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Utilization of Bagasse Waste For Bio-Oil Extraction from Sugarcane Juice Vendors in Banyuwangi Regency

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Abstrak. Limbah ampas tebu yang dibuang secara terbuka tanpa pengolahan lebih lanjut dapat mencemari lingkungan dan menimbulkan bau yang tidak sedap. Oleh karena itu, perlu diterapkan suatu teknologi untuk mengatasi masalah limbah ampas tebu ini, yaitu dengan menggunakan teknologi daur ulang limbah padat menjadi produk bio-oil yang memiliki nilai guna. Pemanfaatan limbah ampas tebu sebagai bahan baku bio-oil juga merupakan salah satu alternatif untuk mengurangi polusi estetika. Penelitian ini dilakukan dengan menggunakan limbah ampas tebu yang berasal dari pedagang minuman sari tebu di Kabupaten Banyuwangi. Bio-oil adalah senyawa anorganik yang dihasilkan melalui proses pirolisis. Tujuan dari penelitian ini adalah untuk menghasilkan bio-oil dari pemanfaatan ampas tebu yang jarang dimanfaatkan sehingga memiliki manfaat ekonomis dan sebagai energi alternatif yang berkualitas dan ramah lingkungan. Selain itu, penelitian ini bertujuan untuk mengetahui konsentrasi dan komposisi bio-oil hasil pirolisis ampas tebu. Hasil analisis dalam penelitian ini menunjukkan bahwa kandungan lignoselulosa yang tinggi dalam ampas tebu berpotensi untuk dimanfaatkan menjadi bio-oil

Katakunci: Ampas Tebu, Biomassa, Bio-oil, Pirolisis

Abstract. The disposal of sugarcane bagasse waste, often done through open dumping without further treatment, poses environmental pollution and unpleasant odors. Consequently, the implementation of technology is essential to address this issue, specifically by employing a solid waste recycling technology to produce bio-oil, which holds significant value. Utilizing sugarcane bagasse waste to create bio-oil presents an alternative to minimize aesthetic pollution. This research, sourced from sugarcane bagasse waste obtained from sugarcane beverage vendors in Banyuwangi Regency, explores the conversion of bagasse into bio-oil through the pyrolysis process. Bio-oil is an inorganic compound produced during the pyrolysis process. The aim of this study is to generate bio-oil from underutilized sugarcane bagasse, providing a functional and economically valuable alternative energy source that is

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both high-quality and environmentally friendly. Additionally, the research aims to determine the concentration and composition of bio-oil resulting from the pyrolysis of sugarcane bagasse. The analysis reveals that the high lignocellulosic content in sugarcane bagasse has the potential to be utilized for bio-oil production.

Keywords: Bagasse, Biomass, Bio-oil, Pyrolysis

1. Introduction

Waste is the residual result from business materials or production activities, whether from factories or households, that is no longer utilized. If the remaining production waste is not reused, it can lead to problems by causing waste accumulation that may pollute the environment. Proper treatment is required to maximize the processing of waste, turning it into something more useful and economically valuable, provided it is processed and handled correctly. Bio-oil is an inorganic compound in liquid form produced through the pyrolysis process [1].

There are two types of waste: inorganic waste, which cannot be decomposed or does not decompose on its own, and organic waste, which can decompose naturally, such as bagasse waste. However, even though bagasse waste can decompose naturally, improper disposal, often through open dumping without further processing, can still lead to environmental pollution and unpleasant odors [2].

Based on these considerations, a technology needs to be implemented to manage bagasse waste, such as using solid waste recycling technology to produce biomass products, like bio-oil, that have utility value. Utilizing bagasse waste to produce bio-oil is also an alternative to minimize aesthetic pollution, as observed in the practices of sugarcane juice vendors who only extract the juice, discarding the bagasse [3].

According to the United Frameworks Convention on Climate Change , biomass is non-fossilized, organic, and biodegradable material derived from plants, animals, and microorganisms. Biomass includes by-products, residues from agricultural waste, forest products, and industries related to non-fossilized and biodegradable fractions. The primary components of biomass are various chemicals (molecules) containing predominantly carbon (C) atoms; when burned, carbon is released into the air in the form of carbon dioxide. Biomass is a product of the photosynthetic reaction of carbon dioxide with water, consisting of carbon, oxygen, and hydrogen in the form of complex macroscopic polymeric structures: cellulose, hemicellulose, and lignin. Typically, biomass contains 40-60% cellulose by weight, 20-40% hemicellulose, and 10-25% lignin on a dry weight basis. In cases of thermal degradation, the most easily degradable component is hemicellulose, followed by cellulose, with lignin being the most resistant [4].

Biomass is a material derived from vegetables, fruits, weeds, grass, and agricultural and forestry waste that has the potential to become an alternative energy source by converting it into bio-oil through the pyrolysis process [5]. Bio-oil is an inorganic compound in liquid form produced through the pyrolysis process. The liquid produced by the pyrolysis process is referred to by various names. Some call it pyrolysis liquid, pyrolysis oil, bio-oil, wood liquid, wood oil, wood distillates, pyroligneous tar, pyroligneous acid, and liquid wood. Bio-oil has a color range from dark green to dark red, approaching black, depending on the materials and processes used to obtain the product. Bio-oil consists of various chemical components from volatile chemicals like formaldehyde, acetic acid, phenol, and anhydrosugar [6]. Bio-oil contains carbon, hydrogen, and oxygen with low sulfur content. The major organic components in bio-oil are lignin, alcohols, organic acids, and carbonyls, making bio-oil an environmentally friendly fuel [7].

The expected benefits of this research for science are to provide information to the community on controlling bagasse waste that can be utilized for bio-oil, offering an alternative use for biomass that is often discarded as waste, and providing a solution as a renewable alternative in Indonesia that is environmentally friendly [8].

The aim of this research is to produce bio-oil from the utilization of bagasse waste, which is rarely utilized, to make it useful and economically valuable as a quality alternative energy source that is environmentally friendly. The research also aims to determine the concentration and composition of bio-oil resulting from the pyrolysis of bagasse waste. Biooil can be used in household products such as lubricants or fuel for oil lamps [9].

2. Method

This research is located in Banyuwangi Regency, with testing conducted at the Environmental Laboratory and the Laboratory of Quality Testing and Development of Marine and Fisheries Products in Banyuwangi. The research implementation was scheduled for July to August 2021, involving the collection of sugarcane bagasse waste over a 2-day period from sugarcane beverage vendors in Banyuwangi Regency.

In the context of this research, the researcher directly collected data from the source or location where the research was conducted. The data used include the results of direct observation notes on the research object, namely sugarcane bagasse waste, and other data obtained from literature, articles, journals, as well as relevant books related to this research.

The main raw material used is sugarcane bagasse waste obtained from sugarcane beverage vendors in Banyuwangi Regency. The equipment used includes a grinder, a fixed-bed reactor with a diameter of 7.5 cm and a height of 23.5 cm, a furnace, thermocouples, an oven, an analytical balance, gas tubes and N2 gas regulators, a condenser, a pycnometer, an Oswald viscometer, a beaker, a set of burettes, Erlenmeyer flasks, measuring flasks, sieves with a particle size range of approximately 0.6 to 0.8 millimeters and 0.42 to 0.6 millimeters, a stopwatch, a pH meter, and a Gallenkamp Bomb Calorimeter.

The bagasse pyrolysis research method involves experimental step consist of starting with preparation steps like cleaning, drying, and shredding the bagasse.The second step consist of pyrolysis process constituent compounds of bagasse into various organic compounds through dry combustion reactions without oxygen. For the production of bio-oil, the bagasse is pyrolyzed on a laboratory scale using a fixed-bed reactor. The finely ground bagasse is weighed and utilized as the feedstock. The feedstock is heated in the pyrolysis reactor and stopped when it reaches the operating temperature (500 - 600°C) during a 2-hour operation. A flow rate of N2 at 200 mL/minute is directed upward from the bottom through the reactor. The N2 flow rate replaces the air flow rate from the reactor, creating anaerobic conditions. The N2 flow is used to transport the pyrolysis products in the gas phase. The gas is then condensed to transform it into liquid, containing bio-oil and water. This liquid is collected in a 500 mL beaker glass to determine its volume, left undisturbed for 24 hours in a dark bottle, and subsequently analyzed for its components using Gas Chromatography-Mass Spectroscopy (GC-MS).

The third stage involves the analysis of components, composition, and physical characteristics of the bio-oil resulting from bagasse pyrolysis. Viscosity analysis of the bio-oil is conducted using a kinematic viscometer. Density analysis of the bio-oil is carried out using a pycnometer. Additionally, calorific value analysis of the bio-oil resulting from bagasse pyrolysis is performed using a bomb calorimeter.

3. Results

Bio-oil or bio-oil is a derivative of vegetable oil. In this study, bio-oil is defined as a product of the pyrolysis process. Bio-oil consists of various different organic compounds and does not mix with oil-based fuels due to its high water content, approximately 15-20%. The significant water content in this bio-oil serves as a binder for hundreds of different molecules, known as microemulsions. The chemical content of bio-oil includes various organic acids, alcohols, ketones, esters, phenolic components, and others [10].

The major organic components in bio-oil are lignocellulose, alcohols, organic acids, and carbonyls [11]. These characteristics make bio-oil an environmentally friendly fuel. Bio-oil can serve as an alternative to hydrocarbon fuels in industries such as combustion engines, boilers, stationary diesel engines, and gas turbines. It is effective as a substitute for diesel, heavy fuel oil, light fuel oil, and natural gas for various boilers [12]. Additionally, it can be used as a raw material for producing biofuels for transportation and industrial power plants. Furthermore, bio-oil is renewable and environmentally friendly.

3.1 Analysis of Concentration and Composition of Bio-Oil from Bagasse Pyrolysis

Based on the conducted research, the composition and concentration of bio-oil from the pyrolysis of sugarcane bagasse are presented in Table 1 below.

Table 1. Concentration and Composition of Bio-oil from Sugarcane Bagasse Pyrolysis

Retention Time	Konsentrasi (%)	Komponen
4,183	3,99	furfural
4.313	16.77	furfural
6,900	0,83	Butirolakton
8,270	4.67	5-metil furfural
8,460	2,73	3-metil-2-cyclopentanedione
10.381	16,42	asam karboksilat
10,841	10,86	3-metil 1,2-cyclopentanedione
12.552	7.54	5-metil 3-metilen-5-heksena-4-metil fenon
13,402	7,05	4-metil fenol
13.692	3.48	7-hidroksi-6-metil 2,4-asam oleat
15,748	1,13	4-metil 2-metoksi fenol
16.033	7.72	4-etil fenol
18,159	1,31	4-etil 2-metoksi fenol
18,639	5,27	4-etil fenol
20,335	6.79	4-etil 2-metoksi fenol
22,736	2.29	4-metoksi-3-(metoksi metil) fenol
24,581	1,14	2,4,5-trimetoksi-α-metil-fenetilamin

Principally, the presence of the oxygenated compound in bio-oil, namely phenolic compounds, leads to a decline in the quality of bio-oil, manifesting as a decrease in pH, reduced stability, lower heating value, and an increase in viscosity [13]. The composition of bio-oil resulting from the pyrolysis of sugarcane bagasse is illustrated in Table 1. Various compounds have been identified in the bio-oil obtained from the pyrolysis of sugarcane bagasse, indicating the presence of relatively complex compounds with multifunctional groups. Table 1 reveals that the predominant component in bio-oil is phenolic compounds, constituting 25.29% Phenolic compounds, as the predominant component in bio-oil, exert significant influence across various domains. They serve as valuable chemical feedstocks, contribute to the energy content of bio-oil, influence its stability and quality, and may have biological effects. Additionally, their presence impacts the environmental performance of bio-oil products, affecting biodegradability and potential toxicity. [14]. The decomposition process of lignin into phenol, phenol derivatives, and aromatic compounds occurs within the temperature range of 250-600°C. The presence of phenolic compounds in bio-oil is a consequence of the thermal decomposition of lignin present in sugarcane bagasse during the pyrolysis process [15]. The higher the lignin content in biomass, the greater the phenol yield in the bio-oil produced from that biomass. reported that the lignin content in sugarcane bagasse is 21.1%.

3.2 Characteristics of Sugarcane Bagasse Bio-Oil

The examination of physical characteristics such as pH, density, kinematic viscosity, calorific value, flash point, acid number, and moisture content is crucial in the production of bio-oil, as it directly impacts engine performance, boiler or furnace utilization in pumping and combustion. Non-compliance of bio-oil with Indonesian National Standards can lead to machinery damage and pose hazards in its use. Physical characteristics are also influenced by the compound content present [16].

Table 2. the characteristic results of bio-oil from the pyrolysis of sugarcane bagasse

Parameter	sugarcane bagasse	Bio-oil Standar
Densitas (Kg/m3)	988	940 - 1200
Viskositas (cSt)	9,43	4 - 78
pH	44,69	0,8
Flash Point (°C)	3	2,3 – 3,3
Nilai Kalor (Mj/kg)	130	100
Densitas (Kg/m3)	4,31	16 - 19

The density of bio-oil is influenced by the heating temperature. In varying heating conditions, the higher the temperature, the lower the resulting bio-oil density. High density is attributed to elevated water content, causing difficulties in the bio-oil combustion process [17]. Viscosity values that do not meet fuel and air atomization standards can lead to reduced evaporation, resulting in incomplete combustion. Higher water content in bio-oil tends to lower viscosity values. The high acidity level in a fuel can affect the corrosion strength of an engine using that fuel. High acidity is caused by the low pH of bio-oil.

pH is a crucial parameter in engine operation, where pH values can induce corrosion in engines made of light steel or aluminum [18]. Low pH values are caused by the high content of phenols and their derivatives in bio-oil [19]. Phenol is considered a weak acid, so high content leads to a low pH. Flashpoint is the lowest temperature at which a fuel can ignite. Heating value is a significant parameter in bio-oil production, where the heating value is used to determine the bio-oil's ability to generate energy [20].

4. Conclusion

From the results of the analysis and discussions conducted, it can be inferred that the presence of a high lignocellulosic content in sugarcane bagasse opens the potential for utilization as a raw material in bio-oil production. The predominant compound component constituting bio-oil from sugarcane bagasse is phenolic compounds, accounting for a percentage of 26.29%. This finding suggests that sugarcane bagasse could be a valuable source for bio-oil production, with a specific focus on extracting phenolic compounds as its main component.

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