

Conference and Exhibition Indonesia Renewable Energy & Energy Conservation  
[Indonesia EBTKE CONEX 2013]

## Bioenergy Plants in Indonesia: Sorghum for Producing Bioethanol as an Alternative Energy Substitute of Fossil Fuels

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### Abstract

Indonesia's energy demand is increasing every year. Bioenergy plants are expected to be one of the solutions to fill energy demand in Indonesia. Sorghum is a bioenergy plant that can be used in Indonesia for producing bioethanol. Sorghum bioethanol is produced from sorghum biomass waste processing results with fermentation process. Ethanol is derived from fermented sorghum which is about 40-55%. Sorghum bioethanol can be used as an alternative fuel that is renewable and can be used as a substitute for fossil fuels.

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Selection and peer-review under responsibility of the Scientific Committee of Indonesia EBTKE Conex 2013

*Keywords:* bioenergy plants; renewable energy; sorghum; bioethanol; biomass waste; fermentation process

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### 1. Introduction

Currently, the world is started to lack of energy sources from fossil fuels. Therefore, it is necessary to attempt to find alternative sources of renewable energy [1]. In Indonesia, the issue of energy crisis also crowded discussed in recent years. Energy crisis occurred due to start depletion of fossil fuel reserves. Because of excessive human consumption and dependence on fossil fuels is causing fuel reserves become depleted, while the time required for its renewal thousands and even millions of years. Vegetable-based fuels are expected to reduce the shortage of fuel, so

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the fuel needs will be met. Vegetable-based fuels can also reduce environmental pollution, making it more environmentally friendly [2].

As cereals plants (grains), sorghum has a multiuse benefits. In addition, the seeds used as food, stems and leaves for fodder, the sugar contained in the seeds (carbohydrate) or liquid / juice / sap stem (sweet sorghum) can be processed into ethanol (bioethanol). Sap is made from sorghum can used for bioethanol industry has developed in many countries such as USA, China, India and Belgium. Nowadays, the productivity of sorghum bioethanol in the United States totaled 10000 liters/ha, India 3000-4000 liters/ha and China 7000 liters/ha. As biofuels, sorghum bioethanol used in various purposes, such as blended with gasoline (premium) for motor vehicles or better known as gasohol. In India, beside gasohol, ethanol sorghum is also used as a fuel for lighting lamps (pressurized ethanol lantern) called "*Noorie*" which produces 1250-1300 lumens (about equivalent to a 100 W light bulb). Sorghum bioethanol is also used as a cooking stove fuels (ethanol pressurized stove) that produce heat capacity of 3 kW [3]. This paper explained about the process of making sorghum bioethanol and the advantages of it to fill the energy requirement in Indonesia.

## 2. Material and method

The method which is used for write this paper by literature review about:

### 2.1. Renewable energy in Indonesia.

Renewable energy is developed and used in Indonesia. It is caused by the energy decrease which is made from fossil fuel, so that we look for another energy which can fuel cell energy demand. There are many kind of renewable energy which can be used in Indonesia like wind energy, solar cell, wave energy and bioenergy. Bioenergy is one of the potential energy which is made from bioenergy plant. Some bioenergy plants in Indonesia are red alga, sugar cane and sorghum.

### 2.2. Sorghum plants.

Sorghum is one of bioenergy plant. It can produce bioethanol who use as a fuel. This bioethanol is produced by fermentation process

### 2.3. The process of making bioethanol.

Material that used in the bioethanol production is seed sorghum which is milled (grinding) to get the starch [4]. Grain sorghum is crushed into flour sorghum with size 100 mesh and the characteristic of grain sorghum is shown in table1.

Table 1. The characteristic of sorghum grain [5].

Substance	Sorghum Grain Content (%)
Starch	13.60-18.40
Protein	10.00-14.40
Water	0.75-1.35

Besides that, it is also used *Saccharomyces cerevisiae*, nutrient (NPK and Urea) and some reagents for analysis. In general, the process of making bioethanol from sorghum can be seen in Fig. 1.

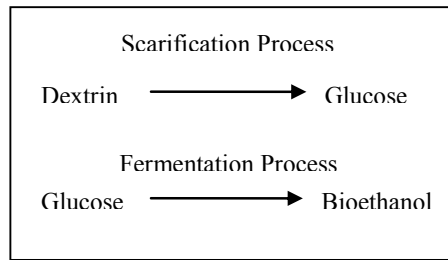


Fig. 1. Process of making bioethanol from sorghum [4].

In the process of producing sorghum bioethanol, there are some important factors to consider because it may influence the products of bioethanol. The factor which is influenced for the result of bioethanol production are the length of time is fermentation and scarification, the number of additional starter, fermentation temperature, sterilization equipment, and the success of the process of distillation. All these factors can be varied for bioethanol optimization.

### 3. Result and discussion

#### 3.1. Sorghum plants.

In Indonesia, sorghum has been recognized by farmers, especially in Java, NTB, and NTT, but the cultivation and development is still very limited. Sorghum is a potential crop to be cultivated and developed in Indonesia, particularly in arid regions. The sorghum excellences are in resistance to drought, high production, production costs are relatively inexpensive and more resistant to pests and diseases compared with other crops. The sorghum plant is shown in Fig. 2.



Fig. 2. Sorghum Plants [3].

In terms of agronomy, crop sorghum growing requirements that do not require a spoiled, has a wide adaptability, low input crop, and more drought resistant sorghum or otherwise can live in stagnant water. In addition, sorghum can be planted with “*ratun*” systems that require less labor, because the plants can be harvested two to three times for planting only once [3]. Sorghum plant can be used for various things such as food sources, as a source of animal feed, as fuel energy from plants, and industrial raw materials.

### 3.2. Bioethanol from sorghum plants

#### 3.2.1. Ethanol

Ethanol is a liquid which is widely used for various purposes based on its concentration. Chemical properties of ethanol are not toxic, can be used as a solvent in the chemical and pharmaceutical industry, a mixture of gasoline, cosmetics and medicines. Ethanol also has physical properties: molecular weight is 46.070 g / mole; density at 20 ° C is 0.789 gr/cm<sup>3</sup>; boiling point is 78.4 ° C; Specific gravity 0.7851 at a temperature of 20°C.

There are two methods used to produce ethanol, the hydration of ethylene and fermentation. However, due to an increase in crude oil prices, the production of ethanol made from raw materials containing starch such as cassava, sweet potatoes, corn, sorghum and corn. As well as materials that contains sugar and cellulose through a process of fermentation and distillation. In the anaerobic conditions, the yeast produces ethanol, based on Gay-Lussac equation:



Based on the above fermentation reaction, one molecule of glucose in the fermentation will produce 2 molecules of ethanol and carbon dioxide. Based on weight 1gram glucose will theoretically produce 0.51 grams of ethanol. Because most of the carbon source used for biomass formation, so that the actual ethanol yields ranged from 90-95% of the theoretical. [6]

#### 3.2.2. The process of making sorghum bioethanol

Bioethanol is ethanol produced from biomass raw materials such as cassava, maize, potatoes, wheat, sugarcane, beet, and sorghum. Bioethanol can be used as an alternative fuel that is renewable and is used as a substitute for fossil fuels [7].

In Indonesia, production of sorghum still dwarfs, the national average only about 4000-6000 tons per year which is expected to produce bioethanol 4000-7000 liters / ha / year. Bioethanol from sorghum is also not used optimally by the society.

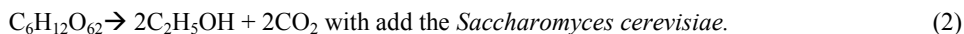
Sorghum juice contains glucose levels are quite large because of the quality of sweet sorghum juice is equivalent to sugar juice and not fully utilized to obtain the alcohol from sorghum juice with fermentation process.

Table 2. Comparison of the composition of sorghum juice with sugar juice [8].

Composition	Sorghum Juice	Sugar Juice
Brix (%)	13.6-18.4	12-19
Sucrose (%)	10.0-14.4	9-17
Reduction Sugar (%)	0.75-1.35	0.48-1.52
Total Sugar (%)	11.0-16.0	10-18
Ami lum (ppm)	209-1764	1.50-95
Aconite Acid(%)	0.56	0.25
Dust (%)	1.28-1.57	0.40-0.70

Sorghum is produced bioethanol by fermentation and distillation process. In general, the bioethanol production process includes five phases. The first stage is the process of grinding. The second stage is composed of a process pre fermentation include pH reduction process, the sterilization process, and the process of making a starter with add nutrients and *Saccharomyces cerevisiae*. The third stage is the processes of fermentation for 48 hours with add starter inoculum of the manufacturing process and add antifoam. The fourth stage is the distillation process. The fifth stage is sieve molecular dehydration [7].

Sorghum to ethanol conversion obtained cannot reach 100% (perfect), this is because not all the glucose can be converted into ethanol, but most of the glucose will be converted into CO. The theoretical conversion of ethanol formation from glucose was 51% with the following reaction:



Conversion obtained under the conversion theory, this is because at the time of fermentation possibility of other microbial contamination. A bad sterilization is also resulted incomplete conversion [9]. Besides that, the conversion also depends on the length of the fermentation process, many starters are added, and the quality of sorghum juice is used.

### 3.2.3. The sorghum bioethanol optimization

To obtain bioethanol with good quality, the optimization process should be done by modifying the factors that influence the result of the process of making bioethanol. Based on several experiments that have been performed before, there are some values obtained in the optimization of sorghum bioethanol making process.

- The optimum point is the addition of 9% volume starter with 11.82% ethanol content.

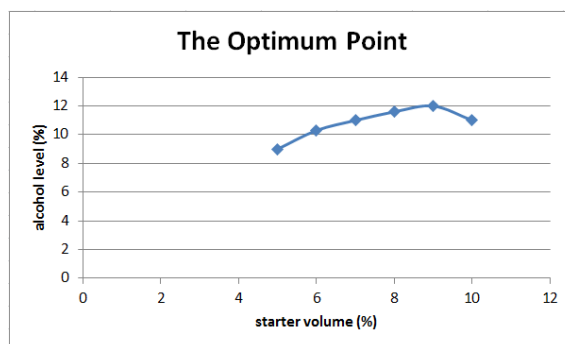


Fig. 3. The optimization of starter volume in % [9].

- The initial sugar concentration results the best sorghum starch liquefaction is 14.001 g / l at temperature 95°C. The best liquefaction temperature is at temperature 95 ° C with ethanol concentration of 40 g / l and time 48 hours of fermentation [4].
- Soaking using 0.2% NaOH solutions for longer soaking time increased the extractable protein content. With the increase of extractable protein content mean that the protein content in sorghum flour is decreased.

Table 3. Extractable protein content [5].

Soaking with NaOH	2 hours	3 hours
Extractable protein content (%)	6,45 8,03	6,45 8,03

### 3.3. The advantages of sorghum bioethanol

Sorghum that has been processed into ethanol can be used as a substitute for kerosene fuel with ethanol content of 40-60%, for laboratory and pharmacy needs 70-90%, and a 90-100% for premium materials [10]. With this bioethanol is expected that fossil fuels can be substituted by using bioethanol from sorghum.

Replacement of fossil fuels with bioethanol can help to reduce the energy crisis that occurred in Indonesia. In addition, bio-ethanol is also more environmentally friendly than fossil fuels so that, besides to reducing the energy crisis, bio-ethanol also helps to protect the environmental sustainability.

#### 4. Conclusion

Sorghum is a bioenergy plants that can be developed in Indonesia to produce bioethanol. Ethanol is derived from fermented sorghum which is about 40-55% depending on the quality of sorghum juice, fermentation and sterilization processes. Bioethanol can be used as an alternative energy source in Indonesia.

#### Acknowledgements

Acknowledgements will be gotten after this paper presentation and judgment in Indonesia CONEX-EBTKE 2013.

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