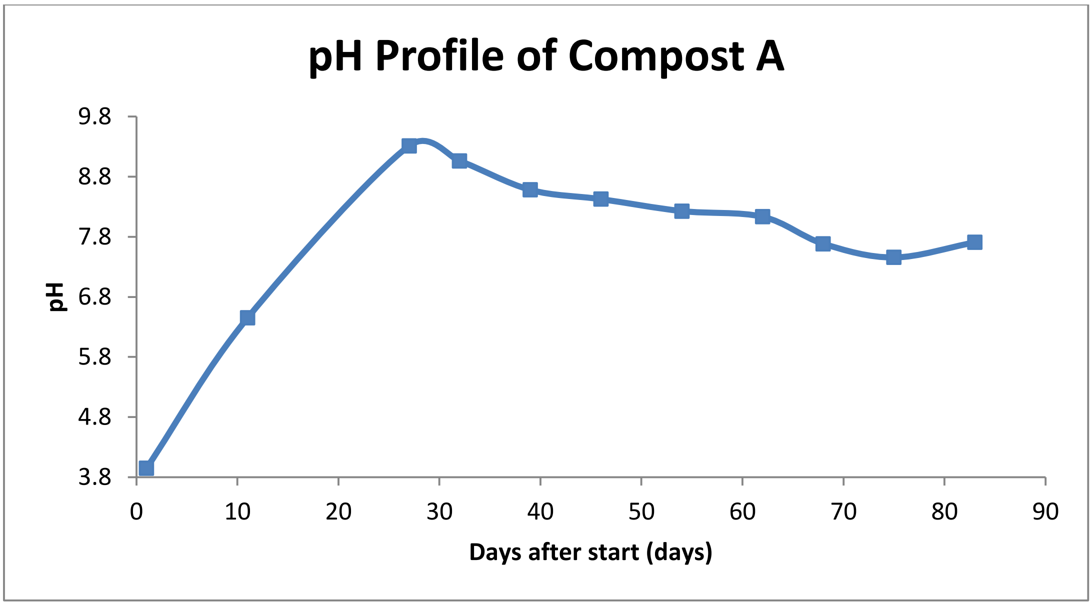


Figure 21: pH Profile of Compost A.

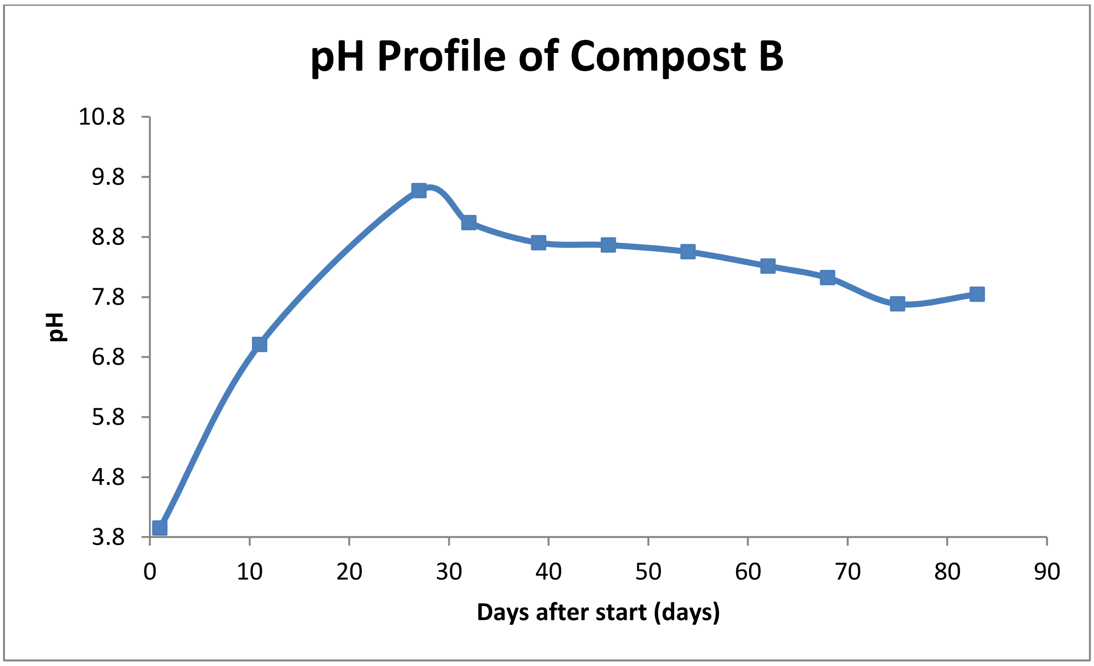


Figure 22: pH Profile of Compost B.

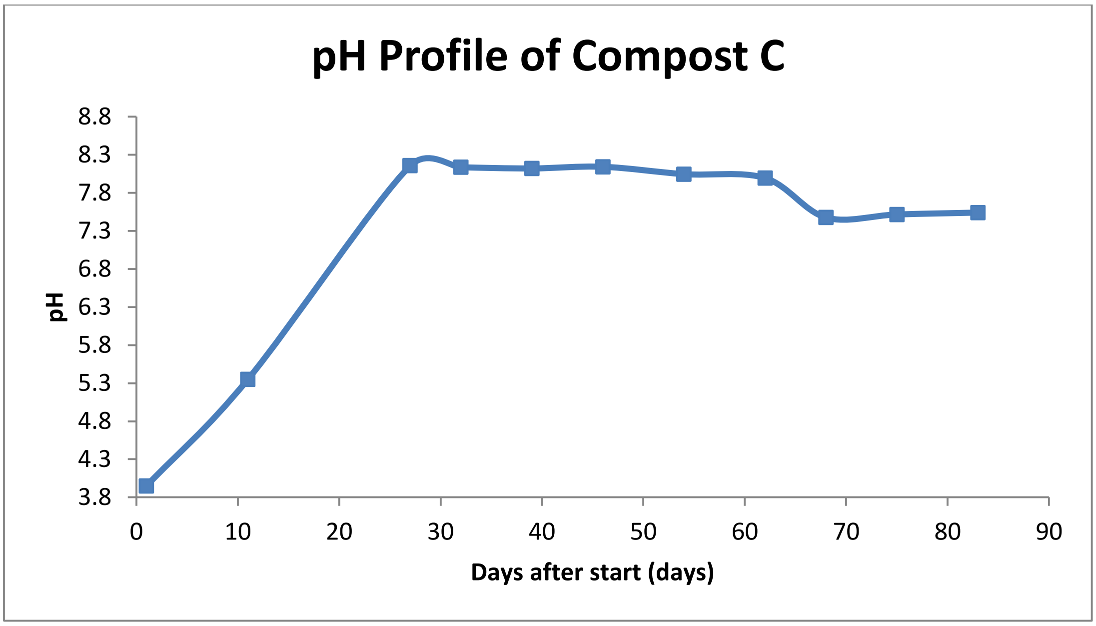


Figure 23: pH Profile of Compost C.

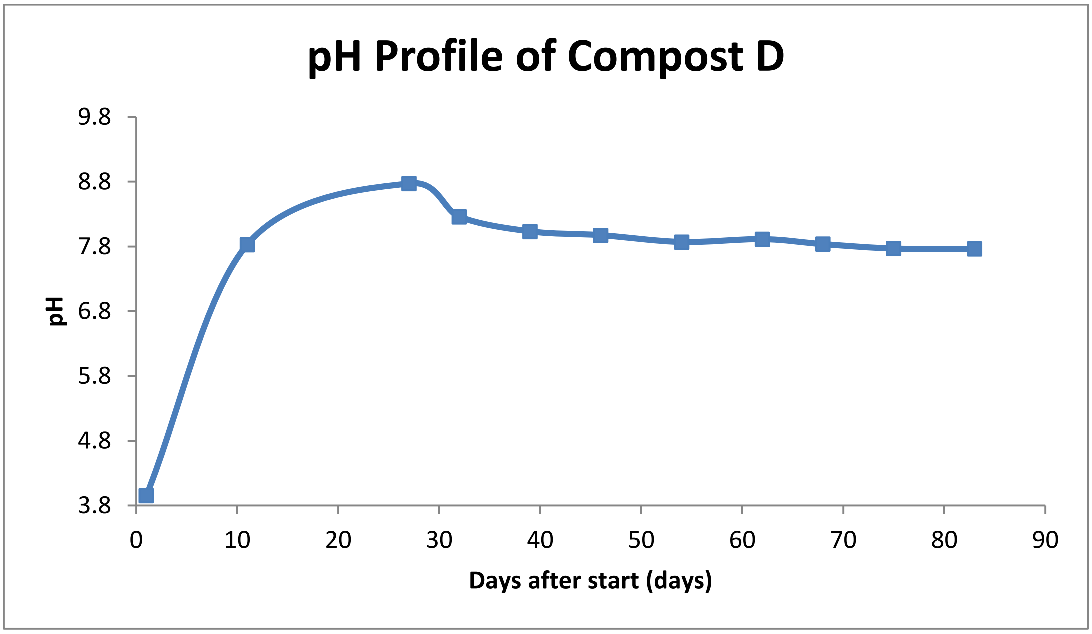


Figure 24: pH Profile of Compost D.

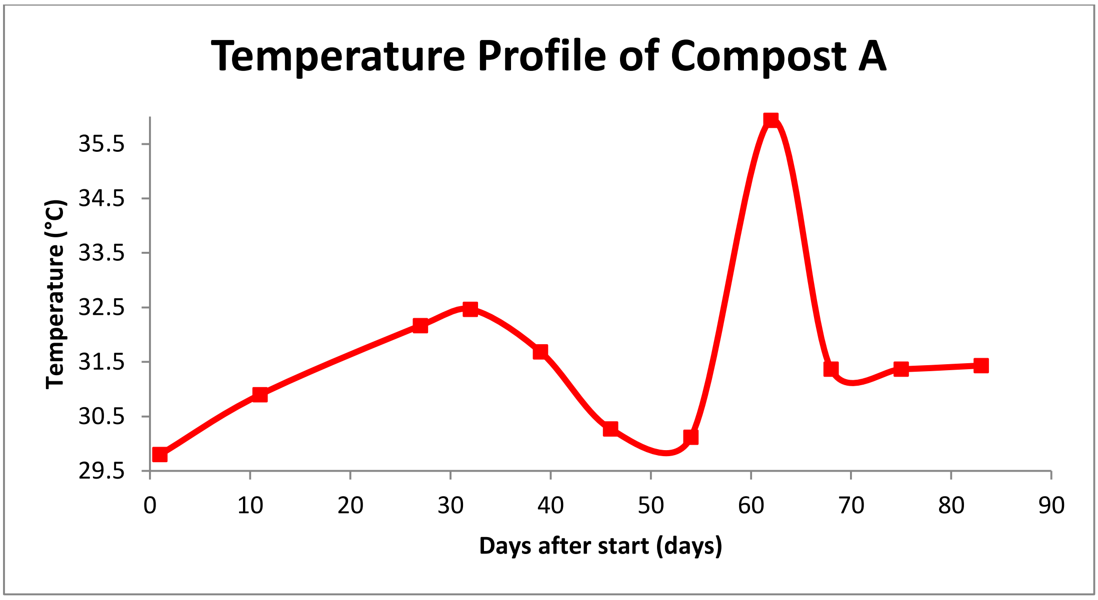


Figure 25: Temperature Profile of Compost A.

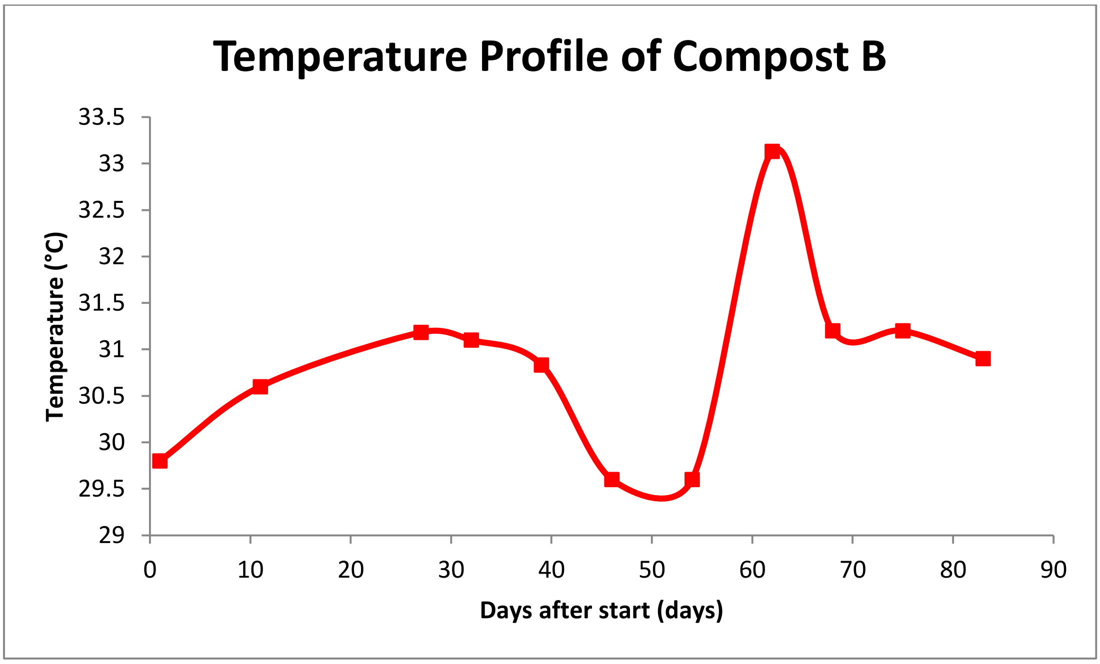


Figure 26: Temperature Profile of Compost B.

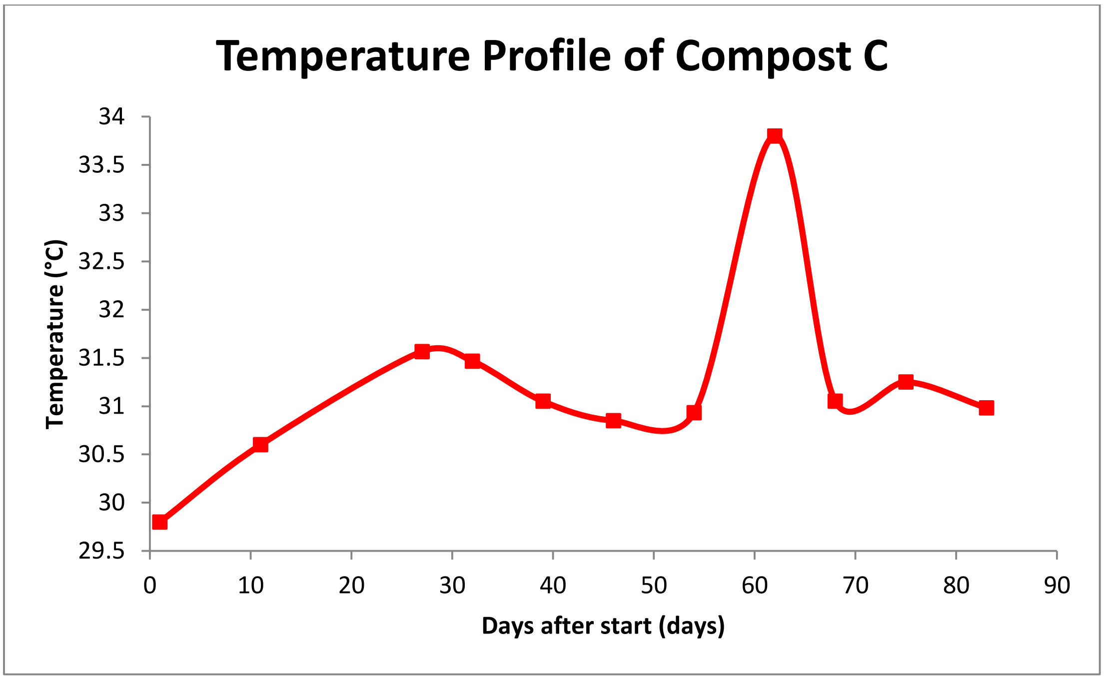


Figure 27: Temperature Profile of Compost C.

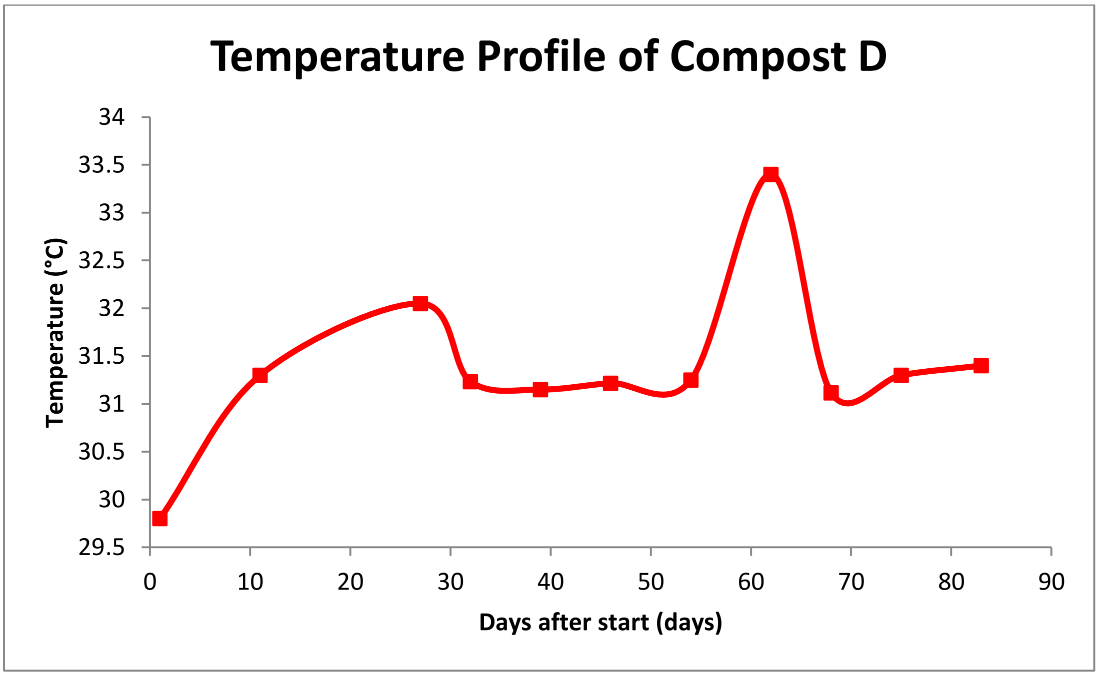
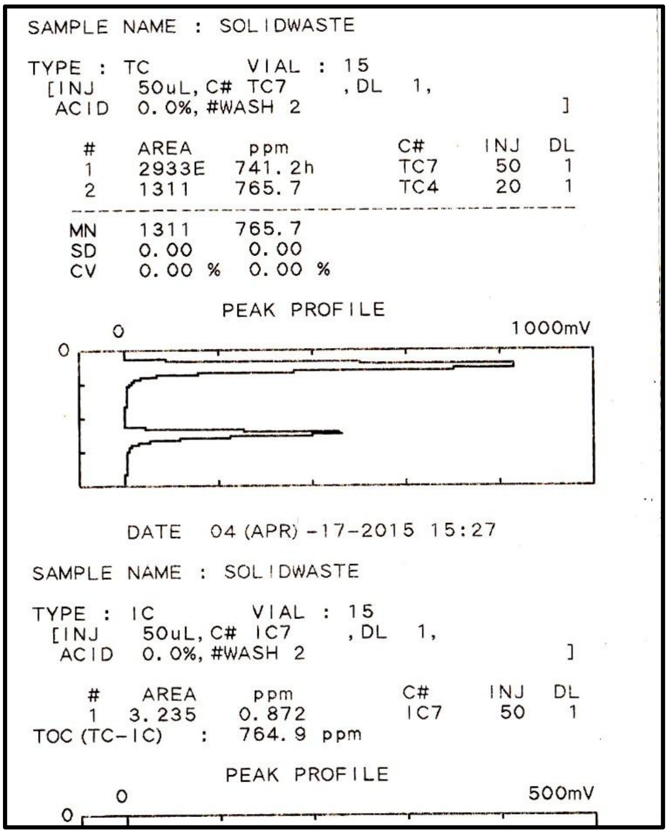
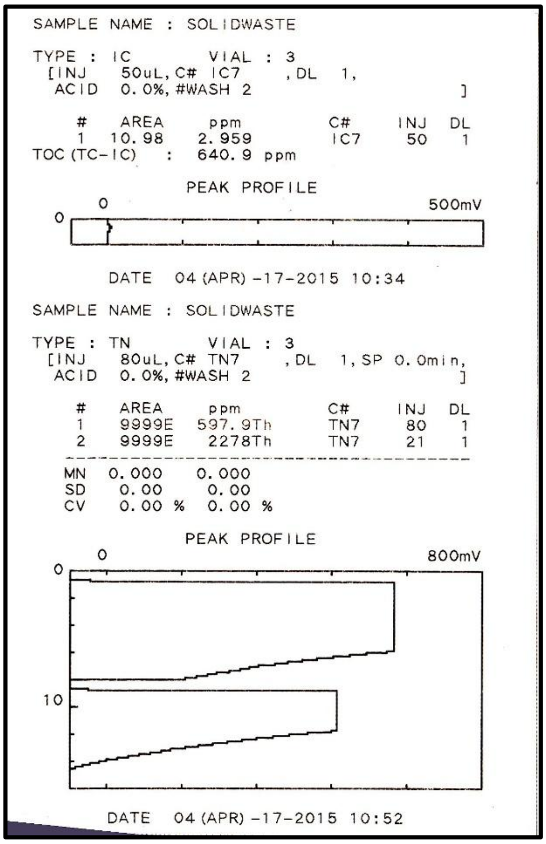


Figure 28: Temperature Profile of Compost D.



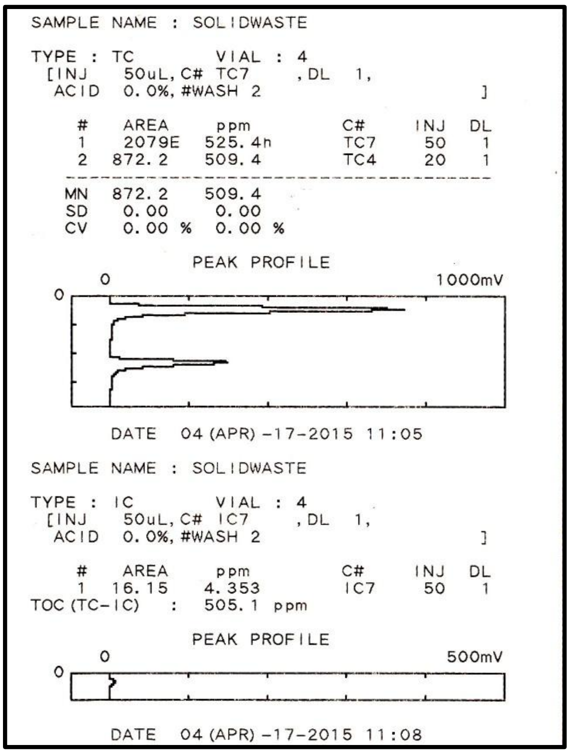
```
SAMPLE NAME : SOLIDWASTE

TYPE : TC          VIAL : 15
 [INJ    50uL, C# TC7     , DL   1,
  ACID   0.0%, #WASH 2                      ]

    #     AREA      ppm           C#     INJ   DL
    1     2933E    741.2h         TC7     50    1
    2     1311     765.7          TC4     20    1
   ----------------------------------------------
   MN     1311     765.7
   SD     0.00      0.00
   CV     0.00 %    0.00 %

              PEAK PROFILE
        0                                1000mV
   0

        DATE   04 (APR) -17-2015 15:27

SAMPLE NAME : SOLIDWASTE

TYPE : IC          VIAL : 15
 [INJ    50uL, C# IC7     , DL   1,
  ACID   0.0%, #WASH 2                      ]

    #     AREA      ppm           C#     INJ   DL
    1    3.235     0.872          IC7     50    1
TOC (TC-IC)    :   764.9 ppm

              PEAK PROFILE
        0                                 500mV
   0
```

Figure 29: Total Organic Carbon of Compost A.



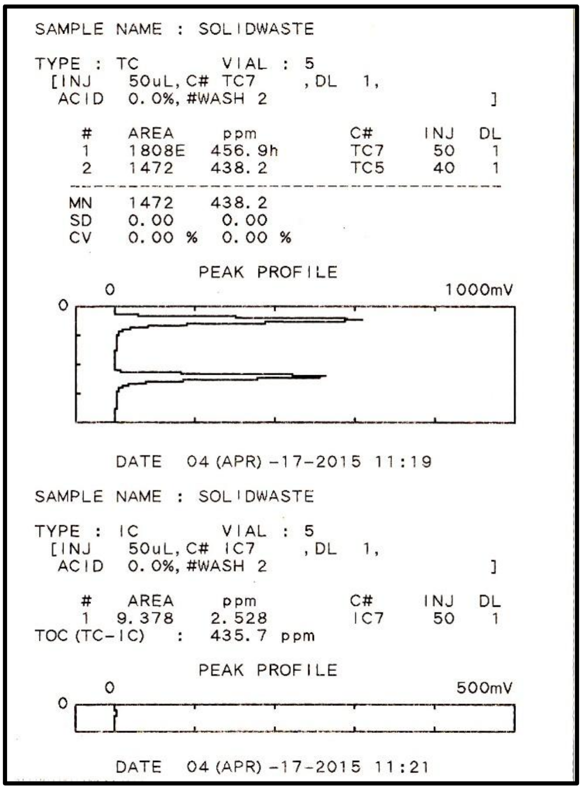
```
SAMPLE NAME : SOLIDWASTE

TYPE : IC          VIAL : 3
 [INJ    50uL, C# IC7     , DL   1,
  ACID   0.0%, #WASH 2                      ]

    #     AREA      ppm           C#     INJ   DL
    1    10.98     2.959          IC7     50    1
TOC (TC-IC)    :   640.9 ppm

              PEAK PROFILE
        0                                 500mV
   0

        DATE   04 (APR) -17-2015 10:34

SAMPLE NAME : SOLIDWASTE

TYPE : TN          VIAL : 3
 [INJ    80uL, C# TN7     , DL   1, SP 0.0min,
  ACID   0.0%, #WASH 2                      ]

    #     AREA      ppm           C#     INJ   DL
    1     9999E    597.9Th        TN7     80    1
    2     9999E     2278Th        TN7     21    1
   ----------------------------------------------
   MN    0.000     0.000
   SD     0.00      0.00
   CV     0.00 %    0.00 %

              PEAK PROFILE
        0                                 800mV
   0

  10

        DATE   04 (APR) -17-2015 10:52
```

Figure 30: Total Organic Carbon for Compost B.



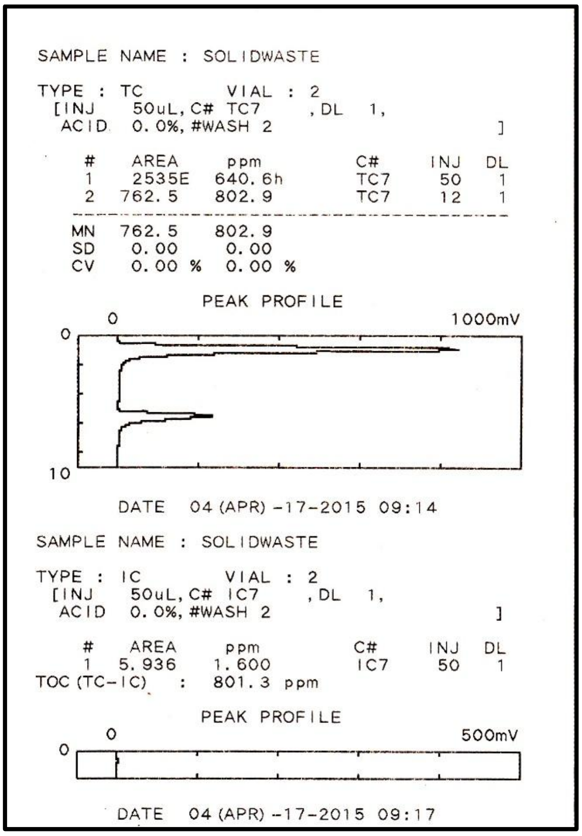
```
SAMPLE NAME : SOLIDWASTE

TYPE : TC          VIAL : 4
 [INJ   50uL, C# TC7     , DL   1,
  ACID  0.0%, #WASH 2                   ]

    #    AREA     ppm        C#    INJ  DL
    1    2079E   525.4n      TC7    50   1
    2   872.2    509.4       TC4    20   1
   -----------------------------------------
   MN   872.2     509.4
   SD    0.00      0.00
   CV    0.00 %   0.00 %

              PEAK PROFILE
       0                          1000mV
  0

        DATE   04(APR)-17-2015 11:05
SAMPLE NAME : SOLIDWASTE

TYPE : IC          VIAL : 4
 [INJ   50uL, C# IC7     , DL   1,
  ACID  0.0%, #WASH 2                   ]

    #    AREA     ppm        C#    INJ  DL
    1   16.15    4.353       IC7    50   1
TOC(TC-IC)   :   505.1 ppm

              PEAK PROFILE
       0                          500mV
  0

        DATE   04(APR)-17-2015 11:08
```

Figure 31: Total Organic Carbon for Compost C.



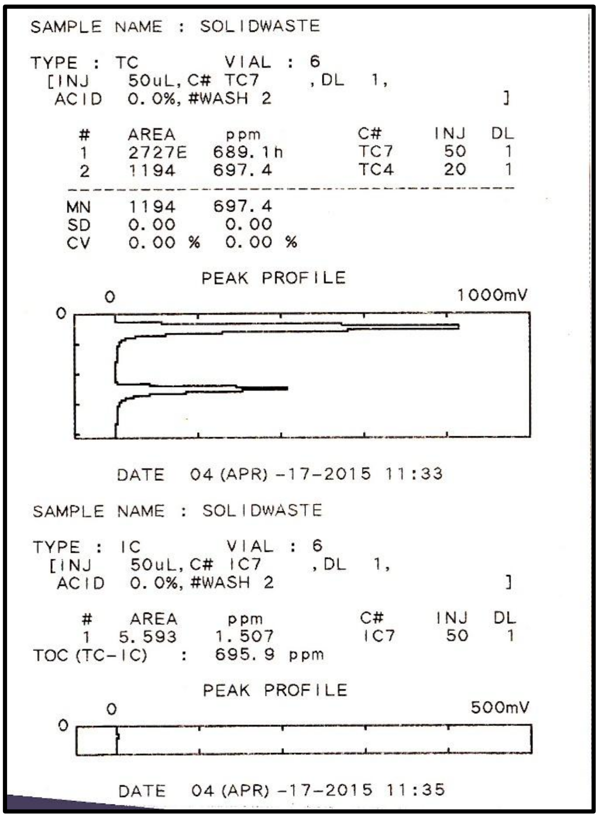
```
SAMPLE NAME : SOLIDWASTE

TYPE : TC          VIAL : 5
 [INJ   50uL, C# TC7     , DL   1,
  ACID  0.0%, #WASH 2                   ]

    #    AREA     ppm        C#    INJ  DL
    1    1808E   456.9h      TC7    50   1
    2    1472    438.2       TC5    40   1
   -----------------------------------------
   MN    1472     438.2
   SD    0.00      0.00
   CV    0.00 %   0.00 %

              PEAK PROFILE
       0                          1000mV
  0

        DATE   04(APR)-17-2015 11:19
SAMPLE NAME : SOLIDWASTE

TYPE : IC          VIAL : 5
 [INJ   50uL, C# IC7     , DL   1,
  ACID  0.0%, #WASH 2                   ]

    #    AREA     ppm        C#    INJ  DL
    1   9.378    2.528       IC7    50   1
TOC(TC-IC)   :   435.7 ppm

              PEAK PROFILE
       0                          500mV
  0

        DATE   04(APR)-17-2015 11:21
```

Figure 32: Total Organic Carbon for Compost D.



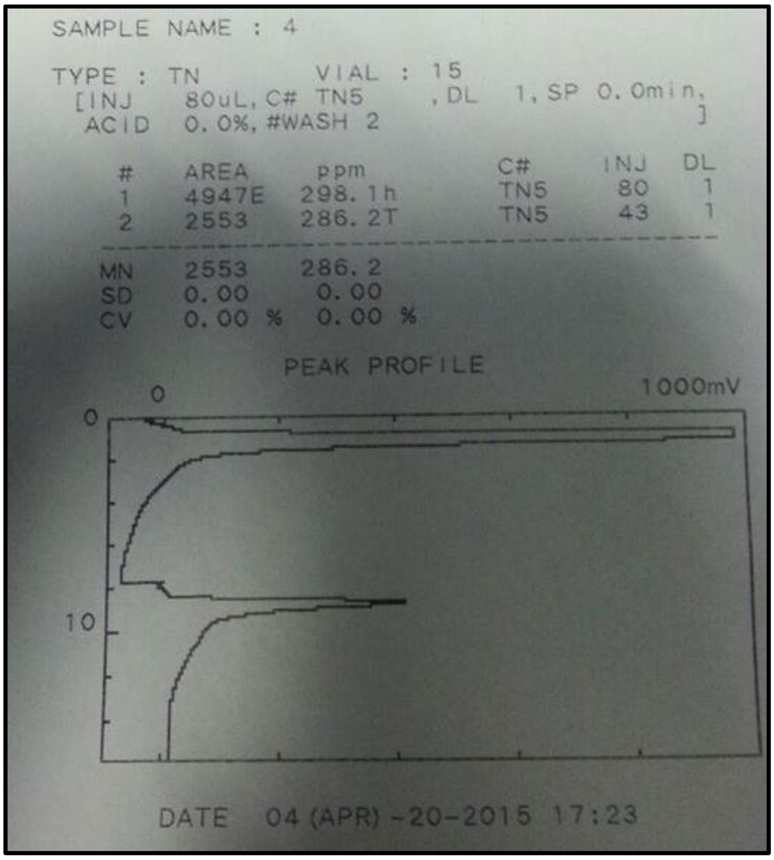
```
SAMPLE NAME : SOLIDWASTE

TYPE : TC          VIAL : 2
 [INJ    50uL,C# TC7     ,DL   1,
  ACID   0.0%,#WASH 2                   ]

    #    AREA     ppm        C#     INJ  DL
    1    2535E   640.6h      TC7     50   1
    2   762.5    802.9       TC7     12   1
   -------------------------------------------
   MN   762.5    802.9
   SD    0.00     0.00
   CV    0.00 %   0.00 %

              PEAK PROFILE
       0                          1000mV
 0

 10

       DATE   04(APR)-17-2015 09:14
SAMPLE NAME : SOLIDWASTE

TYPE : IC          VIAL : 2
 [INJ    50uL,C# IC7     ,DL   1,
  ACID   0.0%,#WASH 2                   ]

    #    AREA     ppm        C#     INJ  DL
    1   5.936    1.600       IC7     50   1
TOC(TC-IC)   :   801.3 ppm

              PEAK PROFILE
       0                          500mV
 0

       DATE   04(APR)-17-2015 09:17
```

Figure 33: Total Organic Carbon for Initial Compost.



```
SAMPLE NAME : SOLIDWASTE

TYPE : TC          VIAL : 6
 [INJ    50uL,C# TC7     ,DL   1,
  ACID   0.0%,#WASH 2                   ]

    #    AREA     ppm        C#     INJ  DL
    1    2727E   689.1h      TC7     50   1
    2    1194    697.4       TC4     20   1
   -------------------------------------------
   MN    1194    697.4
   SD    0.00     0.00
   CV    0.00 %   0.00 %

              PEAK PROFILE
       0                          1000mV
 0

       DATE   04(APR)-17-2015 11:33
SAMPLE NAME : SOLIDWASTE

TYPE : IC          VIAL : 6
 [INJ    50uL,C# IC7     ,DL   1,
  ACID   0.0%,#WASH 2                   ]

    #    AREA     ppm        C#     INJ  DL
    1   5.593    1.507       IC7     50   1
TOC(TC-IC)   :   695.9 ppm

              PEAK PROFILE
       0                          500mV
 0

       DATE   04(APR)-17-2015 11:35
```

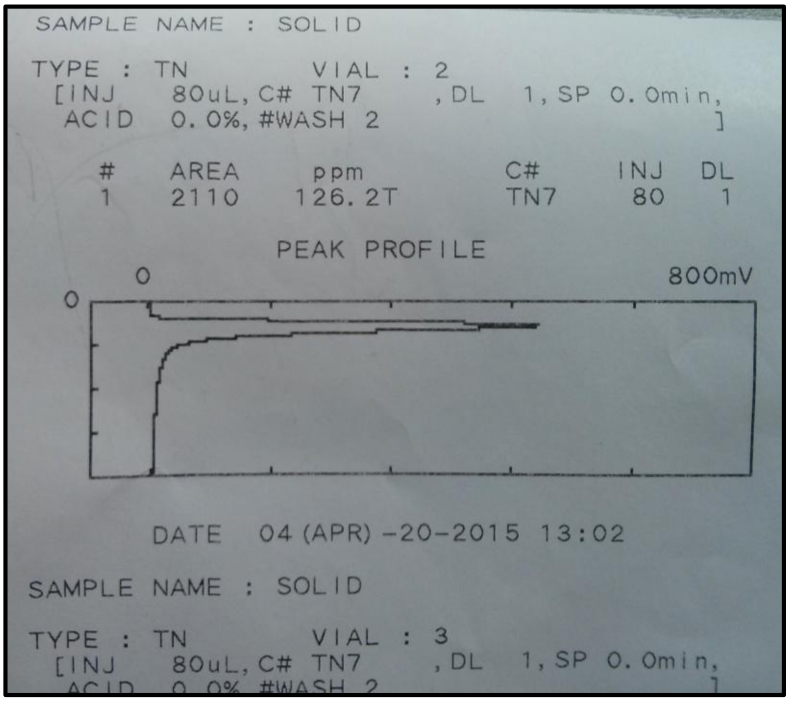
Figure 34: Total Organic Carbon for Commercial Compost.



```
SAMPLE NAME : 4

TYPE : TN          VIAL : 15
  [INJ    80uL, C# TN5      , DL   1, SP  0.0min,
   ACID   0.0%, #WASH 2                         ]

     #    AREA      ppm          C#      INJ   DL
     1    4947E    298.1h        TN5      80    1
     2    2553     286.2T        TN5      43    1
   ----------------------------------------------
    MN    2553     286.2
    SD    0.00      0.00
    CV    0.00 %    0.00 %

                PEAK PROFILE
```

```
     DATE   04(APR)-20-2015 17:23
```

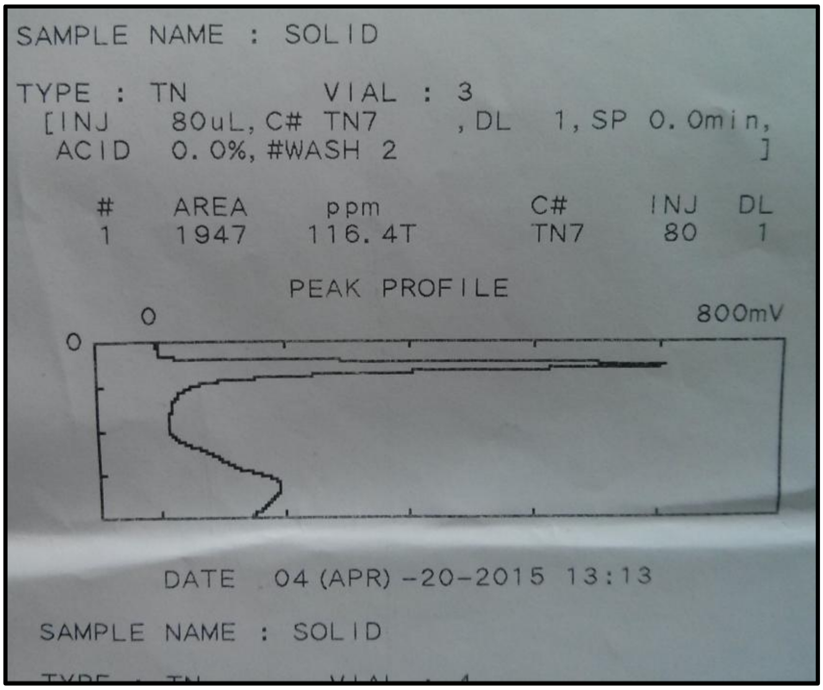
Figure 35: Total Kjeldahl Nitrogen for Compost A.



```
SAMPLE NAME : SOLID

TYPE : TN          VIAL : 2
  [INJ    80uL, C# TN7      , DL   1, SP  0.0min,
   ACID   0.0%, #WASH 2                         ]

     #    AREA      ppm          C#      INJ   DL
     1    2110     126.2T        TN7      80    1

                PEAK PROFILE
```

```
     DATE   04(APR)-20-2015 13:02

SAMPLE NAME : SOLID

TYPE : TN          VIAL : 3
  [INJ    80uL, C# TN7      , DL   1, SP  0.0min,
   ACID   0.0%, #WASH 2                         ]
```

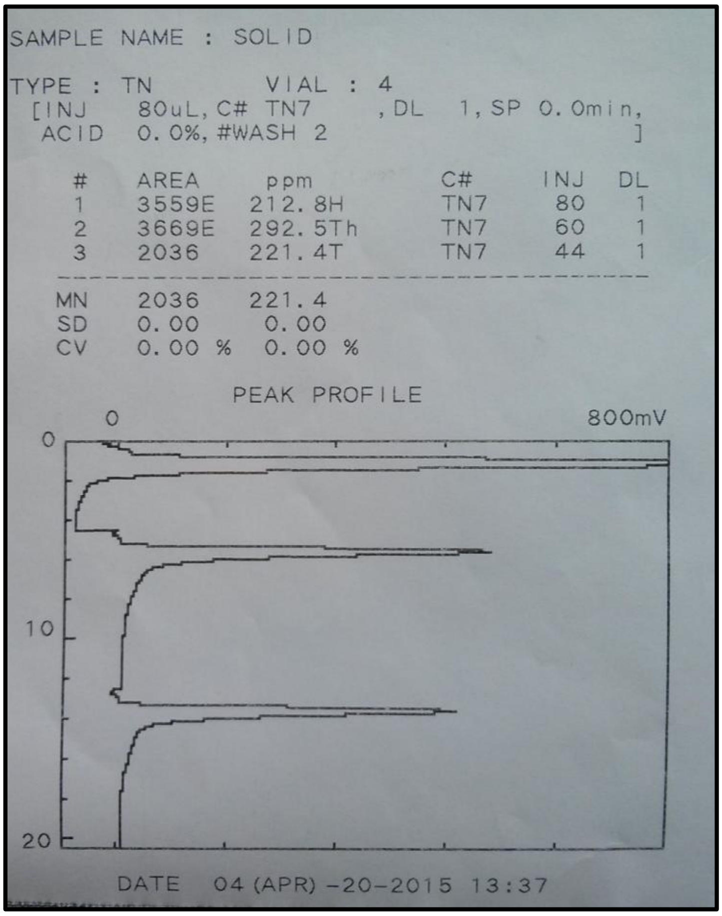
Figure 36: Total Kjeldahl Nitrogen for Compost B.



```
SAMPLE NAME : SOLID

TYPE : TN          VIAL : 3
 [INJ    80uL, C# TN7      , DL   1, SP 0.0min,
  ACID   0.0%, #WASH 2                        ]

    #    AREA      ppm          C#      INJ   DL
    1    1947    116.4T         TN7      80    1

                  PEAK PROFILE
```

```
          DATE  04(APR)-20-2015 13:13

  SAMPLE NAME : SOLID
```

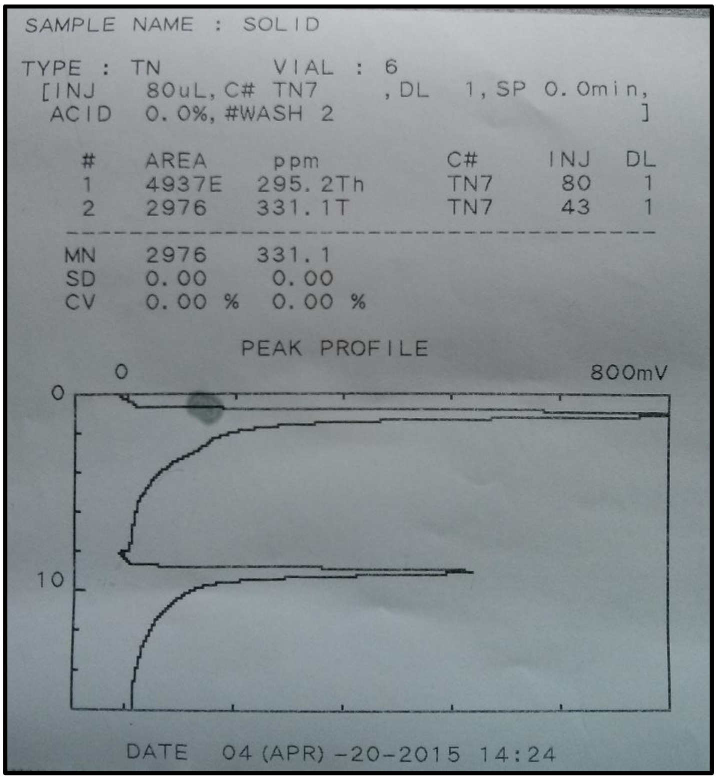
Figure 37: Total Kjeldahl Nitrogen for Compost C.



```
SAMPLE NAME : SOLID

TYPE : TN          VIAL : 4
 [INJ    80uL, C# TN7      , DL   1, SP 0.0min,
  ACID   0.0%, #WASH 2                        ]

    #    AREA     ppm           C#     INJ   DL
    1    3559E    212.8H        TN7     80    1
    2    3669E    292.5Th       TN7     60    1
    3    2036     221.4T        TN7     44    1
   ------------------------------------------------
   MN    2036     221.4
   SD    0.00       0.00
   CV    0.00 %     0.00 %

                 PEAK PROFILE
```

```
       DATE  04(APR)-20-2015 13:37
```

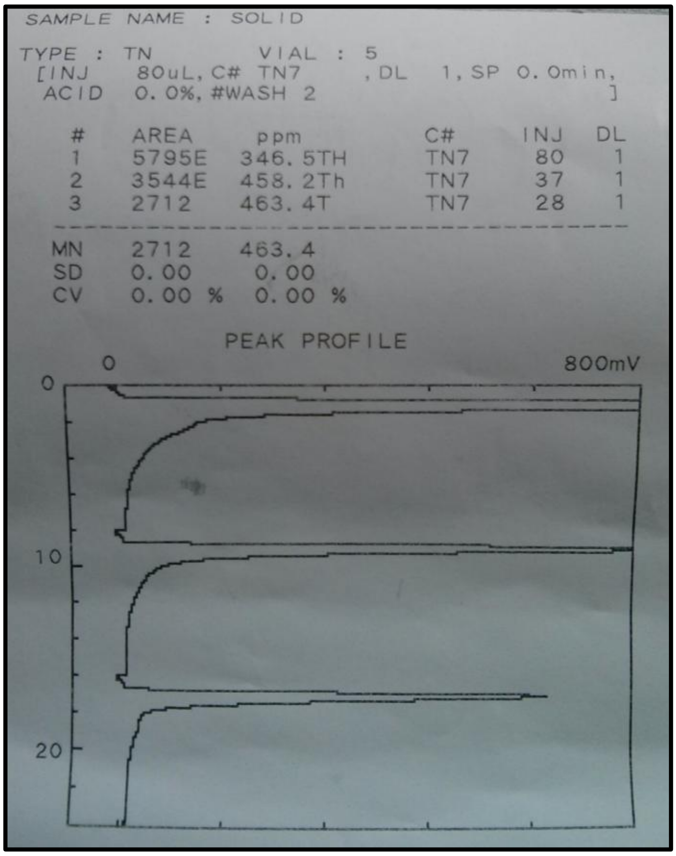
Figure 38: Total Kjeldahl Nitrogen for Compost D.



```
SAMPLE NAME : SOLID

TYPE : TN          VIAL : 6
 [INJ   80uL,C# TN7      ,DL   1,SP 0.0min,
  ACID  0.0%,#WASH 2                        ]

    #    AREA     ppm          C#     INJ   DL
    1    4937E   295.2Th       TN7     80    1
    2    2976    331.1T        TN7     43    1
  --------------------------------------------
   MN    2976    331.1
   SD    0.00     0.00
   CV    0.00 %   0.00 %

              PEAK PROFILE
```

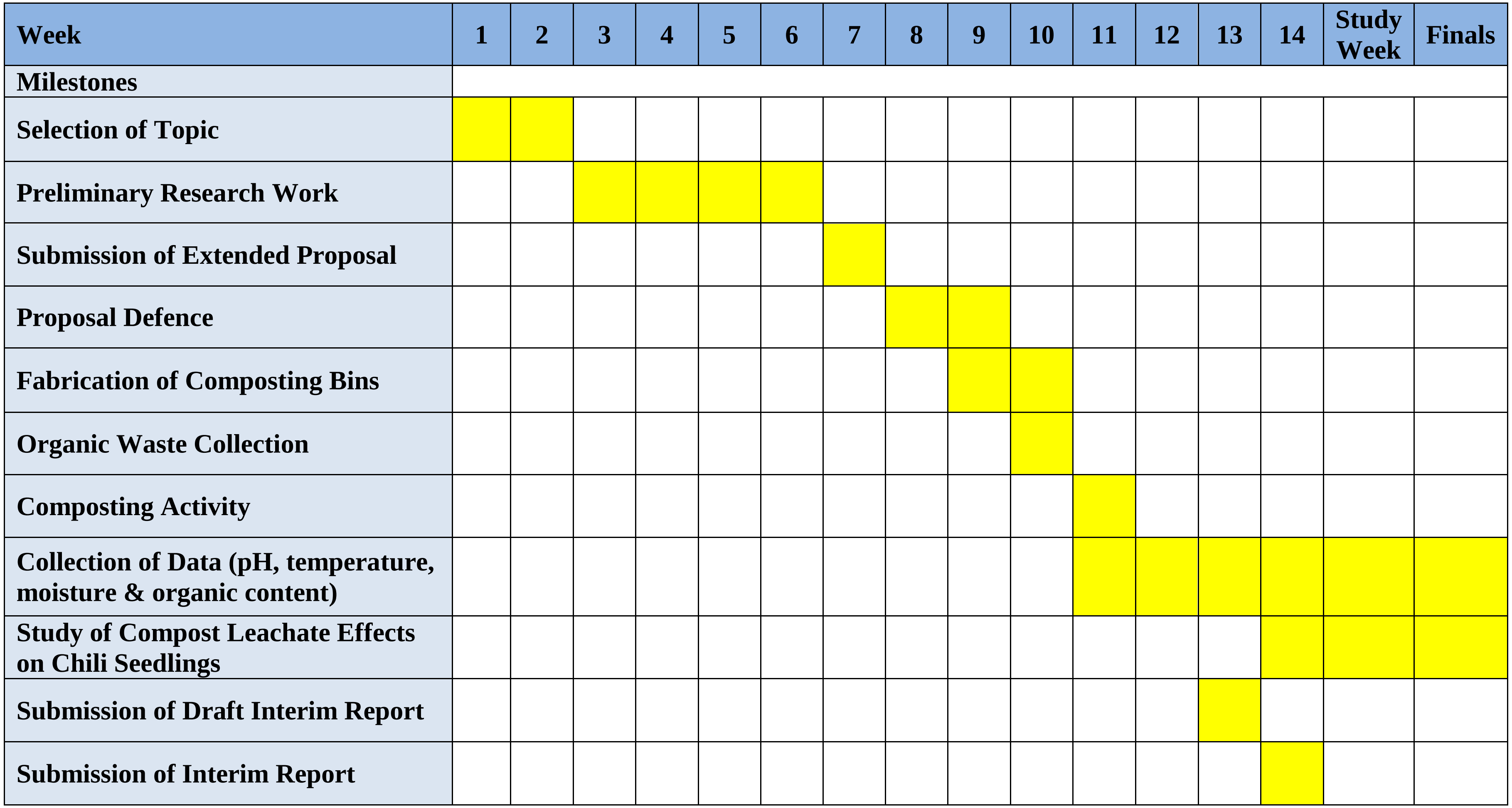
```
        DATE   04(APR)-20-2015 14:24
```

Figure 39: Total Kjeldahl Nitrogen for Initial Compost.



```
SAMPLE NAME : SOLID

TYPE : TN          VIAL : 5
 [INJ   80uL,C# TN7      ,DL   1,SP 0.0min,
  ACID  0.0%,#WASH 2                        ]

    #    AREA     ppm          C#     INJ   DL
    1    5795E   346.5TH       TN7     80    1
    2    3544E   458.2Th       TN7     37    1
    3    2712    463.4T        TN7     28    1
  --------------------------------------------
   MN    2712    463.4
   SD    0.00     0.00
   CV    0.00 %   0.00 %

              PEAK PROFILE
```

Figure 40: Total Kjeldahl Nitrogen for Commercial Compost.



Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Study Week	Finals
Milestones																
Selection of Topic	🟨	🟨														
Preliminary Research Work			🟨	🟨	🟨	🟨										
Submission of Extended Proposal							🟨									
Proposal Defence								🟨	🟨							
Fabrication of Composting Bins									🟨	🟨						
Organic Waste Collection										🟨						
Composting Activity											🟨					
Collection of Data (pH, temperature, moisture & organic content)											🟨	🟨	🟨	🟨	🟨	🟨
Study of Compost Leachate Effects on Chili Seedlings														🟨	🟨	🟨
Submission of Draft Interim Report													🟨			
Submission of Interim Report														🟨		

Figure 41: Gantt Chart for Final Year Project 1.

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Milestones															
Collection of Data (pH, temperature, moisture & organic content)	🟨	🟨	🟨	🟨											
Calculation and Analysis of Data					🟨	🟨	🟨								
Submission of Progress Report							🟨								
Preparation for Dissertation and Final Report								🟨	🟨						
Pre-SEDEX										🟨					
Submission of Draft Final Report											🟨				
Submission of Dissertation (soft bound)												🟨			
Submission of Technical Paper												🟨			
Viva													🟨		
Submission of Dissertation (hard bound)															🟨

Figure 42: Gantt Chart for Final Year Project 2.