Sugar Production Process in Sri Lanka

Udara S.P.R. Arachchige, Heshanka S, Udakumbura M.G.P.M, Peiris H.I.S, Bandara A.M.P.A, Nishantha P.G.U, Sandeepa A.W.S, Ruvishani L.S, Jinasoma P.N.D, Pathirana N.M.H, Ekanayaka S.S
Faculty of Technology, University of Sri Jayewardenepura

Abstract—There are varies type of industries are working all over the world for creating varies types of products. The sugar industry is one of the industries in which possess to food industry category. As a raw material of the sugar industry, it can be either sugar cane or sugar beet. However, in the tropical region, sugar cane is the most viable option. Availability of the land, soil, raw materials, climate, and other factors are the main things to develop the sugar industry. When using sugar cane in sugar industry sugar is not the only product there are few by-products that can be produced. Power can be cogenerated using bagasse, Ethanol and animal foods can be created using molasses and the rest of the waste (filter cake) can be used as a fertilizer for sugar cane. When it comes entire process of the sugar industry if sugar industry in a position to be used modern and well efficiency techniques to extract sugar,economic support which comes from sugar industry can be maximized not only that environmental impact caused can be minimized because every single of waste can be used as other products in sugar industry not only that the amount of the product can also be increased. The sugar manufacturing process, environmental pollution, waste minimization , process optimization is discussed with recommendations for further implementation.

Key words: By products, Ethanol, Sugar cane, Sugar, Waste.

1 INTRODUCTION

In Sri Lanka, sugar produce by using sugar cane, because sugar cane grows in tropical or subtropical countries [1]. The total production capacity mainly depend on the sugar content of the sugarcane which is basically depend on the sugar cane quality and the efficiency of the juice extraction [2]. Content of poor quality/ High-quality sugar is given in the Table 01.

Table 01. content of High quality and poor-quality sugar [3]

	High quality cane	Poor quality cane
Juice per 100kg of cane	50kg	40kg
% sugar in juice	22	17
Sugar per 100kg of cane	10kg	7kg

After extracting raw juice from sugarcane, bagasse is used for cogenerating electricity. The fiber content of the bagasse is a very important fact when cogenerating electricity. Ethanol and animal foods are created using molasses and rest (filter cake) is used as fertilizer. This is the entire process ongoing in Sri Lankan sugar industry as shown in Fig 1.

Sugar cane convert solar energy to chemical energy in form of biomass. In Sri Lankan sugar harvest, sugar contains 3.5% molasses (light brown sugar) to 6.5% molasses (dark brown sugar) based on total volume. Though Sri Lanka has a good potential to have the best yield in sugar,It only produces about 27,000 MT, sugar per one crushing period (6-8 months) which is about 4.5% of the total consumption of the country [4]. In cogenerating electricity sugar cane, which has more bagasse (fiber) is needed the amount of bagasse is greater so that the loss of sucrose in the bagasse increases [3].

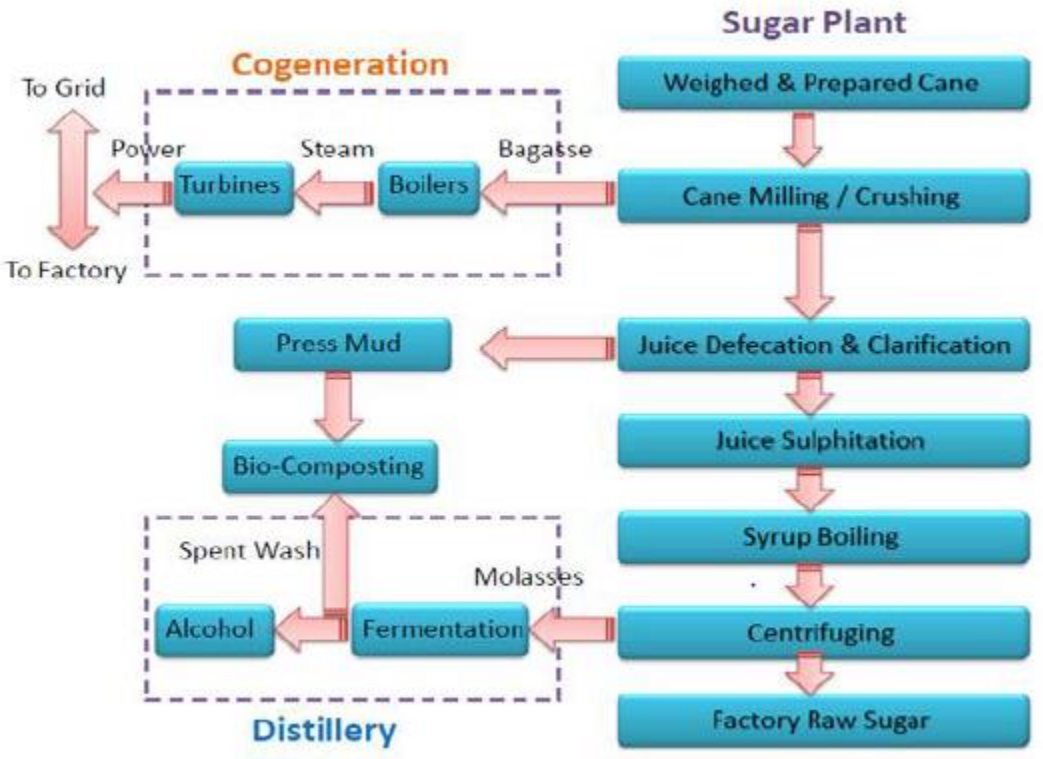

Fig. 1.Process Flow diagram of sugar industry [5]

2 SUGAR DEMAND

In Sri Lanka produces only 4.5% of sugar consumption [4], though Sri Lanka is a tropical and worm country [6]. Sugar cane crushing period is 6-8 months per year and in this period 270,000 metric tones are produced. Rest of 95.5% sugar needed is imported from South American courtiers. The Sugar requirement of the country is estimated to be 665,733 Mt per annum therefore, spending Rs. 38 Billion in Foreign expenditure to import [7].

Sugarcane quality is a very important fact such as sucrose, sugarcane hygiene, and fiber content. The above factors affect the amount of sugar that can be extracted from sugarcane not only that but also the quality or purity of juice. Through an agricultural research best type of sugar cane can be harvested. When selecting the type of sugar cane about fiber content should be concerned. Fiber content is needed to cogenerate electricity. Approximately 8 tons of sugar is produced from 100 tons of cane [3].Cultivating enough amount of sugar cane to fulfill the requirement of the country is not enough to success this achievement, the efficiency, and the products should also be increased.

Milling rates continuously increase therefore upgrade should be done as necessary. This is very expensive and it is essential to maximize the productivity of existing equipment. To simplify the mill operations new technology should be used.

3 SUGAR PRODUCTION PROCESS

In Sri Lanka sugar production industry mainly used sugarcane for extracting sucrose to producing raw sugar. Sugar production is dependent on the quantity and quality of sugarcane which delivered to factory. Basically, sugar production is continuous and 24 hours' operation. So there is essential to regular sugar cane supply for sugar production. During the rainy season sugarcane harvesting is stopped and cultivation is started. In sugar manufacturing process there are several steps are included. Some of them are juice extraction, clarification, concentration, crystallization, and separation of crystals.

The canes are thoroughly cleaned and cut to the small pieces and dropped over a continuous belt of steel plates. These small pieces passing through the two roller crushers and four sets of mills. Process of this section is extraction the juice. Normally about 90-95% of juice can be extracted in this section. After screening extracted raw juice comes to the raw juice tanks. To maintain pH value their lime is added and this method called as cold liming. Then juice goes through the two heaters and it helps sediment mud properly in the clarifier. There five compartments consist in the clarifier. Then clarified juice collected when overflow of each compartment. In a mixing tank separated mud in the subside is mixed with bagacillo and mixture brought to the mud filter. To get the maximum sucrose from the mud there is hot water sprayed from the top of the filter. In this way, it can be recovered 99% of sucrose.

Usually clarified juice contains some of extra water and dissolved solids. In the evaporation process removes about 75% of water, and the end product is called a syrup. Then the pan boiling process, vacuum pans from sugar seeds from the syrups. In this process sugar crystals is developed by adding sugar slurry, which is prepared at the laboratory. The crystals along with the molasses are whirled in centrifugal machines where the molasses are removed. When sugar leaving the centrifugal machine contains about 1-1.5% of moisture. Therefore, drying of sugar done by using the rotary dryer where the excess moisture is removed from the sugar crystals [3]. Then after of these all process steps stored raw sugar is bagged and sent to the market. In Sri Lanka sugar industry, they only produced raw sugar called as natural brown sugar.

In sugar production process it can be separated in too few sections.

- Harvesting:
- Cane preparation
- Extraction:
- Clarification:
- Filtration:
- Evaporation:
- Crystallization (sugar boiling):
- Centrifugation:

- Drying:

In this section, a brief overview of the sugar production process industry, Efficiency improvement concepts in sugar mills and state-of-the-art technologies are briefly discussed [8].

Harvesting: This process is usually done manually or mechanically. Before done this mechanically sugar cane filed is burning [8]. Green harvesting method is better than burning because of high emissions of particulate matter and smoke, which can be harmful to humans and livestock not only that 30 % of the energy available in the plant is destroyed [8] [9]. The positive effects of green harvest method are affected by the soil fertility, soil structure, soil C levels and biological activity [9].

Extraction: Before extraction, cane preparation is done to remove unwanted particles attached to the sugar plant.The next step is chopped the sugar cane plant to prepare for the crushing. But when using mechanical harvest this chopping step can be skipped and the same step can be done using harvesting machines and plant energy consumption can be minimized [8]. After sugar cane is driven through the mill and juice is extracted.The milling process is shown in below Fig 2.

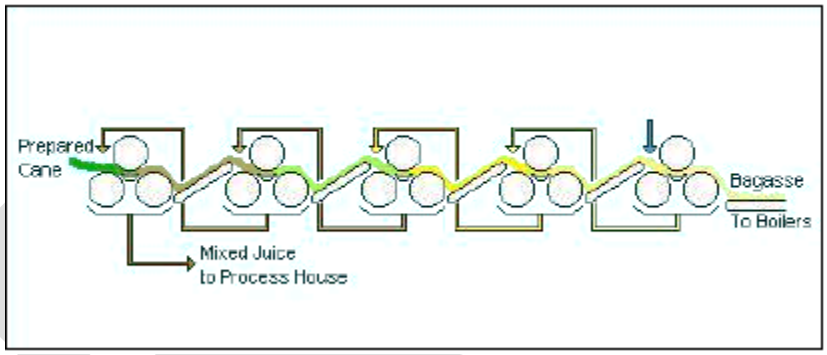

Fig. 2. Milling process of sugar cane [8]

Clarification and Filtration: In these two steps impurities of the juice, suspended matter and insoluble particle are removed.

Evaporation: Juice which comes after the above processes called molasses is heated with low-pressure steam in the purpose of removing water and have more concentrated molasses. The steam which is used for Cogenerate can be taken after rotating turbines for evaporator uses. This is done using sets of vessels called multiple effect evaporators. Evaporator and its process are shown in Fig 3.

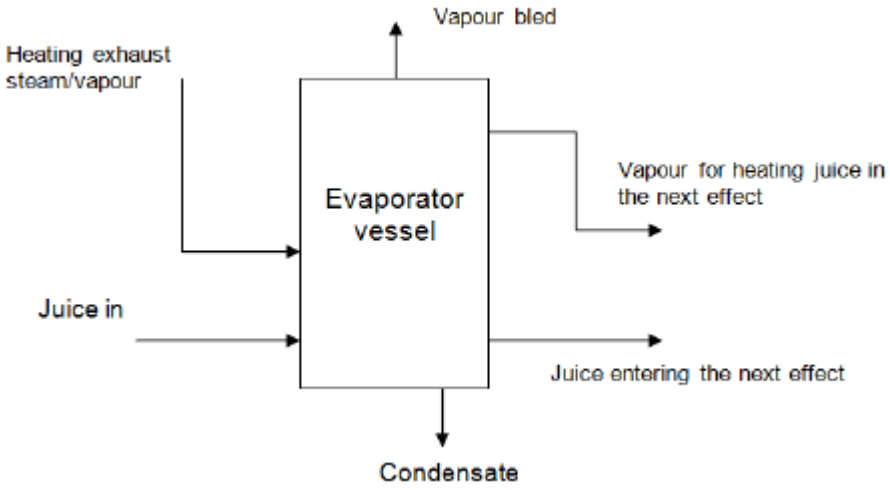

Fig. 3. A single evaporator vessel [8]

Crystallization: In here sugar syrup is converted to crystal. The steam which is needed for the crystallization is usually obtained from the evaporators [8].

Centrifugation: separating crystal and molasses is done in this step. A set of centrifuges is driven by this system where hydraulic motors having adjustable pumps are driven by motors. Deacceleration, as well as acceleration, can be adjusted by adjusting the pumps. In such arrangements, a centrifuge that is being accelerated gets indirectly driven by a Deaccelerating centrifuge as the latter will regain energy as it Deaccelerates and drives a hydraulic motor which in turn enables pumping fluid allowing the pump to act as a motor for the accelerating centrifuge [8].

Drying: Before pack raw sugar is dried using hot air. Air preheater can be used to dry. Air preheater can be established in the chimney of cogenerating section and save energy.

The sugar production process in the factory and the improvement that should be implemented in Sri Lanka sugar industry are discussed above.

4 COGENERATION OF ELECTRICITY

Bagasse is used to cogenerate electricitybagasse is a fibrous matter which remains after sugarcane is crushed to extract their juice. Approximately for every 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse [5]. To archive, the maximum efficiency of cogenerating electricity mostly depends on the thermodynamics principles [10]. Varies aspect should be concerned to maximize the efficiency.

- Moisture content include in bagasse
- The efficiency of the boiler
- Using insulation methods to avoid heat losing

- Maintaining necessary steam pressure.
- The efficiency of the turbine

The above requirements are the major things. In here this is acts as a mini thermal power plant therefore to make use exhaust gasses energy economizer, air preheater, reheater, and superheater should be placed [10]. Reheater only places if there are two or more turbines.

Economizer: Is essentially a feedwater heater, heat is taken from flue gases for this purpose. Before supplying to the boiler feed water should be fed to the economizer before supplying to the boiler. This is directly affectedby the overall efficiency of the power plant [10].

Air Preheater: Increases the temperature of the air supplied for bagasse burning by deriving heat from flue gases. This is increased thermal efficiency and increased steam capacity per square meter of the boiler surface[10]. Superheater: The steam produced in the boiler is normally wet hence steam is directed through a superheater.Inside the superheatedsteam is dried and superheated. It helps to increase overall efficiency and avoidturbine blade corrosion by avoiding condense of water on the blade [10].

In combustion, the boiler requires a supply of a sufficient quantity of air not only that but the removal of exhaust gases also for this purpose draught system is required as shown in Fig 4. In a mechanical draught system there two blowers [10].

1. Induced blower.
2. Forced blower.

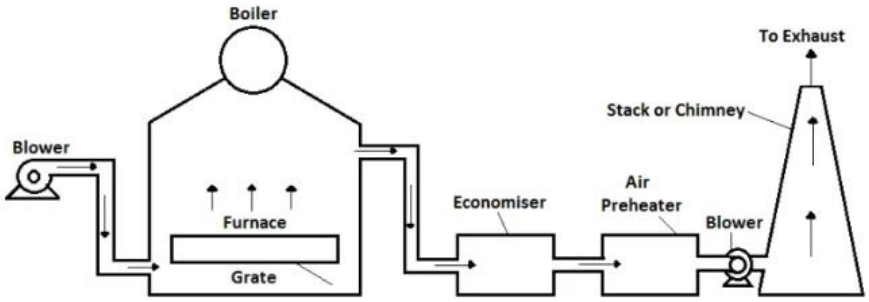

Fig. 4. draught system [11]

After rotating the turbine using steam, steam should be sent to the evaporator to boil off the water in the sugar syrup. In this process,steam transmission line should be well insulated to minimize the heat loss.After condensed steam should be direct to the boiler.

5 ETHANOL PRODUCTION

Nowadays fossil fuel depletion has become the worst crisis in the world, Bioethanol can be used as a substitution for fossil fuels. In here will investigate ethanol production from sugar-containing juices obtained from sugarcane (in Sri Lankan case use sugar cane to produce ethanol) that are the most attractive choice because of their cost-effectiveness and feasibility to use. There are three types of fermentation processessuch as batch, fed-batch, and continuous are usedto produce ethanol from the sugary juices. The

most common microorganism used in fermentationis the yeast (*Saccharomyces cerevisiae)* though the bacterial species *Zymomonasmobilis* is also used nowadays. Several factors related to the fermentation greatly influences the process and their optimization is the key point for efficient ethanol production from these feedstocks [12].

5.1 Impact of Different Factors on Fermentation Ethanol Production

Several factors affect the production of ethanol such as temperature, pH, fermentation time, agitation rate and initial sugar concentration. These factors are discussed in detail in this paper.

5.1.1 Temperature

Temperature is an important factor in the process and ethanol production.For their better growth of Microorganisms used in the fermentation process have an optimum temperature range. Therefore,to have a proper microbial growth and higher yield of ethanol, it is necessary to predetermine an optimum temperature during fermentation. Fermentation temperature range is between 20 and 35°C and high temperature in almost all fermentation processes creates problems[13].

5.1.2 pH

Controlling pHethanol production can be enhanced through fermentation. In general, H+ concentrations in fermentation broth can change the total charge of the plasma membrane affecting the permeability of some essential nutrients into the cells. The optimum pH range for S. cerevisiae used in fermentation for ethanol production is 4.0–5.0. Optimal pH values should be investigated and use to enhance productivity[13].

5.1.3 Fermentation Time

Inefficient fermentation causes a shorter time in fermentation because ofthe inadequate growth of microorganisms. While higher fermentation time causestoxic effects on microbial growth.Therefore, it is very important to manage the time to have a better yield in ethanol[13].

5.1.4 Agitation Rate

Agitation is a very important factor to increasethe yield of ethanol during fermentation by. Agitation also increasessugar consumption and reduces the inhibition of ethanol on cells. It is reported that the useful agitation rate is 150–200 rpm for yeast cells in fermentation. But excess agitation rate is not suitable for smooth ethanol production[13].

5.1.5. Sugar Concentration

Initial sugar concentration is an important fact to have a good yield of ethanol. as it has a direct effect on fermentation rate and microbial cells. Increasing sugar concentration to some level, fermentation rate will be increased.In batch fermentation, increased ethanol productivity and yield can be obtained at higher initial sugar concentration, but it takes longer fermentation time and hence increases the recovery cost. Considering these facts, the optimum sugar concentration should be used to carry out the process [13].

Producing ethanol from free fermentable sugars is more economic than starch feedstocks as the former can directly be used in fermentation without any prior treatment. However, better yield also depends on the selection of microorganisms and fermentation mode and techniques and the factors that are affected by the process. Optimizing the process of ethanol production contribute to the economic aspect directly because of its uses.

6 ENVIRONMETAL POLLUTION

Cultivation and processing of sugar affected the environment in a bad manner in this such cases, loss of natural habitats, excessive use of water, excessive use of agrochemicals, disposal of polluted wastewater and air pollution. This directly affects to degradation of wildlife, soil, air and water in sugar-producing and downstream ecosystems [14].

6.1 environmental impacts through the loss of natural habitats

Because of the technology improvement, large machinery and agrochemicals help farmers to grow large areas. This cause the removal of more land for farming. Rainforests, grasslands, and wetlands are being devastated for crops such as sugar cane and sugar beet [14].

6.2 Intensive use of water

Sugarcane is a thirsty crop with low water requirements, similar to rice and cotton, it takes normally 390 gallons of water to produce 1 kilogram (2.2 pounds) of sugar from sugarcane; Sugar beet needs 243 gallons of water. Hence to sugarcane and sugar beet plantations threatens the water supply for the people living below [14].

6.3 Heavy use of agrochemicals, discharge, and runoff of polluted effluent and air pollution

Nutrients from erosional soils and applied fertilizers often interfere with water supply. Sugarcane processing also harms important environmental areas. Water quality has led to a slowdown in some areas, and as a result, production has intensified into sandy soils. Since such soils are easily leaked, production can only be sustained over time [14].

Sugar mills produce wastewater, emission, and waste products that affect the environment. Large amounts of plant material and silt washed out of the mills, decaying freshwater, absorbing the available oxygen and leading to massive fish slaughter. In addition, milling emits pipe gases, soap, ash, ammonia, and other substances. Ready to plant cane, remove any protective cover and allow the soil to dry. This affects the overall microbial diversity and mass. In addition, exposed surface soils can be easily washed away from the slope and nutrients are leached from the surface soil. Removing sugarcane from the fields will gradually reduce fertility and force growers to rely on fertilizer [14].

6.4 Solution

This includes changes in national and international policies, investment in appropriate irrigation infrastructure, in fact, measures to mitigate environmental impacts often bring economic benefits to farmers and mills. The long-term development of the sugar industry provides an opportunity to reconcile environmental and social needs [14].

7 CONCLUSION

In this article discussed the production process of sugar industry and its economic support to Sri Lankan society. The main unit operations of the sugar industry, ethanol production, waste recycling and reusing, power generation are considered. The energy optimization, process optimization, waste minimizations steps has to be further discussed.

REFERENCE

[1]NPCS, Processing of Sugarcane and By-Products of Molasses,https://www.entrepreneurindia.co/Document/Download/pdfanddoc-124045-.pdf[Accessed date 12/26/2019]

[2]Practical Action, Sugar Production from Sugar Cane,https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/4f7cd73d-af10-4c0f-a3fe-64851661b3dc.pdf[Accessed date 12/26/2019]

[3]GunawanGunawan, Tajuddin Bantacut. PRODUCTION AND PRODUCTIVITY IMPROVEMENT THROUGH EFFICIENCY SUGAR MILL

[4]http://lankasugar.lk/sevenagala/index.php/products, [Accessed date 12/26/2019]

[5]CHAPTER 4 SUGARCANE – ITS BYPRODUCTS AND CO-PRODUCTS, OPPORTUNITIES FOR DIVERSIFICATION: AN OVERVIEW, https://shodhganga.inflibnet.ac.in/bitstream/10603/192958/5/chapter_-_4%20sugarcane%20an%20overview.pdf, [Accessed date 12/26/2019]

[6]https://en.wikipedia.org/wiki/Sri_Lanka, [Accessed date 12/26/2019]

[7]http://www.lankasugar.lk/index.php/sugar-introduction/sugarcane-industry, [Accessed date 12/26/2019]

[8]ByEyerusalemBirru, Supervisors: Andrew Martin (Professor), Catharina Erlich (Asst. professor). Sugar Cane Industry Overview and Energy Efficiency Considerations.

[9] Rachid CTCC, Santos AL, Piccolo MC, Balieiro FC, Coutinho HLC, et al. (2013) Effect of Sugarcane Burning or Green Harvest Methods on the Brazilian Cerrado Soil Bacterial Community Structure. PLoS ONE 8(3): e59342. doi:10.1371/journal.pone.0059342.

[10]Thermal Power Station. https://www.ikbooks.com/home/samplechapter?filename=303_Sample-Chapter.pdf

[11]https://www.theengineerspost.com/boiler-draught/.[Accessed date 12/26/2019]

[12]HossainZabed, Golam Faruq, Jaya Narayan Sahu, Mohd Sofian Azirun, Rosli Hashim, and AmruNasrulhaq Boyce.**Bioethanol Production from Fermentable Sugar Juice**

[13]AsmamawTesfaw and Fassil Assefa. **Current Trends in Bioethanol Production by Saccharomycescerevisiae: Substrate, Inhibitor Reduction, Growth Variables, Coculture, and Immobilization**

[14]Sugar and the environment, https://wwf.panda.org/?22255/Sugar-and-the-Environment-Encouraging-Better-Management-Practices-in-Sugar-Production-and-Processing