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## Quality evaluation of a jaggery prepared from developed three pan jaggery making furnace

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**Abstract**

Sugarcane (*Saccharum officinarum* L.) is an oldest crop known to man, India contributing 18% of total world production of sugarcane. A three pan jaggery making furnace was developed with low carbon content food grade steel. The effect of two independent variables viz., Striking temperature 118 °C and 120 °C (2 levels) and Depth of juice 25%, 50% and 75% (3 levels) were studied on the quality parameters of the jaggery like total sugars (%), reducing sugars (%), non-reducing sugars (%) and colour transmittance (%) and sensory analysis was conducted for prepared jaggery samples. The treatment with 120 °C striking temperature and 50% depth of juice was found to be best among all the treatments.

**Keywords:** Sugarcane, sugarcane juice, jaggery, jaggery making furnace

**Introduction**

Sugarcane (*Saccharum officinarum* L.) is an oldest crop known to man and a major crop of tropical and sub-tropical regions worldwide. India is the second largest country in sugarcane production in the world after Brazil, contributing 18% of total world production of sugarcane. Among the total production of sugarcane 80-90% is used for the manufacturing of white sugar, jaggery (gur), and khandsari (unrefined sugar). In India, jaggery and khandsari is one of the major food industries. India has recognized as one of the leading traders and exporters of Jaggery to the world. There are mainly three types of jaggery available on the market, namely solid jaggery, liquid jaggery, and granular jaggery. Around 80% of the jaggery prepared in India is solid jaggery (in the form of solid structure) and the remaining 20% comprises liquid and granular jaggery (Singh, 1999)<sup>[21]</sup>.

It is used in pharmaceutical formulations as well. Granular jaggery is also common in rural regions, especially. Due to its low cost and high nutritional value, the significance of jaggery is increased. Jaggery is a wholesome diet compared to khandsari. Daily use of jaggery may increase human lifespan (Kumar, 1999)<sup>[8]</sup>. The jaggery is rich in nutrients, protein and vitamins naturally present in sugarcane juice, and making it one of the world's most nutritious and healthy sugars. It has the reputation of being a medicinal sugar and is prescribed for health problems such as dry cough, sputum cough, indigestion, constipation, etc. as ayurvedic medicine. The micronutrients in jaggery have antitoxic and anticarcinogenic properties. Its dietary intake can avoid the toxicity associated with air pollution and the risk of lung cancer (Rao *et al.*, 2007)<sup>[17]</sup>.

Traditionally, the boiling pan is composed of mild steel (MS). The carbon content of MS is very large which needs to be replaced by low carbon content food grade steel like SS304. Therefore, a three pan jaggery making furnace was developed with low carbon content food grade steel. The present work aims to find the quality parameters of raw sugarcane juice and jaggery made from the developed furnace.

**Materials and Methods**

The investigations were carried out in the Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh (Gujarat). The sugarcane with best quality and fresh as variety Co 6304 was purchased from nearby farmer's field. Sugarcane was thoroughly cleaned and then juice was extracted by using locally available horizontal roller crusher by crushing it three times.

The juice was filtered with the help of plastic strainer and it was collected in cans. The quality evaluation of raw sugarcane juice was carried out.

The effect of two independent variables *viz.*, Striking

temperature (2 levels) and Depth of juice (3 levels) were studied and these variables coded as A and B respectively (Table 1). The levels of parameter values were carefully chosen based on the literature available.

**Table 1:** Treatment details

Treatment	Combinations	Detail
T <sub>1</sub>	A <sub>1</sub> B <sub>1</sub>	Striking temperature 118 °C + 25% pan depth
T <sub>2</sub>	A <sub>1</sub> B <sub>2</sub>	Striking temperature 118 °C + 50% pan depth
T <sub>3</sub>	A <sub>1</sub> B <sub>3</sub>	Striking temperature 118 °C + 75% pan depth
T <sub>4</sub>	A <sub>2</sub> B <sub>1</sub>	Heating temperature 120 °C + 25% pan depth
T <sub>5</sub>	A <sub>2</sub> B <sub>2</sub>	Striking temperature 120 °C + 50% pan depth
T <sub>6</sub>	A <sub>2</sub> B <sub>3</sub>	Striking temperature 120 °C + 75% pan depth

### Preparation of jaggery

The jaggery was made in the developed three pan jaggery making furnace (Plate 1). The experiment mainly consist of crushing of sugarcane juice, heating, clarification of juice, concentrating, jaggery formation, cooling and moulding. The process flow chart of experiment is given in Fig. 1.



**Plate 1:** Developed three pan jaggery making furnace

The depth of the juice was considered as the depth of juice in to the pan-1. As per the calculations the quantity of juice required for 25%, 50% and 75% depth of juice were 7.5 litre, 16 litre and 25.5 litre respectively. Calcium carbonate (CaCO<sub>3</sub>) available in laboratory was used to maintain the pH of the sugarcane juice. This is also helpful in the clarification of the sugarcane juice (Rao *et al.* 2007) [17]. Quantity of the lime solution used for 25%, 50% and 75% depth of juice were 9.3 ml, 20 ml and 31.8 ml respectively. For removing all the suspended solids, impurities and make the juice clear clarification of juice was carried out. The *Bhendi* mucilage was added to juice after it reaches to 85 °C to eliminate the presence of strong suspension in it. For the removal of the scum from sugarcane juice, the 0.2% concentration of *bhendi* powder mucilage is required (Chavan *et al.* 2007) [5]. After complete removal of scum the hot juice was dumped in to the pan-2 by opening the valve. In second pan sodium hydrosulphite (hydros) a chemical clarificant was added as a bleaching agent to improve the colour. Amount of sodium hydrosulphite used for 25%, 50% and 75% depth of juice were 0.26 g, 0.56 g and 0.89 g respectively (Jadhav *et al.* 2002) [6]. The pre heated sugarcane juice from pan-2 was poured in to pan-3. In pan-3 evaporation and agitation of the

juice of the juice was takes place and juice became concentrated. The sugarcane juice was boiled up to the striking temperatures of 118 °C and 120 °C. After juice reached to striking temperature it's become the concentrated thick jaggery liquid which is removed from the pan-3 and collected in metal container. After that thick liquid was cooled down to room temperature until the jaggery was formed. The prepared jaggery was transferred to the plastic container and stored until the biochemical analysis takes place.

### Measurement of quality parameters

The moisture content of sugarcane juice was estimated according to method of AOAC (1984) [2]. The density of sugarcane juice was estimated according to method suggested by Ranganna (1986) [15]. The apparent viscosity of juice was determined by glass Oswald viscometer at room temperature (Ranganna, 1986) [15]. The viscosity analysis was carried out using clean and dry viscometer. The moisture content of jaggery was determined by standard hot air oven method reported by AOAC (1975) [1]. The 20 g sample was dried in a hot air oven by applying a few drops of ethanol to the sample at temperatures of 70 ± 2 °C before the samples reached Moisture Equilibrium (EMC). The method stated by the AOAC (1975) [1] was used for estimating the jaggery ash content. The biochemical parameters of sugarcane juice and jaggery were also measured. The diluted solution (1:10) of jaggery was used to determine the pH of the jaggery using the pH meter (Eutech pH700, Eutech Instruments, Mumbai). A handheld refractometer (0-28 °Brix) (Erma, Tokiyo, Japan) was used to measure the total soluble solids (TSS) in degree Brix of sugarcane juice. Titratable acidity of sugarcane juice and jaggery was estimated as reported by Ranganna (2000) [16]. The total sugar in sugarcane juice and jaggery was measured using a method of phenol sulphuric acid (Chandegara, 2005) [3]. For reducing sugar estimation of sugarcane juice and jaggery, Nelson Somogyi method suggested by Rathod and Chatrabhuji (2010) [18] was used. Sucrose of sugarcane juice and jaggery was calculated as the difference between total sugar and reducing sugar (Mandal *et al.* 2006) [11]. Colour transmittance of the jaggery was determined by as per the method given by Mandal *et al.* (2006) [11]. True protein of the jaggery sample was determined by using Lowry's method (Lowry *et al.* 1951) [9]. Iron and calcium were quantify by MP-AES diacid digestion method as suggested by Rajani, (2018) [14].

Sensory characteristics of all the jaggery sample were obtained for different sensory attributes by a panel of 10 panellists. A nine-point Hedonic scale score card was provided to the panellists to judge the quality of the product with respect to appearance, texture, taste and overall acceptability.

### Statistical analysis

The statistical analysis for experiment was carried out as per the Factorial Completely Randomized Design (FCRD) with two independent variables and three replications (Panse and Sukhatme, 1985)<sup>[13]</sup>. All the treatments were compared at 5% level of significance using the critical difference test. The analysis of variance (ANOVA), standard error of mean (S.Em), critical difference (CD), coefficient of variance (CV) and mean values for dependent parameters were tabulated and the level of significance was reported.

### Results and discussion

#### Physical and biochemical properties of sugarcane juice

The physical and biochemical properties of sugarcane juice

are presented in Table 2. From the table, it can be observed that the mean values of physical properties viz., moisture content (%), density (gm/cm<sup>3</sup>) and viscosity (cP) of sugarcane juice with their standard deviation was observed to be  $82.26 \pm 0.16$  (%),  $1.06 \pm 0.03$  (gm/cm<sup>3</sup>) and  $3.08 \pm 0.06$  (cP), respectively. Biochemical properties viz., TSS ( $^{\circ}$ Brix), pH, titratable acidity (%), total sugars (%), reducing sugars (%) and Non-reducing sugars (%) of sugarcane juice with their standard deviation is observed to be  $18.97 \pm 0.21$  ( $^{\circ}$ Brix),  $5.47 \pm 0.06$ ,  $0.32 \pm 0.02$  (%),  $15.57 \pm 0.51$  (%),  $0.66 \pm 0.05$  (%) and  $14.91 \pm 0.47$  (%), respectively. Similar results were also reported by Mathur (1986)<sup>[12]</sup> Chauhan *et al.* (2007)<sup>[4]</sup> and Sankhla *et al.* (2012)<sup>[20]</sup>.

**Table 2:** Mean values of physical and biochemical properties of sugarcane juice

Parameter	Value
Moisture content (% , wb)	$82.26 \pm 0.16$
Density (gm/cm <sup>3</sup> )	$1.06 \pm 0.03$
Viscosity (cP)	$3.08 \pm 0.06$
TSS ( $^{\circ}$ Brix)	$18.97 \pm 0.21$
pH	$5.47 \pm 0.06$
Titratable acidity (%)	$0.32 \pm 0.02$
Total sugars (%)	$15.57 \pm 0.51$
Reducing sugars (%)	$0.66 \pm 0.05$
Non-reducing sugars (%)	$14.91 \pm 0.47$

#### Effect of process parameters on biochemical properties of jaggery

##### Effect of striking temperature on biochemical parameters of jaggery

The effect of striking temperature on different biochemical parameters such as total sugars, reducing sugars, non-reducing sugars and colour transmittance is given in Table 3. It can be seen from the table that, the total sugars, reducing sugars, and non-reducing sugars increased with the increase of striking temperature, where as other colour transmittance

decreased with increase of striking temperature. Maximum amount of total sugars (87.42%) was found for the striking temperature 120  $^{\circ}$ C as compared to 118  $^{\circ}$ C. This might be due to more water evaporated with increase in temperature. Similar results were also reported by (Madhava *et al.* 2015)<sup>[10]</sup>. The reducing sugars was found higher (10.85%) for the striking temperature 120  $^{\circ}$ C as compared to 118  $^{\circ}$ C. It might be due to acid inversion with increase of juice temperature. These results were in agreement with (Wandre and Bhanavase 1994)<sup>[22]</sup>.

**Table 3:** Effect of striking temperature on biochemical parameters for jaggery making process in developed three pan furnace

Treatments	Dependent Variables			
	Striking temperature ( $^{\circ}$ C)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
(1)	(2)	(3)	(4)	(5)
118 $^{\circ}$ C	87.13	10.65	76.47	52.01
120 $^{\circ}$ C	87.42	10.85	76.56	49.47
S. Em $\pm$	0.43	0.14	0.46	0.26
CD at 5%	NS	NS	NS	0.80

Higher non-reducing sugars (76.56%) was found for the striking temperature 120  $^{\circ}$ C as compared to 118  $^{\circ}$ C. Striking temperature 118  $^{\circ}$ C resulted higher colour transmittance of prepared jaggery (52.01%) from sugarcane juice as compared to jaggery prepared at striking temperature 120  $^{\circ}$ C (49.47%). It might be due to higher temperature which caused caramelization of the jaggery. The effect of striking temperature on total sugars, reducing sugars and non-reducing sugars were found non-significant whereas the effect of striking temperature on colour transmittance was found significant.

##### Effect of depth of juice on biochemical parameters of jaggery

The effect of depth of juice on biochemical parameters for

jaggery making in developed three pan jaggery making furnace viz., total sugars, reducing sugars, non-reducing sugars and colour transmittance is given in Table 4. The maximum value of total sugars, reducing sugars and non-reducing sugars (87.84, 11.22 and 76.62%) is found for the 75% depth of juice and minimum value (86.69, 10.28 and 76.40%) was found for the 25% depth of juice. From the data it can be concluded that as the depth of juice increases the value of total sugars, reducing sugars and non-reducing sugars are also increases. The highest colour transmittance (55.31%) is found for the 25% depth of juice and lowest (46.81%) is found for the 75% depth of juice. From the data it is clear that the effect of depth of juice on total sugars and non-reducing sugars was found non-significant whereas for reducing sugars and colour transmittance was found significant.

**Table 4:** Effect of depth of juice on biochemical parameters for jaggery making process in developed three pan furnace

Treatments	Dependent Variables			
	Depth of juice (%)	Total sugars (%)	Reducing sugars (%)	Non- reducing sugars (%)
(1)	(2)	(3)	(4)	(5)
25%	86.69	10.28	76.40	55.31
50%	87.29	10.76	76.53	50.12
75%	87.84	11.22	76.62	46.81
S. Em±	0.53	0.17	0.57	0.32
CD at 5%	NS	0.54	NS	0.98

### Combine effect of depth of juice and striking temperature on biochemical parameters of jaggery

Combine effect of striking temperature and depth of juice on biochemical parameters for jaggery making in developed three pan furnace such as total sugars, reducing sugars, non-reducing sugars and colour transmittance were recorded and presented in Table 5. The statistical analysis shows the combine effect of striking temperature and depth of juice on total sugars, reducing sugars, non-reducing sugars and colour transmittance found non-significant.

Treatment combination A<sub>2</sub>B<sub>3</sub> (120 °C and 75%) was found highest value of total sugars (87.91%). Treatment combination A<sub>1</sub>B<sub>1</sub> (118° C and 25%) was found lowest value

of total sugars (86.46%). The data is graphically depicted in Fig. 2(a). From the Fig. 2(a), it is clear that total sugars increased as the striking temperature and depth of juice increased. Similar trends was observed in results were found by Khan *et al.* (2011)<sup>[7]</sup> and also by Said and Pradhan (2013)<sup>[19]</sup>. Maximum reducing sugars (11.26%) was reported for treatment combination A<sub>2</sub>B<sub>3</sub> (120° C and 75%) and minimum reducing sugars (10.11%) was reported for treatment combination A<sub>1</sub>B<sub>1</sub> (118° C and 25%). From the Fig. 2(b) it is clear that reducing sugars of prepared jaggery increased as the striking temperature and depth of juice increased. The results are in agreement with Said and Pradhan (2013)<sup>[19]</sup> and Khan *et al.* (2011)<sup>[7]</sup>.

**Table 5:** Combine effect of depth of juice and striking temperature on biochemical parameters for jaggery making

Treatments	Dependent Variables			
	Striking temperature °C, Depth of juice (%)	Total sugars (%)	Reducing sugars (%)	Non- reducing sugars (%)
(1)	(2)	(3)	(4)	(5)
118 °C, 25%	86.46	10.11	76.353	57.2
118 °C, 50%	87.16	10.68	76.482	50.9
118 °C, 75%	87.76	11.18	76.587	47.9
120 °C, 25%	86.91	10.46	76.455	53.4
120 °C, 50%	87.43	10.85	76.580	49.3
120 °C, 75%	87.91	11.26	76.658	45.7
S. Em±	0.751	0.247	0.804	0.451
CD at 5%	NS	NS	NS	NS

Treatment combination A<sub>2</sub>B<sub>3</sub> (120° C and 75%) was reported maximum non-reducing sugars (76.65%) and minimum non-reducing sugars (76.35%) was found for the treatment combination A<sub>1</sub>B<sub>1</sub> (118° C and 25%). It was clear that non-reducing sugars increased as the striking temperature and depth of juice increased (Fig.2(c)). Similar findings were given by Khan *et al.* (2011)<sup>[7]</sup>, and also by Said and Pradhan (2013)<sup>[19]</sup>. Maximum colour transmittance was found for the treatment combination A<sub>1</sub>B<sub>1</sub> (118 °C and 25%). Minimum colour transmittance was found for the treatment combination A<sub>2</sub>B<sub>3</sub> (120° C and 75%). From the Fig. 2(d), it is apparent that colour transmittance decreased as the striking temperature and depth of juice increased. The findings were matched with Khan *et al.* (2011)<sup>[7]</sup>.

The biochemical parameters decides the quality of jaggery. The results shown in table suggested that 120 °C striking temperature and 50% depth of juice had given best results as total sugars (87.43%), reducing sugars (10.85%), non-reducing sugars (76.58%) and colour transmittance (49.3%).

### Sensory evaluation for jaggery prepared in three pan furnace

The sensory evaluation *viz.*, appearance, texture, taste and overall acceptability of jaggery prepared in developed three pan jaggery making furnace was carried out by 9-point hedonic scale. The effect of striking temperature and depth of juice on sensory score of appearance, texture, taste and overall acceptability of jaggery prepared in developed three

pan jaggery making furnace are graphically shown in Fig. 3. The maximum appearance score (7.5) was observed in treatment A<sub>2</sub>B<sub>2</sub> *i.e.*, 120 °C striking temperature and 50% depth of juice followed by A<sub>1</sub>B<sub>1</sub> *i.e.*, 118 °C striking temperature and 25% depth of juice. Minimum appearance score (5.1) was observed in A<sub>2</sub>B<sub>3</sub> *i.e.*, 120 °C striking temperature and followed by A<sub>1</sub>B<sub>3</sub> *i.e.*, 118 °C striking temperature and 75% depth of juice. Maximum texture score (7.9) was observed in treatment A<sub>2</sub>B<sub>2</sub> *i.e.*, 120 °C striking temperature and 50% depth of juice, whereas minimum texture score (4.7) was observed in A<sub>2</sub>B<sub>3</sub> *i.e.*, 120 °C striking temperature among all the treatments. Maximum taste score (7.7) was observed in treatment A<sub>2</sub>B<sub>2</sub> *i.e.*, 120 °C striking temperature and 50% depth of juice, whereas minimum taste score (6.3) was observed in A<sub>2</sub>B<sub>3</sub> *i.e.*, 120 °C striking temperature among all the treatments. Maximum overall acceptability score (7.7) was observed in treatment A<sub>2</sub>B<sub>2</sub> *i.e.*, 120 °C striking temperature and 50% depth of juice, whereas minimum overall acceptability score (5.4) was observed in A<sub>2</sub>B<sub>3</sub> *i.e.*, 120 °C striking temperature among all the treatments. Thus, on the basis of sensory evaluation of jaggery prepared in developed three pan jaggery making furnace, highest scores of appearance, texture, taste and overall acceptability was obtained in treatment A<sub>2</sub>B<sub>2</sub> *i.e.*, 120 °C striking temperature and 50% depth of juice.

Considering the over all aspects of the study *i.e.* physical parameters of three pan jaggery making furnace, biochemical parameters of jaggery and sensory characteristics, it may be

concluded that treatment A<sub>2</sub>B<sub>2</sub> i.e., 120 °C striking temperature and 50% depth of juice was found to be best among all the treatments. So, further analysis of the treatment A<sub>2</sub>B<sub>2</sub> was carried out.

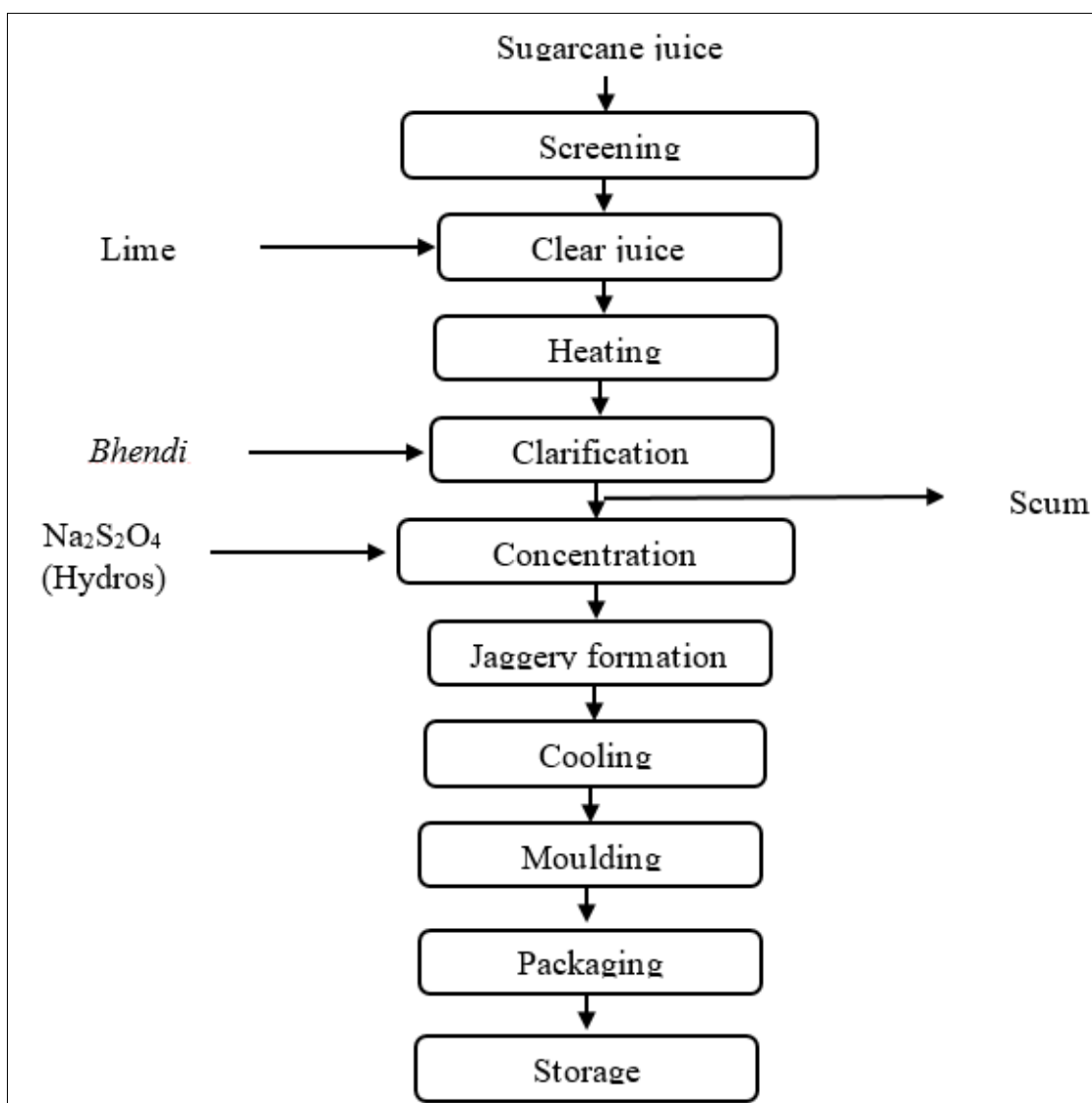
#### Proximate analysis of the jaggery at recommended treatment

The biochemical properties of jaggery are elaborated in Table 6. From the table, it can be clearly seen that the mean values

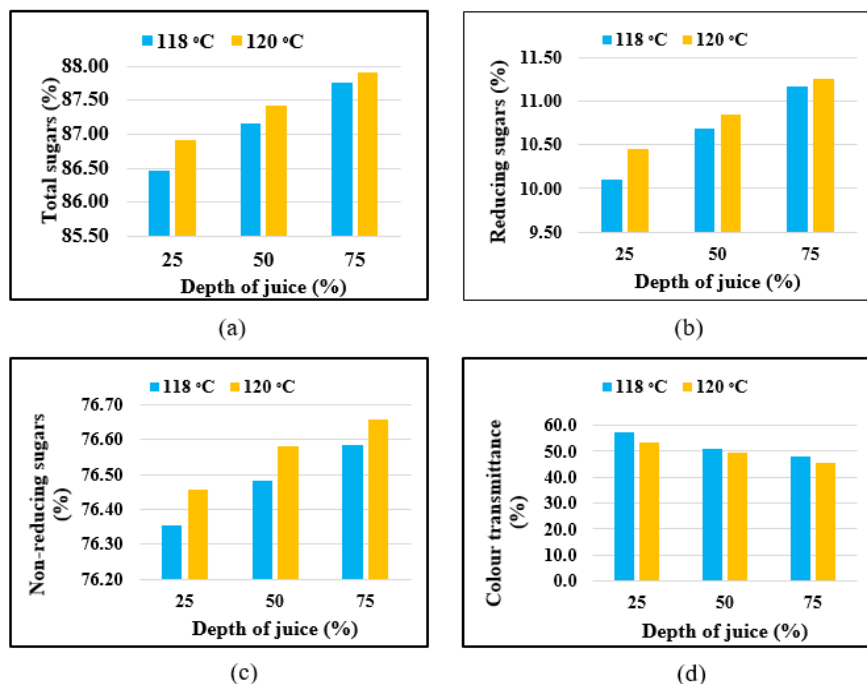
of biochemical properties viz., total sugars (%), reducing sugars (%), non-reducing sugars (%), pH, true protein (%), titratable acidity (%), iron (mg/100g), calcium (mg/100g), moisture (%) and ash (%) of jaggery with their standard deviation was observed to be  $87.42 \pm 1.04$  (%),  $10.84 \pm 0.51$  (%),  $76.58 \pm 1.55$  (%),  $6.75 \pm 0.03$ ,  $0.45 \pm 0.05$  (%),  $0.47 \pm 0.04$  (%),  $11.3 \pm 0.2$  (mg/100g),  $8.2 \pm 0.05$  (mg/100g),  $8.57 \pm 0.13$  (%) and  $1.82 \pm 0.02$  (%), respectively.

**Table 6:** Proximate analysis of the jaggery at recommended treatment

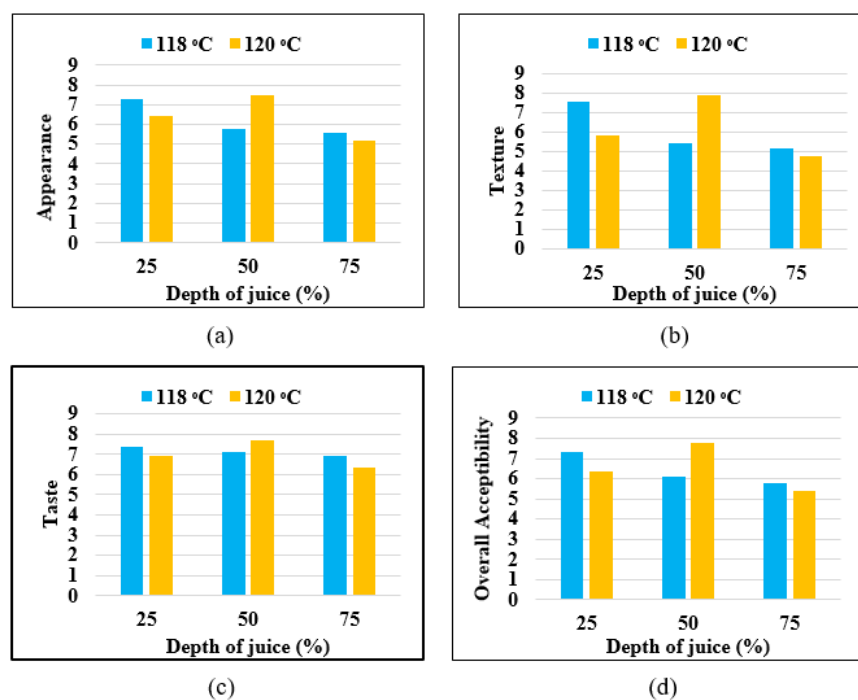
Parameter	Value
Total sugars (%)	$87.42 \pm 1.04$
Reducing sugars (%)	$10.84 \pm 0.51$
Non-reducing sugars (%)	$76.58 \pm 1.55$
pH	$6.75 \pm 0.03$
True protein (%)	$0.45 \pm 0.05$
Titratable acidity (%)	$0.47 \pm 0.04$
Iron (mg/100g)	$11.3 \pm 0.2$
Calcium (mg/100g)	$8.2 \pm 0.05$
Moisture (%)	$8.57 \pm 0.13$
Ash (%)	$1.82 \pm 0.02$



**Fig 1:** Flow chart of preparation of jaggery



**Fig 2:** Combine effect of striking temperature and depth of juice on biochemical properties for jaggery making process: a) Total sugars b) Reducing sugars c) Non-reducing sugars d) Colour transmittance



**Fig 3:** Effect of jaggery processing condition on sensory properties of jaggery

## Conclusion

Study was aimed to find the quality parameters of jaggery prepared from developed three pan jaggery making furnace and to evaluate the effect of process parameters such as striking temperature and depth of juice on quality of jaggery it was found that treatment A2B2 i.e., 120 °C striking temperature and 50% depth of juice was found to be best among all the treatments and the data were in accordance with the previous scientific work.

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