CERTIFICATION OF APPROVAL

Management and Processing of Waste Generated In UTP Cafeterias

by

Mzolisi Gulwa

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

____

(Name of Main Supervisor)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
December 2008

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.

MZOLISI GULWA

ABSTRACT

Management and processing of waste is motivated by concern for public health in this case the public being the community of UTP. The problem of waste management at the university is evident from the stagnant dirty water (which is direct result food waste) found in the open channels that come from the cafeterias. This raises concerns about the health and aesthetics of the campus and this is a problem that needs a solution. The management and processing of waste generated at canteens was tried to be solved by application of the composting process. The waste was collected from the busiest and biggest canteen (village four) on campus. After the collection it was transported to the composting site behind block13 for the start of the composting. The waste generated at these canteens consists of food waste, plastics, cardboards, tins and cans. Their compositions by percentage weight are 69, 14, 9 and 8% respectively. Food waste contains the most energy with a value of 137 667.9 kJ daily and the total energy that can be recovered amounts to 445 344.9 kJ. Yard waste is one of the largest wastes generated at UTP and it was used mainly to adjust the C/N ratio by providing a high carbon concentration to balance nitrogen rich food waste. Sludge is also used in some of the experimental runs as way to determine if the introduction of microorganisms has an effect compared to naturally occurring composting. The parameters used to monitor the process were moisture content, temperature, pH and C/N ratio. Eight different batches consisting of different compositions of feedstock were used in order to find the right mixture of the feedstock which will be recommended for the actual processing of the waste. Four of these eight bathes commenced naturally and in the other four microbes was introduced in the form sludge. pH fluctuated around the neutral value for almost all the batches. Batches with bigger percentage of yard waste were poor in maintaining any moisture and the more food waste a batch contained the better in maintaining the moisture. Temperature was not a useful parameter as it did not deviate much around the surrounding environment temperature of 28°C. After seven weeks it was that the addition of sludge had no effect in the process. After comparing the batches' physical characteristics batch C (food waste: 60%, yard waste: 40%) was the best performing batch with batch A (100% food waste) being the worst performing batch.

AKNOWLEDGEMENTS

I am grateful to Dr. Amirhossein Malakahmad, Department of Civil Engineering, for his technical help, splendid guidance and valuable suggestions throughout the course of this project. Whom without his continuous encouragement and unwavering patience, would have been extremely difficult to maintain my focus.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

Solid waste management involves many categories that are interdependent and these include waste generation, handling of the waste, storage, collection, transportation, processing and finally disposal of the waste (Tchobenoglous, Kreith and Williams, 2002).

Ideally when dealing with solid waste the hierarchy options noted by the US EPA are source reduction, recycling and composting, waste transformation and land filling.

Source reduction refers to methods applied to prevent the waste from ever forming. This can be practiced by both consumers and manufacturers. Consumers can be involved in this option by using their products more efficiently. The manufacturer's role can be practiced by manufacturing of products that are more durable and less toxic thereby increasing their lifespan.

Recycling is the separation of reusable materials from the waste and returning them to the manufacturer for reuse in making the same products. Composting can be seen as another form recycling as it stabilizes waste for reuse in soil amendment or as a growing medium.

Waste transformation which can also be referred to as waste-to-energy techniques involves taking advantage of the energy content of the waste. Some processes to achieve this include incineration and anaerobic digestion. Both these processes require a high degree of technical skills to be applied safely and economically.

Land filling should be the last option to be considered when dealing with solid waste management. Even so this option is usually unavoidable.

In UTP not all of these options are applied to the waste that is generated at cafeterias. The waste generated is collected, stored and then transported to disposal. This waste is stored as it was collected without any separation. The main sources of waste generated at UTP cafeterias is from over preparation of food, leftovers from plates of consumers of the prepared food, cooking losses, spoiled food and packaging and spills.

The waste generated at cafeterias of UTP consists of food waste, plastics, cardboards, paper, tins and cans. The main problems which pose health risks are associated with the food waste. The foul smells around the cafeterias are caused by the food waste. Also as a direct consequence of food waste there is sometimes dirty water found in the open channels behind the cafeterias.

With regard to the options recommended by the US EPA for sold waste management, this project focused on option two of the hierarchy recycling and composting particularly composting.

Composting is a process whereby microorganisms breakdown organic matter to form a soil like material called humus rich in nutrients which can be used as a growing medium. For a successful composting to occur there are certain parameters that have to be satisfied. Some of these parameters include temperature, moisture content, pH and C/N ratio.

Concerning the C/N ratio these two elements have to be balanced such that this ratio is thirty (Cornell waste institute, 1990) but this is an ideal value. The food waste from UTP kitchens contains a lot of moist green vegetables and fruits rich in nitrogen. Because of this another ingredient rich in carbon is needed for the compost to balance this high nitrogen content. Yard waste comprising of dry brown leaves will be used for this purpose. The brown color of the leaves caused by deterioration after falling from trees indicates high carbon content (Trautmann, Cornell).

Composting occurs naturally but microorganisms can be introduced to start off the process. Bacteria will be introduced to compost in the form of sludge. This sludge will be colleted at the university's sewage treatment plant.

For this project eight experimental batches of different compositions will be used to find the best performing mixture of these materials (food waste, yard waste and sludge). Of the eight batches four will commence naturally and the other four will contain sludge to see the effect of introducing bacteria compared to naturally occurring compost.

Temperature, moisture content, pH and C/N ratio will be the parameters used to monitor the composting process.

A simple thermometer will be used fro the recordings of the temperature. Dry and wet weights of compost extracts will be used for moisture content calculations. pH measurements will be done on compost extracts using a laboratory pH meter. The two elements carbon and nitrogen, total organic carbon (TOC) and total kjeldahl nitrogen machines will be used.

After the composts have matured and stabilized they will be compared to each other to choose which one of the eight compositions performed the best

1.1 Problem statement

Primarily management and processing of waste is motivated by concern for public health in this case the community of UTP being the public. The waste generated at UTP cafeterias consists of food waste, plastics, cardboards, paper, tins and cans. The plastics, cardboards, paper, tins and cans do not pose a problem to the health of UTP. The fore the main problem lies with food waste. The overnight storage of this food waste produces a foul smell of which the buildup poses a health problem. Stagnant wastewater is sometimes seen in the open channels behind the cafeterias. This is a direct result of the food waste that is generated at these kitchens. These problems associated with food waste raises concerns about health and aesthetics of the campus. This project is going to address the problems associated with waste generated at these cafeterias especially the ones associated with food waste.

1.2 Objectives

The general objective of this project is to find an environmentally friendly, preferably low tech, engineering method that is not expensive to the problems associated with management and processing of waste generated by the kitchens on university campus. More precisely:

- Eliminate or reduce the negative effects of food waste at cafeterias using composting
- Find the best composition of food waste and yard waste to use in composting
- Determine the effects of introducing microorganisms (sludge) in composting food waste as opposed to naturally occurring compost

1.3Scope of study

UTP has nine cafeterias in total. Two are situated at the new academic complex, one at the old campus academic campus and the remaining six at the residential villages. The six village cafeterias have the almost the same menus and the ones on campus at the new complex are the same. Considering the availability of time and the amount of waste generated at these canteens only the biggest and busiest canteen will be considered for the purpose of this project. As a result village four will be the cafeteria of choice.

Chapter 2: Literature Review and Theory

2.1 Composting theory

Composting is a process by which bacteria break down organic matter in order to stabilize it to produce carbon dioxide, water, heat and humus. Humus is a dark earth (soil like) organic material such as such as decayed leaves and plants. The carbon dioxide comes from the conversion of oxygen.

This part of the report reiterates parts of the literature review concerning the composting process. It discusses the physical, chemical and biological characteristics of the process. In addition to these sections it will also discuss the methods employed in monitoring the process. These methods are for total organic carbon (TOC), total kjeldahl nitrogen (TKN), temperature, pH and moisture content.

2.1.1 Physical parameters

The composting process is affected by many factors including physical characteristics of the compost feedstock. The key factors concerned in this section are temperature, moisture content and particle size.

(a) Temperature

The temperature is one of the most important parameter because it shows the progress of composting. The heat produced during composting is a by-product of the process which is dependant on other factors such as size of pile, moisture content, the type of aeration and carbon to nitrogen ratio. The Environmental protection agency (U.S) has a regulation that temperature should be kept at minimum operating conditions of 40°C for five days to achieve significant pathogen reduction plus four hours of temperatures exceeding 55°C in that same period.

(b) Particle size

The particle size of the feedstock affects the rate at which the composting progresses. Small sized particles have more surface area for the reaction to take place which facilitate the rate of the process by increasing it.

(c) Moisture content

The moisture content of the compost is another important factor and has to be kept in the range between 50 to 60% according to Nancy Trautman of Cornell University and Haug (1993). At lower levels percentages the activity of the microorganisms is limited. At higher levels above 60%, the aerobic process becomes anaerobic and it starts to smell.

The size and shape of the compost system is critical to the aeration of the system. These factors also determine if the system will lose or retain the heat it produces.

2.1.2 Chemical parameters

This section discusses the chemical aspects of the composting process. Carbon and nitrogen are the most important elements for a successful experiment. Carbon to nitrogen ratio is a way to keep these elements within limits. The carbon is used as an energy source by bacteria and is also used as a building block of microorganism's cells. Nitrogen is vital to the function and growth of these microbes. This ratio is optimum at thirty according to the Cornell waste institute. This is due to that the carbon is converted thirty times faster than the nitrogen is used up. If this ratio is lower than optimum, this means than the nitrogen is in excess of the optimum. Excess nitrogen results in nitrogen being converted in ammonia gas distinguished by its suffocating smell. At higher levels of this ratio means that the nitrogen is limited and with less nitrogen there will be a decrease in microbial growth resulting in a slow rate of the process. Usually green moist organic matter is rich in nitrogen and those brown in color are rich in carbon.

White, R.K. maintains that oxygen is critical for the production of carbon dioxide. Without enough oxygen the process might turn anaerobic digestion with undesirable odor. Optimum concentration of oxygen is that greater than 10%

In addition to these elements, minerals and nutrients and pH is one other factor that is chemically significant. Haug (1993) again specifies a pH in the range between 5 and 8.5 around the neutral value. At the beginning of the digestion process the pH drops due to the fact that the bacteria release acid when they break down organic matter. The drop in pH facilitates the growth of the microbes resulting in more bacteria to digest the material. At low pH (<4.5) the activity of the bacteria is limited and may cause anaerobic conditions.

2.1.3 Biological parameters

Composting in general occurs in three stages which can be categorized in terms of temperature. These categories are the mesophillic, thermophillic and the curing or the cooling stage. In these three stages, different cultures of microorganisms are involved.

The microorganisms involved in the mesophillic range rapidly break down the soluble readily available compounds. As bacteria break down the material they produce heat causing the temperature to rise rapidly. This stage is at the beginning of the process and lasts from days to weeks.

After this stage when the temperature is above 40°C another type of microorganism take over from the mesophillic bacteria. The microorganisms involved here are called thermophillic bacteria. The optimum range of temperature for this type of bacteria is between 40°C and 60°C. The advantage to this type of bacteria is that at these temperatures pathogens are destroyed. During this stage the break down is of more resistant compounds such as lignin which are not readily available for biological reaction.

2.2 Energy content

As it was stated before that one of the option that can be considered in waste management is waste transformation into energy. The energy that can be extracted from waste material can be estimated.

Reported below in the table form Environmental Engineering, Howard Peavy and Donald Rowe are typical energy content figures for solid waste material. It contains a range of values for each group components of the waste.

Table 1. Typical data on energy contents of different waste materials

Component	Range (kJ / kg)	Typical (kJ / kg)
Food waste	3 500 – 7 000	4 650
Paper	11 600 - 18 600	16 750
Cardboard	13 950 – 17 450	16 300
Plastics	27 900 – 37 200	32 600
Textiles	15 100 – 18 600	17 450
Rubber	2 300 - 18 600	23 250
Leather	15 100 – 19 800	17 450
Garden trimmings	2 300 – 18 600	6 500
Wood	17 450 – 19 800	18 600
Misc. organics	11 000 - 26 000	18 000
Glass	100 - 250	150
Tin cans	250 - 1 200	700
Ferrous metals	250 - 1 200	700
Dirt, ashes, brick etc.	2 300 – 11 650	7 000
Municipal solid waste	9 300 – 12 800	10 500

(Source: Environmental engineering, Howard et al.)

These values can be used to estimate energy that can be extracted from the waste using the waste generation rate multiplied by the values in the above table.

Food waste composting optimization and standard design has not been perfected yet due to the fact that food waste compositions vary greatly due to different eating habits from place to place (Chang, 2008). The effects of compositions on food waste composting using weight fractions of carbohydrates, protein and fats in order to predict important parameters (composting time, peak temperature, final and lowest pH values, carbon dioxide accumulation etc.) was investigated by James Chang.

In this investigation synthetic food waste was used as feedstock for the process. The experimental setup was made up of twelve runs in total. The food waste was prepared in such a way that the C/N ratio ranged between 12.8 and 56.6 and the compositions had different fractions of carbohydrates, protein and fats. The assumption was that only these were active for the biological reaction and all other minor components were inert and did not affect the composting process.

One of the terms defined in this paper was acidification time. It is defined as the time required for the pH to reach its minimum value. It is further explained that as the bacteria start to degrade the material they produce acid and these acid are in turn broken down further as the process goes on. The rates (acid accumulation and acid degradation) at which these two phenomenons happen are not equal at first. The acid accumulation rate is greater that the acid degradation rate as the acid is produced continuously. This causes the pH to drop. The acid degradation rate picks up until a point where these two rates are equal and this is the point when pH reaches its minimum.

The results showed that the experimental runs with more nitrogen finished quicker that others and the degradation in these runs was faster. The runs with more fat than others showed slow rate. This is explained by the fact that nitrogen facilitates the growth of microorganisms.

The results also showed sharp temperature peak and minor broader peaks. The sharp peaks are interpreted as the degradation of easily degradable materials like simple sugars and these occur in the early stages of the process. The broader peaks which occurred later in the process were the degradation of much harder material to degrade such as plant cell structures.

Chapter 3: Methodology

The methodology used in this project is divided into three categories or stages comprising namely of collection, transportation and process monitoring. Collection will entail details of how and where the waste was acquired and stored before transporting it to the composting site (behind block 13) for the experiments. The experiments to be carried out will be using three components material namely food waste, yard waste and sludge. The yard waste will consist of brown dry leaves collected from the area between village two and the lecturer's village. Before the experiments begin the yard waste will be shredded first. Considering the hours for the collection (7am – 10pm) the transportation of the waste to block 13 will take place in the hours after 10pm after the cafeterias are closed. The food waste will be collected from village four cafeterias and the sludge will be collected from UTP sewage treatment plant. A wheelbarrow from the concrete laboratory will be used for the transportation from village four to block 13. The three categories mentioned earlier will detail the events beginning from the collection of the feedstock to the beginning of the last stage which is the start of the experiments.

3.1 Collection

3.1.1 Food waste

The food waste was collected from village four cafeterias between the hours seven (when the canteens open) in the morning and ten in the evening (when the canteens close). Between these hours the food waste is stored in garbage bags which are left open in the bins. The reason for keeping them open is to allow for the oxygen to pass through the waste to avoid anaerobic conditions to develop. After the canteens are closed the food waste is sifted of the material that is not food and kept or packed in separate garbage bags ready for transportation to building 13 for the experiments. The waste is kept in the cold storage in the environmental laboratory ready for the experiments.

3.1.2 Yard waste

This component material consists of leaves which are dry and brown in color high in carbon content to match up nitrogen rich food waste from the vegetables and fruits. The area behind village two is filled with trees which are fully grown. The leaves that fall from the trees are collected and stored in refuse bags every week. This component is actually very abundant all around the campus where ever there are trees. Arrangements have been made for some of the refuse bags to be taken to block13 for the experiments. Before the experiments starts the yard waste will be shredded in order to facilitate faster reactions due to more surface area that is exposed. Below are two figures 1 and 2 which show the yard waste (leaves). In these figures the yard waste is shown before and after they are shredded for the experiments.

Figure 1. Yard waste before shredding

Figure 2. Yard waste after being shredded

3.1.3 Sludge

Composting is a naturally occurring process but even so microorganisms can be introduced into a system in order to start it off. In this project four out of the eight compositions will contain sludge for purposes of introducing the microorganisms. This is done with intention of evaluating if this introduction is necessary or not in terms of speed of the process.

The sludge will be acquired from the UTP sewage treatment plant during its operating hours between 8am and 5pm. This sludge will be collected from drying beds of the sewage treatment plant. The condition of the sludge to be used here is such it is very dry physically and has a brown color. It will also be collected and stored in the same manner as the food waste.

3.2 Transportation

This stage will take place after collection is done. After the canteens are closed at ten in the evening the waste will be stored in open containers overnight. A wheelbarrow will be used to carry the food waste from village four to block 14. This wheelbarrow will be borrowed from the concrete laboratory. The leaves will not pose the same difficulty as the food waste in terms of weight; they are significantly lighter, implying easy transportation. Upon delivery of the yard waste to block 14 it will be shredded first before the experiments starts to facilitate the chemical and biological reactions by providing more surface area. The sludge will be transported immediately after the collection to the environmental laboratory and stored in the cold storage before it is used in the experiments.

3.3 Process monitoring

This part of the methodology is the beginning of the experiments and the whole progress of composting. The key parameters to be monitored for the experiments are temperature, pH, total organic carbon, total kjeldahl nitrogen and moisture content. The experiments are divided into eight bathes designated A to H with different compositions of the feedstock. Compost extracts will be taken from the batches once every week for monitoring the progress of the composting using the mentioned parameters. The eight batches are divided into two divisions of four. One division is laced with sludge (A to D) and the other without the sludge (D to H).

The compositions of the batches are as follows;

Table 2. Batch compositions without the sludge

Batch	Kitchen waste (%)	Yard waste (%)
A	100	0
B	85	15
C	60	40
D	35	65

Table 3. Batch compositions with the sludge

Batch	Kitchen waste (%)	Yard waste (%)	Sludge (%)
E	80	0	20
F	75	5	20
G	55	25	20
H	30	50	20

The percentages in the above tables indicate percentages of the total weight of the ingredients. The total weight of each experiment is four kilograms. These weight compositions are largely due to the availability of the components.

The composts were carried out in food plastics baskets shown in the following figure.

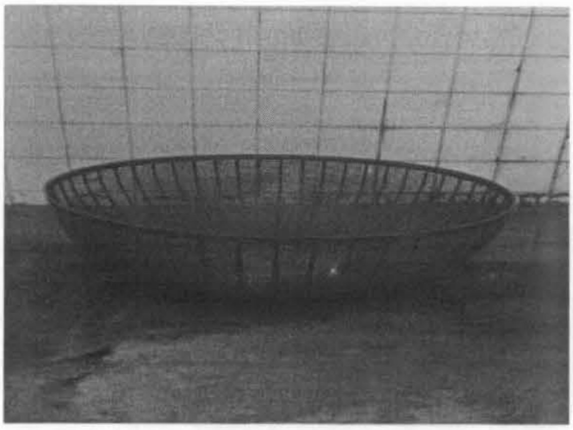


Figure 3. The plastic baskets in which the composts were carried out

3.4 Methods

The progress of the compost system can be observed or measured in many different ways. Total organic carbon, total nitrogen, temperature, pH and moisture content will be used as parameters to monitor the compost progress in this project. This section will detail how each of these parameters will be used to monitor the progress and give details of the procedures.

3.4.1 Total organic carbon (TOC)

TOC is total organic carbon is a measure of all the carbon a substance contains. Its value is measured in a total organic carbon machine and is given in percentages. In order to use this equipment the sample to be measured must be oven-dried beforehand. The steps followed in the procedure are;

- Dry a small sample for 24 hours in a 105-110 C Celsius oven;
- Place a small piece of fiber in a quartz sample cup;
- Measure not more than 50 mg of the material;
- Place the material on top of the fiber in the quartz sample cup;
- Place the cup inside into TOC machine;
- Start the procedure;
- Record the results.

3.4.2 Temperature

Composting is best kept at temperatures greater than 40 C. Although composting occurs at lower temperatures (as lower as 10 C), at these temperatures the microorganisms perform at their best. If the temperature rises up to levels greater than 50 C pathogens will be destroyed. If temperature rises above 65 C the microorganisms will start to die so temperature must be kept lower than this value. At the beginning of the process the temperature will rise to about 50 to 60 C and stay at these levels for days up weeks cited from the practical handbook of composting engineering by Haug (1993). He also notes that heat generation is a function of the remaining concentration of easily degradable organic matter among other factors. This stage is called the active composting stage. The temperature then gradually drops marking active composting stage slowing down and the curing stage begins.

A thermometer will be used to measure the temperature of the compost. The temperature will be measured in a number of locations because the compost might have hotter and colder pockets which are dependant on moisture content.

3.4.3 pH

pH of compost is a critical parameter to monitor the decomposition. pH of compost is optimum around neutral to acidic (5 to 8) according to Cornell waste management institute and Haug. The acidic environment is conductive for the growth of microorganisms. Organic acids are formed during the first stages of the process and later neutralized resulting in neutral compost.

The method to be used for pH measurements compost is compost extraction and the procedure is as follows;

- Spread compost in a thin layer in a pan, and dry for 24 hours in a 105 to 100 C oven;
- Weigh or measure 5 g sample of the oven dried compost into a small container;
- Add 25 ml distilled water to each sample;
- Mix thoroughly for 5 seconds then let stand for 10 minutes;
- Read pH with calibrated meter.

3.4.4 Moisture content

Composting is very sensitive to the level of moisture of the compost. The best range for compost moisture content is between 40 and 60%. If it is lower than the lower bound of this range , the activity of the microorganisms will be limited. At the other end of this moisture content limit, the compost is too wet and anaerobic conditions will be favored and the compost will develop a foul smell. Moisture content is determined by the following these steps;

- Weigh a small container;
- Weigh 10 g of the material into the container;
- Dry the sample for 24 hours in a 105-110 C oven;
- Reweigh the sample, subtract the weigh of the container and determine the moisture content using the following equation;

$$M_n = \frac{W_w - W_d}{W_w} \times 100$$

In which;

$M_n = moisture\ (\%)\ of\ material\ n;$

$W_d = dry\ weight\ of\ the\ sample;$

$W_w = wet\ weight\ of\ the\ sample.$

3.4.5 Total Kjeldahl Nitrogen (TKN)

This procedure is used to determine the amount of ammonium nitrogen contained in a sample. Concentrated Sulphuric acid is used to digest the sample converting all the nitrogen into ammonium in a phase called digestion. After digestion the sample is distilled in order to trap the ammonia in a boric acid solution. In the last stage of the procedure, the solution is titrated with a dilute solution of Sulphuric acid to determine the ammonia. The step by step procedure provided by the environmental laboratory is given below;

(a) Digestion

- Check list of samples. Check weight to use for liquid and also measure the weight according to the application note. All operations done in the fume board;
- Add Sulphuric acid (98% pure) according to the application note;
- First close the nose;
- Put the nose at the back;
- Place into the digestion unit;
- Hook up exhaust tube to all nose at the back;
- Switch on the scrubber;
- Switch on the water tap;
- Add color indicator;
- Switch on digester unit to 10;
- Digest for 30 minutes;
- Reduce the digester unit to 5;
- Digest for 15 to 20 minutes;
- Switch off digester unit;
- Cool for 30 minutes;
- Switch off the tap water inlet;
- Remove all suction tubes.

(b) Distillation

- Switch on system and warm for 10 minutes;
- Switch on tap water;
- Dilute sample and add 50 ml of distilled water;
- Add 70 ml of Sodium hydroxide;
- Start distillation for 3 minutes;
- Add boric acid (60 ml) for trapping ammonia;
- Stop distiller

(c) Titration

- Titrate using 0.25 M Sulphuric acid using a color indicator;
- Determine volume of Sulphuric acid used to change color
- Calculate TKN using the following formula;

$$\frac{mg}{L} Nitrogen = \frac{(A - B)280}{weight\ of\ sample\ used\ (g)};$$

Where A = volume to titrate the sample and;

B = volume to used to titrate the blank sample.

3.4.6 The bag test

This test is meant to determine if a final compost product is ready for curing or further decomposition is still needed. For this purpose a simple bag test will be performed to determine if the composts is ready for its final storage.

A bag test is performed by following these steps;

- Take a small sample of the compost;
- Wet the sample thoroughly;
- Seal sample in a plastic bag;
- Store the closed plastic bag for week at room temperature.

If after these steps when opening the bag an earthly soil like smell comes out of the bag the compost is ready for its final storage. This method is available at the Pennsylvania state university (college of agricultural science).

Chapter 4: Generation of UTP waste

The flow chart in Figure 4 below describes concisely how the waste at UTP cafeterias is generated. From the raw ingredients the food prepared and used packaging goes straight to the disposal unit. The food is then served and consumed by customers and the leftovers are collected and then stored in refuse bags placed in rubbish bins in the disposal unit. Each cafeteria fills approximately one rubbish bin everyday.

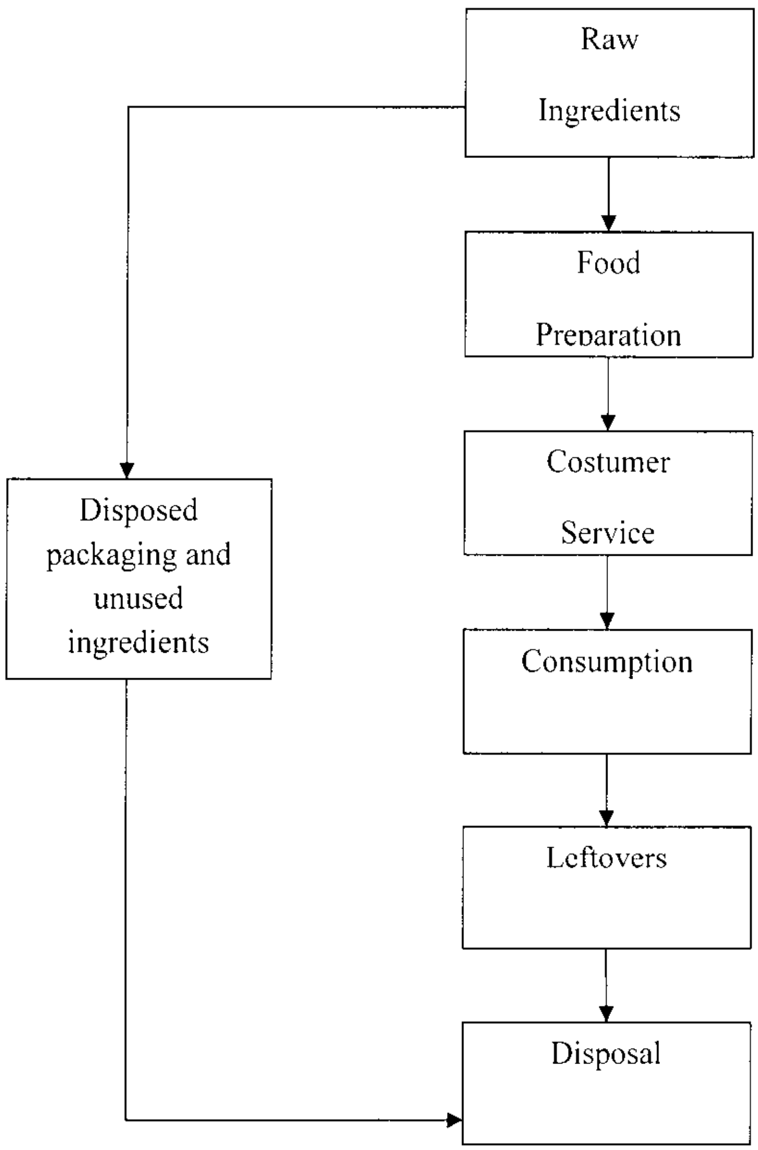


Figure 4. Summary of how the waste is generated at canteens

Below in Figures 5 and 6 shows photos of the disposal units available on campus. These disposal units are storage facilities for the waste. They house rubbish bins but in other cafeterias the rubbish bins are kept outside. In the following photos there are different types of rubbish bins. Figure 5 shows pictures that are kept in the disposal units. The other photo in Figure 6 shows rubbish bins that are used to collect leftovers from plates of customers and then transferred to the other rubbish bins in Figure 5.

Figure 5. Rubbish bin in storage unit in village 2

Figure 6. Bins used to collect food waste from the tables

4.1 Composition analysis

The original plan for the analysis of the waste was to take two canteens of the nine available at UTP, one representing the new complex and the other one representing the residential villages. Over 2-3 weeks each canteen was to be visited three times a week Monday, Wednesday and Friday. During these visits the total waste was to be weighed. Then the waste would be separated into groups corresponding to the type of waste namely food waste, plastics, paper, tins and cans. After this these waste groups would be weighed again to get the percentage proportions of each.

This plan was abandoned after I found out in the first week that it takes at least two to three hours to go through just one rubbish bin performing the above mentioned method. The solution to this was to pick the busiest cafeteria and let that one represent all the UTP cafeterias. Fortunately the busiest canteen was also the biggest canteen which is the village four canteens.

Village four cafeterias have seven rubbish bins. The visits were made in the following two weeks after hours. The time period to do this was between after midnight and eleven in the morning which coincide with the time of collection of the waste.

The waste was divided into groups of food waste (includes paper), plastics, cardboards, banana peels, tins and cans. The scale used for weighing the material has the maximum capacity of 30kg.

4.2 Physical and elemental composition of the waste.

Waste generated at UTP kitchens consists of the following components which are food waste, plastics, paper, cardboards, tins and cans. In terms of their wet weights percentages food waste is the largest followed by plastics, cardboards, tins and cans. After collection the waste is separated into individual components they are all mixed up in the refuse bags. The resulting condition of the waste is such that it becomes pasty. This pastiness is increased by the gravy and oils that are discarded from the kitchen and added to the waste. The refuse bags that are used to store the waste are closed resulting in foul odors to develop.

Food waste

Below in Figure 7 the typical waste before it is collected for transportation to disposal is shown. As evident from the figure the food waste is not separated or sorted in any way.

Figure 7. The condition of the food before collection

Food waste consists of leftovers from plates of customers and also leftovers from the kitchen. Leftovers from the kitchen also consist of food and raw meat (chicken, beef and fish) which is discarded from cooking. Below in Figures 8 and 9 samples of these leftovers that make up the food waste is shown.

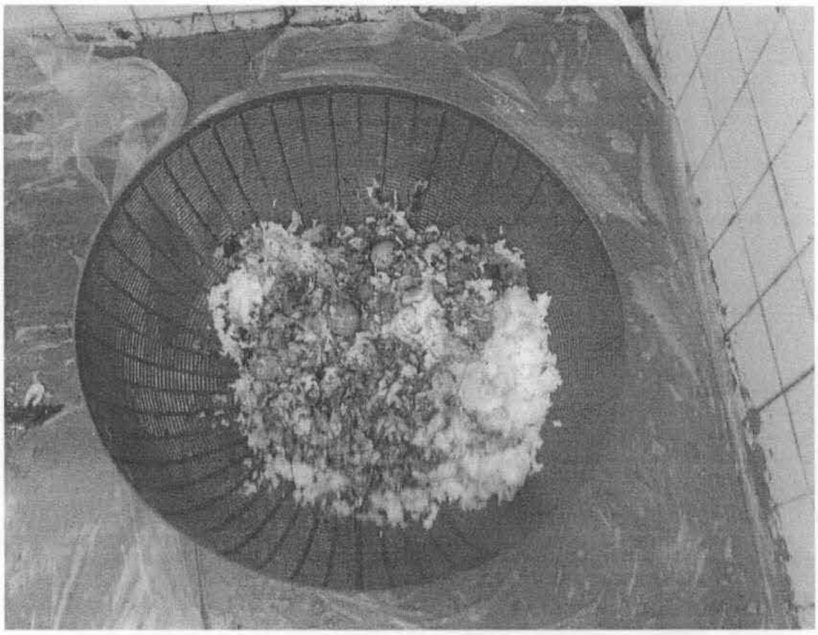


Figure 8. Leftovers from cooking and eating

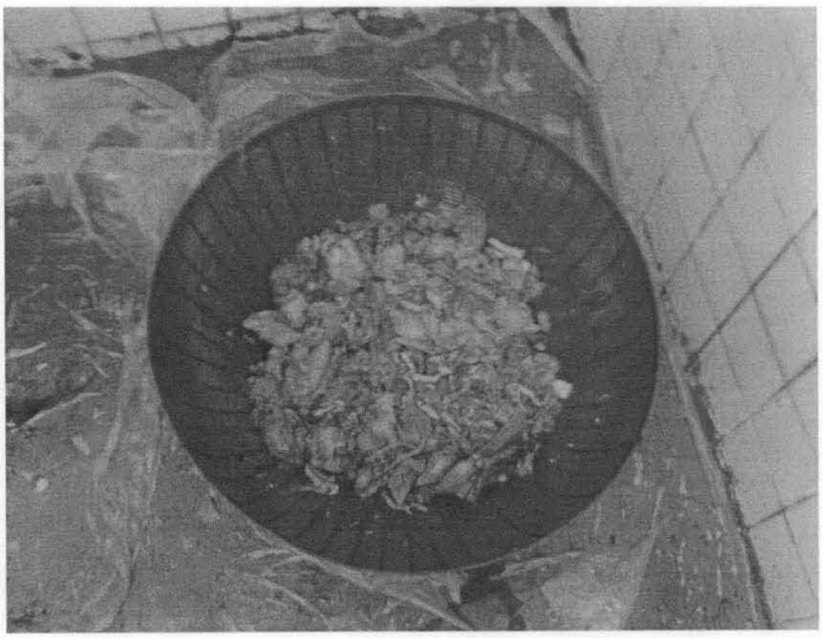


Figure 9. Meat leftovers that makeup some of the food waste.

Plastics

Figure 10 below show the types of plastics that are part of the waste generated at cafeterias. Most of the plastics originate from packaging of ingredients (food, fruits, vegetables and meat). Also part of the plastics consists of juice and waster bottles and in a small percentage PVC materials such as spoons and forks are also found in the waste.

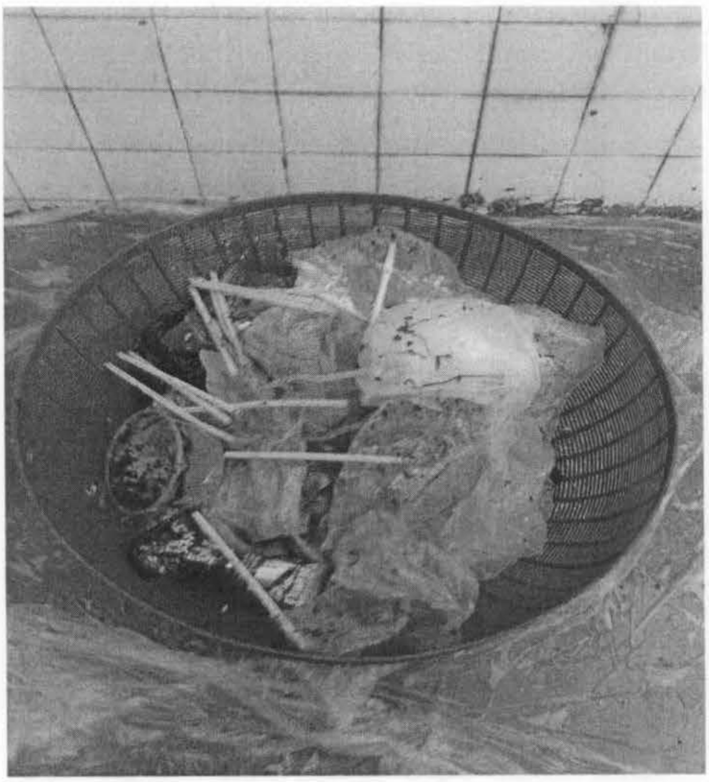


Figure 10. Typical plastics that are found in waste

Cardboards

Cardboards from in the waste come from packaging of materials to be used in the kitchen. Below is Figure 11 showing some of the cardboards found in the waste. Most of the cardboard material comes from the trays that carry eggs as eggs are very common in the menu items of the canteens.

Figure 11. Cardboards form packaging and egg trays

Tins and Cans

Most of the tins from beverages are rarely found in the waste they are collected separately directly from the tables. Tins and cans that feature in the waste are those of dairy products. Sample pictures of tins and cans are shown in the figure below.

Figure 12. Tins and cans of vegetables and dairy products

Paper

As mentioned before the percentage of the paper will be included in the food waste because its separation from the food waste is impossible due to its stickiness

Chapter 5: Results and discussion

5.1 Results

5.1.1 Waste generation rates

The results for waste generation rate are summarized in the following table. The data contained in the table below as indicated was collected in a span of four weeks. The last column contains averages of the four visits. The first row is the waste generation of food waste and these values also include paper which is mostly tissue that could not be separated from the food. Food waste contributes largest amount of waste (29.606 kg / day) followed by plastics (6.67 kg / day) and cardboards (4.35 kg / day) then tins and cans (3.70 kg / day). The banana peels contributes to the food waste but in the table it is separated because they come as separated from the canteen. The average total weight of the waste generated at canteens is 47.92 kg / day.

Table 4. Waste generation rates

Waste group	Visit 1 (kg/day)	Visit 2 (kg/day)	Visit 3 (kg/day)	Visit 4 (kg/day)	Average (kg/day)
Food	32.342	30.332	26.363	29.387	29.606
Plastics	8.400	7.000	5.940	5.333	6.67
Cardboards	3.923	4.870	3.497	5.123	4.35
Banana peels	2.720	6.480	2.283	2.900	3.60
Tins and cans	3.660	4.020	2.290	4.820	3.70
Total	51.045	52.702	40.363	47.563	47.92

The pie chart below is a graphical representation of the table above. It shows the composition percentages of generation rates weight. As depicted the food waste is the largest with 61% followed by plastics at 14%, cardboards at 9% and banana peels and tins and cans with both contributing approximately 8%.

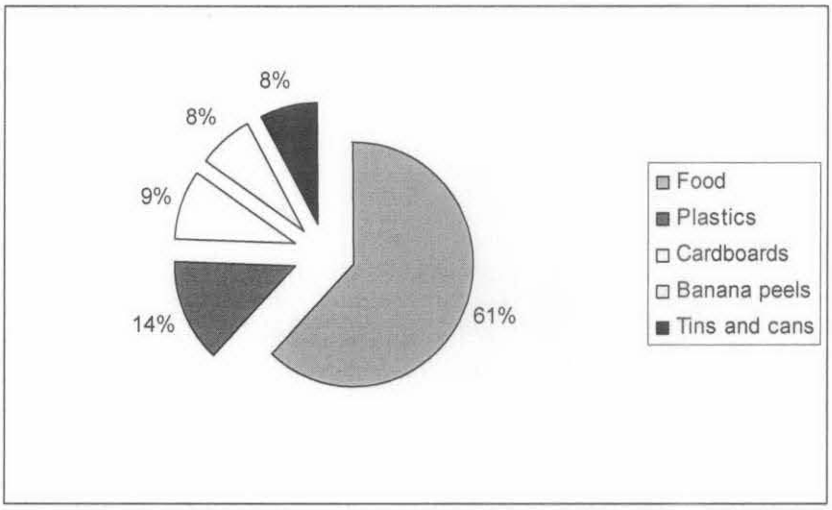


Figure 13. Chart depicting the % wet weights of the waste

5.1.2 Energy content

Below is a table containing estimates of energy content which can be extracted from the waste material collected. These values are represented in the last column as total energy. They are determined by multiplying the generation rates with energy content in column three. The food waste as expected has the highest energy content compared to other waste materials with a value of 137 667.9 kJ / day and cardboards with the lowest value of 70 905 kJ / day.

Table 5. Estimated energy contents of the waste

Component	Waste generation rate (kJ/day)	Energy content (kJ/kg)	Total energy(kJ/day)
Food	29.606	4 650	137 667.9
Plastics	6.670	32 600	217 442
Cardboards	4.350	16 300	70 905
Banana peels	3.600	4 650	16 740
Tins &cans	3.700	700	2 590
Total	47.92		445 334.9

In the above Table 5 the banana peels are treated as food waste, its energy content is that of the food waste. It should be noted that the energy estimation assumes that all the energy from the waste can be recovered which is highly unlikely.

5.1.3 Total organic carbon

Table 6. Percentage carbon of the compost feedstock

Sample	Sample size, mg	Concentration, %carbon
Yard waste	43.300	20.96
Sludge	46.500	1.60
Food waste	48.800	21.08

The above Table 6 contains values of carbon content of the feedstock (yard waste, sludge and food waste). The food waste has the largest value of carbon concentration of 21.08% followed by the yard waste with a value of 20.96% and the sludge with the lowest value of 1.06%. The sample size in the table in the second column indicates the amount that was used for the test. The regulation for this value is that it should not be greater than 50mg.

Table 7. Initial percentage carbon for each batch composition

Sample	Sample size, mg	Concentration, %carbon
A	48.800	21.08
B	45.200	27.43
C	48.400	23.33
D	46.200	19.24
E	46.800	16.62
F	41.200	21.02
G	37.800	22.94
H	30.100	26.88

The values represented in the Table 7 above are percentages of initial carbon content at the beginning of the initial mix of all batches. The value of batch A is taken as that of food wastes since batch A only contains food as its feedstock. Batch A has the biggest value of carbon concentration of 27.43% with batch H with the second largest value of 26.88%. Batch E has the lowest value of 16.62%. Bathes D and E are the only ones that have values less than 20% with all the other batches exhibiting values above 20%. Column two has the sample size as mentioned before.

5.1.4 C/N ratio

The values from Table 7 of total organic carbon for each batch were used together with initial total kjeldahl nitrogen (TKN) values of each batch to construct the following table of C/N ratios of the batches.

Table 8. Initial C/N ratios

Batch	C/N ratio
A	8.78
B	12.61
C	12.96
D	13.50
E	5.91
F	7.69
G	9.42
H	13.01

5.1.5 Moisture content

The moisture content of the feedstock for the experiments is contained in the following table. Food waste is wettest of the three components with 25.96% followed by the yard waste at 4.22% and the sludge at 3.89%. These values are the initial moisture contents before the mixing. Following the table is a graph of moisture contents for all the batches at the initial stage of the mixing. The food waste is again taken as the same value as batch A because they are the same thing.

Table 9. Moisture contents of the compost feedstock

Sample	Moisture content, %
Yard waste	4.22
Sludge	3.89
Food waste	25.96

The graphs below show variations of moisture contents of the batch experiments over the period of six weeks. The two graphs represent four batches each, batches without sludge (A to D) and batches with sludge(E to H). The vertical axis is the moisture content in percent and the horizontal axis represents the time in weeks. The samples were extracted from the compost once a week for six weeks immediately after turning or mixing. The samples were taken to the laboratory for drying in the oven for 24 hours at 105 degrees Celsius. The sample amount taken for this purpose was approximately 10g. All the batches show the same pattern with only one peak at week one after the initial mixing. This peak was due to the addition of water to increase the moisture content as the batches seemed too dry. They all lost moisture rapidly over the next four weeks.

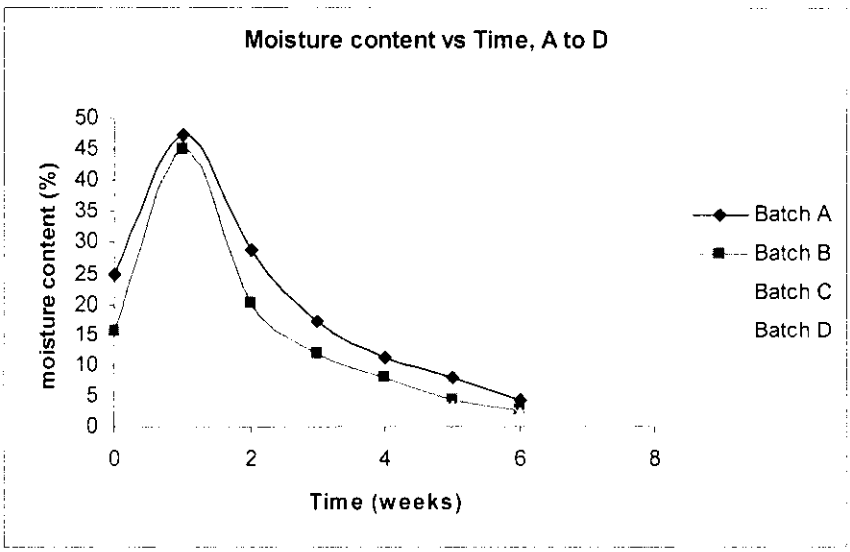


Figure 14 .Graph showing how moisture varied with time for batches without sludge

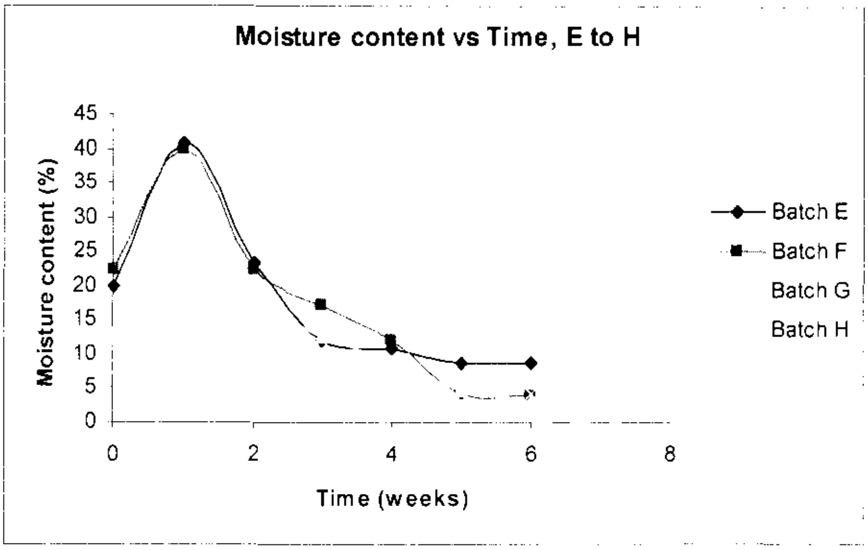


Figure 15.Graph depicting how moisture varied with time for batches with sludge

Batch A – initial: 25%, peak: 47.32 %,

Batch B – initial: 15.58%, peak: 45 %,

Batch C – initial: 7.19%, peak: 18.23%,

Batch D – initial: 7.50%, peak: 15%,

Batch E – initial: 20.05%, peak: 40.81%,

Batch F – initial: 22.32%, peak: 39.98%,

Batch G – initial: 12.55%, peak: 20.99%,

Batch H – initial: 7.24%, peak: 18%.

5.1.6 Temperature

The graphs below show the temperature variations of the bathes over time. The temperature readings were taken over the span of six weeks. The temperatures were taken using a thermometer placed in the middle of the compost pile. These readings were taken before mixing or turning took place. The thermometer was left in the compost for at least three minutes to allow for the temperature reading to stabilize.

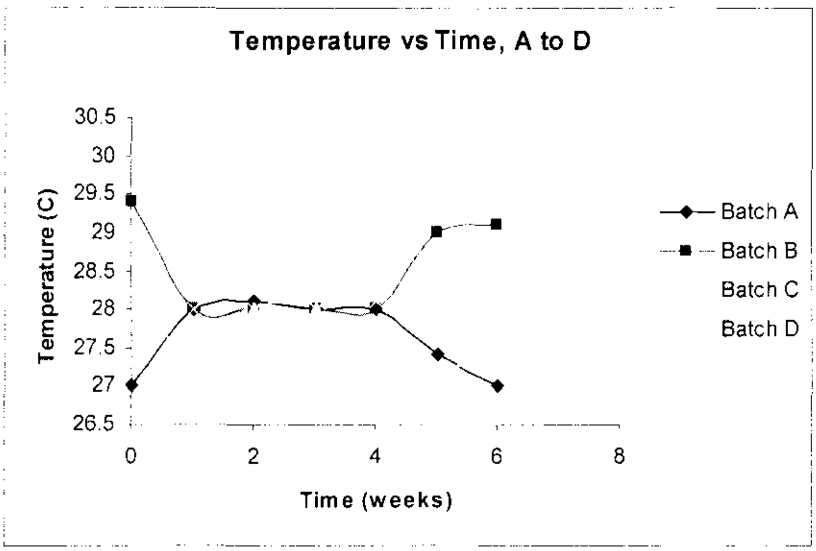


Figure 16.Graph depicting how temperature varied with time for batches without sludge

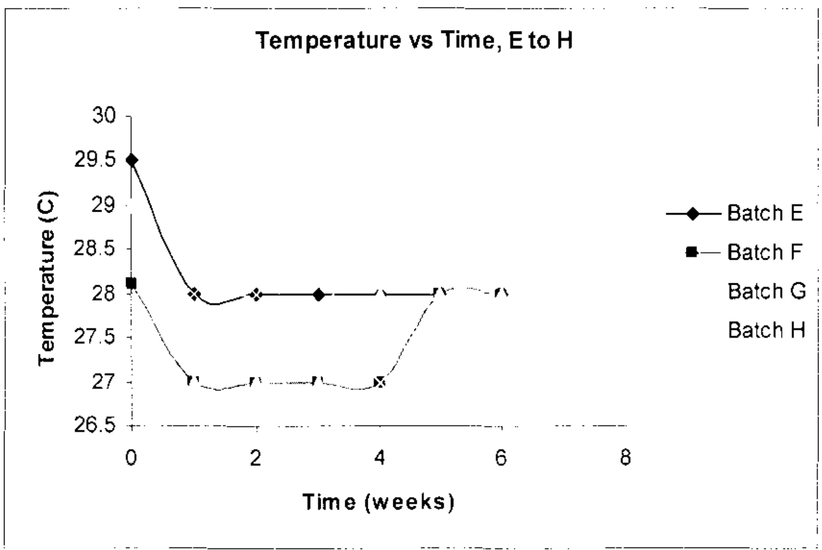


Figure 17.Graph depicting how temperature varied with time for batches with sludge

Batch A – highest: 28.1°C, lowest: 27°C,

Batch B – highest: 29.4°C, lowest: 28°C,

Batch C – highest: 29°C, lowest: 27°C,

Batch D – highest: 30°C, lowest: 28°C,

Batch E – highest: 29.5°C, lowest: 28°C,

Batch F – highest: 28.1°C, lowest: 27°C,

Batch G – highest: 28.1°C, lowest: 27°C,

Batch H – highest: 29°C, lowest: 27°C.

5.1.7 pH

The graphs below are of pH versus time. The pH readings once a week for six weeks from the samples used for moisture content which were dried in the 105°C oven for 24 hours. These graphs show one peak at week one and a partial peak at three. All batches show the same pattern except for batch G which shows a decrease in week one.

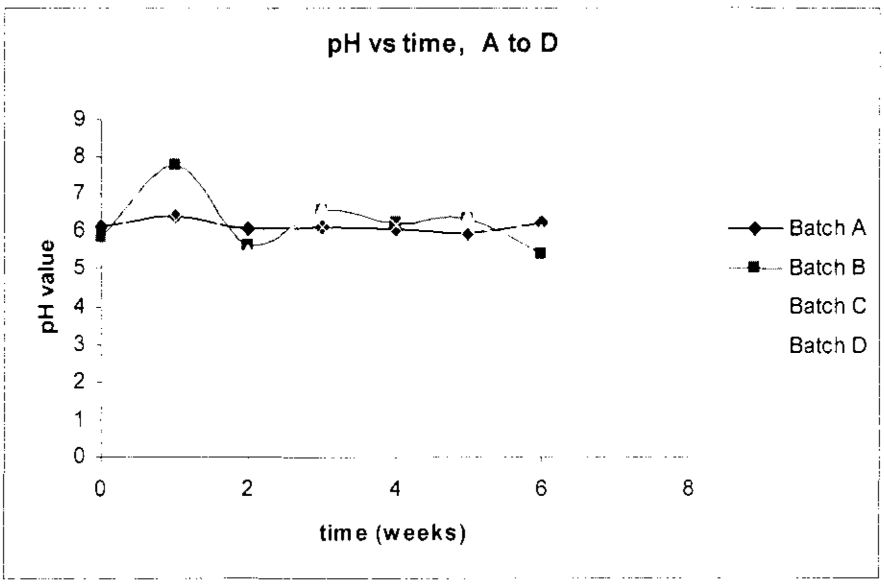


Figure 18.Graph depicting how the pH varied with time for batches without sludge

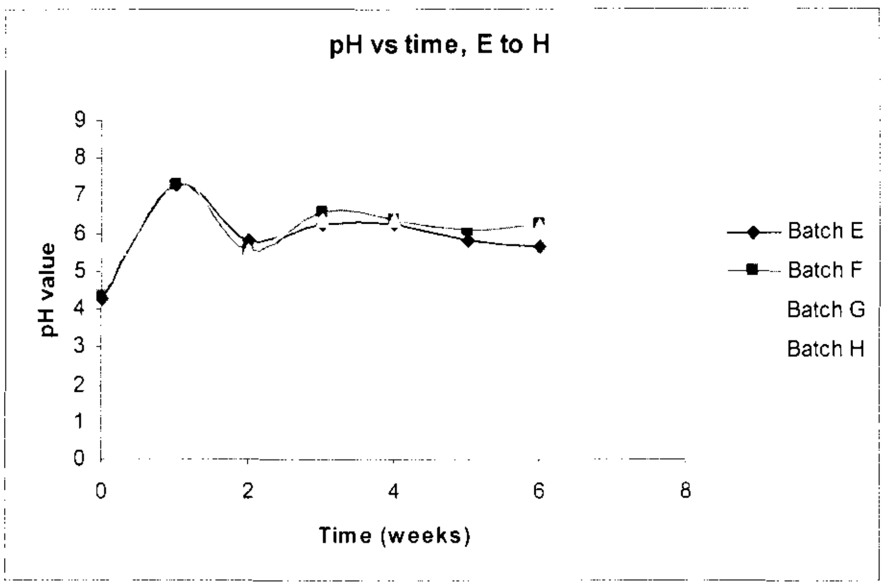


Figure 19.Graph depicting how the pH varied with time for batches with sludge

Batch A – initial: 6.125, first peak: 6.418, second peak: 6.234,

Batch B – initial: 5.851, first peak: 7.799, second peak: 6.560,

Batch C – initial: 5.543, first peak: 7.353, second peak: 6.641,

Batch D – initial: 4.971, first peak: 6.275, second peak: 6.167,

Batch E – initial: 4.307, first peak: 7.307, second peak: 6.270,

Batch F – initial: 4.333, first peak: 7.313, second peak: 6.612,

Batch G – initial: 5.546, trough: 5.284, peak: 6.377,

Batch H – initial: 4.998, first peak: 7.647, second peak: 5.323

5.2 Discussion

Cafeterias are primarily a food serving facility so as expected the waste material that contributes the most is the food waste. Plastics are next in terms weight followed by cardboards and tins and cans. The plastics, cardboards, tins and cans are mainly from packaging of this food, bottles and drinks. Paper waste is mainly tissue that people use as they eat and could not be separated as they were entangled with the sticky food, so the food waste includes them. Table 4 shows the average waste generation is 47.92 kg / day. These results as shown in Table 4 are very consistent; they don't vary much from each other. Because food waste is the largest component it follows that it will have the highest values of energy that can be extracted from the waste. In the literature review it is mentioned that the energy from any waste material can be estimated by using Table 1. The values from this Table 1 are used to multiply the waste generation rates of individual components to get the total energy that can be extracted. These results show that the total energy is 445 344.9 kJ / day. Food has the highest energy content which is also evident from its carbon content.

The wet weights of the individual component show the food as the biggest waste material with a 69% share followed by the plastics at 14%, cardboards at 9% and tins and cans at 8%.

Table 6 shows values of the total carbon of the feedstock of the compost yard waste, sludge and food waste. This is all the carbon that these materials are made up of. The yard waste was chosen for use because it was suspected that it has a very high carbon concentration. This is evident from the table with a value of 20.96%. Also the food was suspected to have high nitrogen content which turned out to be true so the yard waste was another way to balance this with its high carbon content as the ratio between these elements has to be kept in check. The results also show a high carbon content for batches A to D. this is because the contents of these batches are made up of high carbon content materials (food and yard).

The C/N ratio is a very good way to predict the progress of compost. From Table 8 it is seen that all the batches are no where close to the optimum of thirty mentioned earlier. All of them have values less than the optimum value. What this means is than nitrogen is in excess for all the batches. When the nitrogen content is in excess some of the nitrogen will be loss in the form of ammonia the gas. At the beginning of the experiments the compost area smelled like yeast. This yeast smell was supposed to be ammonia being lost as a gas which has a suffocating smell. Maybe the yeast smell exhibited by the composts was the ammonia gas mixed with the foul smell of the food waste.

Moisture is another critical component in determining the success of the process. Authors have stipulated that this is optimum around 50 to 60% (Haug, 1993). batches A, D and E have one of the highest moisture contents which is due to the fact that they are composed of high percentage of food waste which has the highest moisture content of the out of the feedstock, the graphs of moisture content showed the same pattern fro all batches. in week one water was introduced to all the batches in order to facilitate bacterial activity as the compost piles have to be moist for bacteria to operate at their best. After this water addition moisture content for all batches decreased dramatically. It should be noted that despite this decline in moisture content batches with more kitchen than others tend to retain moisture better than their counterparts but all batches performed poorly in retaining moisture.

One reason for this could be the size of the piles coupled with the compost site which is in the open vulnerable to wind conditions especially at night.

When taking temperature readings of a compost pile ideally the recordings must be taken at different locations on the compost pile and taking average of the readings. This is because the temperature might be different at different locations on the pile depending on moisture pockets of the pile (Cornell, 1990).

Throughout the whole six weeks there were no temperature variations of more than two degrees Celsius. this could have been attributed to the fact that al batches lacked the ability to retain moisture, also the fact that a great area of the compost pile was exposed to the air and this compared to its small volume (total mass of all batches was four kilograms) played a great deal in dissipation of heat,

Another disadvantage of the plastic baskets used for the compost is the cold concrete floor it was placed on. Overall all the batches lacked the ability to retain any heat.

When bacteria break down organic matter they release acids (Chang, 2008). These acids are in turn broken down further during the process.

From the peak in week one there was a decline in pH resulting from the production of the acids. Around week two the rate at which these acids are broken down increased. This is denoted by the increase from pH graphs after this week. This pH drop from week one is the biggest from the graphs for all batches. As Chang states, at the beginning the degradation is of easily degradable material. In this case this was the degradation of the food waste in the composts. Other pH drops are smaller compared to the one between week one and two. This means that the degradation was of harder materials to digest in this case the leaves which make up the yard waste.

One of the objectives was to find the effects introducing microorganisms in the form of sludge. This means finding if there is a difference or an advantage in adding the sludge. This is answered by looking if there are any differences between batches A to D and batches E to H. From the patterns of the parameters there was no difference apparent. Both sets of batches performed in almost exactly the same way. Introducing sludge in food and yard waste composting has no effect.

Towards the end there were no more fluctuations. pH stabilized around the values that indicate maturity.

Nitrogen contents of fertilizers differ greatly depending on what use the fertilizer is for. For the purposes of the project an assumption of what the compost will be used for has to be made. Out of all the uses compost can be used for, vegetarian growth was chosen. This means that these composts will be compared industry standards of fertilizers that are meant for growth of a vegetarian nature. Usually fertilizers do not just specify nitrogen they come as N-P-K (nitrogen, phosphorus and potassium). Unfortunately for this project this proved impossible to come up with. Since the compost extracts are a solid material, testing for these elements was hard because the environmental laboratory only has means for only nitrogen in this state (solid). For other elements (P and K) they only provide for liquid state material so other ways for determining these elements had to be devised. One way to test for P and K of solid material is to digest the compost extracts in the TKN machine so that they become liquid and it is then you can use the equipment meant for liquid state testing. After this digestion the material have to be filtered of any residues as the equipment uses light deflection to determine these elements. This alternative option was short lived because after cooling the digested liquid it congealed or formed a gel which prevented the determination of these elements. Luckily for the nitrogen the digestion is followed by a distillation process which dissolves the gel and sometimes not all of it. This shortcoming does not allow for the comparison of the composts to industry standards of fertilizers. Other means of determining the best batch had to be improvised.

After maturity was satisfied for all the batches using bag test the best performing batch composition was chosen by comparing the physical characteristics of the final products. Photographs of the final compost products can be found in appendix 1.1, 1.2, 1.3 and 1.4.

Batch A only had food as its feedstock as a result due to wind conditions compost caked forming little hard balls of humus. Also this batch had a lot of impurities like little stones, plastics and undigested bones. Batches E and F resembled A in these characteristics they also formed hard little balls and having these impurities. All these Batches (A, E and F) have the same color of light brown compared to other composts which had a much deeper shade of brown. Based on these characteristics Batches A, E and F poorly compared to other batches (B, C, D, G and H). Batch B preformed better too it has a rich dark color but compared to the remaining batches (C, D, G and H) it has far more impurities. So the best batch of all the eight is between batches C, D, G and H. Batches D and H have more yard waste than kitchen waste. Yard waste is harder to digest than kitchen waste and take longer to digest too. This means that out of the four that is left C and G perform better than D and H in terms of composting time. Since the addition of sludge has not advantage meaning that there's no need for its addition out of the remaining two (C and G) batch C is chosen as the best performing batch composition.

Chapter 5: Conclusion

The general objective of this project was about management and processing of waste generated at cafeterias at UTP and a solution that low cost and low tech was preferred. Composting is not only recommended by the US EPA as a strategy for solid waste management but also a process that can be in expensive and doesn't require a high level of technical skill. It stabilizes organic matter to form a nutrient rich substance. This is advantageous even if the waste is to be disposed after the process because it protects the environment by reducing the green house gases emissions that would have been present in the waste at the landfill. Compost also reduces the amount of the waste to be disposed of. It also offers an alternative to chemical fertilizers which could be harmful if used incorrectly.

The other objectives of this project were to use composting to determine the percentage compositions of each food waste and yard waste for a successful composting process. Another objective was to determine if introducing bacteria into the system had any effect or advantages. The best composition of the two materials was found to be 60% food waste and 40% yard waste. The addition of microorganisms in the form of sludge had no advantages to the naturally occurring composting.

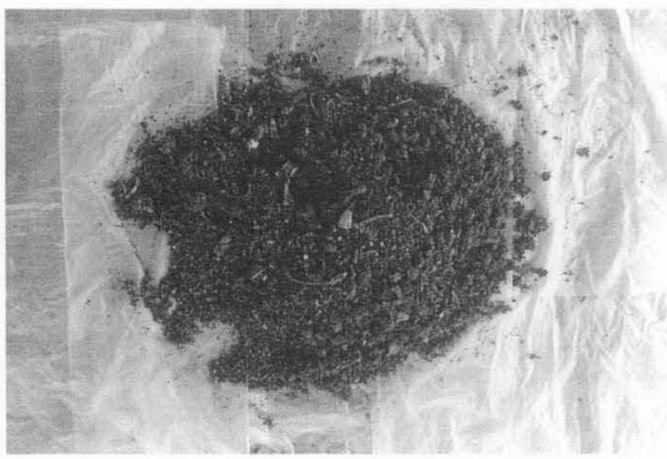
Chapter 6: References

1. Wastewater Engineering Treatment and Reuse, Metcalf & Eddy, McGraw Hill;
2. Environmental Engineering, Howard Peavy, Donald Rowe, George Tuhobanoglous, McGraw Hill;
3. Energy Studies, Shepherd .W, Shepherd D.W, Imperial College Press;
4. The Manure composting Manual, Alberta Agriculture, Food and Rural Development;
5. Nancy Trautmann, Cornell Center for the Environment;
6. Elaina Olynciw, Biology at Randolf, New York;
7. Adams, R.C.F. MacLean, J.K Dixon et al. The utilization of organic wastes in New Zealand, 1951;
8. Bird, R.B. Steward, Lightfoot E.N., Transport Phenomena, John Wiley & sons;
9. Haug, R.T, 1993, The Handbook of Compost Engineering, Lewis Publishing
10. Sawyer, C.N, McCarty, Chemistry for Environmental Engineering 3rd Edition, McGraw Hill.

APPENDICES

Appendix 1.1: Photographs of the final compost product for batches A and B.

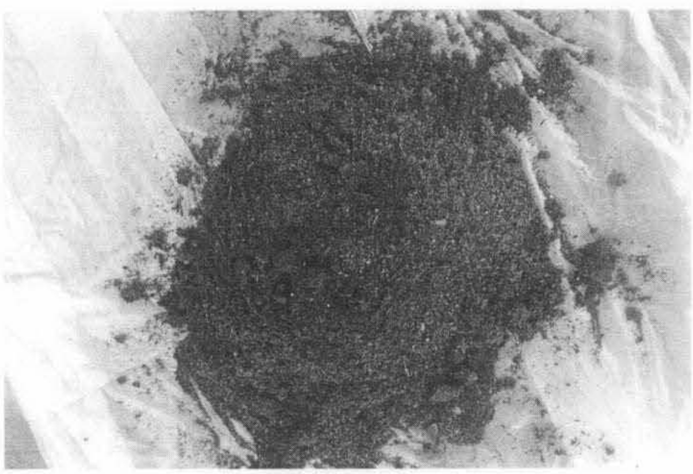
Batch A



Batch B

Appendix 1.2: Photographs of the final compost product for batches C and D

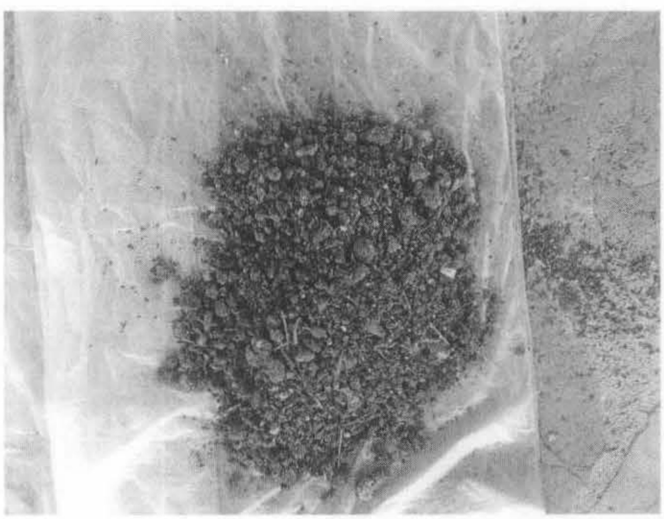
Batch C



Batch D

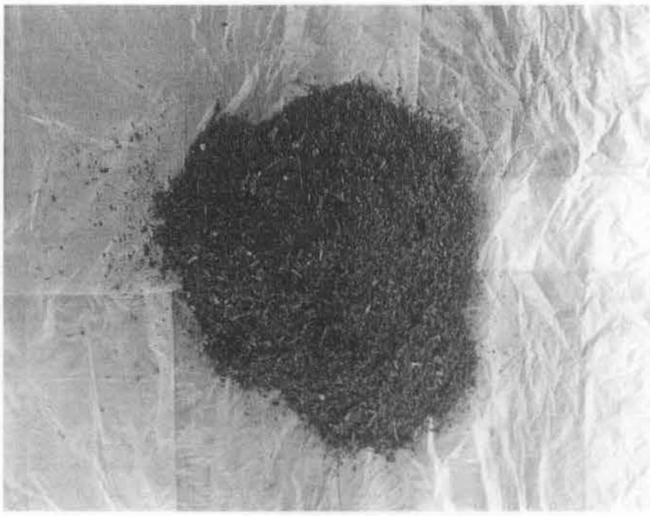
Appendix 1.3: Photographs of the final compost product for batches E and F

Batch E



Batch F

Appendix 1.4: Photographs of the final compost product for batches G and H



Batch G

Batch H