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Biomass by-product from crystal sugar production: A comparative study between Ngadirejo and Mauritius sugar mill

Gunawan[1], T Bantacut[2], M Romli[2] and E Noor[2]

[1]Post Graduate Program of Agroindustrial Technology, Bogor Agricultural University, Bogor
[2]Department of Agroindustrial Technology, Bogor Agricultural University, Bogor, Indonesia
*gunawan.samin@gmail.com

Abstract. Sugarcane has been used as raw material in crystal sugar industry. Sugar cane that contains high sugar will be utilized into crystals sugar. In addition, the productivity of sugarcane is large enough in 2016 approximately 360 713 tons/year. Crystal sugar itself is a daily necessity for its use in the food and beverage industry. Problem that occurs in Indonesia is the energy consumption. The sugar mills supposed to be an independent energy source which means it can produce its own energy by utilization the material that is available in the sugar mills such as by-product (bagasse, molasses, filter cake, etc.), the by product in every production stage are quite a lot in sugar industry especially in Indonesia. In this paper, a comparison between two sugar mills was examined between Ngedirejo sugar mill and Mauritius sugar mill which has the same geological state as Indonesia. The results of comparison between the two sugar factories demonstrated the difference in terms of productivity of the sugar that has been produced and the effectiveness of the production process in a sugar mill seen from the amount of waste and the by product.

1. Introduction

Sugar cane is one of the large available commodity in Indonesia. The area of sugar cane in Indonesia reached 445.520 ha in 2016 with a productivity of 2 222 971 ton [1]. Such area makes sugarcane as potential raw material in the process of making white crystal sugar.

The production process of white crystal sugar is through several stages such as grinding, refining, evaporation, cooking, and crystallization. Each stage produces output and by-product in the form of biomass. Process of white crystals sugar production was known as close loop system, indicating that there is energy and material rotation in production process system characterized by the use of by-product from the production process for the sake of the sugar mills.

The use of biomass in sugar mills has long been known. Sugar mill produce biomass in the form of bagasse, filter cake and molasses which can be reused as fuel to generate energy for the production process of white crystal sugar. Ngadirejo and Mauritius sugar mill have conducted biogas cogeneration process to utilize by-product of production process into electrical energy that can be used to support the production process of white crystal sugar. Both sugar mills produce considerable amount of biomass from sugar production process. Sugar cane is associated with sugar production, such as in Mauritius, where most of the country's power plant comes from efficient system installed in sugar mills. This paper examines the difference of white crystal sugar production process at Ngadirejo and Mauritius sugar mill concerning how much output and by product produced in sugar cane extraction process at each sugar mill and how much energy can be generated from the biomass conversion process in the form of bagasse produced at the mills.

2. Materials and Methods

The research method is analyzing mass and energy balance of Ngadirejo and Mauritius sugar mill as benchmark. Benchmarking is a very important parameter of performance comparison measurement showing the level of performance of the mills to the industry standard. The research stages conducted through literature study, field observation, interview and data processing.

3. Results and Discussions

3.1 Ngadirejo and Mauritius Sugar Mill

The case study is conducted by comparing the production process of white crystal sugar at the Ngadirejo and Mauritius sugar mill. Ngadirejo sugar mill is one of the sugar factories located in Kediri, East Java, Indonesia. Mauritius sugar mill is located on the African Continent which has similar geological condition to Indonesia. Therefore, the production process of white crystal sugar has the same characteristics due to similarity of geological structures of both regions. Generally, the production process of white crystal sugar is almost the same in every sugar mill, as well as between Ngadirejo and Mauritius sugar mill. The difference is in the raw materials capacity, production and by-product produced. Stages of white crystal sugar production process in Ngadirejo and Mauritius sugar mill is similar that is through several stages including the process of milling, refining, evaporation, cooking and crystallization.

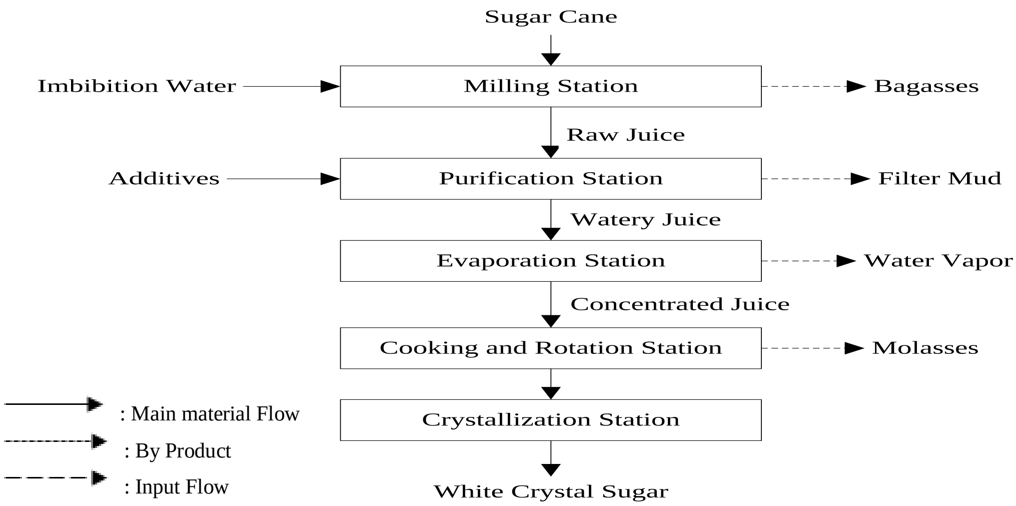

Figure 1. Flowchart of white crystal sugar production

It appears that most of sugar factories produce white crystalline sugars through the same stages (Figure 1). It is assumed that both sugar mills have an input of 1 ton, and after calculating the mass balance (Figure 2) it is known that Ngadirejo sugar mill produces white crystal output of 8.22% and Mauritius sugar mill of 10.96%. Differences in output show that Mauritius sugar mill is more effective than Ngadirejo sugar mill in the process of sugar production. The difference of output at the sugar mills shows that the less white crystal sugar produced the more losses it generates. Ngadirejo sugar mill with total production of 8.22% resulted in losses of the whole process of 55.4% compared to Mauritius sugar mill by 26.3%, a significant difference from the two factories. According to Subyanto [2], decrease in crystal sugar productivity and increased losses in sugar mills occurs due to inefficiency of machine or tool. It is confirmed by Wauters and Mathot [3] which states a decrease in the productivity of sugar crystals can be caused due to many losses produced. Decreased productivity of crystalline sugars can occur due to malfunctioning machines, loss in process, and external factors.

3.2 Baggase Availability in White Crystal Sugar Production

Sugar crystals production is essentially done through several stages namely milling, purification, evaporation, cooking, and crystallization [4]. Extraction is the initial stage of sugar crystals production process that occur at the mills. The main raw materials of sugar cane will be processed first at a milling station which produces a watery syrup (*nira*) output and by-product bagasse. Nira will be processed at the next station while bagasse as by-product will be reused by sugar mills. Bagasse produced from milling stations is potential to be used in some industries such as whiteboard, paper, fuel and especially for combusting which will generate energy. The last role of bagasse is combusting which is usually used by sugar mill to generate additional energy for white crystal sugar production process. Bagasse used as fuel in boiler station as energy source of sugar mills.

Historically, sugar mills have been designed to meet their energy needs by burning bagasse. Bagasse is a potential biomass as a renewable energy source and available substantially in sugar mill. In 100% of sugarcane, the resulting bagasse varies from 23% - 40% [5,6]. This depends on sugarcane fiber, which usually ranges from 12 % to 19%. The average composition of sugar industry in Indonesia is 52.9% of waste water, filter mud 3.5%, bagasse 32.0%, molasses 4.5%, sugar 7% and ash 0,1%. Water content of Bagasse from sugar milling process is 49% -52%, sucrose is 1.5% -3.0%, brix is 4% -7%, not sugar is 2.5% -4 %, and coir by 10% -16%. The value of bagasse as a fuel depends heavily on the gross calorific value (GCV), which is depend on the composition, particularly water content and calorific value of sugar cane which is primarily depend on its sucrose. GCV bagasse ranges from 2275 kcal/kg for bagasse moisture 50% to around 3426 kcal/kg for moisture content 25%. The average ratio of steam to bagasse is usually 2. At a density of 130 kg/m^3, bagasse storage requires a lot of space, therefore need a boilers to burn as much as possible. According to Deepchand [7], Mauritius sugar mill has produced 105 GWh of electricity from 210 tons of bagasse (0.5 GWh/ton).

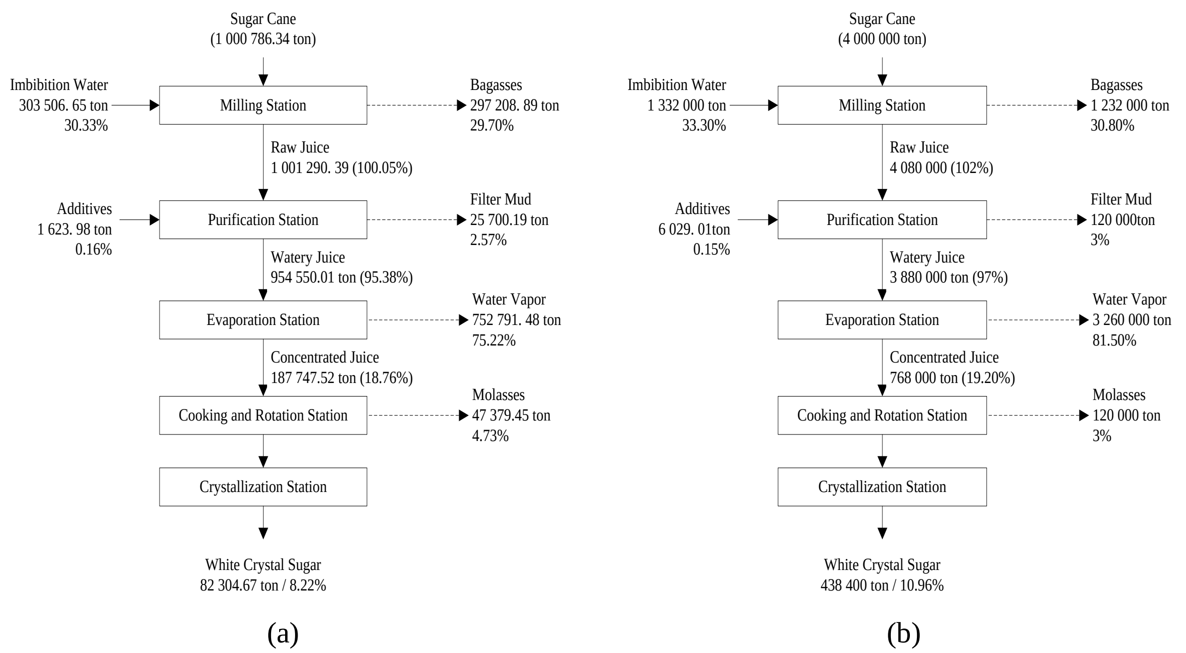

Figure 2. Mass balance between Sugar mill Ngadirejo (a) and PG.Mauritius (b)

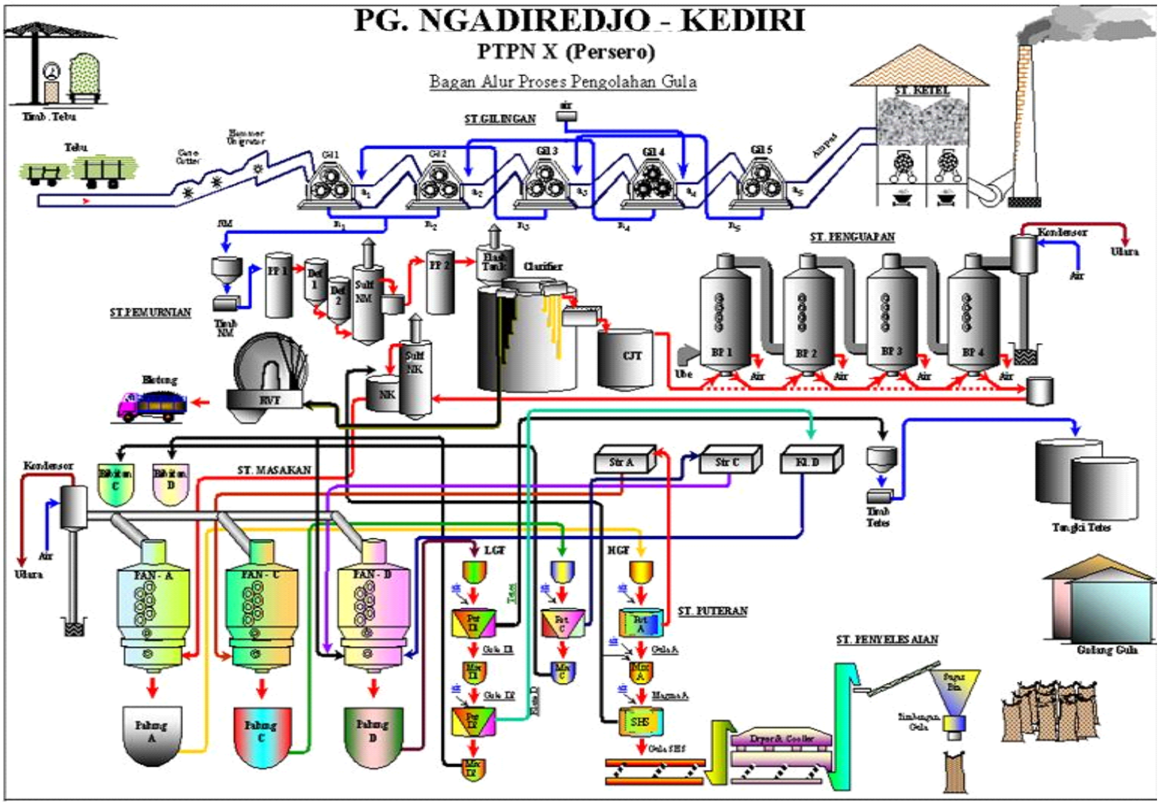

Figure 3. Flowchart of sugar production processing at Ngadirejo sugar mill

The process of white crystal sugar production with sugarcane raw materials at Ngadirejo and Mauritius sugar mill is using 1 ton of sugar cane as the initial input (Figure 3). During the extraction process, dilute juice, bagasse and waste/losses will be generated. There is a difference of output, by product and losses generated between two sugar mill though having the same input bases. Table 1 shows a clear distinction between Mauritius and Ngadirejo sugar mill. It appears that Mauritius sugar mill produces more output and bagasse than Ngadirejo sugar mill. In addition, due to the losses, Mauritius sugar mill produces fewer losses. This shows that the production process of white crystal sugar at Mautitius sugar mill is more effective and efficient compared to Ngadirejo sugar mill.

Table 1. Comparison of mass balance at Milling station

Input	Unit	Ngadirejo Sugar Mill	Mauritius Sugar Mill
Sugar cane	Ton	1,00	1,00
Imbibition Water	%	30.33	33,3
Additives	%	0,0016	0,0015
Loss Milling Station	%	0,444	0,375
Output			
Raw Juice	%	100.05	102.00
By Product			
Bagasse	%	29.70	30.80

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Bagasse difference between the two sugar mill is 1.1%. This suggests that more energy can be generated at Mauritius sugar mill than Ngadirejo sugar mill. By-product or losses produced at a production stage can be affected by the effectiveness of a machine used [2]. In addition to the effectiveness of the machine, it can also be affected by the amount of imbibition water added during grinding. Bagasse as by-product at milling station can be converted into energy for sugar mill during the production process. Utilization of bagasse as additional energy source at sugar mill has been done because provide sufficient high energy where the electricity generated increases with the high percentage of fiber [8]. Bagasse generated from the biomass produced by the sugar mill itself, renewable in nature and will benefit economically [9]. The use of bagasse as energy source will directly contribute to clean energy use compared to fossil-based energy that can damage the environment.

3.3 Convertion Process

Sugar mill is also known as self-sufficiency energy which means supply its own energy[10]. Most of sugar milling the world already supply the energy needed to process sugar from sugar cane biomass as raw material of white crystal sugar. The process of utilizing bagasse as energy source for Sugar Mill is also known as cogeneration. Cogeneration is activity to produce electrical and thermal energy simultaneously from a fuel combustion process. The process of bagasse cogeneration is shown in Figure 4.

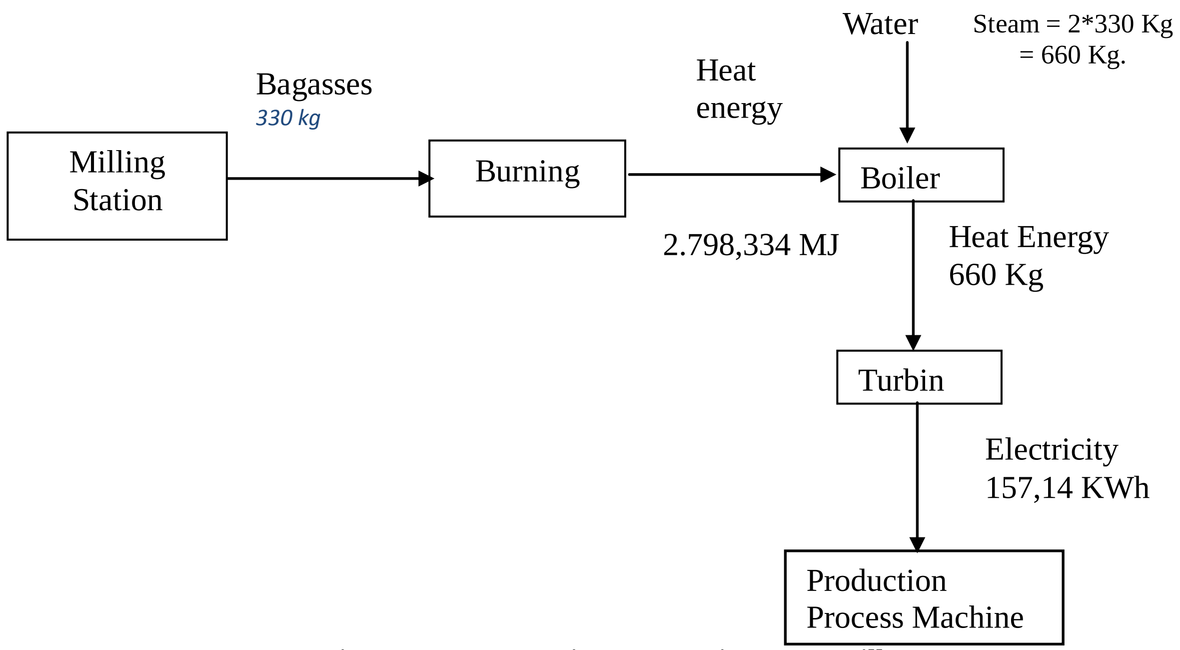

Figure 4. Cogeneration Process in Sugar Mills

The process of bagasse conversion into energy at sugar mills generally uses two important components namely boilers and turbines. Conversion begins in combustion process at the boiler, using bagasse as fuel generated from the milling station. The boiler will produce steam which the vapor will directly enter the turbine to convert into energy. The resulting electrical energy will then be used for the production process of white crystal sugar.

How much electrical energy generated from Bagasse in sugar mills can be calculated. Saechu [11] explains 1 kg of bagasse can be converted in to 2 kg of steam. Meanwhile 4.2 kg of bagasse can generate 1 KWh of electricity. Calculations of bagasse conversion to energies as as follow [11]:

1 kg bagasses → 2 kg vapor - - - - -> 4.2 kg vapor → 1 KWh

If we assumed that in milling station produces 330 kg bagasse, it will show that from 330 kg bagasse can produce 2772 KWh (330 * 2 * 4.2). Bagasse conversion process in Ngadirejo and Mauritius sugar mill to electrical energy is 141.43 KWh and 146.7 KWh respectively. Mauritius sugar mill produces more additional energy compared to Ngadirejo sugar mill due to more by-product generated. In addition, the overall calculation shows that Mauritius sugar mill produces more by-products and generates more electrical energy. The results of by-product calculations are presented in Table 02.

Table 2. Calculation of by-product potential

Sugar mill	Electricity (KWh)		
	Generated	Required	Surpluss
Ngadirejo	944,93	25	919,93
Mauritius	971,63	20	951,63

Source : [10,12, 13, 14]

Table 02 shows calculations of potential by-product during the production process of white crystal sugar. In addition to bagasse, other by products of sugar mill can also be used as energy source such as molasses, can be converted into energy for sugar mill production process. Both sugar mill produces enough electrical energy to be used during the production process. It appears that the sugar mill is capable to supply its own electrical energy and can be used for other purposes. This confirms that sugar mills are generally able to supply their own energy and even have considerable energy reserves.

4. Conclusions

Mass balance between two sugar mill showed that both of sugar mill produce by product that potential to become energy raw material especially in Mauritius sugar mill that produce 30.80% by product (bagasse) higher than Ngadirejo sugar mill. The higher by product production by the sugar mill, the higher energy that can be produce and convert to electricity. It can be concluding that Mauritius sugar mill is more efficient and effective in produce as we can see in the by product and losses during the white sugar production process. The low productivity of a sugar mill can be caused due to several things such as ineffective machine condition.

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