CHAPTER I
INTRODUCTION

1.1 Background of Study

Food waste (FW) is refers to any food items that are prepared for human consumption but end up uneaten (Chen et al., 2017). This organic refuse originates at multiple points within the food supply chain, spanning from agricultural production to end-user consumption, and includes residues from sources like food processing plants, restaurants, households, and also institutional cafeterias (Chen et al., 2017). According to reports from the Food and Agricultural Organization (FAO), nearly 1.3 billion tons of food, including fresh produce such as fruit and vegetables, bakery, dairy items, and meat are lost throughout the global supply chain annually (Chen et al., 2017).

Food waste is a general phenomenon in many affluent societies or countries. Studies indicate that the Southeast Asian region discards approximately 33% of its food supply (Yang et al., 2016). In the Malaysian context, research shows that the typical household disposes of between 0.5 and 0.8 kilograms of food daily. This challenge is projected to intensify due to ongoing economic development, population expansion, and urbanization. Demographic forecasts indicate that Malaysia's population will grow to 33.4 million by 2020 and further to 37.4 million by 2030 (Chien Bong et al., 2017). Based on data provided by Solid Waste Corporation (SWCorp) of Malaysia, approximately 15,000 tons of food are wasted every day. Out of this total, 3,000 tons are still edible and should not be thrown away. To address this issue, the transformation of this abundant organic stream into valuable resources via appropriate technological treatment emerges as a highly promising and sustainable waste management approach (Ahmad et al., 2021).

In developed countries, Europe and Asia, anaerobic digestion (AD) technology is commonly used for processing FW on a large scale. Countries such as Germany, Spain, the UK, and Korea have AD plants with capacities of 2500 tons per year or more. A successful pilot-scale study in India has demonstrated the use of Anaerobic Digestion (AD) for Food Waste (FW) processing, complemented by biogas plants developed at various institutes. Meanwhile, China initiated demonstration projects for FW disposal in 2010, designating up to 100 pilot cities. Anaerobic Digestion technology has been employed in over 90% of these initiatives (Li et al., 2018).

AD is a way to treat organic waste using biological processes. It's becoming more popular because it can turn waste into useful energy and nutrients. Compared to landfilling, composting, and incineration, AD takes up less space and uses less energy. This process uses organic waste like food waste (FW), agricultural waste, and also municipal solid waste (MSW) as its main materials (Phun et al., 2018). For this process to maintain efficiency and stability, several essential conditions must be fulfilled. Among the most significant is the presence of an active microbial community, which is generally introduced through the application of an inoculum. In anaerobic digestion, an inoculum consists of microorganisms that are introduced to initiate and support the degradation of organic substrates such as FW into biogas. A key strategy for optimizing anaerobic digestion is the use of a substrate-adapted inoculum, which directly contributes to greater process stability and efficiency (Filer et al., 2019).

The considerable energy density inherent in food waste renders it an increasingly attractive feedstock for anaerobic digestion systems aimed at optimizing biogas yield (Phun et al., 2018). Food waste can produce higher quality methane because it contains more lipids and proteins than feedstock rich in carbohydrates. Including fat and protein-rich materials in anaerobic digestion can greatly boost the amount of biogas produced. Methane yields range from approximately 0.27 to 0.642 m^3 CH_4 per kg VS, the AD system used two stages with alternation between mesophilic and thermophilic, as well as the use of co-substrates such as meat residue or cow manure as inoculum. (Phun et al., 2018).

According to Banks et al. (2011), the role of food waste as an anaerobic digestion feedstock extends to the circular economy, where it contributes to increased agricultural revenue and a reduction in greenhouse gases through more efficient practices. Biogas produced in anaerobic digestion mainly consist 50% to 75% methane (CH_4) and 20% to 40% carbon dioxide (CO_2), with methane being the predominant combustible component. Notably, methane possesses a significantly higher global warming potential than CO_2, about 21 times greater (Felton et al., 2014). In most cases, the methane produced by anaerobic digesters is injected into internal combustion engines to generate electricity (Cowley & Brorsen, 2018). AD can be performed in batch mode using pilot-scale systems. Khelifa Zouaghi et al. (2021), conducted and pilot plant AD, pilot-scale experiments employed a stainless-steel reactor with a total capacity of 30 liters. In the context of anaerobic digestion, batch operation refers to a digestion process where substrate decomposition occurs in a single cycle without material addition or removal during a specified retention period (Apriandi et al., 2023).

Research by Komilis et al. (2017) on the anaerobic digestion of food waste in a batch reactor system resulted in a methane production of 335 L CH_4/kg VS. In another study, the pilot-scale anaerobic digester produced an average of 0.136 m^3 of methane (Miller et al., 2020). A pilot plant is a small-scale facility meant to test and develop production processes before industrial application (Manikandan, 2021).

In the anaerobic digestion process, mathematical kinetic models play a fundamental role. They facilitate the optimization, forecasting, simulation, and monitoring of system performance across varied conditions, while also enabling the prediction of kinetic model parameters and providing a clearer understanding of the process mechanisms (Pramanik et al., 2019). Kinetic analysis is commonly used to describe the degradation of food waste and methane generation. Studies have employed several mathematical models, including the Modified Gompertz model, the Logistic Function model, and the First Order model to examine the kinetic behavior of anaerobic digestion. These modeling approaches are instrumental in calculating key parameters like the potential for methane generation, its duration of the lag phase and the rate of production. The resulting kinetic values, such as methane yield and production rates, are not fixed, they fluctuate based on the specific model employed and the unique properties of the substrate, which indicate variations in biodegradability and reaction kinetics (Yu et al., 2018; Chelliapan et al., 2024).

In this research, the food waste includes a mixture of uneaten food scraps and waste from food preparation collected directly from one of the canteens at UTHM. Food waste used as substrate undergoes several processes, including separation, cutting, and grinding for homogenization. Meanwhile, In this experiment, digested sludge from a functioning biogas facility in Yong Peng, Johor, served as the microbial inoculum. The immediate onset of methane production without any initial delay demonstrated the appropriateness of the selected inoculum for the anaerobic process (Seswoya & Karim, 2017). The operational differences from the previous study by Fadzil et al. (2021) are a working volume of 84 L (26 days), which means that the weight of the substrate and inoculum used will also different from the current operation, as well as a slower stirring speed of 70 revolutions per minute (rpm). This research aims to provide a deeper understanding of the methane production potential from food waste generated by a cafe or canteen at UTHM through the anaerobic digestion process using a 110 L pilot-plant digester working under batch mode. The findings on the feedstock and inoculum, methane accumulation, and methane yield were discussed.

1.2 Aim and Objectives

1.2.1 Aim

The aim of this study is to evaluate the suitability of food waste from a UTHM cafeteria as a feedstock for methane production via anaerobic digestion under batch mode and ambient temperature. This will be achieved through a comprehensive evaluation that includes feedstock and inoculum characterization, performance monitoring of a pilot-scale digester, and kinetic analysis of the methane production process.

1.2.2 Objectives

1. To characterize the food waste as a feedstock for methane production, and the inoculum as well;
2. To operate pilot plant and monitor daily methane production from the pilot-scale anaerobic digester treating food waste in batch mode;
3. To assess the performance of the pilot plant anaerobic digester treating food waste in batch mode based on the organic removal;
4. To calculate the ultimate methane yield from the pilot plant anaerobic digester treating food waste in batch mode;

5. To evaluate the kinetic of the methane production using the First-order kinetics model, Modified Gompertz models, Logistic Function models, and Tranference Function models.

1.3 Benefits of The Research

The benefits of this research are:

1. Give insight into the methane potential from the food waste digestion at batch mode using pilot plant anaerobic digester;
2. Food waste is recycled as the feedstock for anaerobic digestion, promoting sustainable waste management;
3. The experimental setup/design for the methane production can be used for another study.

1.4 Scopes

The scopes of this research are:

1. To measure food waste and inoculum composition through measurements of TS (APHA 2012, Method 2540 B), VS (APHA 2012, Method 2540 E), and COD (USEPA Reactor Digestion HACH Method 8000);
2. To establish anaerobic digestion batch experiments where food waste serves as the feedstock and the inoculum is sourced from a biogas plant;
3. The pilot plant digester was operated at an inoculum to substrate ratio (ISR) of 2:1 VS/VS, ambient temperature, and a mixing speed of 120 revolutions per minute (rpm);
4. The measurement on the methane production was done until the methane production is nearly ceased;
5. The performance of pilot plant digester was measured using organic removal (in %);
6. To validate the predictive capabilities of the First Order Kinetic Model, Modified Gompertz Model, Logistic Function Model, and Transfer Function Model by comparing the methane production predictions generated by these models with actual experimental results.

1.5 Systematics of Writing

The systematics of this proposal are:

CHAPTER I **INTRODUCTION**

This chapter contains the background of study, and objectives of the research, scopes, benefits of the research, and systematics of writing.

CHAPTER II **LITERATURE REVIEW**

This chapter presents literature related to the research and the preparation of the final project report, including explanations on food waste, parameters of food waste characteristics, methods of food waste treatment and disposal, anaerobic digestion process, reaction involved in methane production from food waste, factors affecting anaerobic digestion, organic removal, COD reduction, and methane production from food waste.

CHAPTER III **RESEARCH METHODOLOGY**

This chapter explains the research stages that were carried out to achieve the research objectives. It describes the time and place of research, research flowchart, literature review, development of methodology, FW and inoculum collection, experimental setup for methane production, and analytical method. Data analysis using descriptive statistical analysis is also included, particularly for characterization and analysis kinetic models.

CHAPTER IV **RESULT AND DISCUSSION**

This chapter contains the results and their comparison and discussion with existing literature data. The results and discussion are limited to the study's objectives.

CHAPTER V CONCLUSIONS AND SUGGESTIONS

This chapter contains conclusions limited to the research objective and suggestions for further study to enhance the understanding of the subject matter.