UNIVERSITI PUTRA MALAYSIA

DRYING BEHAVIOUR OF FOOD WASTE AND LEFTOVERS FOR TRENCH COMPOSTING

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By

AZIZ KHALIDA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

To my beloved father Muhmmad Azam Aziz,

My beloved mother Nooria Fikri,

&

Strong supporters from my husband Qais Aziz,

and my siblings,

Parwiz Aziz, Arsalan Aziz,

Asooda Aziz, Bahara Aziz, and Muzhda Aziz

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chair : Muhammad Heikal Ismail, PhD
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With the global population growth of 7.6 billion, food waste has affected the environment, and the economy gradually, which has recently received much attention worldwide. Food waste recycling is a vital waste management parameter in the household and food processing industry. This study aims to describe the kinetics of drying food waste and leftovers and their usage as raw materials in trench compost to improve soil quality in terms of pH value, electric conductivity (EC), and nutrient concentrations while reducing leachate and greenhouse gas emissions. The collected food waste and leftovers were equally divided for the pretreatment procedure. The samples were subjected to the soaking process in warm distilled water at 70°C for five minutes and the remaining were left untreated. Subsequently, both pretreated and non-pretreated food waste and leftovers were subjected to hot air drying at 80°C, 90°C, and 100°C. Dried samples were then subjected to trench composting by mixing with garden soil according to a 5/3 ratio. According to the findings, the air temperature and pre-treatment substantially impacted the dehydration rate, effective diffusivity, activation energy, and nutrient content, pH value, and EC in the final products of trench compost. The final product of pretreated dried leftover at 80^0C after trench compost had the highest value of C, N, H, and S (36.53) %, and, micronutrient (K =880.1 mg/L, Ca= 83.99 mg/L, Cu= 1.88 mg/L, Mg =53.12 mg/L, and Zn=14.95 mg/L) compare to pretreated dried food waste at 80^0C after trench compost. While final product dried of food waste at same condition had 29.73% total of CNHS, and micronutrient (K =392.2 mg/L, Ca= 109.8 mg/L, Cu= 0.98 mg/L, Mg =58.35 mg/L, and Zn=11.4 mg/L). Overall, the nutrient content of dehydrated leftovers after trench compost was premised to improve soil quality. In conclusion, the dehydrated food waste and leftovers retard decomposition and minimize odor, allowing for more frequent waste collection.

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

PERILAKU PENGERINGAN SISA BUANGAN DAN BAKI MAKANAN UNTUK PENGKOMPOSAN

Oleh

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Dengan peningkatan populasi global sebanyak 7.6 bilion, sisa makanan telah menjejaskan alam sekitar dan ekonomi secara beransur-ansur di mana baru-baru ini mendapat banyak perhatian di seluruh dunia. Kitaran semula sisa makanan adalah parameter pengurusan sisa yang penting dalam isi rumah dan industri pemprosesan makanan. Kajian ini bertujuan untuk menerangkan kinetik pengeringan sisa dan sisa makanan serta penggunaannya sebagai bahan mentah dalam kompos parit untuk meningkatkan kualiti tanah dari segi nilai pH, kekonduksian elektrik (EC), dan kepekatan nutrien di samping mengurangkan pelepasan. larut lesap dan gas rumah hijau. Sisa makanan dan lebihan makanan yang dikumpul telah dibahagikan kepada dua kumpulan yang sama rata untuk pra-rawatan dan bukan pra-rawatan. Kumpulan pra-rawatan telah direndam dalam air suling suam pada suhu 70°C selama lima minit. Selepas itu, kedua-dua sisa buangan dan baki makanan yang telah dirawat dan tidak dirawat telah tertakluk kepada pengeringan udara panas pada suhu 80°C, 90°C, and 100°C. Sampel kering dikenakan pengkomposan parit dengan mencampurkannya bersama tanah kebun untuk nisbah 5/3. Menurut penemuan, suhu udara dan pra-rawatan banyak memberi kesan kepada kadar dehidrasi, difusi berkesan, tenaga pengaktifan, kepekatan nutrien, nilai pH, dan EC dalam produk akhir kompos parit. Produk akhir sisa baki kering yang dirawat pada 80°C mempunyai nilai C, N, H, and S (36.53) % tertinggi dan mikronutrien (K =880.1 mg/L, Ca= 83.99 mg/L, Cu= 1.88 mg/L, Mg =53.12 mg/L, and Zn=14.95 mg/L). Ia adalah lebih tinggi daripada mikronutrien sisa buangan makanan. Manakala, produk akhir sisa buangan makanan pada keadaan yang sama mempunyai 29.73% jumlah C, N, H, and S dan mikronutrien (K =392.2 mg/L, Ca= 109.8 mg/L, Cu= 0.98 mg/L, Mg =58.35 mg/L, and Zn=11.4 mg/L). Secara keseluruhannya, kandungan nutrien sisa dehidrasi selepas kompos parit dipremiskan untuk meningkatkan kualiti tanah. Kesimpulannya, sisa makanan yang dehidrasi dan sisa melambatkan penguraian dan meminimumkan bau, membolehkan pengumpulan sisa lebih kerap.

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

°C	Degree Celsius
D_{eff}	Effective diffusivity
D_o	Diffusivity constant
E_a	Activation energy
EC	Electrical conductivity
g	Gram
GHG	Greenhous gas
H_2O	Water
L	L thickness in meter
ln	Logarithm
m	Meter
M_{bd}	Mass of bone dry
m_c	Critical moisture content
m_e	Equilibrium moisture content
M_i	Initial mass
MR	Moisture ratio
R	Universal gas constant (8.314 J/(mol·K))
s	Second
T	Temperature in Celsius
t	Time in second
T_a	Temperature in Kelvin
x_i	The moisture content at the time i
x_o	Initial moisture content

CHAPTER 1

INTRODUCTION

1.1 Background of study

The increasing global population growth of 7.6 billion has increased waste generation throughout the world. In 2016, the Food Aid Foundation announced that Malaysia has lost almost 15,000 tons of food waste, including 3,000 tons of unavoidable food per day (Sulaiman & Ahmad, 2018), and around 15 million tons (234 kg/person/year or 50% of food) were lost annually in the United Kingdom (Salemdeeb et al., 2017). As one of the big problems in the world, food waste has enormously aggravated the climate, animals, and human beings, which has recently attracted a great deal of global attention (Mohd Thani et al., 2019). Most developing countries lose billions of dollars per year due to food waste. This problem does not stop at the point where food was discarded. Around 95 percent of discarded food goes down in areas where anaerobic digestion processes nitrogen, carbon dioxide, or other gases, which has a catastrophic effect on global warming. Food waste issues appeared to be growing over the next 25 years because of intensive economic and population growth in most Asian countries particularly Malaysia (Melikoglu et al., 2013).

All edible food items produced but not consumed for human consumption due to physical defects can be defined as food waste. Leftovers are defined as the food that remains from a meal. Food waste processing is attributed in the large part to the environmental effects of food waste systems ((Voběrková et al., 2020). Thus, different sources of food are wasted from the food processing plants and household/commercial kitchens, restaurants, and cafeterias (Ghafar Abd, 2017). Waste incorporates some of the cooked and uncooked waste from livestock, animal waste, leftover, food waste, etc (Kannah et al., 2020). The high nutritional values of wasted food could be turned into useful items such as natural manure and biogas energy through appropriate processing. The handling of waste through natural composting may be an effective method of minimizing waste generation (Bashir et al., 2018).

Food waste produces methane, a gas that absorbs heat at a considerably higher rate than other greenhouse gases such as carbon dioxide, because methane has a shorter lifespan than carbon dioxide, the effect is also greater. That will quickly heat the earth. Carbon emissions from food waste that could have been avoided ranged from 2000 to 3600 kg per ton (Zaki, 2019). In the last few years, food waste has increased in Malaysia, affecting the country's solid waste management system, including landfills and incineration. The government was currently constrained to alternative food waste disposal solutions such as compost, animal feed, and dehydration of food waste (Lim et al., 2016). Nowadays, significant factor considerations must be considered before implementing food waste disposal units as a wide-ranging solid waste management option, as solid waste they are related to emissions of greenhouse gasses and other environmental damage. Continued research and development in food waste could better manage this choice to become a sustainable alternative to landfilling, and incarnation (Ismail et al., 2020a; Arumugam et al., 2021).

Food waste and leftovers can be exploited as raw materials for manufacturing vital commercial compounds. The moisture content of food waste which contains carbohydrates, proteins, lipids, and nutraceuticals is normally over 80 percent (Chhandama et al., 2022). Using food waste with a high moisture content of 75 to 95 percent has the greatest negative impact on the environment due to increased greenhouse gas emissions and leachate released into the soil. The best solution to this problem is to dehydrate the food waste, which can then be used as animal feed or raw materials for fertilizer (Sotiropoulos et al., 2016).

Dehydration has recently been investigated as a method of reusing food waste, especially in the context of animal feed and biofertilizers. Dehydration of food waste resulted in a 70% reduction in mass and a lower energy cost than regular food waste treatment. Drying removes water from the organic material, which inhibits hydrolysis and so biodegradation. The low water content of the post-dehydration material delays decomposition and decreases odor, allowing for less frequent waste disposal. Circulating fluid, when heated to approximately 140°C, eliminates any microbes present in waste by drying it out (Vakalis et al., 2018). The physical and chemical properties of dried food make it a useful feedstock for value-added products like compost and animal feed (Schroeder et al., 2020).

Composting is a method of removing and recycling organic material to modify the structure and quality of the soil. There are several composting techniques available for converting organic waste into fertilizer (Li et al., 2013). Vermicomposting is a type of composting in which worms are used to break down food waste. This method benefits rural agricultural areas by preserving the vitality and health of the soil. By increasing soil aeration and delivering nutrients, vermicomposting promotes the growth and spread of beneficial microorganisms in the soil ecosystem (Karmegam et al., 2021). This method also has the disadvantage of causing the death of worms on a large or small scale due to a lack of food, food that is either too dry or too moist or an overheated bin (Yatoo et al.,2021).

Bokashi compost is another type of fermentation that relies on anaerobic digestion. The fertilizer mostly consists of rice bran, rapeseed meal, rice husks, sugar molasses, and water. Effective Microorganisms are used to ferment feedstocks in the Bokashi technique. The use of Effective Microorganisms (EM) facilitates and expedites the degradation process. This process takes two to four weeks to degrade organic material. The final product of this process can be utilized to rehydrate and feed the soil (Banda, 2022). To be effective, it must be continuously supplemented with Bokashi bran or another EM inoculation. If this procedure is not properly controlled, odor difficulties may develop (Lew et al., 2021).

Composting in pits or trenches is another technique for organic waste management. This is a low-cost method because it only requires raw materials such as kitchen waste or other types of waste like leaves and grass clippings. Following that, no more cost will be incurred for the compost area, since composting will occur naturally in the soil. Composting will typically take place in garden space, making it easy to transfer the compost to established plants (Paritosh et al., 2017). For dehydrated food waste, trench compost is one of the recommended methods. Because, it does not require determining moisture levels, aeration, or sifting as with a compost pile (Reber Creative, 2010).

The study aims to examine the impacts of pre-treatment on drying kinetics, and the influence of dry food waste and leftovers in the final product to improve soil quality in terms of pH value, electric conductivity (EC), and nutrient concentrations. The collected samples were pre-treated for five minutes with distilled hot water at 70^0C, pre-treated and non-pre-treated food waste, and leftovers were subjected to hot air drying at three different temperatures (80,90,100) ^{0}C. Then trench compost was made by mixing dried food waste and leftovers in a 5/3 ratio with garden soil and keep it them in the compost box for four weeks. The finding will be a good consensus to reconfigure solid waste management since the latest food waste treatment policy focuses on waste production reduction and less on recycling (Ravindran et al., 2016).

1.2 Problem statement

Food waste management is the most difficult issue for authorities in developing countries. Increasing volumes of solid waste, such as those generated by commercial properties, farms, and residences, are being diverted to unsanitary landfills, posing serious health and environmental risks to the local population (A. Sharma et al., 2022).The water content of food waste is one of the more important factors because it quickly causes food and agricultural waste to decompose. Nowadays, drying techniques have been implemented in developed and developing countries to boost the efficiency of urban food waste, decrease reliance on fossil fuels, and clean up waste sites (Pilnáček et al.,2021). Drying procedures can minimize the mass of water in food waste and the most crucial parameters for dewatering food waste and lowering the total mass of wastage within the framework of the waste management plan are drying time, drying rate, effective diffusivity, and activation energy that defines the mechanisms of heat and mass transfer during the drying process (Noori et al., 2022).

With the increasing awareness of environmental pollution, dehydrated food waste become more actable in food waste management. But the presence of oil-coated layers and impurities such as salt, and dust on the organic material might disturb the efficiency of drying kinetics (H. O. Wang et al.,2018). Hence, in this study, the pre-treatment methods have been chosen to remove the impurities and the oil-coated layer on the surface of food waste, and leftovers are soaked in the distilled heated water at 70°C until the impurities are completely removed without changing the properties. And pre-treatment improves drying kinetics and quality in the final product after trench compost.

Food waste easily decomposes into high-quality compost due to its high water and nutrient content. Bio-compost created from food waste can help increase the soil's fertility and compensate for a deficiency of organic matter (S. L. Lim et al., 2016). But employing organic waste with high moisture content in the composting process creates significant challenges over time, including increased greenhouse gas emissions, leachate, and odor (Ahmed & Gupta, 2010). Due to the higher moisture content throughout the composting process, bacteria, yeasts, and mold grow more quickly and produce odor and leachate, which harm the environment (Ayilara et al.,2020). Since dehydrated organic materials have several advantages including light weight, low moisture content, low odor, and biological inertness. Due to high quality and low moisture content dehydrated food waste is more acceptable for storage and transportation than novel recycling procedures such as composting or anaerobic digestion (Limão, 2016). So, this study aims to describe the kinetics of drying food waste and leftovers and their usage as raw materials in trench compost to protect the environment from odor and leachate.

1.3 Objectives

- To evaluate the drying behaviour of food waste and leftovers subjected to hot air drying at temperatures of (80,90, and 100 ^{0}C).
- To investigate the effects of pre-treatment on the drying behaviour of food waste and leftovers subjected to hot air drying at the temperature of (80,90, and 100 ^{0}C).
- To determine the effects of dehydrated food waste and leftovers on compost soil properties.

1.4 Assumption/Hypothesis

Based on the research that has been conducted, the drying kinetics of food waste and leftovers aid to provide an insightful comprehension of the mechanism of moisture transfer. One of the factors that help to improve drying kinetics is pre-treatment with distilled hot water. Because the purpose of the pre-treatment is to eliminate the oil, impurities, and contaminants on the surface of the food waste and leftovers. A direct application of dehydrated food waste and leftovers as a soil amendment appears to be implausible. Since food waste and leftovers rehydrate and create fungus. Thus, dry food contains significant nitrogen and carbon, and it should be composted before being placed in the soil. For dehydrated food waste, trench compost is one of the recommended methods. Because, it does not require determining moisture levels, aeration, or sifting as with a compost pile and it is a great way to create organic fertilizers to improve soil aeration and restraining power.

1.5 Significance of Study

The importance of using dehydrated organic waste to minimize the weight and volume in a limited amount of time in certain cases such as composting can be advantageous. The low water content of the compost inhibits biological decomposition, limits odor pollution, and thereby decreases the frequency at which household waste must be processed. Furthermore, as opposed to wet food waste and leftovers, dry crops are much easier to manage. The dried waste's physicochemical properties mean that it could be used to create high materials such as biogas, thermal energy, and compost in a renewable and environmentally friendly manner.

1.6 Scope of Study and Limitation

1.6.1 Drying kinetics

Pre-treated and non-treated food waste and leftovers were dried under continual air conditions by using a laboratory oven at (80^0C, 90 ^{0}C, and 100 ^{0}C). Throughout the drying process, the moisture reduction was tracked. During the drying process, the effects of pre-treatment on the drying parameters, as well as drying kinetics, were investigated. Based on the drying curves, drying kinetics is calculated.

1.6.2 Drying Analysis

The dehydrated food waste and leftovers from various drying conditions were examined for sensitive assessment of moisture content, moisture ratio, drying rate, effective diffusivity, and activation energy were all included in the assessment.

1.6.3 Pre-treatment of feedstock

The impact of pre-treatment on the consistency of dehydrated food waste and leftovers was studied. The raw materials were soaked in warm water at 70 degrees for five minutes as part of the pre-treatment process.

1.6.4 Preparation of trench compost

Trench compost has been selected in this study as a composting performance. The maturation period of trench composting wholly, by mixing dried and ground food waste and leftovers with a ratio of 5/3 garden soil for four weeks.

1.6.5 Physiochemical analysis

A study of physical and chemical properties can be carried out of the compost from food waste and leftovers. The analysis of physical properties includes the pH value, total Nitrogen, total sulfur, total carbon, determination of micronutrients (Cu, Ca, Mg, K, and Zn), and electric conductivity of the trench compost.

1.7 Summary

In conclusion, dehydration of food waste and leftovers based on the product contains one of the best methods to minimize waste management. The lower moisture content of food waste can aid in managing the organic substrate's water content throughout the composting process. Additionally, purified dry food waste is pathogen-free, has a suitable carbon content, and sufficient nitrogen content, and can be used as a compost feedstock. Consequently, this study aims to ascertain the drying kinetics of food waste and leftovers at different temperatures (80 ˚C, 90 ˚C, 100 ˚C), as well as the effects of pre-treatment on the drying kinetics and the influence of dry food waste and leftovers in the final product to improve soil quality in terms of pH value, electric conductivity (EC) and nutrient concentrations. For this study, trench composting was chosen as a composting quality. Trench composting took one month to completely mature, and it was done by mixing dry and ground food waste and leftovers with garden soil in a 5/3 ratio. It's a good way to recycle food waste while still developing organic fertilizers that improve soil aeration and water-holding ability.

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