Journal of Clean Technology

REVIEW ARTICLE

Bioethanol Production from Sago Waste as Renewable Energy: A Review

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Received: 2023-08-01, Revised: 2023-09-02, Accepted: 2024-01-17, Published: 2024-02-15

Abstract

Energy consumption has increased rapidly because the world population has grown, so has energy consumption for industrial needs. Now Indonesia still uses fossil fuels as the main energy source, because of their non-renewable nature, the continuous use of fossil fuels causes scarcity problems. Bioethanol production is currently getting more intense, this is because there are several factors that cause it to be more intense, namely market stability, low costs, sustainability, the composition of alternative energy fuels and the catastrophic depletion of fossil fuels. Sago waste can be used as an environmentally friendly renewable resource. Bioethanol production process from sago waste using enzymes and fermentation with the help of microorganisms. The bioethanol production process from sago waste has four main parts. The first thing to do is the pre-treatment process, namely drying the sago pulp and delignification process. Samples from the delignification process will then be used in the hydrolysis process with a catalyst in the form of HCl. The results of the hydrolysis were fermented at a pH of 5 and tape yeast was added. Then in the distillation process requires filtrate which was then evaluated qualitatively using K2Cr2O7 reagent. The mixture derived from the fermentation process using baker's yeast and wet sago pulp can produce bioethanol levels up to 45.70%. The process of making bioethanol from sago waste through a baker's yeast fermentation process is expected to help advance the bioethanol production process as a renewable energy source in Indonesia.

Keywords: Bioethanol, Renewable Energy, Sago Waste, Fermentation, Yeast

Introduction

Energy is one source of life for living things. Energy consumption has increased rapidly because the world's population has grown, so has energy consumption for industrial needs (Figure 1). Now Indonesia still uses fossil fuels as the main energy source, because of their non-renewable nature, the continuous use of fossil fuels causes scarcity problems [1] [2]. For example, in Indonesia around 2002 oil reserves were around 5 billion barrels, natural gas around 90 TSCF, and coal around 5 billion tons [3]. If no new reserves are found, it is estimated that oil will run out in less than 10 years, gas in 30 years, and coal in about 50 years [4].Therefore, we need a solution to the energy demand issue. Organic resources like plants or waste organic matter with a high sugar content that may be turned into bioethanol are potential sources of alternative energy [5]. Due to its stable market, cheap price, long-term viability, alternative energy fuel , and significant fossil fuel depletion, industrialization of bio ethanol has currently increased [6].

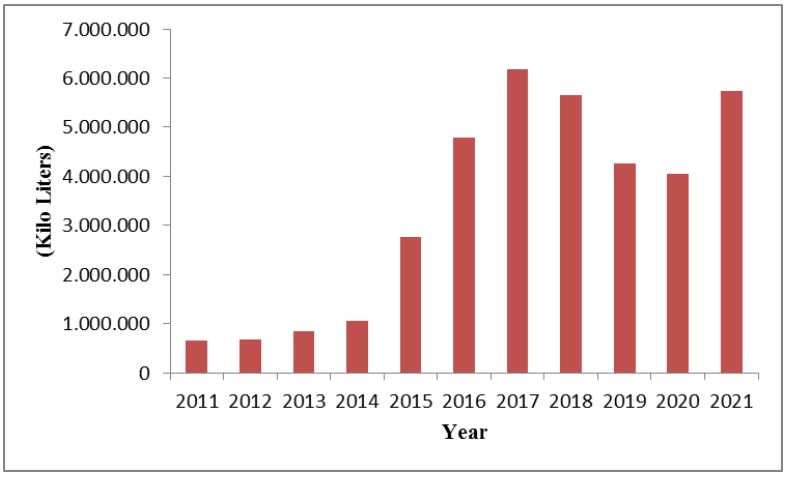

Figure 1. Consumption of gasoline fuel in Indonesia (2011-2021) [7]

Bioethanol or ethyl alcohol is chemically known as C_2H_5OH or EtOH [8]. Bioethanol is a clear, colourless liquid biofuel that can be biodegradable and has the potential to be a potentially substituting gasoline with an ecologically friendly fuel for power automobile engines [9]. Bioethanol can be produced from anaerobic fermentation with yeast from several biomass feedstocks which are divided into four generations [10]. The 1st generations used foodstuffs or carbo, the 2nd generations used waste or cellulose substrates, the 3rd generations used microalgal substrates, and the 4th generation modified microalgae to increase cell production and lipid content [11] [12]. Due to problems with the need for food and land, the majority of the 1st generation of bioethanol was abandoned. In contrast, the 3rd generations and 4th generations still require development because of the complexity of their production methods [13]. The 2nd generation with agricultural waste to become bioethanol still has to be changed or developed so that it can be used. Several steps are required to convert agricultural substrate waste into bioethanol, including pra-treatment, fermentation and purification procedures [14].

Sago is a non-timber forest product that supports food sustainability. With an area of approximately 1,130 million hectares, or 51% of the 2,203 million hectares of sago, Indonesia has the largest sago area in the world in Southeast Asia, followed by Papua New Gini (43%). However, in terms of usage, Indonesia still lags behind Thailand and Malaysia, which have an area of 1.6% and 0.3%, respectively [15]. Indonesia's Riau, Sulawesi, Maluku, and Papua are potential sago-producing regions [16]. Sago starch is produced from fibres sago and waste liquid from the production of sago. Sago pulp both solid and liquid may be processed to provide a sustainable energy source and environmentally friendly [15]. Sago trash, sago skin waste, and sago water waste are the three main forms of waste produced by the industry sago starch extraction. Sago waste weighs roughly 25% and 14% of a sago block's total weight [17]. According to reports, sago pulp contains important substances including cellulose and starch. Sago pulp consists of 66% starch and 34% fibers and raw proteins, crude oil, ash and fat to produce a renewable energy source [15]. Sago solid waste is lignin-based biomass, which includes important substances like cellulose and starch. Bioethanol production process from sago waste using enzymes and fermentation with the help of microorganisms [18].

Fermentation is a popular conventional method and natural metabolic mechanism for converting lignin-based biomass into bioethanol [19]. Fermentation can convert sugar into alcohol and CO2 by microbes that usually use the yeast Saccharomyces cerevisiae [20]. Carbohydrates will be broken down first into simple sugars by hydrolysing cellulose into glucose units [21]. Microbial fermentation is a more efficient fermentation process because it can reduce barriers to cellulase enzyme activity [22]. However, during the process by microbes there are several factors that need to be considered such as pH, temperature and media pressure which always need

monitoring so that they are not easily infected [19]. Bioethanol products need to be refined further to create fuel with a purity of 99,99%; the procedure purification that is frequently used is process multilevel distillation [23].

This reviewed paper discusses sago waste processing into high-quality fuels utilizing integrated life cycle analysis and availability of raw materials to maximize bioethanol production in Indonesia. The method used in processing sago waste into bioethanol in this journal is the pretreatment, fermentation and rectification methods. The technology examined in this study is anticipated to help Indonesia utilize waste from agriculture in products with high marketplace quality and utility.

Materials and methods

1. Materials

One of Indonesians primary food is sago. Sago is eaten everyday by the people of Maluku [24]. The production of sago is converted to starch to produce sago pulp from the fiber sago and waste liquid that is able to be recycled into environmentally acceptable energy sources and a renewable energy source [25]. Sago has many benefits and relatively good nutritional content (Table 1). In the processing of sago flour, starch and sago waste are obtained with a ratio of 1:6 [26]. Every sago processing will produce sago waste of around 75 - 83% [15]. Sago production in Indonesia is around 381,065 tonnes per year, with a ratio of flour to waste of 1:6 the capacity of sago waste substrate is around 2,286,390 tons per year. The amount of abundant sago waste has not been obtained put to good use and only allowed to accumulate in places - places processing of sago flour thus causing environmental pollution [27]. Sago waste must be utilized optimally, one of which is as bioethanol because sago waste contains 65.7% starch which can be hydrolysed into sugar and processed into bioethanol as a renewable energy source [25].

Table 1. Nutritional Label of Sago [28]

Nutrition	**Concentration (gr)**
Carbohydrates	51,6
Protein	0,3
Calcium	27
Phosphor	0,013
Iron	0,0006
Vitamin B1	$1e^{-5}$

2. Methods

Sago waste-derived biomass can be converted into methane, biogas, biohydrogen, and bioethanol through bioconversion, offering a promising renewable energy option. Bioethanol is an intermediate product generated during the anaerobic fermentation of different sugar varieties [29]. Typically, the production process for bioethanol using sago waste as a feedstock is divided into four primary stages [25].

2.1 Pretreatment Process

As mentioned in the earlier description, sago waste includes starch, therefore it necessitates pre-processing to hydrolyze the starch into glucose [30]. The pretreatment step is a pivotal and crucial aspect in the overall processing phase [31]. The first thing that was done in the pre-treatment process in this study was drying the sago waste by means of sago waste was to cut the sago scraps into long strips and put in an oven at 120°C for 4 hours to dry. Subsequently, sago residue is meticulously sliced, thoroughly blended, and sifted using a 50-mesh sieve. The

objective of transforming sago waste into a powdered state is to accelerate the enhancement of the reaction by expanding the surface area of contact between the catalyst and the biomass [32]. The next pretreatment process is the delignification process. The delignification process aims to reduce the lignin content in cellulose in sago waste [33]. The delignification process was carried out on dry sago waste powder and wet sago waste powder. In the dry sago waste powder, 1400 ml of 0.01 M NaOH solution was introduced to 100 grams of dry solid sago waste and then heated to 90° C while continuing to stir. The mixture was filtered through a filter to separate solids and powders, washed with water at a temperature of 100°C and subsequently cooked. at 100-105°C for 4 hours. In the wet sago waste powder delignification process, 1400 ml of 0.1 M NaOH solution was introduced to 100 grams of wet solid sago waste. The mixture was heated to 90° C with constant stirring for 60 minutes. The mixture was allowed to cool to room temperature and filtered. Two delignified samples are then used for the hydrolysis process.

2.2 Hydrolysis Process

Hydrolysis using chemical catalysts has been extensively examined both employing acids and alkalis within a specific concentration interval [34]. The use of a chemical catalyst in hydrolysis is a cost-effective and straightforward technique owing to the accessibility of a proficient catalyst [35]. Acidic catalysts, like HCl with diverse concentrations, have been examined to decompose sago waste into reducing sugars [30]. The process in this review starts with sixty grams of sago waste powder (wet and dry solid) extracted from the pre-treatment process, for 100 ml of solution was obtained, 12% HCl was added as a catalyst. This solution was poured into a three-necked flask equipped with a condenser and heated for 60 minutes at 95°C. Afterwards, 65 ml of liquid sago waste was broken down with 45 ml of 12% HCl. As an output of hydrolysis, it ferments at pH 5.

2.3 Fermentation Process

The main process in the bioethanol production process occurs in the fermentation process [36]. In the fermentation process, the filtrate that had been hydrolysed in the previous hydrolysis process was put into a 100-millilitre vessel and 4 M NaOH is continuously mixed until a pH of 5 is reached. After that, 6 grams of (NH4)2SO4 and 6 grams of (NH2)2CO were added as nutrition's in the fermentation process. Nutritional compounds that usually become nutrients in the fermentation process viz carbon, nitrogen and phosphorus compounds [37]. The next process is sterilized at 120°C for 15 minutes, after that it is cooled down. The solution was induced with 1 g/l sucrose before adding the yeast. 100 grams of yeast is mixed in the process. Furthermore, the vessel was closed tightly, the hose in the vessel was connected to another vessel filled with water, and cultured at 25-30°C for 15 days, then in the liquid used in the evaporation process.

2.4 Rectification Process

Although it requires high heat levels and low thermodynamic efficiency levels [38]. the repair is the most popular separation method of boiled filtrate through the distillation of boiling stones added at 80°C and qualitatively evaluated with reagent K2Cr2O7 To determine how much and how much bioethanol is produced by each agent, a gas refractometer and gas chromatography (GC) are used[39].

K2Cr2O7 is used to perform chemical qualitative tests to confirm bioethanol in brewed filtrate [40], K2Cr2O7 solution, 2 mL, Divided between Two test tubes. Each tube is given five drops of concentrated sulfuric acid, which is then added and stirred with Strong.1 ml of ethanol Added to Each First Tube and Second Tube. So that there is a Colour Change, Filtrate Colour containing bioethanol converts into Green Colour or Blue Colour. Bioethanol concentrations of distillates are determined using the analysis of the bioethanol index. Bioethanol data index. Refractive is used to express and try ethanol content to a percentage. Using distillation, bioethanol produced from Tapi and Yeast Pulsate is purified.

GCMS Profile Bioethanol Analysis (Gas Chromatography-Mass Spectrometry) is performed by reading the spectrum on Gas Chromatography and Mass Spectrometry instruments [41]. For example, compounds with many compounds show the highest amount of value in the GC spectrum. Therefore, the compounds in the sample can be identified using retention time data from relevant literature mass spectrometers are then used to analyze suspected compounds. Gas chromatography has the function of separating compounds from samples, which produces this phenomenon. It is possible to get mass spectrometry results in various sizes.

This work has utilized both quantitative analyses using GCMS and qualitative data in the form of bioethanol profiles. GCMS analysis has produced bioethanol charts detailing the indicated peak values of each sample handled. This investigation yielded quantitative information in the form of bioethanol content. The refractometer employs quantitative analysis to examine such data. The results describe the influence of yeast dreg and the kind of sago on ethanol content in addition to ethanol content.

Results and discussion

1. Based on Waste Types and Yeast, Distilled Fermented Sago Waste Bioethanol Profiles

A chromatogram from the GC range generated from glucose fermentation distillation is used to determine the ethanol content of the material produced inside the remedy settings. (Table 2) indicates that the lowest bioethanol content is understood inside the dry and yeast-stable sago organizations, while the Truth is the internal part of the strong sago and yeast organizations. Get it from the sago dreg and yeast sago companies. The ensuing bioethanol content comes from 14.567%, 12.014%, 45.702%, 45.702%, 0.950%, 2.227%, and 1.801% mound-hound, respectively. The chromatogram vicinity is exemplary in comparison to ethanol status, with an originality of one hundred nm and a retention period of 1,944. Au greater Shoots seem On the numbers of art, ATP, BTP, and ITP, temporarily only One shot is available on the numbers of BRT and KRT chromatograms. The dots in the chromatogram image show the price of the ethanol solution that is used in the procedure. [25]Long-lasting fermentation causes ethanol to oxidize into carboxylic acid or other forms of solution, which causes extra-high shoots to show up on the chromatogram.[42]

Table 2. Bioethanol Level of Each Treatment [25]

Code	Refractive Index	Alcohol Content (%v/v)
ART	1.339	14.567
ATP	1.338	12.014
BRT	1.354	45.702
BTP	1.333	0.950
KRT	1.334	2.227
KTP	1.333	1.801

2. Bioethanol production from sago waste fermentation

Sago pulp is a waste that contains lignocellulosic [43]. Materials containing lignocellulosic can be processed into bioethanol, which can be used as an alternative fuel to replace gasoline for motor vehicles [44]. The lignocellulosic consists of lignin, cellulose and hemicellulose which are components of plant cell walls [45]. In this discussion, Sago waste can be converted into bioethanol through three stages of the process, namely the delignification process, the hydrolysis process, and the fermentation process. Cellulose is converted into simple sugars by hydrolysis,

and sugars are broken down into ethanol by yeast fermentation [46]. Each sago has a different amount of lignocellulose depending on the type [25]. Therefore, the type of sago used will affect the concentration of bioethanol formed. The maximum bioethanol concentration obtained was 45.7021% from wet sago waste which was fermented using Saccharomyces cerevisiae from bread yeast.

3. Effect of sago waste type and yeast type on bioethanol production process

Sago waste, both solid and liquid, contains carbon which can be utilized as a culture medium for the growth of microorganisms [47]. Solid sago waste and liquid sago waste have different chemicals and different amounts of carbohydrates. Solid sago waste has more carbohydrates than liquid sago waste, due to in liquid sago waste some carbohydrates dissolve in the environment [25]. Differences in the composition of solid sago waste and liquid sago waste causes differences in the concentration of the bioethanol produced. The maximum bioethanol concentration of 45.7021% was obtained from solid sago waste which was fermented using wet bread yeast (BRT) (Table 3). Moist and firm sago meat contains high levels of carbohydrates. The carbohydrates in this type of waste produce large amounts of glucose after hydrolysis. Glucose is fermented to alcohol by yeast under anaerobic conditions [48]. Bread yeast contains S. cerevisiae bacteria [49]. These bacteria help optimize glucose-ethanol fermentation [50]. The optimal fermentation process results in a higher alcohol content.

Table 3. Bioethanol Content for each Index Treatment code [25]

Code	Retetation Time	Area	Vol (ml)	Bioethanol Content (%)
ART	2.085	3069.7010	1.00	14.567
ATP	2.010	1899.8379	1.00	12.014
BRT	1.994	205.2795	1.00	45.702
BTP	2.006	355.0000	1.00	0.950
KRT	1.994	111.5241	1.00	2.227
DLL	2.095	361.2514	1.00	1.801

Conclusions

Sago waste is ideal feedstock for bioethanol production, also known as lignocellulosic biomass. In the hydrolysis process Acidic compounds such as 12% HCL can convert lignocellulose into glucose. Then the glucose produced is fermented with baker's yeast anaerobically to produce different levels of bioethanol. The level of bioethanol produced shows that it is influenced by sago pulp and the type of khamr used. The mixture derived from the fermentation process using baker's yeast and wet sago pulp can produce bioethanol levels up to 45.70%. This is due to wet sago solid waste contains more lignocellulosic whereas bread yeast contains Saccharomyces Cereviceae, where in anaerobic conditions these two microorganisms can convert glucose into ethanol. The process of making bioethanol from sago waste through a baker's yeast fermentation process is expected to help advance the bioethanol production process as a renewable energy source in Indonesia.

Acknowledgements

We would like to thank Universitas Negeri Semarang and Mr. Zuhriyan Ash Shiddieqy Bahlawan S.T., M.T., for his guidance as a lecturer in the Energy Balance course.

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