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Use of solar energy to improve the performance of a jaggery manufacturing unit

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ABSTRACT

Jaggery is a, boiled sugar cane juice used as a sweetener. Because the combustion process in the jaggery industry has an energy-intensive nature, previous literature studies have introduced various changes in processes and equipment to affect its energy efficiency. This study helps to comprehend commodity alterations and utilization in jaggery by proffering an exergy analysis. The baseline process has been modified operationally to calculate the efficiency of exergies and exergy destruction. By the amendments have respectively enhanced thermal performance and exergy efficiency by 11.2 percent and 0.8 percent. Extensive exergies were expended as excessive energy as flue gas which, due to change requests, was reduced by 11.5 percent. The data indicate that while environmental flue gas was the most apparent type of gas, exergy destruction by irreversible combustion factors caused the largest type of resource use. The study in this report increases the efficiency of energy use as well as setbacks through exergy analytical form.

Keywords: *Jaggery, sugar, bagasse, energy, temperature.*

1. INTRODUCTION

Jaggery is unrefined natural sugar that is consumed in Asia, Africa, the Caribbean and Latin America, respectively. Its production is an important part of the Indian sub-agriculture continent's industry, which is prevalent mostly in the rural population, 65% of the total. Some 30% of the sugar cane produced in India is made from jaggery and non-refined sugar. Rao et al. (2007) also confirmed 24.5 percent of cane manufactured in India in 2007 used by the jaggery sector. An accessible pot furnace is used to focus rod juice as mandated in a conventional Jaggery method. It is an intensive energy process that has brought researchers to understand and explore strategies for minimizing the use of energy in the energy and mass transformation process. For example, in the Anwar (2010), for the purposes of improving energy efficiency, the company applied the concept of fines to the open pan jaggery (31.34 percent)

2. LITERATURE REVIEW

To reduce excess air and thus improve energy efficiency, air inlet dampers were used. Sardeshpande et al. (2010) altered the energy consumption rate to improve energy efficiency in yet another study done. A test to establish the advection thermal conductivity in Boiling Canes Sage was carried out by Tiwari et al. (2004). La Madrid et al. (2016) conducted a study showing the use of CFDs to design energy efficient jiggering machines with high energy efficiency. A follow-up study by La Madrid et al. (2017) found that a heat exchanger for fire tubes would achieve better thermal performance than traditional flat tubes by means of CFD analysis. It should be noted that all the above studies are based on an energy analysis. The restriction of this approach is that the analyst cannot consider energy Quality and not be able to identify irreversible locations throughout the process. In this paper, the main contribution is to provide a better view of the losses in the process of resource transformations through exergy testing. The study also complements the scarce range of literature to make the Jaggery process more resource efficient.

This paper is based on an experimental study carried out by Sardeshpande et al. (2010), in which the energy efficiency is evaluated and improved through operational process changes in a four-pole furnace system. The fuel feed rates of the four-piece oven system were essentially altered to improve the energy performance. This paper offers an exergy analysis of the same process to better understand the resource and consumption transformations during the procedure. ll baseline flows and modified scenario shall be exergy modelled, and the exergy efficiency and destruction calculations shall be carried out. The result generated by an exergy analysis is directly impacted by exergy not only the structure but also the ecosystem, and subsequently a comparison ecosystem. The chemical composition of every reference environment model is defined, and the derived exergy values are necessarily linked to this model. The generally recognized and used comparison ecosystem for this study is used by Szargut et al. (2005). CIRCE (2008), unless otherwise specified, shall extract the chemical exergy values of elements and compounds derived from the selected ecosystem for comparison.

Resource use analysis is not divided into categories of mass or energy, both of which are demonstrated in common physical units. This is useful when comparing various improvements in production process energy, materials, and water efficiency. Furthermore, both its mass and its energy is preserved when resource transformations occur, even when its useful potential is lost, making resource consumption difficult to account for in energy analysis.

In turn, the transformations in resource are accompanied by exergy consumption linked to irreversibility in real processes, known as destruction of exergies. This makes exergy especially useful when a system aims to consider the consumption of natural resources. For those reasons, exergy analysis was regarded as an appropriate method in environmental science for resource accounting.

Jaggery normally produced in open terrestrial griddle furnaces was used as sweetener in many places in India from earlier civilizations. The raw materials used to prepare jaggery are sugar cane juice and bagasse extracted after sugar cane crushing. Out of the total sugar cane produced in India each year, approximately 2/3 are used for sugar production, 1/5 is for jaggery production and the remainder is for trade purposes. The jaggery preparation is regarded as a small-scale industry, creating jobs for many rural India trainers. 65-85% of sucrose, 10-15% of sugar reduction, 3-10% of moisture and insoluble matter are the remainder.

The preparation of jaggery with an open earth pan furnace requires mechanical and thermal energies. Mechanical power is necessary to generate the jaggery in the oven to obliterate the sugar cane and the heat is needed to heat the sugar cane juice. Bagasse as well as sugar cane syrup is generated as a by-product of sugar cane fissures. At the beginning, the humidity of bagasse is approximately 40-50 percent. The humidity level can be decreased to 8–10 per cent by drying the bagasse on a flat plate and then dry bagasse used in the open kiln to produce heat via incineration.

It was found that about 45 per cent of the total energy produced by combustion was used to produce jaggery, and the rest was lost by flue gasses, ash, and furnace walls. Sugarcane juice is three different phases used for preparing jaggery in the open earth pan. The first process phase is started with delivery of sensitive heat to raise the temperature of the sugar cane juice from the ambient to its boiling point (approximately 6% of the total energy generated during the combustion procedure). In the sugar cane juicing the required pH shall be added measured amounts of additives such as lady finger, phosphoric acid and calcium carbonate (each at approximately 30-50 g/100 kg of sugar cane).

The second phase involves the removal of water at the saturation/boiling temperature from the sugar cane juice. The amount of heat supplied during this phase is considered latent in the vaporization required to convert water into a steam (about 39 percent of the total energy produced by a combustion process). At this time, floating residues called molasses is formed (approximately 3-5,000 kg of sugar cane juice) and must be removed from the open surface. The sugarcane juice is rich in concentrates at the end of the second phase when water is removed entirely.

3. MATHEMATICAL MODELLING

The heat supplied (about 0.1% of total energy produced) is used during a last phase of jaggery preparation to increase the temperature of the sugar cane juice from its boiling point to its striking point. The highlight is the temperature at which sugar cane juice is transformed into a semi-solid paste that slides onto the surface of the pan rather than sticking to the pot. At this stage, the semi-solid sugar cane juice is removed and cooled down to room temperature, so that the jaggery can be prepared. This is represented in the figure below.

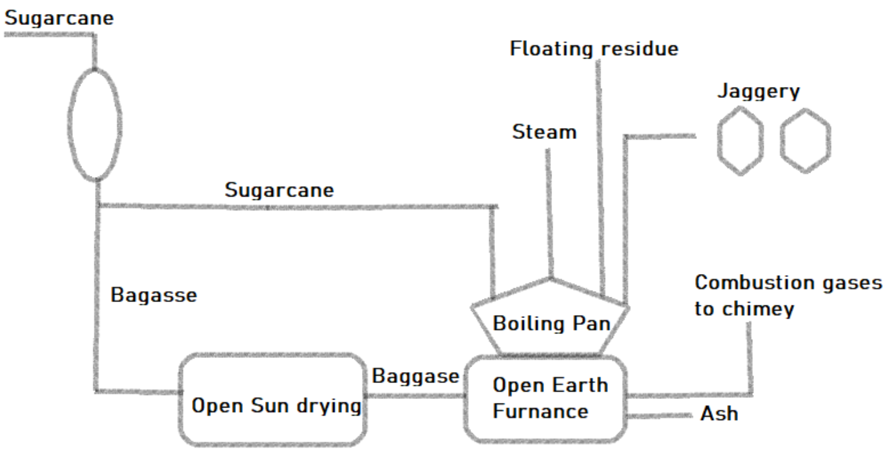

Figure 1: Sugarcane Industry Model

Solar drier can be used to pre-heat the furnace's air and remove the bagasse moisture content that improves the combustion efficiency. Equation (1) applies to the mass preservation of the inputs and outputs of Jaggery to write mass balance unit of preparedness:

$$(\dot{m}_{in} - \dot{m}_{out}) + \dot{m}_{gen} = \partial m/\partial t$$

For a continuous conduction mode, Equation 1 cannot be altered in such a way as:

$$(\dot{m}\ in - \dot{m}\ out) = 0$$

Into or out of the production unit, the aggregate mass flow rate is equal to equation 2. The production unit is equipped with various sugar cane juice masses, additives, dry bagasse and combustion air. The production unit produces various bulk amounts of jaggery, floating waste, vapour, flow gas and ash. The combustion line and the sugar cane to the jaggery prepping line result in mass conservation:

$$\dot{m}\ db + \dot{m}\ da = \dot{m}\ fg + \dot{m}\ ash$$

$$\dot{m}\ sj + \dot{m}\ add = \dot{m}\ jag + \dot{m}\ fr + \dot{m}\ st$$

In Equation 3m˙ db, m˙ da are the mass flow rates of dry bagasse and dry air supplied for combustion. m˙ fg and m˙ ash are the mass flow rates of flue gases and ash produced in the combustion. In Eq. (4), m˙ sj, m˙ add are the mass flow rates of sugarcane juice and additives, m˙sj mass flow rate of jaggery produced, m˙ fr mass flow rate of floating residue and m˙ st is the mass flow rate of steam produced due to evaporation of water in the sugarcane juice.

For energy efficiency, Equation 5 is used to create the balance of energy for the preparedness unit Jaggery between multiple endpoints.

$$(\dot{E}in - \dot{E}out) + \dot{E}gen = \partial E/\partial t$$

If the energy generation does not add up and the energy transmission procedure is a simple linear process, Equation 5 can be written as:

$$\dot{E}in - \dot{E}out = 0$$

In Equation 6, E˙in the energy input rate of the production plant is equal to and equal to the heat generated by the furnace burning dry bagasse:

$$\dot{E}in = \dot{m}\ db(CV)db$$

4. RESULTS AND DISCUSSION

The effect of inlet temperature on the performance of the jaggery preparation plant has been shown by analytical calculating the sugarcane juice and inlet temperature air. The plant performance was determined using the following calculations based on unit jaggery. For the analytical calculations, the following assumptions were made:

- The production of 1 kg jaggery shall take about 2.39 kg of dry bagasse.
- Around 20 per cent of the sugar cane crushed is the mass of dry bagasse produced.
- Approximately 65% of the sugarcane juice produced is broken down.
- Dry bagasse is 16 230 kJ/kg in calorific value.
- The sugarcane juice is composed of 0.5 g/kg each of its additives (calcium carbonate, phosphorous acid and okra).
- Floating residues (molasses) of sugarcane juice are generated at the rate of 10.25 g/kg.
- The combustion fuel ratio is 5.4.
- The specific flue gas heat is roughly equal to the air heat.
- The variable parameters were the inlet temperature of the sugarcane juice and the inlet temperature to the oven. Different quantities of energy per kg of production jaggery are calculated
- Variable sensible heat from the inlet temperature to hot temperature for sugar cane juice, Esj, with various inlet temperatures of sugar cane, Tisj, are shown in the figure 1 below.

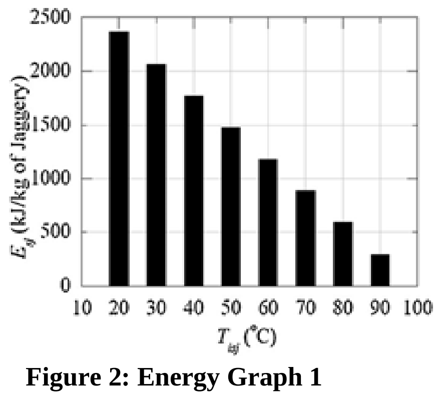

Figure 2: Energy Graph 1

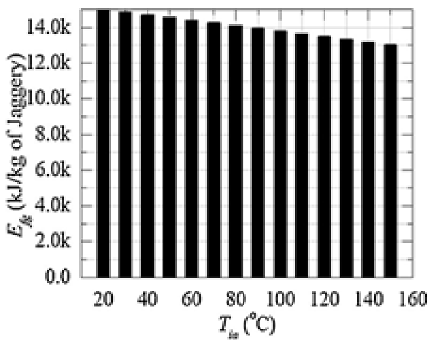

Figure 3: Energy Graph 2

The variation of sensible heat energy, Esj, saved when the inlet temperature of sugarcane juice is changed from 30 ◦C to 100 ◦C with that when the inlet temperature is 20 ◦C is shown in Figure 2. Figure 2 also shows the changes in dry bagasse saved by changing the temperature of the inlet of sugarcane from 20 to 100 C at inlet temperature. Figure 2 shows that from 0,02951 kg to 0,23604 kg/kg jaggery preparation the amount of dry bagasse can be stored. The dry bagasse can be utilized for the paper and pulp industry as an alternative fuel and raw product. Savings in the dry consumption of bagasse in prepared jaggery will contribute to farmers' revenue.

Efg for different temperatures in the air intake, Tia, are also shown on the next figure in the heat losses by flue gases. It was observed that there was a change of Efg between 14 990.08 kJ/kg jaggery and 13 001.60 kJ/kg jaggery, as the temperature of air entry to the open earth oven changed from 20 kJ/kg to 150 kJ/kg. Through fluid gasses that increase the performance of the preparation cycle, the amount of heat lost can be minimized.

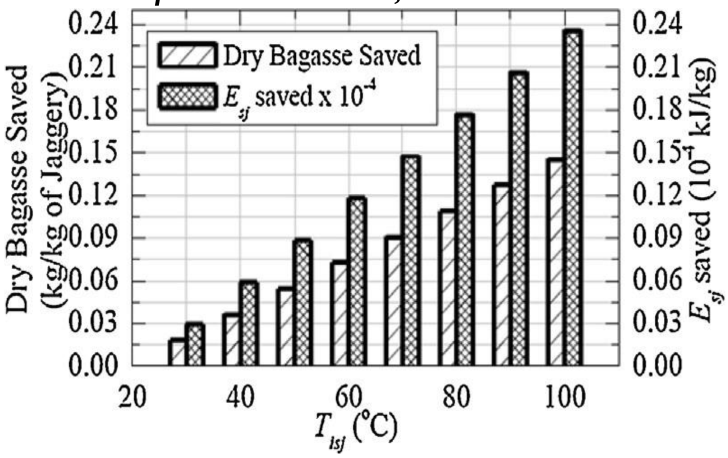

Figure 4 : Dry bagasse vs Energy saved Graph 1

The amount of Efg saved by changing the temperature of the inlet of sugarcane juices from 30 to 150 kb to 20 kb to 20 kb in the following figure. A change from 20 to C to 100 to C is shown in the figure, too, in the dry bagasse which are saved as the air inlet temperature changes. The figure shows that from 0.00942 kg to 0.12252kg/kg of preparation for jaggery is the amount of dry bagasse that can be saved.

The pre-heating level either of the sugar cane juice or of inlet air depends on the solar collector's performance or solar dryer. If the sugar cane juice is pre-heated near to boiling point, the highest percent gain in dry bagasse is secured. Similarly, if the inlet air temperature is over 120 °C, the gain from saved dry bagasse is higher.

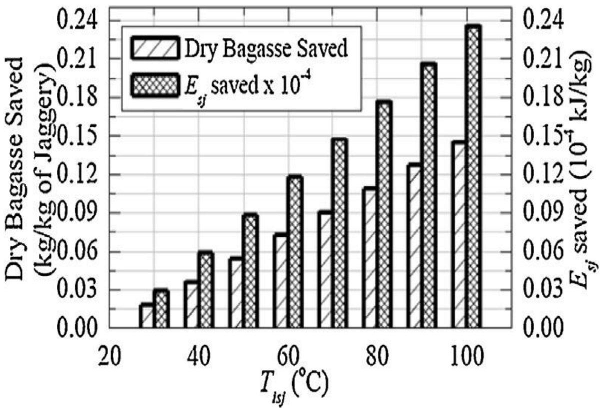

Figure 4 : Dry bagasse vs Energy saved Graph 2

5. CONCLUSION

Dry bagasse is used as the raw material for combustion in the conventional process of jaggery preparation. Approximately 45% of the combustion energy is used effectively for jaggery preparation; the rest of the energy is lost to flue gas, ash and walls. A great deal of energy is needed for removing water from the sugarcane juice around 39.22 percent. Roughly 6.08% are used as sensitive heat, increasing the sugar cane juice temperature from the initial to boiling value, and 0.1% is used to increase its boiling temperature to a significantly higher level. Approximately 2360,44 kJ of heat energy and 0,23604 kilograms of dry bagasse were found when the sugarcane juice was preheated by its boiling temperature.

6. REFERENCES

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