PERFORMANCE ON FOOD WASTE COMPOSTING USING BLACK SOLDIER FLY LARVAE (BSFL) BASED ON PHYSICAL PROPERTIES IN TAMAN PURA KENCANA, JOHOR

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A project report submitted in partial
fulfillment of the requirement for the award of the
Degree of Master of Civil Engineering

Faculty of Civil Engineering and Built Environment
Universiti Tun Hussein Onn Malaysia

APRIL 2023

Specially dedicated to my dearest parents

Mr. Md Tahir Bin Md Yusoff and Mrs. Nor'aini Binti A. Jamal,

To my beloved siblings

Muhammad Hamdan Bin Md Tahir and Balqis Binti Md Tahir,

To my cherished supervisor

Assoc. Prof. Ir. Dr. Noor Yasmin Binti Zainun,

To my lecturers, coarse mates, and friends

For all their encouragement, dedication, and unconditional support.

ACKNOWLEDGEMENT

First and foremost, Alhamdulillah, all praise to Allah SWT for showering His blessings and helping me to complete this research successfully. He keeps giving me strength and simplifying my problems while conducting this research. Without Him, this research could not be done but He keeps helping me all the way which made me feel trully blessed. Alhamdulillah.

In the meantime, I would like to thank Assoc. Prof. Ir. Dr. Noor Yasmin for her enthusiasm and expert advice throughout this research which genuinely helped me to graduate on time. It was a great honour for me to have her as my supervisor. Next, my appreciation goes to SWM Environment Sdn. Bhd. in Taman Pura Kencana for transporting food waste bins from households and restaurants to the site at Solid Waste Research Centre (SWRC), UTHM.

Other than that, I am extremely grateful to have my dearest parents, Mr Md Tahir and Mrs Nor'aini, who always stay by my side and give me unconditional supports to complete this research. They have been the best listeners to all of my problems and sharing their ideas whenever i feel lost in this research. Their love and supports keep me strong every single time in completing this research.

Last but not least, my thankfulness goes to my supportive siblings especially to my sister, Balqis Tahir. She always brightened up my day when I was feeling down and not motivated. In a nutshell, my appreciation goes for those who supported me to complete this master directly and indirectly.

ABSTRACT

Black Soldier Fly Larvae (BSFL) is known as an effective insect for food waste treatment which could help in accelerating the composting process. This relates to the aim of this research which is to determine performance on food waste composting using BSFL in the case study area. Therefore, this research is conducted by identifying food waste generation in Taman Pura Kencana, Johor. At the same time, to compare lifecycle of BSF in case study with previous study and to identify decomposing process of food waste samples based on physical properties. Lastly, to identify decomposing rate and evaluate performance on decomposing rate of food waste samples using BSFL. Sample of respondents for food waste generation in Taman Pura Kencana consists of 38 households and 10 restaurants using Raosoft Sample Size Calculator. Food waste generation data were collected for 3 months from April to June 2021. Lifecycle of BSF in case study was monitored at the Solid Waste Research Centre (SWRC) by recording time interval between each phase of lifecycle compared to previous study. Decomposing process of food waste samples using BSFL was measured through physical properties namely moisture content, temperature and pH. In the meantime, decomposing rate of food waste using BSFL was analysed through decomposing days and calculations using same quantity of BSFL but different amount of food waste samples. Total food waste generation from respondents in Taman Pura Kencana was 1057.03 kg. Lifecycle of BSF in SWRC took 38 days to 57 days per cycle compared to previous study which took about 42 days per cycle. The most suitable food waste sample using 12 g of BSFL was sample T5 regarding to the highest value of DMCR. Based on decomposing rate of food waste samples using BSFL, average waste reduction index (WRI) by decomposing food waste samples using BSFL was from 7.90 (%/day) to 9.30 (%/day) which was the highest compared to composting by other insects (4.0%/day to 7.0%/day).

ABSTRAK

Larva Lalat Askar Hitam (BSFL) dikenali sebagai serangga yang berkesan untuk rawatan sisa makanan yang boleh membantu dalam mempercepatkan proses pengkomposan. Ini berkaitan dengan matlamat penyelidikan ini iaitu untuk menentukan prestasi pengkomposan sisa makanan menggunakan BSFL di kawasan kajian kes. Oleh itu, kajian ini dijalankan dengan mengenal pasti penjanaan sisa makanan di Taman Pura Kencana, Johor. Pada masa yang sama, untuk membandingkan kitaran hayat BSF dalam kajian kes dengan kajian lepas dan mengenal pasti proses penguraian sampel sisa makanan berdasarkan sifat fizikal. Akhir sekali, untuk mengenal pasti kadar penguraian dan menilai prestasi ke atas kadar penguraian sampel sisa makanan menggunakan BSFL. Sampel responden bagi penghasilan sisa makanan di Taman Pura Kencana terdiri daripada 38 isi rumah dan 10 restoran menggunakan Kalkulator Saiz Sampel Raosoft. Data penjanaan sisa makanan dikumpul selama 3 bulan dari April hingga Jun 2021. Kitaran hayat BSF dalam kajian kes dipantau di Pusat Penyelidikan Sisa Pepejal (SWRC) dengan merekodkan selang masa antara setiap fasa kitaran hayat berbanding kajian lepas. Proses penguraian sampel sisa makanan menggunakan BSFL diukur melalui sifat fizikal iaitu kandungan lembapan, suhu dan pH. Dalam pada itu, kadar penguraian sisa makanan menggunakan BSFL telah dianalisis melalui hari penguraian dan pengiraan menggunakan kuantiti BSFL yang sama tetapi jumlah sampel sisa makanan yang berbeza. Jumlah penjanaan sisa makanan daripada responden di Taman Pura Kencana ialah 1057.03 kg. Kitaran hayat BSF dalam SWRC mengambil masa 38 hari hingga 57 hari setiap kitaran berbanding kajian terdahulu yang mengambil masa kira-kira 42 hari setiap kitaran. Sampel sisa makanan yang paling sesuai menggunakan 12 g BSFL ialah sampel T5 berkenaan dengan nilai DMCR tertinggi. Berdasarkan kadar penguraian sampel sisa makanan menggunakan BSFL, purata indeks pengurangan sisa (WRI) dengan penguraian sampel sisa makanan menggunakan BSFL adalah daripada 7.90 (%/hari) hingga 9.30 (%/hari) iaitu yang tertinggi berbanding pengkomposan oleh serangga lain. (4.0%/hari hingga 7.0%/hari).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AD	-	Anaerobic Digestion
BSF	-	Black Soldier Fly
BSFL	-	Black Soldier Fly Larvae
EXP	-	Experiment
FAO	-	Food and Agriculture Organisation
SWRC	-	Solid Waste Research Centre
UTHM	-	Universiti Tun Hussein Onn Malaysia

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Sustainability was described as the evaluation of environment, economic, and social impacts of available waste alternative treatments as presented in Figure 1.1 below.

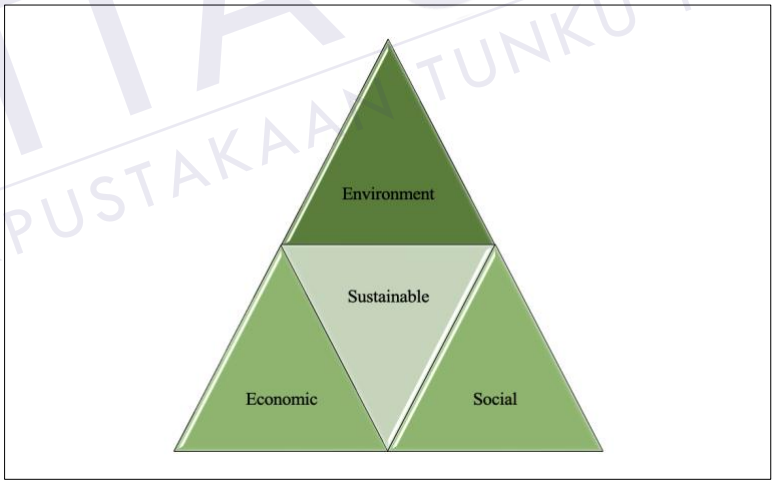

Figure 1.1: Three typical factors in sustainability (Purvis *et al*., 2019)

Sustainable waste management is a multidisciplinary subject constantly being discussed by governments, researchers, and members of the public to reduce waste production and also protect the environment (Fami *et al*., 2019). According to Cucchiella *et al*. (2017) sustainable waste management could be visible when materials were reused, recycled and disposal waste was reduced to conserve landfills for future generations. Significantly, some major factors needed to be analysed in sustainable

waste management namely current population of human beings, population growth, and per capita waste generation in that area (Mohd Yatim *et al*., 2019).

According to Worldometer (2020), the world population was 7.8 billion in 2020 which increased 1.05% from 2019. The rise of human population added to economic growth and evolution in standards of living which subsequently generated an excessive amount of waste in most developing countries (Bharadwaj *et al*., 2020). Saadoun *et al*. (2020), stated that every year, each city in the world produced 2.01 billion tonnes of municipal solid waste and 33 % of this waste was not managed environmentally.

In 2020, the population of Malaysia was estimated at 32 million (Worldometer, 2020). According to World Bank statistics, each person would produce about 0.74 kg of waste per day (Saadoun *et al*., 2020). Based on the statistics, the estimation of waste in Malaysia could lead to 24 million kg per day which is an enormous amount (Dwivedi, 2019).

At the same time, according to the Department of Statistics Malaysia (DOSM, 2020), the population in Johor was stated as 3.78 million which could cause an increase in generation of waste in this state. According to Hingha *et al.* (2017), Johor produced 1,590,000 tonnes per year of municipal solid waste which placed it as the second highest for waste production in Malaysia after plastics. Specifically, Taman Pura Kencana in Batu Pahat produced the highest amount of waste approximately 44% was from food waste due to the population of human beings in that area (Abdul Kadir et al., 2017). Hence, the amount of waste was related to the population growth which keeps increasing every year.

Broadly, waste was characterised as the end part of a product life cycle which usually is not useful or unwanted thus to be disposed of in landfills (Dwivedi, 2019). Waste falls into two main categories namely biodegradable waste and non-biodegradable waste. Biodegradable waste, also known as wet waste, includes kitchen waste, garden waste, and sanitary waste. Non-biodegradable waste refers to dry waste such as paper, plastics, containers, metals, glass, rubber, clothing, and furniture (Saadoun *et al*., 2020). Mohd Yatim *et al*. (2019) mentioned that 64% of waste produced in Malaysia was municipal solid waste which placed it as the highest rank of generated waste composition. In the meantime, industrial waste accounted for 25% while commercial waste produced 8% and the last was construction waste at 3%.

Particularly, the highest component in municipal solid waste was organic waste which made up approximately 60% of such waste in Malaysia (Jawa *et al*., 2021).

Organic waste generally consists of a mixture of from households or restaurant waste such as food waste and garden waste (Pavlas *et al*., 2020). According to Mohd Yatim *et al*. (2019) about 50% of total daily waste was food waste which currently was disposed in landfill sites and incinerators.

The disposal of the waste was managed by Solid Waste Management Corporation and Public Cleansing (SWCorp) which established as complementary to the success of the Management Policy National Solid Waste. In general, this policy aimed to create a management system which comprehensive, integrated, and cost effective as required by a conservation minded society environment and public welfare. Three concession companies were appointed for conducting solid waste collection services and public cleansing for seven states under Act 672 Solid Waste Management Act and Public Cleansing 2007 (SWCorp, 2018). States in Kuala Lumpur, Putrajaya, and Pahang were using Alam Flora Sdn. Bhd. as the company to do waste collection services while SWM Environment Sdn. Bhd. was choosen to provide waste collection services in Johor, Melaka and Negeri Sembilan. The third concession company was Environment Idaman Sdn. Bhd. which conducted waste collection services in Kedah and Perlis (Niyaz *et al*., 2020).

One of the biggest challenges to dispose of food waste was non-adequate landfill sites as there were too much waste to fill up the sites in a short time. Moreover, human population was getting increase annually which led to high cost of land and lack of land available (Mohd Yatim *et al*., 2019). Other than that, assorted environmental problems could occur from landfill sites and incinerators such as groundwater contamination, leachate, toxic gases, and odor diffusion which mostly came from food waste. These problems also related with condition of weather in Malaysia that experiencing hot and rainy days which suited for microbes to degrade solid waste and food waste. At the same time, degradation of the waste could diffuse leachate together with bad odour (Mohd Yatim *et al*., 2019). Regarding to these issues, food waste needed to be managed sustainably to prevent environmental problems and subsequently provide convenient infrastructure for future generations.

Thus, Kim *et al*., (2021) mentioned that one of practical sustainable waste managements to dispose food waste was using Black Soldier Fly Larvae (BSFL) in composting method. This method was also approved by other researchers namely Almqvist, (2021); Isibika, (2022); and (Deng *et al*., 2022) which agreed that application of BSFL in composting was safe to the environment as it could reduce

harmful gases and not using any harmful chemicals. Additionally, BSFL was also non-harmful insects which not transmitting any diseases towards humans and other animals (Kumar *et al*., 2022).

In the meantime, composting food waste using BSFL was convenient to be applied due to none requirements of any complicated technologies which genuinely cost effective (Kim *et al*., 2021). Furthermore, consumption of food waste by BSFL produced high nutrients of organic fertilizers which suitable for plantations and organic farming (Muhamadi Saifulizan, 2021). Other than that, Seo *et al*., (2021) mentioned that BSFL could be transform into food products for animals or they can be directly used in animal feeding. This could provide income to the owners by selling organic fertilizers and BSFL as animals' food while operating composting method.

Above all, composting food waste using BSFL was preferable compared to discarding food waste to landfills sites and incinerators. This method could provide a lot of benefits in terms of environment, economic and cost. Hence, application of BSFL in composting food waste could be performed to manage food waste issues in this country.

1.2 Problem Statement

Hingha *et al.*, (2017) mentioned that food waste was being the main problem in Johor as it was the second highest percentage of waste composition after plastic waste. Specifically, Taman Pura Kencana in Batu Pahat is the highest ranking for generating food waste (Abdul Kadir *et al*., 2017b). According to Abdul Kadir *et al*., (2017b) production of food waste in Taman Pura Kencana became a main contributor of waste composition where they generated about 47.87% of food waste per week. The food waste in this mix area of residential and commercial sources mostly came from households and restaurants. Most of the food waste consisted of leftover, expired food, rotten fruits, and vegetables.

Subsequently, SWM Environment Sdn. Bhd. was the concession company who managed the waste collection in Taman Pura Kencana, Batu Pahat. The food waste was disposed of by using landfill site and incinerator at Seelong Environmental Centre in Kulai, Johor since 2018 (SWCorp, 2018). The food waste was collected by SWM

Environment Sdn. Bhd. about two times a week using 3 tonne lorry which 74 km in distance. This landfill was too compact with many types of waste which particularly about 50% of the waste was full with food waste especially came from restaurants and households. Some of the methane gases while disposing the waste in landfill was not fully trapped due to inefficient technology which made the surrounding environment was not good for human's health.

Furthermore, the Seelong's landfill was too compact with waste due to the closure of CEP Renggam Landfill which supposedly to be the prioritized landfill area to be used for discarding waste in Batu Pahat District. The closure of CEP Renggam Landfill was due to breaking of infiltration leachate pools thus releasing ammonia from CEP to Sungai Benut. This problem was becoming crucial when leachate contamination was affecting human's need and animal's life near that area when there was no water supply and a lot of dead fish in Sungai Benut at that time.

Other than that, according to SWM authorities, one cell in landfill sites could be used for disposing waste about 3 to 6 years. Due to this issue, inadequacy of landfill's cells in Seelong may occurred in the year of 2022 because this landfill was receiving about 500 tonnes of waste every day. This issue caused the authorities needed to find other cells in landfill area and also adding up another incinerator to prolong the life expectancy of landfill sites. However, the issue became more vulnerable when the cost of providing one incinerator including maintenance cost was about RM10 million as well as contributed to high global warming. At the same time, bad odour and water pollution, along with harmful gases which exposed to the environment due to disposing waste at landfill site and incinerator could affecting humans' health. On the other hand, operation and maintenance cost for landfill was about RM 9 million per year while transportation cost for the garbage truck from Taman Pura Kencana to Seelong's landfill was RM 54,000 per year.

Regarding to high presence of negative effects by disposing food waste to landfill sites and incinerator, another option which could be apply was composting method. Rastogi *et al*., (2020) stated that composting was the preferable method due to its low cost of investments and high sustainability when handled it rightly. At the same time, Kuo *et al*., (2019) stated that composting was suitable to dispose food waste as this method was unexpensive and could produce organic fertilizer at the end of the process. However, unproper way of composting contributed the transmission of disease, bad odour, greenhouse gases and also took longer time to complete the

decomposition process of food waste (Dilip Kumar *et al*., 2022). Niyaz et al., (2020) stated that composting food waste without using any insects to help the decomposing process were slower than composting food waste using insects.

As a result, some countries have been used insect to help in composting food waste. The most practical insect in composting food waste was Black Soldier Fly Larvae (BSFL) which stated by previous researchers namely Seo *et al*., (2021); Lombardi *et al.,* (2021); and Giordano *et al*., (2020). The use of Black Soldier Fly Larvae (BSFL) in composting method could accelerate the process compared to the conventional composting (Seo *et al*., 2021). Other than that, BSFL were non-harmful insects to humans and other animals which could also produce less harmful gases compared to landfills and incinerators (Huis *et al*., 2020). Composting using BSFL was effective which could increase the sustainability of food waste management and avoid the unfavourable conditions in composting method (Liu *et al*., 2020).

1.3 Research Questions

Taman Pura Kencana in Batu Pahat, Johor was chosen as location of study to conduct the research in order to achieve the objectives of this research. At the same time, this research was conducted to identify performance of Black Soldier Fly Larvae (BSFL) on food waste composting. Thus, the research questions for this study are ;

1) What is the quantity of food waste generated in Taman Pura Kencana, Batu Pahat, Johor?
2) What is the difference between lifecycle of Black Soldier Fly in case study compare with previous study?
3) How decomposing process of food waste samples using Black Soldier Fly Larvae?
4) What is the decomposing rate and evaluation performance on decomposing rate of food waste samples using Black Soldier Fly Larvae?

1.4 Objectives

There are four main objectives of this study which are:

1) To evaluate food waste generation in Taman Pura Kencana, Batu Pahat, Johor.
2) To compare lifecycle of Black Soldier Fly in case study with previous study.
3) To determine decomposing process of food waste samples using Black Soldier Fly Larvae based on physical properties.
4) To establish decomposing rate and evaluate performance on decomposing rate of food waste samples using Black Soldier Fly Larvae.

1.5 Scope of study

This study was focusing on composting method using Black Soldier Fly Larvae (BSFL) as a natural breakdown of organic matter which stated as the practical method from previous researchers stated by Liu *et al*., (2020). Other than that, this method could be applied due to inclination number of food waste production at landfill sites. In the meantime, physical properties which measured in this research were moisture content, temperature, and pH values.

Moisture content of the food waste and residue were using gravimetric method by heating food waste at 105-degree Celsius in the oven for 24 hours. Temperature of the surrounding area was measured by using temperature meter while temperature for food waste was taken by food thermometer. Temperature for residue was measured using soil thermometer. At the same time, pH value of the food waste was recorded by using digital pH meter while pH for residue of the food waste samples were measured using digital soil pH meter.

Due to limitation time and cost, only one case study area was chosen which is Taman Pura Kencana in Batu Pahat, Johor. Besides, this area was chosen by virtue of highest number of food waste production from that area mentioned by Abdul Kadir *et al*., (2017b). Other than that, composting food waste using BSFL was never being done in Taman Pura Kencana by any previous researchers. Thus, this research was to identify the performance of Black Soldier Fly Larvae (BSFL) in composting method by using food waste from respondents in this area.

The respondents were 38 households and 10 restaurants which among communities in case study area. Total 48 respondents out of 671 (households and restaurants in Taman Pura Kencana) were selected in this study as it more than the minimum sample respondents stated in Raosoft Sample Size Calculator. Other than that, margin of error and confidence level were not more than 10% and more than 80% respectively which accepted in experiment research.

A food waste bin was provided at each restaurant and household regarding to record food waste data made by respondents in this study. Every respondent had been advised to separate unnecessary things such as straws, tissues, and plastics before put the food waste inside the food waste bins. The food waste bins were collected 2-3 times a week with the help of SWM Environment Sdn. Bhd. which then being placed at Solid Waste Research Centre (SWRC) in UTHM.

Specifically, food waste generation in Taman Pura Kencana was identified according to average total food waste in 3 months namely April, May and Jun 2021. Other than that, a comparison between lifecycle of Black Soldier Fly Larvae (BSFL) in case study with previous study were identified in this study. In the meantime, decomposing process of food waste samples using BSFL based on physical properties were established in this research. Last but not least, decomposing rate of food waste samples were identified and evaluation performance on decomposing rate of food waste samples using BSFL was evaluated in this study.

1.6 Significance of study

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