Experimental Jet Flame Bioethanol Sago Pulp Fuel as an Energy Source for Isolated Areas in Papua Province, Indonesia

Numberi Johni Jonatan[1,*], *Tiper* Uniplaita[1], *Arifia* Ekayuliana[2],
Praptiningsih Gamawati Adinurani[3], *Muhannad* Illayan Massadeh[4],
and *Afrida* Rizka Farzana[5]

[1]Department of Mechanical Engineering, Faculty of Engineering, Cenderawasih University, Jl. Kamp Wolker, Yabansai, Jayapura 99351, Papua, Indonesia
[2]Department of Mechanical Engineering, Jakarta State Polytechnic, Jl. Prof. DR. G.A. Siwabessy, Depok 16425,West Java, Indonesia
[3]Department of Agrotechnology, Faculty of Agriculture, Merdeka University of Madiun, Jl. Serayu No.79, Madiun 63133, East Java, Indonesia
[4]Department of Biological Sciences and Biotechnology, Faculty of Science, The Hashemite University 13133, Zarqa, Jordan
[5]IPB University, Jl. Raya Dramaga, Bogor 16680, West Java, Indonesia

Abstract. Papua Island is at the eastern end of Indonesia, with massive potential of natural resources. However, the human resource growth of this province is low. In 2020, the Human Development Index reached 60.62 and the poverty rate was 27.38 %. The lack of energy at isolated areas is the reason for these facts. So, there is a need of research to utilize the local potential, such as sago waste as bioethanol alternative fuel. This research consist of pre-experimental and experimental process. The pre-experimental purpose is to analyze sago pulp material using Scanning Electron Microscope (SEM), where the Carbon Value (CK) is 76 %, proximate 82.4 % carbohydrate content is very feasible in the process as a bioethanol fuel. The experimental process shows bioethanol sago pulp 70 % is very viable as a fuel, in research applications laminar jet flame bioethanol atmospheric at a fuel mass flow rate of 60 mL min^{-1}, with a temperature of at least 327 ºC up to a maximum temperature of 729 ºC. The results of bioethanol diffusion laminar jet flame temperature testing are very feasible to use in household furnace combustion applications in isolated areas in the Papua region.

Keywords: Clean energy, environmental friendly, *Metroxylon sagu,* renewable energy.

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[*] Corresponding author: jonatan.j.numberi@gmail.com

1 Introduction

Eastern Indonesia, such as Papua and West Papua, is the region with the lowest energy consumption compared to other regions in the region. Total final energy needs in Papua and West Papua increased from 1.3×10^6 t in 2013 to 2.4×10^6 t in 2025 and 7.7×10^6 t in 2050 with an average growth rate of 4.8 % yr^{-1} [1]. Household sector consumption will amount to 10 % of total national energy consumption in 2020 [1]. Data on the potential of renewable energy in Indonesia can be seen in Table 1 below.

Table 1. Renewable energy potential in Indonesia.

Types of energy	Energy potential
Hydroelectric power plant	94.3 GW
Geothermal	28.5 GW
Bioenergy power plant	BPP : 32.6 GW
Biofuel	Biofuel : 200
Solar power plant	207.8 GW
Turbine wind	60.6 GW
Marine energy	17.9 GW

Source: Suharyati *et al.* [2]

Suharyati *et al.* [2] mentions that the potential for new renewable energy in 2025 is 23 % and 31 % in 2050. Bioenergy needs in Indonesia can be converted into Bio 32.6 GW and biofuel mix energy needs amount to 5 % of Indonesia's oil consumption of 1.33 %, to replace 1.48×10^9 L of kerosene with bioteanol [2]. An estimated 51.3 % of the world's sago land is in Indonesia that can be processed into bioethanol fuel. The need for bioethanol instead of gasoline and kerosene will continue to increase by 10 % to 15 % by 2025. So, $30\ 833 \times 10^3$ L of bioethanol mo^{-1} are needed as fuel in the small and medium-sized household and industrial sectors in isolated areas and difficulty accessing energy in the interior of Papua [3]. The zoning map of sago industry development research in Papua can be found in Figure 1, below.

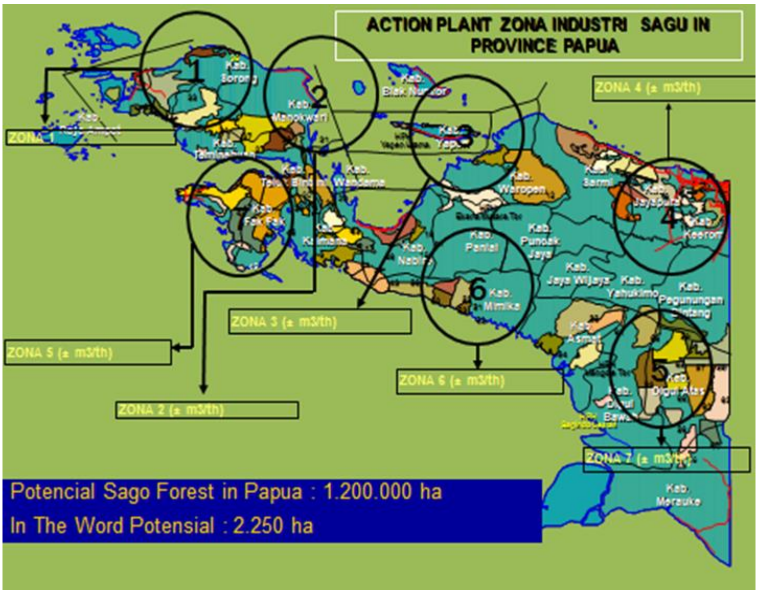


Fig. 1. Zoning research map of sago industry development in Papua Indonesia.

From the background above about energy conditions in Papua, there is a potential for bioethanol energy from sago is very large, data shows 1.25 × 10^6 ha of sago land in Indonesia, as much as 1.2 × 10^6 ha of sago land is in Papua [4]. With a production of about 2 × 10^5 t yr^{-1}, only 56 % can be utilized properly [5]. Data on the potential of sago in Indonesia can be seen in Table 2, below.

Table 2. Potential of sago in Indonesia.

Territory of Indonesia	Natural sago (ha)	Cultivated sago (ha)
Papua	1 200 000	14 000
Maluku	50 000	10 000
Sulawesi		30 000
Kalimantan		20 000
Sumatera		30 000
Mentawai Archipelago		10 000
Riau Archipelago		20 000
Total	1 250 000	134 000

Source: Jonatan *et al*. [4]

2 Research methods

Research methods consist of pre-experimental and experimental. Pre-experimental is field research characterization of the potential of sago waste and experimental to perform sago pulp as a bioethanol fuel [6]. In the application of burning household fuel in Papua communities in isolated areas. Pre-experimental set-ups can be seen in Figure 2, below.

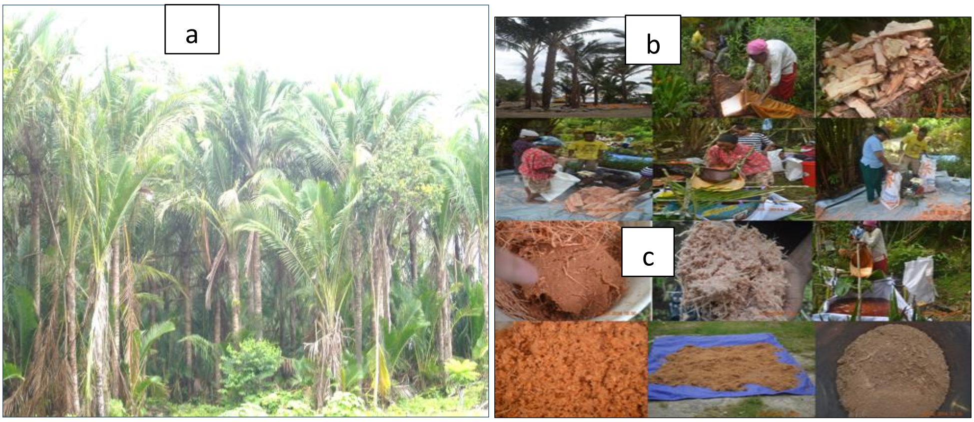


Fig. 2. Pre-experimental characterization of sago pulp.

In Figure 2(a), the sago tree (*Metroxylon sagu* Rottb.) is a plant that breeds through root buds and grows in groups. In Figure 2(b), it is seen that the activity of the sago production process is traditionally in Papua, many sago wastes are produced from sago processing, rich in carbohydrates and other organic materials. In Figure 2(c), the characteristics of sago pulp are sago waste containing lignocellulose, cellulose, and lignin [7]. These substances can be optimally utilized as a source of bioethanol energy [5].

The characterization of sago pulp shows that the content of cellulose and carbohydrate can be utilized optimally as a new material bioethanol energy source [6].

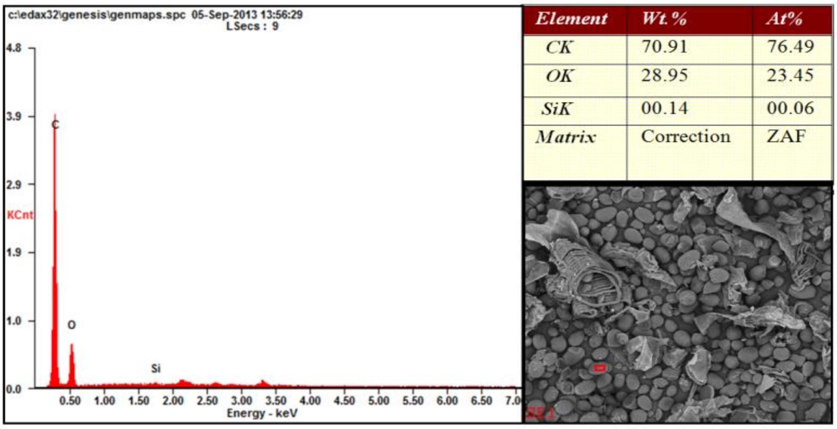
Table 3. Proximate analysis results of sago pulp content.

Test parameters	Numbers
Physical of sago pulp	Brownish color
Water content	16.3 %
Ash	0.50 %
Protein	0.80 %
Fat	0.01 %
Carbohydrate	82.4 %
Coarse fiber	1.67 %

Source: Jonatan *et al.* [2]

In Table 3 it is seen that sago pulp in the form of dregs contains 82.4 % cellulose and the rest in the form of coarse fibber 1.67 % coarse protein, fat, and ash. Based on the percentage of the results of the analysis of sago pulp proxy contains cellulose residues that have the potential as a source of bioethanol energy [6].

Pre-experimental laboratory is carried out to determine the characteristics of sago pulp material using the visualization method of Scanning Electron Microscopic (SEM) and Telescopic Electron Macroscopic (TEM). Photo SEM EDX is performed to look at the structure of hydrocarbon components of sago pulp that can be converted into bioethanol energy [1].



Element	*Wt.%*	*At%*
CK	70.91	76.49
OK	28.95	23.45
SiK	00.14	00.06
Matrix	Correction	ZAF

Fig. 3. Pre-experimental photo SEM EDX (200x) sago pulp.

Experimental characterization of Photo SEM EDX (200x) sago pulp shows that 76.49 % carbohydrate, is very feasible to be processed as bioethanol fuel through a process such as the reaction in Equation 1 and Equation 2.

$$(C_6H_{10}O_5) + H_2O \xrightarrow{a\text{ - }amylase} 2\,(C_6H_{12}O_6) \qquad (1)$$

Cellulose water glucose

$$C_6H_{12}O_6 + 2\,CO_2 \xrightarrow{Saccharomyces} 2\,C_2H_5OH$$

Glucose ethanol (2)

2.1 Sample preparing

Sago pulp as ethanol raw material in this test was obtained from the remaining sago production in Jayapura district of Papua Province. Sago pulp is added clean water until everything is submerged then mashed with a blender and then filtered with a strained cloth. Sago pulp on the filter cloth is collected into a plastic container and dried in the sun, after which it is done to get a smooth sago pulp (escape filter 150 mesh), which is ready to be processed into bioethanol fuel [8].

Fig. 4. Sago dreg sample.

2.2 Hydrolysis

Sago pulp must be in the gelatination process, the gel formed from the heating of the starch will be solid. Then the gel is further destroyed using the enzyme alpha amylase with a temperature above the boiling point (107 ºC). Sago starch is mixed with water with a ratio of 1:6 then heated to a temperature of 60 ºC to 80 ºC until gelatination occurs and followed by the hydrolysis process [9]. During liquefaction, starch is converted to dextrin by the endogenous enzyme alpha-amylase. At this stage dextrin liquefaction results will be continued with saccharification to convert it into simple sugars or glucose through the process of hydrolysis by glucoamilase exoenzyme and cellulose enzymes [10].

2.3 Fermentation

The fermentation process uses *Saccharomyces cereviseae* yeast [11]. Fermentation can be done along with saccharification that lasts for 56 h to 72 h or for 3 d.

2.4 Distillation

Ethanol produced from fermentation is still mixed with various other ingredients from raw materials so it is necessary to physically separate by evaporating ethanol through the heating process to increase the purity and ethanol content of ethanol from 20 % to 40 % [12]. The second stage produces ethanol with a rate of 50 % to 60 %, and the third stage is 70 % to 75 % [13].

2.5 Process

The process of producing bioethanol from sago waste as fuel for remote areas is excellent for helping energy availability for the community [13]. The production process of low levels of bioethanol from sago pulp can be seen in Figure 5, below.

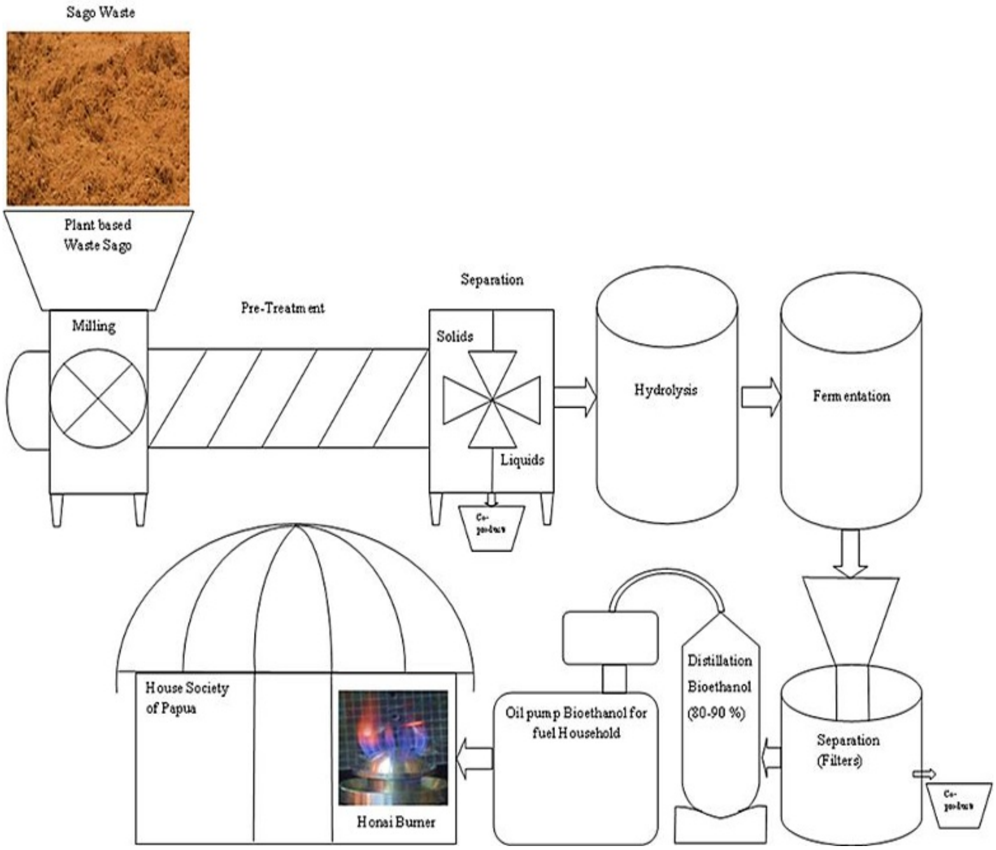


Fig. 5. Experimental scheme of bioethanol production of sago pulp [14].

3 Result and discussion

Characteristic bioethanol contains 35 % oxygen, so it can increase combustion efficiency and reduce exhaust emissions and be environmentally friendly. A combustion reaction is a complete combustion reaction (stoichiometry) in which hydrogen and carbon in the fuel content of 60 % to 90 % C_2H_5OH are oxidized entirely to H_2O and CO_2. Equation 2 also shows that every 0.7 kmol of air in the atmosphere contains 0.79 kmol of nitrogen and 0.21 kmol of oxygen. Combustion applications are performed using burners to measure temperature, heat production rate, combustion time, time reduction variation, and smoke production from bioethanol fuels. Bioethanol combustion is also done to determine the temperature and characteristics of bioethanol flames by diffusion [14]. In the experimental process of burning bioethanol using a one hole burner in a Papua clean stove furnace [15]. The taking of temperature data on the process of burning low levels of bioethanol 70 % to 75 % is done using type K thermocouples installed in the experimental device as seen in Figure 6, below.

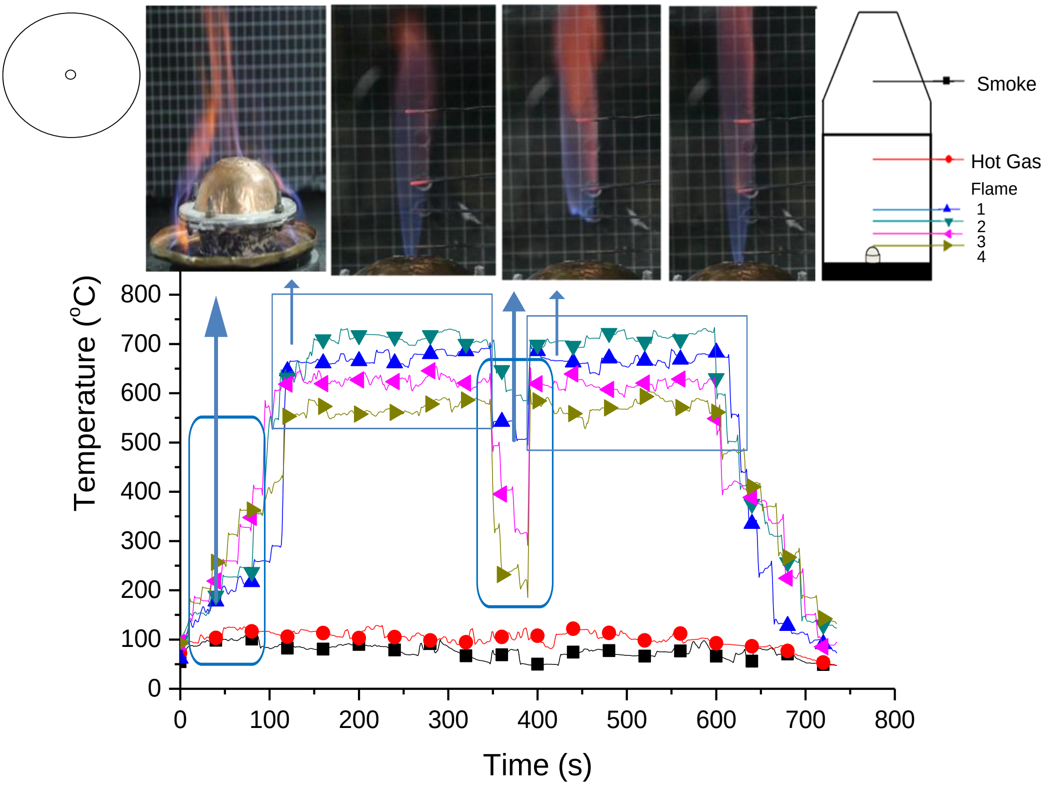


Fig. 6. Flame, hot gas, and smoke temperature in low bioethanol combustion 70 % with burner one hole.

In Figure 6 graph is the result of a 70 % low bioethanol combustion experiment seen in burners with the number of holes one is a flame process that reacts diffusion (diffusion flame) with a ratio between the air mass rate (O_2) 20.94 % to the fuel mass rate of 20 mL min^{-1}. The combustion phenomenon that occurs for 12 min consisting of the preheating zone process for approximately 2 min with an initial ignition temperature of 90 ºC, then continued with the phenomenon of continuous combustion which is seen flame stability is when the reaction of fuel and atmospheric air in the combustion chamber mixes perfectly, namely the ratio between fuel and atmospheric air is balanced so that there is perfect combustion.

The results of the experiment showed changes in the structure of the flame from turbulent to laminar, where the stability of the flame is characterized by a more stable and volatile fire then there will be a jet flame phenomenon then there is no more wasted fuel and meets hot air causing combustion to be stable with a continuous fuel mass rate for approximately 8 min with a minimum temperature with a continuous mass rate of fuel for approximately 8 min with a temperature of at least fuel is maintained at 60 mL min^{-1}.

The blue fire color and shrinking from the base of the nozzle with a height of 10 mm is a reaction zone area and upwards of 70 mm is a flame zone area and the yellow fire area of 40 mm is the product zone area of the fire in this area is a flame that some elements of bioethanol fuel do not burn perfectly so it is characterized by low temperatures and causes flame color to turn yellow to red and there is a release of the resulting element. Combustion process that can be seen from the gas analyzer. Here are the data (CO) 0.01 %, (CO_2) 0.2 % and (HC) 3 mg kg^{-1}. Next is the process of burning independently of the remaining fuel in the burner with a length of approximately 2 min until the fire is completely extinguished. From the results of the experiment showed that bioethanol low levels of 70 % are very feasible as a household fuel substitute for kerosene fuel.

4 Conclusion

This research produces the characteristics of sago pulp that is very feasible to be processed as a raw material for bioethanol energy, so as to encourage the sago industry in Papua as a large industry that can produce bioethanol energy to answer energy needs and energy crisis in isolated areas in Papua Indonesia.

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