Pyrolysis of biomass: Potential and applications

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ABSTRACT – Pyrolysis is a chemical decomposition process technique of biomass through heating without oxygen. The amount of biomass on earth is very abundant. The content of biomass such as cellulose and lignin makes biomass a material rich in carbon. These materials are promising materials to be processed into various valuable products such as biochar and bio-oil. These products are widely used as chemical sources in various applications in adsorption, fertilizer, catalyst, energy storage and chemical sources.

1. INTRODUCTION

Biomass is a term for all organic matter obtained from plants, including algae and trees. Biomass is obtained from green plants that convert sunlight into plant material through the process of photosynthesis including terrestrial and aquatic vegetation and organic waste [1]. The basic principle of biomass is that plants will absorb solar energy through the process of photosynthesis by utilizing water and soil as well as CO_2 from the atmosphere to produce organic material that forms and strengthens plant tissues. The CO_2 cycle in biomass will be shorter than burning petroleum or natural gas in the sense that the CO_2 produced does not affect the CO_2 balance in the atmosphere [2].

The potential of biomass as an energy source for humans is currently estimated to contribute 10-14% of the world's energy [1]. Indonesia is no exception, the potential that can be processed into biomass is very abundant at 146.7 million tons per year and the potential utilization from waste in Indonesia in 2020 can reach 53.7 million tons. Most of this waste is obtained from food crops and plantation products which can certainly be used for biofuel purposes [2].

Pyrolysis is a chemical decomposition process of biomass through heating without oxygen. Biomass is decomposed to various products such as gas, liquid and solid.

The purpose of this mini review article is to compile potential of biomass obtained through the pyrolysis process and its application in the form of biochar and bio-oil based on data from previous research.

2. BIOMASS SOURCES

Biomass is an alternative energy from fossil fuels because it is a carbon neutral energy source. Carbon neutral because in the process the CO_2 released is proportional to the CO_2 absorbed by plants [3]. Classification of biomass based on origin, source, and biodiversity [4] namely biomass from wood species such as stems, twigs, bark, leaves, fruit peels, sawdust, etc. Aquatic biomass comes from waters such as algae, seaweed, or other marine organisms. Biomass from grass and agriculture can be grass, flowers, bamboo, rice, wheat, oil palm, etc. In this case, much of it is in the form of post-agricultural waste, which is mostly not utilized. Biomass can also be in the form of animal manure such as cow, goat, and chicken. Industrial waste biomass in the form of municipal solid waste, wastepaper, sludge waste, fibreboard waste, pallets, and others. Biomass can also be a mixture of various kinds of existing biomass. Based on these biomass sources, it can be seen that biomass is a highly available, sustainable, and low-pollution carbon source. It also has the potential to convert biomass into hydrogen syngas and other valuable chemicals [4].

The main components of biomass are cellulose (42–45%), hemicellulose (28–35%), and lignin (16–33%) [5]. Thus, biomass can be a rich source of carbon through pyrolysis and hydrothermal carbonization processes.

3. BIOMASS PRE-TREATMENT

Pre-treatment is a processing on biomass before it is converted. The pre-treatment process is carried out because the structure of the plant cell walls is not uniform and complex. This will affect the efficiency of the biomass conversion process into biofuels and chemicals. Pre-treatment is needed to improve the quality and uniformity of the resulting product by removing or modifying unwanted structures and functional groups in biomass [6]. The pre-treatment process consists of four types, namely physical, chemical thermal, and biological pre-treatment.

Physical pre-treatment can be in the form of reducing of particle size of the biomass by milling. Reducing of particle size has impact during the pyrolysis of biomass. Chemical pre-treatment can be carried out by treatment with acids, bases, hydrothermal, and washing with water. Acid-base treatment is carried out to remove mineral content in the biomass such as phosphate, chloride, carbonate, and sulphate [6]. Pre-treatment with acid and base reduces metal content in biomass in particular the content of metals calcium and magnesium, a significant decreased when biomass is treated with acid [7]. Thermal pre-treatment includes drying to remove free water content in the biomass in an oven at a temperature between 50-100 ^oC. The high-water content can affect energy efficiency during the energy conversion process [8]. Biological pre-treatment is more environmentally friendly than other pre-treatment methods because it uses natural organisms, namely

various types of fungi to degrade components in biomass [6]. This process does not require high energy.

4. PYROLYSIS

Pyrolysis is a method which requires high temperature in minimum oxygen conditions. Pyrolysis is widely used to change materials that people usually think of as waste into something more useful. Such as biomass that can be converted into biochar, bio-oil and gas [9]. Pyrolysis has various types of pyrolysis namely slow, fast, and flash pyrolysis based on the heating rate, temperature profile and the presence of pressure during pyrolysis.

5. APPLICATIONS OF PYROLYSIS PRODUCTS FROM BIOMASS

Pyrolysis of biomass produces three types of products, namely biochar, bio-oil and gas [9]. Biochar is a carbon-rich solid material produced from the conversion of biomass waste through carbonization and pyrolysis processes and requires activation [10]. The main content of biochar is carbon and oxygen [9]. This product has widely application in soil fertilizer. This carbon material has pores with a high surface area. This material is widely used as an electrode for lithium-ion batteries and capacitors [11]. Biochar is also widely used as a catalyst and adsorbent for dyes/heavy metals [12].

Bio-oil is a liquid oil obtained generally from the pyrolysis process of biomass. Bio-oil itself has various colours (dark red, brown or black), and has a thick structure. Bio-oil has variances in terms of content, quantity, or physical properties depending on the type of raw material (biomass) used [13]. Bio-oil is widely used as a chemical source, which has potential as a fuel feedstock [9].

Biomass produces hydrogen gas during pyrolysis [12]. Production of gas and biochar can be released simultaneously as Wu et al. performance on corn corb pyrolysis in urea atmosphere. They produce biochar containing nitrogen as well as hydrogen gas. Biochar with N content has the potential to be used as fertilizer [14].

6. CONCLUSION

Pyrolysis can convert biomass into other forms of energy. The closed system and the absence of oxygen make pyrolysis one of the methods in the effort to apply clean energy. Biochar and bio-oil are the main products of the pyrolysis process. Biochar itself is generally used in agriculture because it has the potential to enrich soil and help plant growth. Meanwhile, bio-oil is widely applied as an alternative to chemicals and substitute fuel that is more environmentally friendly.

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