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About the Journal

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Production of Bioethanol from Bunches of Palm Oil Using Purification Equipment with Bioethanol Traps

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ABSTRACT

Indonesia's requirement for fossil fuels rises by an average of 10% annually. The supply of fossil energy, which serves as the primary raw material for generating fuel oil, is negatively correlated with the demand for fuel. Fresh Fruit Bunches (FFB), Empty Fruit Bunches (EFB), and fiber were the types of oil palm bunches employed in this investigation. EFB and fiber are industrial by-products that are currently being used inefficiently and frequently pollute the environment. This by-product is still only very minimally processed; it is still stored, burned in the incinerator, used as mulch on oil palm fields, and composted. 51.2 percent cellulose and 16.30 percent lignin are both present in EFB. Lignin makes up 20.0 percent of fiber, whereas cellulose makes up 57.0 percent. Through chemical and enzymatic procedures, this cellulose content may be exploited as a source of reducing sugars. FFB is used as a benchmark to evaluate how effectively the prototype tool works. Different kinds of high-quality bioethanol are produced from each raw source. Different kinds of high-quality bioethanol are produced from each raw source. FFB which have a refractive index of 1.35676 and a volume of 2,192 ml bioethanol, are the best quality of bioethanol made from raw materials. The findings demonstrated that varied volumes and refractive indices were produced depending on how raw materials were treated. The quality generated improves with increased treatment volume. Alkaline delignification was followed by acid delignification to get the optimum grade. EFB material, had a refractive index of 1.34376, 2,105 ml of bioethanol, and a 68.15 percent ethanol concentration. This study is unique in that it includes a bioethanol trap to quicken the conversion of steam into liquid bioethanol. Condensation is completed within 15-20 minutes less due to the presence of bioethanol traps.

1. INTRODUCTION

1.1. *Research Background*

Indonesia's energy demand every year continues to increase, from 2017 by 297 million SBM [1] to 875 million SBM [2] and continue to increase to 989.9 million SBM in 2019 [3]. The largest energy consumption is still dominated by fuel (avgas, avtur, gasoline, kerosene, diesel, and so on) which is mostly used for the transportation sector. Energy needs are inversely proportional to the availability of fossil energy in Indonesia. The availability of fossil energy in Indonesia decreased by 0.21% from 3.2 billion standard barrel tanks (BSTB) in 2019 to 2.5 billion BSTB in 2018 [4].

Overcoming energy scarcity in the future, efforts are made to use alternative fuels supported by the Presidential Instruction of the Republic of Indonesia No. 1 of 2006, concerning the Provision and Utilization of Biofuels as Other Fuels and followed by Presidential Regulation No. 5 of 2006 concerning National Energy Policy, as well as Government Regulation No. 32 of 2008 concerning Provision, Utilization, and Tata Niaga Biofuel.

Alternative fuels are obtained through the use of new and renewable energy, one of which is from vegetable materials. Considering that the need for fossil fuel sources is increasingly encouraging various research and development of cheap, environmentally friendly fuels [5]. Palm oil is one of the vegetable oil-producing crops that have high economic value and abundant availability. From the latest data in 2019, the area of oil palm is 14.6 million hectares [6].

Palm oil is used to produce products in the form of Crude Palm Oil (CPO) and waste in the form of Empty Palm Oil Bunches (EFB). CPO is a reddish-orange vegetable oil obtained from the pressing or extraction process of palm fruit [7]. EFB has a

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fairly high cellulose content of 45% which can be used as a raw material for making bioethanol [8],[9],[10].

Studies on the process of making bioethanol has been carried out with various types of raw materials but have not produced optimal bioethanol products. This is the basis for the author's consideration to conduct research by making prototypes to produce optimal biofuels.

1.2. Literature Review

Fresh Fruit Bunches (FFB) have a palm oil content of 21% mass, kernels 4%, coir 11%, shells 6%, EFB 23% [9]. Empty Bunches of Palm Oil (EFB) and Palm Fiber are solid waste from the CPO production process from FFB. EFB has a composition consisting of water 8.56%, lignin 25.83%, holocellulose 56.49%, α-cellulose 33.25%, hemicellulose 23.24%, and extractive substances 4.19%. The cellulose content contained in EFB is quite high, which can be used to produce bioethanol.

Bioethanol is ethanol made from various agricultural materials with the chemical formula C_2H_5OH. Ethanol has physical properties as colorless, distinctively smelling, volatile, boiling point of 78.32°C, soluble in water and ether, having a density at 15°C 0.7937. Bioethanol has several advantages over other alternative energy. Among them, they have a higher oxygen content of 35%, a high octane value of 108, and are more environmentally friendly because they contain CO_2 emissions of 19-25% [10], [11, [12].

Bioethanol can be obtained from the following three classes of raw materials: the first group is ingredients that contain sugar derivatives including molasses, cane sugar, beet sugar, and fruit juice. The second group is starch-containing ingredients such as grains, wheat, potato, and tapioca. The last group is materials that contain cellulose such as wood, bamboo, and agricultural waste.

The production of bioethanol from palm oil bunches, in general, can be classified into several stages of the process, including Pretreatment, Fermentation, and Purification. Pretreatment is carried out to open the structure of lignocellulose so that enzymes can easily break down saccharide polymers into sugar monomers. The pretreatment process will result in better bioethanol quality [13], [14].

After the pretreatment process, a wash is carried out first which serves to clean the holocellulose and black leachate liquid. Saccharification is the process of converting cellulose into glucose by using cellulose enzymes. The fermentation process is carried out to convert cellulose into glucose using *Saccharomyces cerevisiae*. The processes of saccharification and fermentation are carried out separately. The saccharification process is carried out first and then continued with the fermentation process.

The purification process can be done with 2 processes, namely adsorption, and distillation. Adsorption is a purification process by separating ethanol from other mixed materials by a solid adsorbent surface. The adsorbent is a solid material with a surface area that has fine pores, for example, zeolite. Zeolite as a catalyst only affects the reaction rate without affecting the reaction equilibrium because it can increase the difference in the molecular pathways of the reaction [15]. Distillation is a method of separating ethanol based on the boiling point of the components present in the mixture or based on the ease of evaporation of the material. Tests that can be carried out include specific gravity, viscosity, supple point, specific gravity, and refractory index [16],[17],[18].

1.3. Research Objective

This study aims to evaluate the quality and quantity of bioethanol produced from palm oil bunches starting from the preparation of raw materials to the bioethanol production process.

2. MATERIALS AND METHODS

In this study, raw materials in the form of Fresh Fruit Bunches (FFB), Empty Fruit Bunches (EFB), and palm fiber produced bioethanol with an adsorption and distillation process. The research was carried out by conducting three different treatments for raw materials, namely without a delignification process, acid delignification was carried out, and acid delignification was carried out which was continued with alkaline delignification. The evaluation was carried out by testing, among others: type, weight, viscosity, flash point, specific gravity, and refractive index.

2.1. Preparation

The production of bioethanol is influenced by each process carried out. The first stage is the process of preparing raw materials, namely palm oil bunches. Oil palm bunches are obtained from the palm oil factory of Indopalma Swadaya at the Fort Base of Talang Kelapa District. Then mark is dried by drying it in the sun for two to three days to reduce the water content found in the palm bunches. The dried bunches are then chopped using a machete and sifted until a size of 1-2 m is obtained. after that, an analysis of the initial content of raw materials is carried out.

Figure 1. Preparation of Palm Oil Bunches
(A) Palm Oil Bunch Waste, (B) Palm Oil Bunches, (C) Small Size Palm Oil Bunch

2.2. Acid Delignification

Acid delignification is the process of removing lignin in raw materials used using a strong acid solution, namely HCl [19]. The delignification of this acid is the first variation of the treatment of raw materials. Raw materials that have been mashed as much as 1,000 g are then added 10,000 ml of HCl with a concentration of 10%. The mixture is then heated to a temperature of 121°C for 30 minutes. The solution is then filtered and washed using water until the pH is neutral. The resulting residue is then dried under the heat of the sun.

Table 1. Raw Material Preparation Data

Composition (%)	EFB (%w)	Fiber (%w)
Proximate Analysis		
Volatility	69.78	70.87
Pure Carbon	14.50	15.5
Moisture	7.35	9.56
Ash	8.37	4.0
Analyzes Ultimate		
C	54.37	53.07
H	4.70	4.98
Or	24.02	27.18
N	0.75	0.78
Calorific Value (MJ/kg)	5.08	4.04
Lignin	16.30	20.00
Cellulose	51.2	57.00

Table 2. Acid Delignification Result Data

Raw Materials	Before Delignification (g)	After Delignification (g)
FFB	1000	810
EFB	1000	483
Fiber	1000	641

2.3. *Base Delignification*

Acid delignification is the process of removing lignin in raw materials used using a strong alkaline solution, namely NaOH [20]. Alkaline (base) delignification is a continuation of acid delignification and is a second variation of the treatment of raw materials. Raw materials that have passed the acid delignification process are then added 10,000 ml of NaOH with a concentration of 10%. The mixture is then heated to a temperature of 121^{o}C for 30 minutes. The solution is then filtered and washed using water until the pH is neutral. The resulting residue is then dried under the heat of the sun. Results of Acid Delignification continued by Base Delignification can bee seen in Table 3.

Table 3. Data on the Results of Acid Delignification continued by Base Delignification

Raw Materials	Before Delignification (g)	After Delignification (g)
FFB	1000	464
EFB	1000	331
Fiber	1000	522

2.4. *Hydrolysis*

Hydrolysis is the process of decomposition of substances in chemical reactions caused by water. Hydrolysis breaks down water molecules into Hydrogen cations and Hydroxide anions [14]. The hydrolysis process uses a 1% HCl solution with the ratio of raw materials and HCl is 1: 20 v /v. The solution is then heated to a temperature of 78^{o}C with a closed condition for 90 minutes. The steering solution is cooled and set its pH to 4-4.5 by adding 0.7% NaOH. Hydrolysis Result Data can bee seen in Table 4.

Table 4. Hydrolysis Result Data

Raw Materials	Raw Material Treatment	After Hydrolysis (ml)
FFB	A	14.180
	B	20.740
	C	14.480
RFB	A	14.500
	B	19.740
	C	10.620
Fiber	A	15.750
	B	20.240
	C	16.500

Description: (A) treatment without delignification, (B) Acid delignification treatment, (C) Acid delignification treatment, and continued with Alkaline Delignification.

2.5. *Fermentation*

Fermentation in the bioethanol production process is the process of decomposition of sugar into carbon dioxide caused by enzymes produced by the mass of microbial cells. This fermentation process uses microbes derived from yeast and occurs in a state of being suspended without oxygen for 14 days. Table 5 shows the data of fermentation.

Table 5. Fermentation Data

Raw Materials	Raw Material Treatment	Yeast (g)	NPK (g)	Urea (g)
FFB	A	500	275	150
	B	500	275	150
	C	500	275	150
EFB	A	500	275	150
	B	500	275	150
	C	500	275	150
Fiber	A	500	275	150
	B	500	275	150
	C	500	275	150

2.6. *Purification*

The purification process is a process carried out with the aim of obtaining a full-grade bioethanol product. The purification process is carried out using tools that have been designed by the author. This tool is designed to perform two stages of purification, namely adsorption, and distillation. Adsorption is the process of absorbing water vapor using adsorbents in the form of natural zeolite. Distillation is the process of separating bioethanol from other chemicals based on the boiling point of ethanol. The boiling point of ethanol is 78.37^{o}C so that the setting point used is 80oC with correction ±3^{o}C. Bioethanol purification tool is also equipped with bioethanol trap with vacuum conditions aimed at accelerating the distillation process. The constant operation time is 90 minutes.

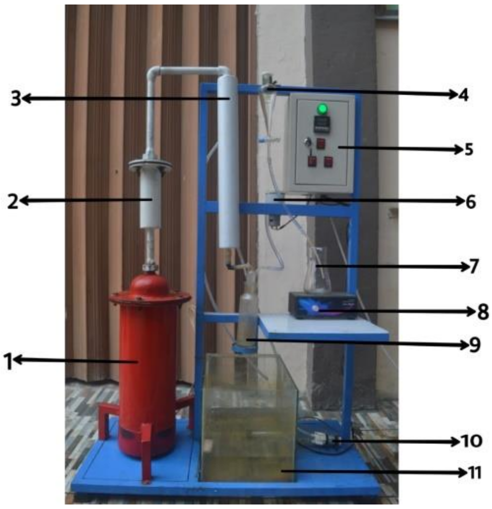

Figure 2. Bioethanol Purification Tools
(1) Rector, (2) Adsorber, (3) Condenser, (4) Blanding Funnel, (5) Control Panel, (6) Vacuum Pump, (7) Product Tube, (8) Stirrer, (9) Bioethanol Trap, (10) Cooling Water Pump, (11) Cooling Water

Table 6. Refined Data

Raw Materials	Treatment	without bioethanol trap (sec)	with bioethanol trap (sec)	Distillate (ml)
FFB	A	1.615	985	14.180
	B	1.730	810	20.740
	C	1.875	680	14.480
EFB	A	1.125	500	14.500
	B	1.378	398	19.740
	C	1.482	305	10.620
Fiber	A	1.130	501	15.750
	B	1.700	345	20.240
	C	1.830	298	16.500

2.7. *Analytical methods*

Biethanol that has been purified will be analyzed for product quality with analytical parameters including density, specific gravity, viscosity, and refractive index.

Table 7. Bioethanol Analysis Data

Raw Materials	Treatment	Density (g/ml)	Specific Gravity	Viscosity (mPa.s)	Refractive Index
FFB	A	0.9980	0.9980	1.1169	1.35378
	B				1.35578
	C				1.35676
EFB	A	0.9970	0.9970	1.0209	1.33881
	B				1.34181
	C				1.34376
Fiber	A	0.9906	0.9906	1.1140	1.33581
	B				1.33890
	C				1.34090

3. RESULT AND DISCUSSION

3.1. *Effect of Raw Material Treatment*

This study used three raw materials with three different treatments. The raw materials used are Fresh Fruit Bunches (FFB), Empty Fruit Bunches (EFB), and Palm Fiber. The variations of the treatment used are without delignification, acid delignification, and acid delignification followed by alkaline delignification. Delignification is the process of removing lignin levels. Lignin can inhibit the conversion of cellulose and hemicellulose into bioethanol so it must be eliminated. Variation is performed to see the influence of acids and bases on the removal of lignin in each raw material.

From the results of the study, it can be seen that the treatment of raw materials affects the mass of raw materials. Changes in the mass of raw materials are due to the loss of lignin contained in the raw materials. The highest mass change treatment was the acid delignification treatment followed by base (alkaline) delignification. Acid delignification eliminates lignin in the raw material, but not all lignins are successfully dissolved by acidic solutions. Delignification is followed by alkaline delignification which is expected to be able to dissolve the remaining lignin.

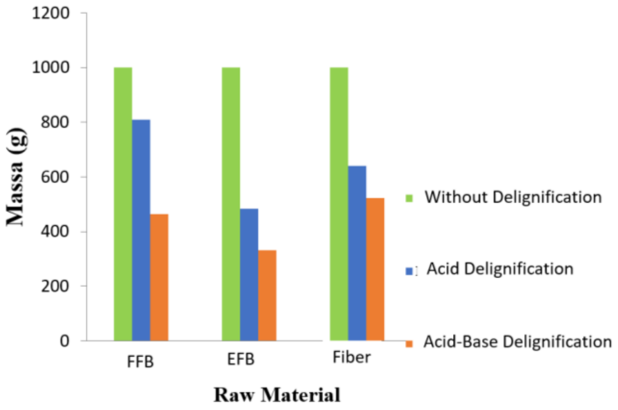

Figure 3. Effect of Raw Material Treatment

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The highest lignin was successfully eliminated in EFB raw materials. Other factors affect the results of delignification, including wasted raw materials. During the washing process so that the pH is normal, filtration and washing are carried out many times so that it can result in the loss of raw materials.

3.2. Bioethanol Produced

Bioethanol is produced through a purification process by using a bioethanol purification tool. Purification of bioethanol is carried out based on the boiling point of ethanol. The boiling point of ethanol is 78.37^{o}C so the set point used is 80oC with a correction of ±3^{o}C.

The amount of bioethanol produced is influenced by the treatment of raw materials carried out. The raw materials carried out are raw material preparation, delignification, and hydrolysis. Variations in the delignification treatment greatly affect the volume of bioethanol produced. This is because lignin can inhibit the conversion of cellulose and hemicellulose to bioethanol so it must be eliminated. The more lignin produced the more volume of bioethanol is produced with the same operating time of 90 minutes.

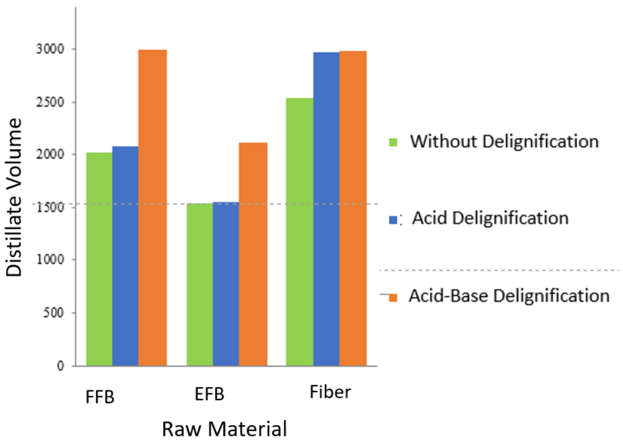

Figure 4. The volume of Bioethanol Produced

The results of the study showed that the treatment of raw materials affects the amount of bioethanol volume produced instead of the quality of bioethanol produced the largest volume of bioethanol produced in time the 90-minute operation is in each raw material with the influence of acid delignification followed by alkaline delignification. This means that more lignin in small amounts does not inhibit the conversion of cellulose and hemicellulose into bioethanol.

This purification tool is equipped with a bioethanol trap. Bioethanol traps are set with vacuum conditions assisted by a vacuum pump. The bioethanol trap is expected to be able to speed up the purification process without reducing the quality of the bioethanol produced. The fermented filtrate is warmed up to separate the bioethanol from other compounds contained in the filtrate. Bioethanol in the vapor state passes through the adsorber to be separated from the moisture. The next process is the condensation of steam into liquid. Condensation of bioethanol vapors into liquid takes quite a long time, therefore the bioethanol trap is expected to be able to speed up the condensation process. The vacuum pump pulls the bioethanol into the vapor state and will be stuck in the bioethanol trap under the conditions of the vacuum chamber.

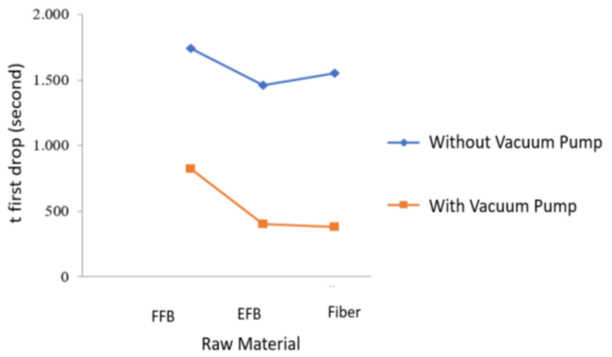

Figure 5. Effect of Bioethanol Trap on Condensation Time

From the results of the research conducted bioethanol trap accelerates the time of the condensation process. The condensation process time can be seen from the time of the first drop of dripping distillate due to the constant operation time of the tool, which is 90 minutes. Bioethanol trap can speed up the condensation time by an average of 15 – 20 minutes without reducing the quality of the bioethanol produced.

3.3. Characteristics of Bioethanol

The resulting bioethanol is analyzed to determine its characteristics. The analysis carried out is density, viscosity, and refractive index. The density of pure ethanol is 0.7893 g/cm^{3} and the viscosity of pure ethanol is 0.980 mPa.s. The average density of bioethanol produced is 0.9952 g/cm^{3}. The density of bioethanol produced is closer to the density of water, which is 1 gr / cm^{3}. It can be seen that the bio ethanol produced still contains a lot of water. The viscosity of the bioethanol produced averages 1.0839 m.Pa.s. Viscosity describes the viscosity of a liquid. The lower the viscosity of the fluid, the more liquid and the greater the movement of the alite substance. It can be concluded that the bioethanol produced is liquid because it has a low viscosity value.

Index refractive analysis on each medium is defined as a comparison between the speed of light in a vacuum and the rapid propagation of light in a medium. The ethanol refractive index is worth 1.36. The refractive index can be obtained using a refractometer measuring instrument. The refractive index can also determine the level of ethanol contained in the resulting bioethanol. The closer the refractive index of pure ethanol, the better the quality of the bioethanol produced.

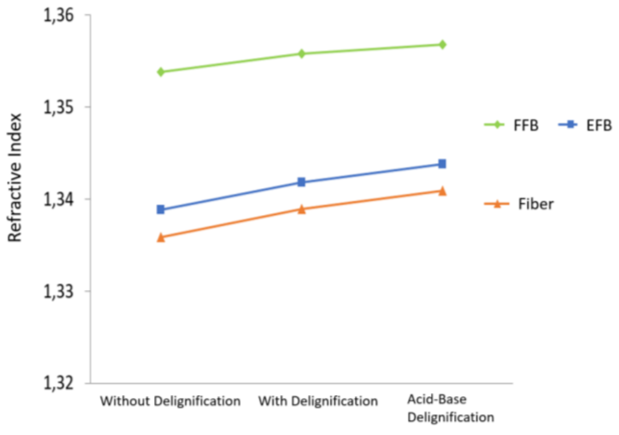

Figure 6. Bioethanol Refractive Index

The quality of bioethanol is not affected by the amount of volume of bioethanol produced. Each raw material produces a different refractive index, this is influenced by the cellulose and hemicellulose content contained in each material. FFB produces bioethanol with a refractive index closest to the value of the pure ethanol refractive index. This is because the cellulose and hemicellulose content in FFB is still intact and has not decreased due to the CPO production process. CPO production can reduce the amount of cellulose and hemicellulose in oil palm bunches. EFB and Fiber are waste from production that causes cellulose and hemicellulose content to decrease and results in the quality of bioethanol not being as good as from FFB raw materials.

The quality of bioethanol can be improved by adding treatment to the raw material. This can be proven from the results of research conducted, that the value of the index refractive will increase if a delignification treatment is carried out (elimination of lignin levels). The refractive index value closest to 1.361 is FFB with acid delignification treatment and continued with alkaline delignification with a value of 1.35676. This means that the smaller the lignin content contained in the raw material will maximize the conversion of cellulose and hemicellulose to bioethanol.

The relationship of the refractive index is directly proportional to the concentration of bioethanol, that is, the greater the refractive index, the greater the concentration of bioethanol produced [16],[21]. The concentration obtained makes the raw curve of ethanol from a concentration of 0% to 96% so that an equation is obtained to measure the concentration of ethanol in the resulting bioethanol.

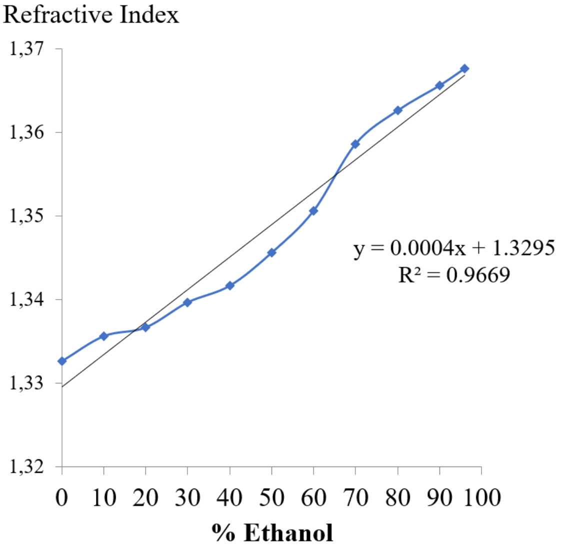

Figure 7. Bioethanol Standard Curve

The above standard curve produces an equation to produce a concentment of bioethanol:

$$y = 0.0004x + 1.3295 \tag{1}$$

where y is the refractive index and x is the concentration of ethanol inside the bioethanol. The highest refractive index is FFB with acid delignification treatment and continued with alkaline delignification with a value of 1.35676. If entered into equation 1, the ethanol concentration in bioethanol is 68.15%.

4. CONCLUSION

Based on the research that has been carried out, it can be concluded that palm bunches can be used as an alternative material for the manufacture of bioethanol. The practice of pretreatment of acid delignification and continued with alkaline delignification can improve the quality and quantity of bioethanol produced. The highest volume with the highest refractive index value is FFB raw materials because fresh fruit is still rich in cellulose and semi-homocellulose. The highest volume is 2,992 ml with a refractive index of 1.35676 and an ethanol concentration of 68.15%.

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