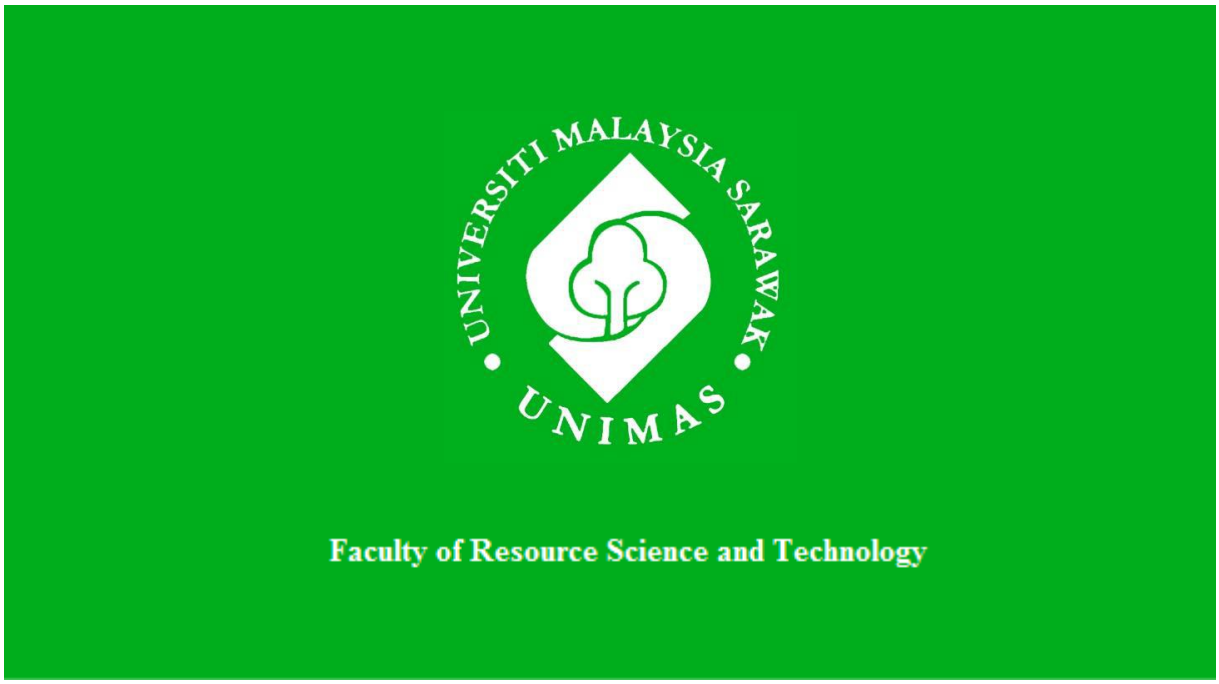

Production of Fertilizer using Food Wastes of Vegetables and Fruits

Tan Lih Min

Bachelor of Science with Honours
(Plant Resource Science and Management)
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Production of Fertilizer using Food Wastes of Vegetables and Fruits

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This report is submitted in partial fulfilment of the requirement for the
Degree of Bachelor of Science with Honours
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2015

DECLARATION

I hereby declare that the thesis is based on my original work. All the quotations and citations have been duly acknowledge. No portion of the work referred to this dissertation has been previously or concurrently submitted for any other degree programs in UNIMAS or other institutions of higher learning.

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Lists of Abbreviations

°C	Degree Celsius
C	Carbon
N	Nitrogen
P	Phosphorus
K	Potassium
FRST	Faculty Resource Science and Technology
UNIMAS	University Malaysia Sarawak
MEA	Malt Extract Agar
mL	milliliter
µl	microliter
V	Volt
cm^3	cubic centimeter
%	percentage
ANOVA	Analysis of Variance
PCR	Polymerase Chain Reaction
DNA	Deoxyribonucleic Acid
CTAB	Cetyltrimethyl Ammonium Bromide
NaCl	Sodium chloride
CIA	Chloroform:Isoamyl Alcohol
NH_4OAc	Sodium acetate
TE buffer	Tris-EDTA buffer
TAE buffer	Tris Acetate-EDTA buffer
EtBr	Ethidium bromide
dNTPs	Deoxynucleotide triphosphates
MgCl	Magnesium chloride
ITS	Internal Transcribed Spacer
ddH_20	Double distilled water
bp	base pair
AC no.	Accession number

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ABSTRACT

Around 8000 tonnes of food and kitchen waste is produced every day in Malaysia. Food waste is sent to landfill for disposal may break down and produce methane gas that cause greenhouse effect. The aims of the research are to produce organic fertilizer from food wastes of vegetables and fruits, to determine the fungi involved during fermentation for fertilizer production, to evaluate the effectiveness of the organic fertilizer on growth of selected vegetable of water spinach (*Ipomoea aquatica*). Fresh vegetables and fruits wastes were collected from Student Pavilion, UNIMAS and fermented in containers for three months. One sample was added with brown sugar to test the effectiveness of brown sugar in fermentation. During fermentation process, the fungi were isolated from solid and liquid samples of fertilizer. Isolation of fungi from samples of fertilizer was used to determine the types of fungi that present in the fertilizer. The physiological factors such as pH and temperature were recorded during fermentation process. The temperature of fermenting samples with and without brown sugar decreased from the 1st day to 90th day. The pH trend of fermenting samples without brown sugar was decreased from the 1st day to 4th day and then increased to 90th day. The pH trend of fermenting samples with brown sugar decreased from the 1st day to 6th day and remained almost constant until 90th day. The evaluation of the effectiveness of fertilizer on the growth performance of water spinach was determined. Liquid organic fertilizers produced from food wastes showed higher plant height and % dry matter than that grown in commercial fertilizer.

Keywords: Fertilizer, food waste, brown sugar, fungi

ABSTRAK

Kira-kira 8000 tan sisa makanan dan sisa dapur dihasilkan setiap hari di Malaysia. Sisa makanan yang dihantar ke tapak pelupusan mungkin dipecahkan dan menghasilkan gas metana yang menyebabkan kesan rumah hijau. Tujuan kajian ini adalah untuk menghasilkan baja organik dari sisa makanan seperti sayur-sayuran dan buah-buahan, menentukan kulat yang terdapat semasa penapaian dan menentukan keberkesanan baja terhadap pertumbuhan sayur-sayuran terpilih seperti kangkung (Ipomoea aquatica). Sayur-sayuran dan buah-buahan segar dikumpulkan dari Student Pavilion, UNIMAS dan menapai di dalam bekas selama tiga bulan. Salah satu sampel ditambah dengan gula perang untuk menguji keberkesanan gula perang dalam penapaian. Semasa proses penapaian, kulat diambil dari sampel baja pepejal dan cecair. Pengambilan kulat dari sampel baja adalah untuk menentukan jenis kulat yang tredapat dalam baja. Faktor-faktor fisiologi seperti pH dan suhu dicatatkan semasa proses penapaian. Suhu penapaian sampel dengan dan tanpa gula perang menurun dari hari 1 hingga hari ke-90. Trend pH penapaian sampel tanpa gula perang menurun dari hari 1 hingga hari ke-4 dan meningkat sehingga hari ke-90 . Trend pH penapaian sampel dengan gula perang menurun dari hari 1 hingga hari ke-6 dan kekal hampir malar sehingga hari ke-90. Penilaian keberkesanan baja terhadap pertumbuhan kangkung dijalankan. Baja organik cecair yang dihasilkan daripada sisa makanan meunjukkan ketinggian tumbuhan dan % bahan kering yang lenih tinggi daripada sayur-sayuran yang ditanam di baja komersial.

Kata kunci: Baja, sisa makanan, gula perang, kulat

1.0 Introduction

1.1 Background

Fertilizers are organic or inorganic, natural or synthetic substances that added to soil to enhance plant growth and production (Turing et al., 2006). Plants depend on the nutrients in soil to carry out metabolic reactions because soil contains basic chemicals for plant growth (Turing et al., 2006). However, the supply of basic chemicals in soil to plants is limited. When plants are being harvested, the nutrient content reduces and causes the reduction of quantity and quality of plants. Fertilizers are applied to replace the chemical materials in soil that are utilized by plants during growth and development (Miller, 2014).

Fertilizers are used to enhance the soil's growing potential because fertilizers are able to provide a better growing condition for plants as compared to natural soil (Turing et al., 2006). Fertilizers provide large amount of macronutrients such as nitrogen, phosphorous and potassium while natural soil may not contain sufficient amount of this macronutrients (Turing et al., 2006). Fertilizers also provide trace elements such as magnesium, calcium and copper that are crucial in plant growth (Miller, 2014).

Different types of fertilizers are applied to different types of crops to improve crop growth and production (Turing et al., 2006). The types of fertilizers are divided according to the amount of nitrogen and other elements (Joseph, 2014). The examples of fertilizer are sodium nitrates, ammonium sulphate and ammonium salts. Sodium nitrates fertilizer enhances the growth of plants such as wheat, barley and root vegetables because it contains nitrogen that is easily release to plants (Joseph, 2014). Ammonium sulphate fertilizer contains sulphur and nitrogen and is usually applied to alkaline soil to maintain pH balance of soil. Alfalfa crops benefit from ammonium sulphate by produces sulphur bearing amino acids (Turing et al., 2006).

Organic fertilizers compose of only plant and animal based material while inorganic fertilizers are produced artificially (Miller, 2014). Inorganic fertilizers are synthetic and chemical fertilizers that are made up of various formulations to apply to different types of crops (Joseph, 2014). Inorganic fertilizers are comes in powder, granular and pellets in boxes or bags and liquid formulation in bottles. Inorganic fertilizers can provide nutrition rapidly to plants and designed for plants to absorb directly macronutrients and micronutrients (Miller, 2014).

Organic fertilizers are natural fertilizers that are made up from animals, plants and minerals (Joseph, 2014). It can be made up from compost, manure, wood ash and peat moss. Organic fertilizers are crucial in agricultural sector because they have positive effect on soil without damage ground water and plants (Joseph, 2014). Organic fertilizers improve soil quality and produce crops with better yield and quality (Turing et al., 2006). Organic matter in organic fertilizers is decomposed by soil organism which is slower than inorganic fertilizers (Miller, 2014). The slow release of organic matter reduces nutrient leaching thus maintain soil fertility. Organic fertilizers can be produced by recycling food waste into useful soil amendment for farming (Morash, 2014). Organic fertilizers from food waste can reduce the usage of conventional nitrogen based fertilizers that may cause leaching in oceans, rivers and groundwater.

Food waste is food material that is unused, discarded and not safe to be consumed by human for avoidable reasons at production line (Pleissner & Carol, 2013). Food waste is edible animals and plants that are harvested to be consumed but not evenly consumed by human because it is spoilt and discarded. Food waste is food appropriate for human consumption that have been discarded whether it is kept before expire date or left to spoil (Pleissner& Carol, 2013). Food waste can be due to oversupply to markets, individual shopping habits or eating habits. The examples of food wastes are fruits and vegetables.

Food wastes from households and business normally are sent to landfill for disposal. Rotten food can breakdown to produce methane gas and is harmful to human if not handle properly (Pleissner & Carol, 2013). Methane is potent greenhouse gas that contributes to greenhouse effect and global warming. Methane gas is 25 times more potent than carbon dioxide in causing greenhouse effect (Barrows, 2011). Food waste causes the emissions of greenhouse gas that increase the surrounding temperature during its production and disposal. Food wastes that dispose in landfills can decompose and produce offensive smell that can harmful to human and environment (Pleissner & Carol, 2013).

Food waste can be reduced by converting into useful form organic fertilizers to reduce health problem caused by food wastes disposal (Pleissner & Carol, 2013). Food wastes can be recycled into organic fertilizer to reduce amount of food waste in landfill and emission of greenhouse gas to surrounding (Morash, 2014). Food wastes can be decomposed in anaerobic digestion by microorganisms to break down food waste into smaller materials and make useful products (Morash, 2014). This process is carried out inside an enclosed system in the absence of oxygen. Methane gas produced can be collected and converted into biogas to transport fuels and produce electivity and heat.

1.2 Problem Statement

Around 1.3 billion tonnes of food is wasted every year in the world (Pleissner & Carol, 2013). Fruits and vegetables that include tubers and roots showed the highest amount of wastage of any food. Around 8000 tonnes of food and kitchen waste is generated daily in Malaysia (Bernama, 2014). The wastes generated can feed on six million nations and solid waste management cost for discarded food cost into billions of ringgit. Most of the food wastes are disposed at disposal site and causes the lack of food waster recovery in Malaysia. Food wastes are normally sent to the landfill for disposal but it may break down and produce large amount of methane gas (Barrows, 2011). This can become a problem because methane gas is 25 times more potent than carbon dioxide in causing greenhouse effect and global warming. Therefore, transforming food wastes into useful product of organic fertilizers is required to decrease the amount of food wastes and methane gas.

1.3 Objectives

The objectives of this research are to produce organic fertilizer from food wastes, to determine the fungi involved during fermentation for fertilizer production, to evaluate the effectiveness of the organic fertilizer on growth of selected vegetable of water spinach (*Ipomoea aquatica*).

2.0 Literature Review

2.1 Processes in production of organic fertilizers

The processes in the production of organic fertilizers from food waste include fermentation, solid state fermentation and composting. In fermentation process, the substrate itself become the carbon source and happens in near absence or absence of free water (Bhargav et al., 2008). However, in solid state fermentation, the process happens in near absence or absence of free water by employing natural substrate and inert substrate as solid support. Composting is an alternative aerobic treatment of food waste which turns waste materials into humus rich product that nourishes plant and conditions soil (Stabnikova et al., 2004). Fermentation, solid state fermentation and composting are alternative approaches to manage biological materials (Merfield, 2012). These processes convert food wastes of vegetable and fruit into useful materials such as organic fertilizers for farming.

2.1.1 Fermentation

Fermentation is an anaerobic process that converts sugar in food waste into acids, alcohol or gases (Merfield, 2012). During fermentation process, microorganism metabolizes nutrients in food waste and produce carbon dioxide, methane and acids (Bhargav et al., 2008). Microorganism such as fungi, bacteria and yeast digest organic compounds in food waste and produce organic acids such as lactic acid, acetic acid and butyric acid (Merfield, 2012). Microorganism uses simple compounds of food source such as sugar, protein and starch in fermentation. The compounds with relatively high C: N ratio and high water content are suitable for fermentation by microorganism (Merfield, 2012). A small amount of water is liberated by microorganism and fermenting materials during fermentation.

The suitable temperature for fermentation is 25°C to 37°C and optimum pH is around 4.0 to 5.5 (Zulkeple et al., 2011). High temperature can kill the microorganism that used in fermentation because most of the microorganism is mesophilic which grow at 20°C to 45°C. Too acidic or alkaline condition is not suitable because food waste is pasteurized and nutrients are preserved for long time when the pH drops below 4.2 (Zulkeple et al., 2011).

2.1.2 Solid State Fermentation

Solid state fermentation is fermentation process that involves microorganism that grows on solid material in the absence of liquid (Bhargav et al., 2008). This process involves inoculation and growth of microorganism on porous particulate solid substrate that contains low moisture content (Kumar & Kanwar, 2012). The nutrients and water content that present in solid substrate support the growth of microorganism and cause the microorganism to produce useful enzyme when grows on solid substrate.

The production of solid state fermentation and the growth of fungal are influenced by temperature. Huge amount of heat is produced during solid state fermentation and the heat produced is proportional to metabolic activities of microorganism (Bhargav et al., 2008). Fungus can grow within a wide range of 20°C to 55°C. Microbial metabolic activity and aeration of fermentation are related to heat transfer of solid state fermentation. High temperature can cause effect on germination, metabolites formation and sporulation of fungal (Bhargav et al., 2008). Fungal growth declined when the temperature for fungal growth beyond or exceed optimal temperature. Fermentation temperature and fermentation days are monitored during fermentation because these factors can affect the production of fertilizers. According to Acton (2012), the suitable temperature for the production of organic fertilizers from food waste was 25.9°C and fermentation days were 36.7 days.

The microorganism that used in solid state fermentation includes yeast, fungi, bacteria and algae (Aggelopoulos et al., 2013). The yeast is used in ethanol production and was grown in medium with glucose and yeast extract at 30°C. The pH was adjusted to around 5.5 because too acidic or too alkaline condition will affect the metabolic activity of microorganism (Aggelopoulos et al., 2013).

2.1.3 Composting

Composting is natural process of recycling and decomposing of organic material into humus rich soil amendment called compost (Risse & Faucette, 2004). Microorganism such as bacteria, fungi and actinomycetes uses nutrients and energy in organic material and convert hydrocarbons into carbon dioxide and water by oxidation (Merfield, 2012). Microorganism in compost starts to reproduce and continue decomposition of food waste (Smith et al., 2014). Carbon, hydrogen and oxygen that originally found in solid material are converting into gaseous forms and release to atmosphere (Merfield, 2012).

Temperature is crucial in composting because the increase of temperature can enhance microbial growth rate, degradation rate and enzymatic production in food waste (Lens et al., 2004). High degradation rate can release more energy, increase the temperature of composting and enhance the process of composting. The suitable temperature for composting food waste is around 50°C to 62°C (Lens et al, 2004). Nakasaki et al. (1992) found that the pH for good composting was nearly neutral in pH is 6.0 to 7.0.

2.2 Production of organic fertilizer

Organic fertilizer is fertilizer that can be produced by waste product such as compost and manure (Boonsiri et al., 2009). Organic fertilizer from organic material of plant and animal under decomposition process can be in solid or liquid form (Sumardiono & Murwono, 2011). The organic substances in organic fertilizer are able to improve biological, physical and chemical properties of soil when added into soil.

Organic fertilizer from waste product can enhance soil quality and improve the quality and quantity of agriculture production (Sumardiono & Murwono, 2011). The production of organic fertilizers can decrease the environmental contamination and increase the quality of sustainable land. The waste product such as sewage sludge, manure, agricultural waste and food waste can be converted into useful material such as organic fertilizer.

2.2.1 Sewage sludge

Sewage sludge is semi solid material that left from the sewage treatment and industrial waste water. Sewage sludge can be removed by composting, agricultural, incineration and landfilling (Stabnikova et al., 2003). Waste water treatment in sewage sludge produces large quantity of surplus sludge. The sludge can become compost and reused as organic fertilizers and soil conditioner in agricultural (Veeken & Hamelers, 1999). The use of sludge compost is sustainable treatment as compared to incineration and landfilling because composed sludge can recycle organic matter and nutrients. The organic matter and nutrients such as nitrogen, phosphorus and potassium are recycled and reused as organic fertilizers to enhance soil fertility and plant growth (Stabnikova et al., 2003).

2.2.2 Manure

Manure is animal and plant wastes that used in organic fertilizers to provide plant nutrients (Owen, 2003). The conversion of manure into organic fertilizers is done by microorganism that degrades organic materials in manure into compost (Sumardiono & Murwono, 2011). The conversion of manure is natural composting and used eight week to complete composting at 65°C to 70°C. This process take longer time than composting food waste because microorganism is slow in degrade cellulose in manure (Sumardiono & Murwono, 2011). Manure that recycled into organic fertilizers is soil conditioner to provide nutrients to plants. Organic fertilizers from manure improve soil fertility, provide nutrients to crops and protect water quality. Manure organic fertilizers are widely used in combination with cover cropping, crop rotation, liming and green manuring (Turing et al., 2006).

2.2.3 Agricultural waste

Agricultural waste is natural and non-natural waste that produced from farming activities such as dairy farming, livestock breeding, seed growing and horticulture (Ahmad et al., 2007). Natural wastes are organic waste from farmyard manures, animal excretion and silage effluent whereas non-natural wastes are plastic, pesticides and waste from oils (Ahmad et al., 2007). Proper management of agricultural waste can maintain healthy condition for farm animals, provide nutrients for crop production and reduce usage of commercial fertilizers (Joseph, 2014). The usage of commercial fertilizers can be reduced by using organic fertilizers from animal waste in farming. Organic fertilizers from animal waste can enhance organic matter content and water holding capacity of soil (Joseph, 2014). The nutrient availability for crop is increased when the soil condition is improved by the addition of animal waste.

2.2.4 Food waste

The conversion of food waste into organic fertilizers by fermentation, solid state fermentation or composting is widely conducted to reduce the amount of food waste produced daily (Stabnikova et al., 2004). Food waste that is not handling properly can cause contamination of groundwater, emission of toxic gas, emanation of odour and attraction of vermin (Okareh et al., 2012). The proper decomposition of food waste can cause the reduction of pathogen and odour (Stabnikova et al., 2004). Food waste such as fruits, vegetables, grain, bread and eggshells can be composed and converted into organic fertilizers (Risse & Faucette, 2014). Food waste such as red meat and bones also can be composed but they take longer period to compose.

Food waste is widely recycled into organic fertilizer because food waste has special features as raw compost agent (Risse & Faucette, 2014). Food waste contains high energy and is suitable for energy production and waste stabilization (Okareh et al., 2012). The ratio of carbon to nutrients of organic wastes is crucial during fermenting and composting process (Ahmad et al., 2007). These processes depend on microorganism that use carbon source to provide energy and nitrogen to build cell proteins (Owen, 2003). Nitrogen is most critical nutrient and requires small amount of phosphorus and other elements. The C: N ratio on range of 25-27:1 is considered as optimum. The low C: N ratio (<25) can cause the loss of nitrogen from compost via ammonia volatilization. However, the high C: N ratio (>40) can cause immobilization of nitrogen in compost and decrease the rate of decomposition. Vegetable and fruit wastes have C: N ratio of ≤27:1 is moderately suitable in fermentation and composting (Ahmad et al., 2007).

The main elements in composting food waste are physical and chemical characteristics of substrate which include the composition and particle size (Okareh et al., 2012). Food waste

has high moisture content and low physical structure as compared to sewage sludge and manure (Risse & Faucette, 2014). Food waste is mixed with bulking agents such as yard waste and sawdust that contain high C: N ratio to absorb more moisture and add structure to the mix thus enhancing composting of food waste (Risse & Faucette, 2014).

Environmental conditions such as temperature and pH affect the degradation of each component of food waste into organic fertilizers. Carbohydrate, protein and cellulose have different optimum temperature, pH and retention times for compositing. Okareh et al. (2012) found that the temperature of composting food waste is in the range of 28°C to 65°C and the pH is 6.3 to 7.1

2.3 Sources that enhance production of organic fertilizers

Food waste materials can be fermented or composed into compost without adding any carbon rich materials. However, the production of organic fertilizers can be enhanced by the additional of carbon source such as brown sugar and molasses. The composting of food waste can be increased by adding sugar source because most of the microorganism is sugar loving organism and they utilize the sugar to break down food waste in fermentation or composting process (Zhang et al., 2013).

2.3.1 Brown sugar

Brown sugar is a type of crystalline sucrose that contains glucose and fructose and a small quantity of molasses which give the brown colour of sugar. Brown sugar is food under medium acid category and make the materials added with it become acidic (Zhang et al.,

2013). Brown sugar is used in Fermented Plant Juice (FPJ) which is made up of fruits, leaves or grasses. Brown sugar can draw out the microorganism, lactic acids and other nutrients that found on the leaves of plants. Carandang and Gentry (2014) used the waste and brown sugar at equal amount (ratio 1:1) and fermented for three months at 25°C to 30°C. The residue was filtered after three months and dark brown liquid with vinegar sour smell was obtained. Brown sugar is added to waste to increase the fermentation rate of food waste because brown sugar contains glucose and can be used as food resource by microorganism (Zhang et al., 2013). Microorganism uses the carbon source in sugar to enhance the breakdown of food waste.

2.3.2 Molasses

Molasses is thick syrup juice that processed from sugar cane plants or sugar beets (Stephanie, 2013). Molasses is added to waste materials because it is one of the effective carbon sources for microorganism and soil organism (Osunkoya & Okwudinka, 2011). Microorganism uses carbon source in sugar to enhance composting of food waste. Sugar in molasses and food waste are breakdown by microorganism to produce organic fertilizers. Molasses is excellent chelating agent which converts the chemical nutrients into materials for plant use (Stephanie, 2013). Molasses is added during the production of organic fertilizers to enhance the soil microbial activity because it can provide energy for soil organism and microorganism such as fungi (Osunkoya & Okwudinka, 2011). Blackstrap molasses is molasses that suitable to be added into waste materials because it contains high concentration of sulphur, iron, potash and micronutrients that found in cane material (Stephanie, 2013) Molasses contains sulphur that can acts as mild natural fungicide and natural deodorizer for fishy teas (Osunkoya & Okwudinka, 2011).

2.4 Benefits of the production of organic fertilizers from food waste

Composting and recycling food waste is part of the integrated waste management strategy that is being gradually recognized by local authorities (Imperial College, 2002). Recycling the food waste can provide benefits for local authorities in terms of financial, environmental and technical aspects.

2.4.1 Financial aspect

Composting or fermenting food waste can provide cost saving for local authorities in waste management and reduce cost spent in refuse collection and waste disposal (Imperial College, 2012). By producing composts from waste materials, the cost on buying commercial fertilizers that provide nutrients to plant and soil can be reduced. The composts produced can be used as organic fertilizers for soil conditioning and nourishment. The compost produces materials that can be used as slow release fertilizer in plantation (Ahmad et al., 2007). The satisfaction can be gained from the improved growth and development of plants in compost amended soil.

2.4.2 Environmental aspect

Composting waste materials can provide sustainable management in biodegradable household waste where producer is responsible in segregation, treatment and ultimate end-use of the waste materials. Compost and organic matter that obtained from recycling of waste materials is renewable and sustainable resource where composting can conserve natural peat land habitats (Imperial College, 2012). Peat replacement by compost is done without increase the cost for improving soil condition. The compost can be used as slow