

CHAPTER I

INTRODUCTION

1.1 Background of Research

Global climate change in addition to its rapid and real increase is one of the main challenges in sustainable development. One of the main causes of climate change is the increasing concentration of greenhouse gases in the atmosphere. The increase in greenhouse gases concentration in the atmosphere is caused by human activities, mainly from the burning of fossil fuels for industrial purposes (Intergovernmental Panel on Climate Change, 2019).

The increase of greenhouse gases concentration in the atmosphere has impacts that are very broad and can affect various aspects of life. One of the main impacts is sudden changes in the climate that can cause extreme weather phenomena, such as increased frequency of heat waves, intense tropical storms, and erratic rainfall that can cause floods and droughts. These environmental disruptions not only threaten ecosystems and biodiversity but also endanger human health and food security (World Meteorological Organization, 2024).

In addition, the increase of greenhouse gases concentration can affect the global temperature, in which the rise of global temperature contributes to the melting of the polar ice caps. Consequently, the melting of the ice causes the sea level to rise and has the potential to submerge coastal areas and small islands. This condition also threatens freshwater availability because saltwater intrusion can contaminate groundwater resources in regions with lower elevation. Furthermore, the melting of the polar ice caps contributes to the acceleration of global temperature increase which worsens climate change (Intergovernmental Panel on Climate Change, 2019).

According to the situation mentioned above, mitigation measures are needed to reduce the potential of negative impacts. One of the mitigation measures that can be conducted is transitioning to utilizing renewable energy sources, mainly to reduce dependency on fossil fuels. One promising solution is the utilization of biomass as an alternative energy that is more environmentally friendly. Biomass

greatly helps in reducing greenhouse gas emissions when they are managed sustainably. In addition, they also provide a renewable and locally available energy option. Other than that, the utilization of biomass can support energy security and economic development in rural areas with the creation of new job opportunities.

Biomass is a renewable energy source that can be processed into solid, liquid, or gas fuels (Demirbas, 2009). One potential form of biomass is pellets made from agricultural and plantation waste. According to Pradana et al (2023), the number of biomasses in Indonesia that has the potential to be utilized as energy source reaches up to 146.7 million tonnes per year. Meanwhile, the potential biomass that is sourced from waste is estimated at 53.7 million tonnes in 2020. Waste from animals and plants all have the potential to be utilized and developed. Food crops and plantations produce quite a lot of waste, which can be used for other purposes such as biofuels.

One of the examples of produces that has the potential to be utilized is jackfruits or also known as *Artocarpus heterophyllus*. According to Central Statistics Agency (BPS) of West Sumatra, the production of jackfruits in West Sumatra reaches up to 11,154 tonnes in the year 2023 with Padang Pariaman Regency being the largest producer at 3,805 tonnes. In West Sumatra, jackfruit is commonly used in several local dishes, such as jackfruit curry lontong and nasi padang, which is served as both a main and side delicacy alongside other vegetables. Therefore, the production of jackfruit is abundant, meaning that the waste produced is also abundant, specifically the outer skin. Despite that, however, its utilization is still limited. With proper handling, jackfruit skin can be made into biomass pellets that have the potential to be an alternative fuel for cooking with low greenhouse gas emissions (Saleem, 2022).

The utilization of jackfruit skin as an alternative fuel is based on its high lignocellulose content, which makes it a potential source of biomass energy. Jackfruit skin contains 3 main components, which are cellulose, hemicellulose, and lignin, that can support the combustion process and produce considerably high heat energy. Up until today, there are several studies that had been conducted in utilizing jackfruit skin, such as using jackfruit skin as biocoagulant to remove COD and TSS

in industrial wastewater, producing plastic using jackfruit skin to decrease non-degradable plastic waste, and biomass briquettes produced from charred jackfruit skin as alternative fuel.

The previous studies that utilized jackfruit skin to produce biomass briquettes were conducted by Arzita et al. (2024) and Kholifah et al. (2024) although the latter mixed the jackfruit skin with banana peels. Both studies focused on testing the quality of the biomass briquettes and obtained results that meet the standard. However, biomass briquettes require binders in order for the charred raw material to stick together during the molding process. Due to that, applying certain concentration of binders can affect the quality of the biomass briquette and increase particulate emissions. Meanwhile, biomass pellets directly utilize the raw material, thereby maintaining the main components of the raw material that are still contained. Because of that, specifically for jackfruit skin, binders are not required when molding them into biomass pellets due to their natural sap. In addition, the moisture content and ash content in jackfruit skin are relatively low after being dried and going through the pellet molding process. Therefore, that has the potential to increase combustion efficiency and reduce particulate emissions when utilized for cooking (Kholifah et al., 2024).

According to Indonesia Environment and Energy Center (2025), the government is targeting a 31% reduction in carbon emissions by 2035. This percentage is significantly higher when compared with the target set in 2019. This step is part of a broader effort to achieve Net Zero Emissions (NZE) by 2060. The goal has the potential to be reached sooner with international support. Therefore, the electricity management program in the national and regional energy policy is established to contribute in reaching that goal. One of the activities that is conducted as contribution is the provision of biomass stoves, one of them being the Top-Lit Updraft (TLUD) type.

The TLUD biomass stove is one of the cleaner and more efficient technologies for combustion. The stove's main working principle is based on top-lit combustion, where the biomass fuel undergoes pyrolysis and gasification processes before being oxidized. That results in more complete combustion and significantly lower

emissions of pollutants. Moreover, TLUD biomass stoves are designed to ensure a steady flame when ignited and produces stable heat. Compared with other stove types, the TLUD type produces low indoor air pollution, has better fuel utilization, and has higher thermal efficiency (Roth, 2011). However, further analysis is needed regarding Particulate Matter 2.5 (PM_{2.5}), carbon monoxide (CO), and carbon dioxide (CO₂) emissions resulted from the combustion of jackfruit skin biomass pellets on the TLUD biomass stove.

This research aims to analyze the quality of biomass pellets produced from jackfruit skin based on SNI 8675:2018 by measuring the density, moisture content, volatile matter, ash content, fixed carbon, calorific value, and sulfur content. The previous studies by Arzita et al. (2024) and Kholifah et al. (2024) only conducted the quality test for biomass briquettes, in which the former also measured the initial flame time and flame duration when using jackfruit skin biomass briquettes as fuel.

Therefore, in this research, the performance of the TLUD biomass stove is also analyzed based on SNI 7926:2013 by measuring the PM_{2.5}, CO, CO₂ emissions, specific fuel consumption, combustion efficiency, and thermal efficiency when utilizing jackfruit skin biomass pellets as fuel. In this research, PM_{2.5}, CO, and CO₂ are the measured emission factors because they are the major indicators of air quality and public health risk, particularly in indoor environments. PM_{2.5} can cause respiratory and cardiovascular diseases due to its small size, while CO is extremely toxic. On the other hand, CO₂ is a primary product of complete combustion, which can serve as an indicator of carbon conversion efficiency. The results of this study are expected to provide insight into the potential of utilizing biomass as a cleaner and more sustainable alternative energy, as well as support carbon emission reduction policies in the household energy sector.

1.2 Purpose and Objectives of Research

The purpose of this research is to evaluate the performance of the Top-Lit Updraft (TLUD) biomass stove based on SNI 7926:2013 by measuring the Particulate Matter 2.5 (PM_{2.5}), carbon monoxide (CO), carbon dioxide (CO₂) emissions, specific fuel consumption, combustion efficiency, and thermal efficiency. The fuel that is utilized on the biomass stove is biomass pellets made from waste, namely

jackfruit skin. In addition, an analysis is conducted to determine the potential of jackfruit skin biomass pellets as a more environmentally friendly alternative when compared to traditional fuels.

The objectives of this research are as the following:

1. To analyze the quality of jackfruit skin biomass pellets based on SNI 8675:2018 concerning Biomass Pellets for Energy.
2. To measure and analyze the concentrations of PM_{2.5}, CO, and CO₂ emitted from the combustion of jackfruit skin biomass pellets fueled in the TLUD biomass stove based on SNI 7926:2013 concerning Biomass Stove Performance.
3. To measure and analyze the specific fuel consumption, combustion efficiency, and thermal efficiency when utilizing jackfruit skin biomass pellets as fuel for the TLUD biomass stove based on SNI 7926:2013 concerning Biomass Stove Performance.

1.3 Benefits of Research

The benefits of this research are as the following:

1. Provides solutions for waste produced from utilizing jackfruits, mainly the skin, for culinary needs and serves as an alternative for fossil fuel, specifically for cooking activities.
2. Provides information regarding the characteristics of jackfruit skin biomass pellets scientifically, thus creating the potential of utilizing them as alternative fuel.
3. Provides information for the community and government regarding the potential of utilizing jackfruit skin biomass pellets as alternative fuel.
4. Provides reference for further research on utilizing biomass waste as alternative fuel.

1.4 Scope of Research

The scope of this research is as the following:

1. The stove that was used for this research was the Top-Lit Updraft (TLUD) biomass stove.

2. The jackfruit skin used to make the biomass pellet was sourced from community plantations in Kuranji District, Padang City. The type of jackfruit used was the unripe jackfruit.
3. The biomass pellet production was carried out in the Integrated Waste Processing Center (PPST), Universitas Andalas.
4. This research covered the parameters of Particulate Matter 2.5 (PM_{2.5}), carbon monoxide (CO), and carbon dioxide (CO₂), specific fuel consumption, combustion efficiency, and thermal efficiency to evaluate the biomass stove performance based on SNI 7926:2013. This measurement was conducted in the Air Quality Laboratory (LKU), Department of Environmental Engineering, Universitas Andalas.
5. For the quality of the biomass pellet, the parameters that were covered were density, moisture content, volatile matter, ash content, fixed carbon, calorific value, and sulfur content in accordance to SNI 8675:2018. The biomass pellet quality test was carried out in the Solid Waste Laboratory (LBP), Department of Environmental Engineering, Universitas Andalas, while the calorific value and sulfur content tests were conducted in the Basic Central Laboratory, Universitas Andalas.

1.5 Writing Systematic of Research

The writing systematic of this research is as the following:

CHAPTER I INTRODUCTION

This chapter contains the background, purpose and objectives of the research, benefits, scope of the research, and the writing systematic.

CHAPTER II LITERATURE REVIEW

This chapter explains the theoretical basis of the research material, supporting data for the research, and other previous researches that are related.

CHAPTER III METHODOLOGY

This chapter explains the time and location of research, the stages, data collections, and data analysis and interpretation.

CHAPTER IV RESULTS AND DISCUSSION

This chapter contains the results that are obtained through the research and their discussion.

CHAPTER V CONCLUSIONS AND SUGGESTIONS

This chapter contains conclusions of the research's findings and suggestions for studies in the future.

