UNIVERSITI PUTRA MALAYSIA

PILOT SCALE ANAEROBIC DIGESTION OF FOOD WASTE

Lim Wei Jie

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By

LIM WEI JIE

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LIM WEI JIE

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Chairman: Chin Nyuk Ling, PhD
Faculty: Engineering

Anaerobic digestion is a green and cost effective in handling a high volume of food waste in Malaysia. The main goal of this study is to assess the effect of substrate compositions on compost quality and profiling pattern of anaerobic digester. This study of food waste digestion using pilot scale Cowtech anaerobic digester was to optimize the proportion of food waste, dry leaf and cow manure as the substrates. The feeding of substrate and discharging of food waste compost were at rate of 40 kg/day at 40% capacity of the pilot scale anaerobic digester. The simplex centroid mixture design was applied to obtain optimum mixture proportion with three responses, including C/N ratio, pH and electrical conductivity.

The optimization experiments were studied with the goal settings of compost qualities including C/N ratio was 21, pH at 8 and electrical conductivity at 1 dS/m for a single digestion of pure food waste and co-digestions of food waste with dry leaf or cow manure. Based on goal settings above, the optimum pure food waste proportion of 51.3% of vegetable waste, 30.3% of fruit waste and 18.4% of meat waste for pure food waste study. When dry leaf was included in the mixture proportion optimization, the optimum mixture was 1.2% of vegetable waste, 4.9% of fruit waste, 7.1% of meat waste and 86.8% of dry leaf. When cow manure was included in the mixture proportion optimization, the optimum mixture was 23.2 % of vegetable waste, 34.3% of fruit waste, 36.5% of meat waste and 6% of cow manure.

The nutrient content from pure food waste compost was compared with those with co-digested of dry leaf or cow manure. The nutrient content of pure food waste was 0.067% in nitrogen content, 0.07% in potassium content and 0.04% in phosphorus content. The mixture of the food waste with dry leaf had the nutrient of 0.061% in nitrogen content, 0.09% in potassium content and 0.08% in phosphorus content. The mixture of the food waste with cow manure compost had nutrient content of 0.063% in nitrogen content, 0.1% in potassium content and 0.08% in phosphorus content.

The addition of dry leaf in food waste mixture has significantly improved potassium content by 27.4% and phosphorus content by 86%, while for the addition of cow manure in food waste mixture has significantly improved potassium content by 41.1% and phosphorus content by 100%. Using dry leaf and cow manure in Cowtech anaerobic digestion is recommend in improving nutrient content of food waste compost.

Profiling pattern in pilot scale anaerobic digester was determined by feeding of pure food waste and mixture of the food waste with cow manure in a steady-state input-output manner. The retention time of anaerobic food waste digestion of 30 days for complete digestion was observed based on measured physic-chemical properties of total carbon content, total nitrogen content and total volatile solid. The 30 days anaerobic digestion period take place efficiently is more than sufficient for a complete anaerobic digestion process.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENCERNAAN ANAEROBIK UNTUK SISA MAKANAN YANG BERSKALA PILOT

Oleh

LIM WEI JIE

Jun 2017

Pengerusi: Chin Nyuk Ling, PhD
Fakulti: Kejuruteraan

Pencernaan anaerobik merupakan kaedah yang bersifat mesra alam dan efektif kos untuk mnguruskan jumlah sisa makanan yang tinggi di Malaysia. Objektif utama dalam kajian ini adalah untuk menilai kesan daripada substrat terhadap kualiti kompos dan corak profil daripada pencerna anaerobik. Pencerna anaerobik yang berjenama Cowtech telah digunakan dalam kajian pengoptimunnan kompos sisa makanan yang bersifat rintis dengan menggunakan sisa makanan, daun kering and tahi lembu. Kadar untuk input substrat and output kompos adalah 40 kg/hari dan kapasiti penggunaan pencerna anaerobic adalah 40 % sahaja. *Simplex centroid mixture* digunakan untuk memperoleh perkadaran campuran optimum dengan menggunakan tiga respons iaitu nisbah C/N ratio, pH dan kekonduksian elektrik.

Matlamat kualiti kompos yang ditetapkan untuk eksperimen pengoptimunnan sisa makanan dan campuran sisa makanan dengan daun kering atau tahi lembu termasuk nisbah C/N iaitu 21, pH iaitu 8 and kekonduksian elektrik iaitu 1 dS/m. Berdasarkan matlamat kualiti kompos tersebut, perkadaran sisa makanan optimum terdiri daripada 51.3% sisa sayur-sayuran, 30.3% sisa buah-buahan dan 18.4% sisa daging. Apabila daun kering digunakan dalam eksperimen pengoptimumnan campuran sisa makanan dengan daun kering, perkadaran campuran optimum adalah 1.2% sisa sayur-sayuran, 4.9% sisa buah-buahan, 7.1% sisa daging dan 86.8% daun kering. Apabila tahi lembu terlibat dalam eksperimen pengoptimuman perkadaran campuran, campuran optimum adalah 23.2% sisa sayur-sayuran, 34.3% sisa buah-buahan, 36.5% sisa daging dan 6% tahi lembu.

Pembandingan kandungan nutrien antara kompos sisa makanan dengan kompos campuran sisa makanan dengan daun kering dan tahi lembu telah dihasilkan. Kompos sisa makanan tulen mengandungi 0.067% kandungan nitrogen, 0.07% kandungan kalium dan 0.04% kandungan fosforus. Campuran kompos sisa makanan

dengan daun kering mengandungi 0.061% kandungan nitrogen, 0.09% kandungan kalium dan 0.08% kandungan fosforus. Campuran kompos sisa makanan dengan tahi lembu mengandungi 0.063% kandungan nitrogen, 0.1% kandungan kalium dan 0.08% kandungan fosforus. Pertambahan daun kering dalam campuran sisa makanan telah meningkat kandungan kalium sebanyak 27.4% dan kandungan fosforus sebanyak 86%, manakala bagi pertambahan tahi lembu dalam campuran sisa makanan telah meningkat kandungan kalium sebanyak 41.1% dan kandungan fosforus sebanyak 100%.

Corak profil dalam pencerna anaerobik ditentukan dengan input sisa makanan dan campuran sisa makanan dengan tahi lembu dengan input-output yang bersifat mantap. Tempoh retensi untuk kompos sisa makanan anaerobik adalah selama 30 hari untuk satu proses yang lengkap dengan diperhatikan berdasarkan sifat fizik-kimia yang terdiri daripada jumlah kandungan karbon, jumlah kandungan nitrogen dan jumlah pepejal meruap. Tempoh 30 hari untuk proses kompos anaerobik adalah sangat lengkap.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Chin Nyuk Ling, PhD
Professor. Ir
Faculty Engineering
Universiti Putra Malaysia
(Chairman)

Yus Aniza Yusof, PhD
Associate Professor
Faculty Engineering
Universiti Putra Malaysia
(Member)

Tee Tuan Poy, PhD
Senior Lecturer
Faculty Agriculture
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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C/N ratio	Carbon-to-nitrogen ratio
ANOVA	Analysis of variance

CHAPTER 1

INTRODUCTION

1.1 Background of study

Food waste is a putrescible and recyclable material in dominant composition (40%-64%) in municipal solid waste in Malaysia (Periathamby *et al*., 2009). Malaysia with a population more than 30 million in 2014 produced up to 8000 tonnes/day of food waste in a day (Anonymous, 2014), which is an increment of 7070 tonnes/day from food waste in 2011 (Anonymous, 2013). The reasons of this escalating quantity of food waste are because of the changes in eating habits as living standards have improved through the years where people can afford more food products than before (Abdul, 2010) and the rapid population expansion and urbanisation (Zamali *et al*., 2009).

Landfill and incineration are the more common methods for food waste disposal. Landfill is a general and widely accepted method for managing food waste as it is cost effective and simple to be applied. However, food waste management via landfill has become more difficult as many landfills have reached their capacity in Malaysia (Moh and Manaf, 2014). Contrarily, incineration method is costly and requires high energy usage and technology. Incineration method is rarely applied for food waste treatment as it creates air pollution (Zhang *et al*., 2014). Both of these methods are unsustainable for managing food waste as they bring significant environment impacts.

In Malaysia, the authority is facing strenuous challenges in food waste handling and treatment. Food waste imparts the current environmental issue due to its improper separation with municipal solid waste and that it attributed to the production of greenhouse gases in landfills. Thi *et al*. (2015) reported that food waste might emit greenhouse gases that bring negative impacts to climate changes. Therefore, there is a need to have a cost effective and environment friendly food waste handling and management system

Food waste is discarded on a daily basis due to living nature of human beings via agricultural, industrial and domestic activities. Due to the feature of high moisture content, high organic content and possesses more than 90% of biodegradability, it is good for using as feedstock in an anaerobic digestion (Li *et al*., 2013a; Abdullah and Chin, 2010; Veeken and Hamelers, 1999). Anaerobic digestion is a biological degradation process, where organic substrates transform to stable and humic-like substances under mesophilic, thermophilic and absence of oxygen condition that can be used as an organic compost (Iyengar and Bhave, 2006; 2014; Li *et al*., 2013a; Zhang *et al*., 2014). Generally, anaerobic digestion is an effective, high economic and high environment feasibility in food waste handling (Chang and Hsu 2008; Zhang *et al*., 2015).

1.2 Problem statement

Food waste is major types of municipal organic wastes in Malaysia. The low cellulose content and C/N ratio of food waste has a potential in resulting acid accumulation, high concentration of ammonia, low compost quality and low biogas production in a mono-digestion (Alburquerque *et al*., 2012; Zhang *et al*., 2014). The co-digestion of food waste with other organic wastes such as green waste and cow manure can improve the compost quality and biogas production yield (Alburquerque *et al*., 2012; Dias *et al*., 2014; Fred *et al*., 2014; Zhang *et al*., 2014). As the food waste is a commonly available waste, it is feasible for anaerobic co-digestion all the times. Anaerobic co-digestion also helps in reducing costs by processing several wastes in a single facility (Alatriste-Mondragon *et al*., 2006).

Rao *et al*. (2011) verified that the maximum methane yield was obtained with optimum mixture in co-digestion of sewage sludge with cow manure and fruit juice water. Besides, Abdullah and Chin (2010) used mixture design to formulate mixture with 44.0% w/w of vegetable scraps, 19.7% w/w of fish processing wastes and 36.2% w/w of onion peels at desired moisture content (60%) and C/N ratio (30%) for commencing a composting process. Besides, Chae and Ahn (2013) found that mixture made up of 25% of food waste, 12% of rice bran and 63% of sawdust was the optimum culture medium to produce fruit body of *Pleurotus ostreatus.* Based on findings above, it is observed that mixture proportions largely affect anaerobic digestion and compost quality.

The compositions of food waste are heterogeneous usually due to different eating habits of human beings, which might hinder the anaerobic digestion. Therefore it is required to mix other organic material to reach an adequate proportional for anaerobic digestion. A standard simulation approach of mixture optimisation is essential to generate appropriate portion of each component in mixture for initiating anaerobic digestion process. Design of experiment is a statistical approach, and it is frequently applied to different engineering problems to improve the performance and to find the optimum process responses. The major advantages of this practice are shorten time taken for development of model, lowered total cost, lowered variance and improved process responses as compared with traditional methods such as trial and error method (Rao and Baral, 2011).

As the quality of compost produced from food waste depends on its compositions and other combination of wastes, this study attempts to investigate the effect of substrate components consisting of food waste, dry leaf and cow manure on compost quality under mesophilic phase and optimisation pattern using simplex centroid mixture design.

1.3 Objective

The general objective of this study is to determine effect of substrate compositions on quality of compost. The simplex centroid mixture design was applied to determine

the optimised proportional of substrate in order to enhance the efficiency of anaerobic digestion using a pilot scale anaerobic digester. The profiling pattern in this pilot scale anaerobic digester was also investigated in order to get a better understanding on general cycle of a complete anaerobic digestion of food waste.
The specific objectives are:

To produce a good quality pure food waste compost in a single digestion and to improve the quality of food waste compost by co-digesting dry leaf or cow manure through a mesophilic phase with the aid of optimization technique.
To determine the profiling pattern in this pilot scale anaerobic digester by feeding pure food waste and mixture of the food waste with cow manure in a steady-state input-output manner.

1.4 Scope of this thesis

It is hoped that at this study helps in alleviating food waste issue and environment pollutions raised by food waste by converting food waste to organic compost.

Chapter 2 provides information on the current status of food waste in Malaysia, previous studies on anaerobic digestion on food waste management, Cowtec anaerobic digester in Malaysia and parameters in monitoring anaerobic digestion process.

Chapter 3 describes the analytical process of measuring chemical properties of substrates and liquid compost, procedure of using anaerobic digester including sorting out plastic material, shredding into smaller size of particles, mixing, then followed by digestion, discharging of liquid compost and burning biogas gas. The information and design of the anaerobic digester is illustrated. The statistical process of obtaining mixture proportional is explained. The profiles of physic-chemical properties of food waste composts when continuing fed with pure food waste and the mixture of the food waste with cow manure was determined using analytical process of measuring physic-chemical properties.

Chapter 4 provides the information and process of regression analysis, interpretation of contour plot and surface plot and model validation in obtaining the optimum mixture proportional. The discussion of nutrient assessment for optimum mixture is presented in this chapter.

Chapter 5 details the profiling pattern in this pilot scale anaerobic digester by feeding pure food waste and mixture of the food waste with cow manure in a continuous steady-state input-output manner.

Lastly, conclusions and recommendation for future studies are made in chapter 6.

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