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Performance Evaluation of IISR Three Pan Furnace for Jaggery Making

Suraj Kumar, S. Patel, Dilip Kumar, Priyanka Singh

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ABSTRACT

The production of jaggery is one of the most traditional processes generally produces in cottage industries. Sugarcane juice is used for the preparation of jaggery. There are many types of furnaces used for the jaggery preparation such as single, double, triple, and four pan furnaces. The improved three pan furnace has been developed at ICAR-Indian Institute of sugarcane research, Lucknow to reduce the excessive consumption of time and bagasse for jaggery preparation along with quality production of jaggery. The performance of the IISR three pan furnace was evaluated through jaggery preparation and various parameter such as consumption of bagasse per kg jaggery production, the consumption of time per batch jaggery preparation and thermal efficiency was estimated as 2.42 kg, 1.81 kg/ kg, 2h 22 minutes, 28.82 % respectively.

Keywords Jaggery, Bagasse, Furnace, Sugarcane.

Suraj Kumar, Dr S. Patel[2]*,
[2]Professor, Department of Agricultural Processing and Food Engineering, SV CAET & RS, FAE, IGKV, Raipur 492012, (CG), India

Dr Dilip Kumar[3]
[3]Principal Scientist, Jaggery Unit, Division of Agricultural Engineering, ICAR-Indian Institute of Sugarcane Research, Lucknow 226002, UP, India

Dr Priyanka Singh[4]
Research Associate, Jaggery Unit, Division of Agricultural Engineering, ICAR-Indian Institute of Sugarcane Research, Lucknow 226002, UP, India
Email : patel347@rediffmail.com.
*Corresponding author

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is a major cash crop in India belonging to the family *Gramineae.* It is usually used to produce sweeteners like sugar, jaggery (*gur*), and *Khandsari.* After Brazil, India is the second largest producer of sugarcane in the world. In India namely, Uttar Pradesh and Maharashtra is the two largest sugar producing states. The yield of sugarcane in the financial year 2019 was estimated approximately 78 thousand kilograms per hectare across India (Statista 2020). The jaggery is a traditional, unrefined, natural sugar that is produced by evaporating water from sugarcane juice in steel or iron pans placed over pit furnaces. It is a concentrated product of cane juice with the molasses. Usually three form of jaggery practices in the market such as solid jaggery, liquid jaggery and granular jaggery.

Solid jaggery is prepared by the concentrating the sugarcane juice. Solid jaggery contains sucrose (65-85 mg per 100 g) and inverts sugars (3-15 mg per 100 g). It also contains important minerals viz., Iron (10-13 mg per 100 g), calcium (40-100 mg per 100 g), magnesium (70-90 mg per 100 g), potassium (10-

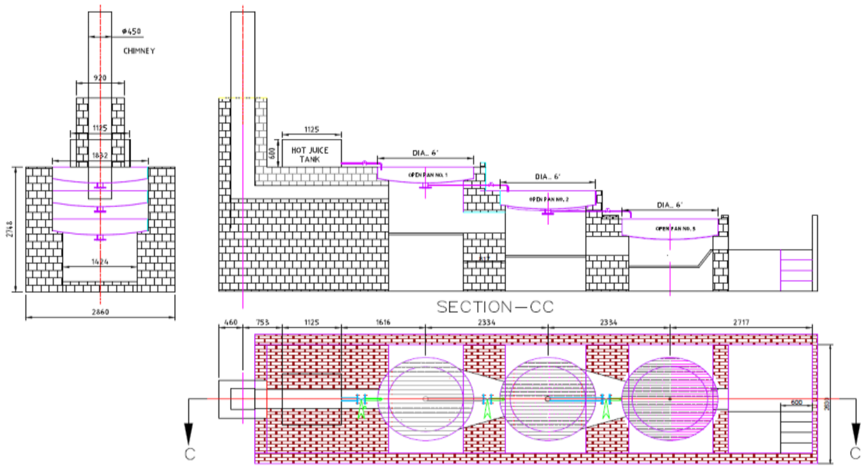

Fig. 1. Construction details of the IISR three pan furnace.

56 mg per 100 g). The production process of jaggery performed on the furnace. There are many types of furnace designs available in India. Generally in Uttar Pradesh and Uttarakhand, three pan jaggery furnace popular, however in Maharashtra single pan and four pans furnace are popular. The main part of construction of jaggery furnace involves combustion chamber, fuel feeding hole, chimney, and ash chamber (Fig. 1).

MATERIALS AND METHODS

Constructional details of the furnace

Primary pan (Boiling pan)

Primary pan is also known as boiling pan where cane juice was heated upto a striking point and jaggery was prepared. The primary pan was made of mild steel (IS2062). It was only pan which was placed above the combustion chamber at 1219.2 mm height from the bottom of the ground. The outer and inner diameter of the boiling pan was 1828.8 mm, 1737.3 mm respectively. The depth of the pan was 277.3 mm along with a concave bottom. The primary was considered as the third and main pan where the juice concentration was takes place.

Secondary pans

Secondary pan involves two pans which were place adjacent by one another. The outer and inner diameter of the secondary pan was 1828.8 mm, 1737.3 mm respectively. The depth of both the secondary pans was pan 277.3 mm along with concave bottom. In the secondary pans the juice was heated by utilizing the waste heat of the flue gas that escapes through the chimney.

Chimney

It was built of masonry structure with 3657.6 mm height from the ground surface level. The wall thickness of the chimney was 63.5 mm. The internal opening of the chimney was square in shape and dimension was 330×330 mm^2 Chimney was made to allow exit of flue gases from combustion chamber of the furnace.

Flue gas passage

An arrangement was made to escape the hot exhaust gases below the ground surface. Passage was made with fire bricks in square shape and connected from the combustion chamber to chimney. This passage was square in shape having 300 × 300 mm^2 cross-sectional area. The length of this passage was 4267.2 mm.

Step grate

It was an iron rod which was mounted 914.4 mm height. The number of iron rod was fitted with parallel arrangement for making the platform for burning of bagasse into the combustion chamber. The bagasse was fed to the step grate into the combustion chamber and the burning of bagasse take place. The ash pit was available below the step grate to collect the ash after burning the bagasse.

Combustion chamber

A deep chamber was made with masonry structure below the ground surface for combustion of bagasse. The diameter and height of the combustion chamber was 1219.2 mm, 1828.8 mm respectively. The boiling pan was installed just over the combustion chamber. An additional man hole from the ground surface was made just beside the chamber to remove the ash from the combustion chamber. Another, purpose of this hole was to facilitate the proper air circulation for complete combustion of bagasse fed into the combustion chamber

Formula-

$$W_{jag} = W_{juice} + W_{deola\ solution} - W_{water} - M_{scum} \quad (1)$$

$$\text{Juice boiling per kg of bagasse consumed} = \frac{W_{juice}}{B} \quad (2)$$

$$\text{Water evaporation rate} = \frac{W_{water}}{T} \quad (3)$$

$$\text{Water evaporation per kg of bagasse consumed} = \frac{W_{water}}{B} \quad (4)$$

$$\text{Bagasse consumption (kg/min)} = \frac{B}{T} \quad (5)$$

$$\text{Bagasse consumed per kg of Jaggery (kg /kg jaggery)} = \frac{B}{W_{jag}} \quad (6)$$

$$\text{Jaggery production rate} = \frac{W_{jag}}{T} \quad (7)$$

The overall energy input energy per batch $(Q_{Input}) = W_{bagasse} \times C_{bagasse}$ (8)

Energy required for heating the juice $(Q_{juice}) = W_{juice} \times C_{pjuice} \times (T_{juice} - T_{initial})$ (9)

Total energy for vaporization of water

$$(Q_{water}) = W_{water} \times h$$

The energy required for jaggery production $(Q_{jag}) = W_{jag} \times C_{pjag} \times (T_{striking} - T_{evap.})$ (11)

Total energy required for jaggery making $(Q_{output}) = Q_{juice} + Q_{water} + Q_{jag}$ (12)

$$\text{Thermal efficiency} = \frac{Q_{output}}{Q_{input}} \times 100 \quad (13)$$

$$\text{Jaggery production efficiency} = \frac{Wjag}{Wjuice} \times 100 \quad (14)$$

Where,

W_{juice} = Weight of juice (kg), W_{jag} =Weight of jaggery produced per batch (kg),$W_{deola\ solution}$ = Weight of deola solution (kg), W_{scum} = Weight of scum removed per batch (kg), W_{water} = Weight of water evaporated during boiling (kg), B = Weight of bagasse consumed (kg), T = Time required for jaggery preparation(min), Q_{output} = Total energy required for jaggery making (MJ), Q_{input} = Heat energy input per batch (MJ), $\eta_{thermal}$ = Thermal efficiency (%), $C_{bagasse}$ = Calorific value of bagasse (kJ/kg), C_{pjuice} = Specific heat of juice (kJ/kg K), C_{pjag} = Specific heat of jaggery(kJ/kg K). $T_{initial}$ = The initial temperature of the juice (^{0}C), T_{final} = Final temperature of juice (^{0}C), $T_{striking}$= Striking temperature of jaggery (^{0}C), T = Total time required for jaggery making (min), Q_{juice} = Energy required for heating the juice (MJ), h= latent heat of vaporization, kJ/kg. T_{evap}. =The temperature of evaporation of water (^{0}C).

RESULTS AND DISCUSSION

During the jaggery preparation process (Fig. 2) the temperature variation of the furnace was periodically recorded (Fig. 3) till the attainment of striking point of cane juice. Prior the boiling of the cane juice the initial climatic parameters as well as juice temperature and TSS was recorded. As per the observation the initial test parameter such as ambient temperature, relative humidity, initial juice temperature, total soluble solid (TSS) were recorded as 26^{0}C, 60.50%, 22^{0}C, 20 °Brix respectively. Further the first boiling was started and the temperature was recorded after each 15 minute

Fig. 2. Jaggery preparation process.

interval. From the temperature observation it was noticed that the temperature of cane juice was increased continuously. The concentration process of juice was continues till the attainment of the striking point i.e. 117± 1^0C of the juice. The time required to reach the striking point temperature was found as 70 minutes for the first boiling operation during the preparation of solid jaggery. At the same time the temperature of the juice in the secondary pan 1and 2 was 80^0C and 95^0C respectively. The reason behind the temperature enhancement of second and third boiling pan might be due to flue gas escaping through the inner passage flowing towards the furnace chimney. The waste heat was used by the heating of secondary pans. This was the benefit of the three pan furnace.

Again the second boiling operation was started by transferring the juice from second pan to boiling pan and first pan to second pan. The total time required to reach the striking temperature of the juice during the second boiling operation was recorded as 42 minutes. Further the third boiling operation was started by the transferring the sugarcane juice from the second pan to the boiling pan.

The total time taken during the third boiling operation was noted as 30 minutes to attain the striking point temperature for solid jaggery preparation. Thus three boiling operation was performed continuously in one batch and total time recorded was 2h 50 minutes for solid jaggery preparation. The water evaporation per minute and per kg bagasse consumption of the furnace was calculated as 2.94 kg and 1.81 kg respectively. The bagasse consumption with respect to time and jaggery production was calculated as 1.61 kg/min, 2.42 kg/kg jaggery respectively. Thus, 2.42 kg bagasse wrequired for 1 kg jaggery production. The thermal efficiency and jaggery production efficiency was estimated as 28.82%, 15.83% respectively.

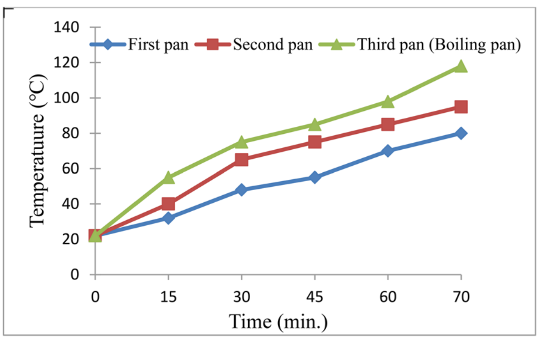

Fig. 3. Temperature profile of pans during furnace operation.

Overall performance of the IISR three pan furnace

Total consumption of bagasse =230 kg
Total jaggery production per batch= 95 kg
Requirement of bagasse per kg jaggery production = 2.42 kg/kg jaggery

Water evaporation rate per kg of bagasse consumed, kg/kg = 11.8
Water evaporation rate, kg /min =2.94
Juice boiling rate, kg/min = 4.22
Bagasse consumption rate, kg /min=1.61
Jaggery production efficiency % =15.83
Energy require to evaporate one kg of water, MJ/kg =2.27
Overall thermal efficiency % = 28.82

CONCLUSION

IISR three pans was a well-designed furnace. The water evaporation rate of the furnace was good along with less consumption of bagasse and time for jaggery preparation. The furnace will be helpful to boost the income of farmers and jaggery industries also through jaggery production.

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