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Screening and Physico-chemical Study of Quality Jaggery Prepared from Different Early and Mid Season Sugarcane Varieties

Shweta, Kanika Pawar, Rakesh Gehlot, Ramesh Kumar, Sudhir Sharma

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ABSTRACT

Background: Jaggery, a traditional sweetener is produced from the sugarcane juice and its quality mainly depends on cane juice quality. It is specific to check, which sugarcane variety is producing the best jaggery in terms of its quality and recovery. Thus, this study was undertaken to screen five different promising early (CoH 160, Co 89003, Co 0238) and mid season (CoH 119, CoH 167) sugarcane varieties and to prepare and evaluate jaggery qualitatively.

Methods: The different sugarcane varieties were harvested at proper maturity, weighed and crushed to extract juice in November, January and March. The juice was analyzed for various physico-chemical parameters *viz*., total soluble solids (°Brix), purity, pol, juice recovery (%) and commercial cane sugar (%). Good quality jaggery was prepared and evaluated for the sensory characteristics. The jaggery was evaluated quantitatively for physico-chemical parameters (reducing sugars, total sugars, sucrose, net rendement value, hardness and minerals.

Result: The jaggery was found to have 8.50-10.70 per cent moisture, 68.82-78.95 per cent sucrose, 7.67-8.83 per cent reducing sugars and 1.45-2.63 per cent ash. The jaggery prepared from Co 89003 had significantly highest sensory scores over jaggery made from all other varieties. Jaggery made from CoH 160 variety was comparable with that of Co89003 variety. The early sugarcane varieties Co 89003 and CoH 160 were found to produce good quality jaggery as compared to mid-late varieties.

Key words: Gur, Jaggery, Physicochemical, Quality, Sensory, Sugarcane, Varieties.

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is an important cash crop of India and is widely used for the production of different sweeteners like sugar, jaggery and *khandsari*. It is being grown in every state of India. In Haryana, sugarcane acreage was about 136 thousand hectares with a total production of 10894 thousand tonnes and 80.1 tonnes per hectare during 2018-19. As per the per cent utilization of sugarcane for the year 2018-19, 66.35 per cent was being used for white sugar production, 14.72 per cent for seed, feed and chewing purposes and 18.93 per cent for *gur* and *khandsari* (Sugar Statistics, 2019). Different sugarcane varieties namely CoH 56, CoH 160, Co 0118, Co 0237, Co 0238 (Early varieties), CoH 99, CoH 119, CoH 128, CoH 167 (Mid season varieties) and CoH 110, CoH 150 (Late season varieties) are grown in Haryana. Besides sugar, these sugarcane varieties are also being used in jaggery, *khandsari* and in ethanol and energy production.

Jaggery is produced in India and being a largest producer of jaggery under unorganized agro-processing sector, India shares 55 per cent of world production. Since the beginning of production of sugarcane in India, it is being used for production of jaggery. Prior to 1920, sugarcane farming was done only for jaggery and *khandsari* industries. Jaggery or *gur* or non-centrifugal sugar (NCS) is a golden-yellow to dark brown colour, coarser, wholesome, traditional and unrefined sugar obtained by boiling or processing juice crushed out of sugarcane. Its processing is one of the largest agro-based cottage industries of unorganized sector in India. In India, production of jaggery occurs mainly in November to May, depending on the location. It is stored for rest of period; although, it is being marketed and consumed throughout the year (Kumar *et al*., 2013). Out of the total World, India produced or consumed about 70% of jaggery (Rao *et al*., 2007). It is marketed in different shapes, colour and texture and is available mainly in three forms *viz*., solid, liquid and granular form. Most of the jaggery (80%) is prepared in solid form and remaining (20%) in liquid and granular form. Jaggery production mainly involves juice extraction, evaporation of water from juice, stirring of

Centre of Food Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125 004, Haryana, India.

Corresponding Author: Kanika Pawar, Regional Research Station, Chaudhary Charan Singh Haryana Agricultural University, Karnal-132 001, Haryana, India.
Email: kanikapawar@gmail.com

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condensed juice, granular formation, moulding to solid state, packaging and storage. Jaggery contains about 65-85% sucrose, 10-15% reducing sugar, 3-5% moisture and remaining made up of proteins (0.35-0.40%), calcium (0.40%), phosphorus (0.045%), iron (0.005-0.020%) and total minerals (0.6%-1.0%). It has several beneficial medicinal properties, which is useful for our body (Sardeshpande *et al*., 2010). Furthermore, it is very good as a cleansing agent. It cleans lungs, stomach, intestines, oesophagus and respiratory tract (Sinha *et al*., 2015). It is often considered as healthier substitute of white and refined cane sugar (Nath *et al*., 2015).

Jaggery quality mainly depends on cane juice quality and hence, if any factor will affect the juice quality, it will definitely bring about a change in the *jaggery* quality. Studies show that jaggery quality preferably depends on chemical composition of juice, irrespective of method of boiling and clarification. The quality of jaggery depends on the sucrose content of juice as well as other chemical constituents like ash, reducing sugars and mineral constituents. These characteristics are determined by the varieties selected, conditions of growth environment such as soil conditions, fertilizer management and an important one is the irrigation system and its frequency (Jambulingam *et al*., 2001). As the jaggery is being produced from the sugarcane juice, it is specific to check, which sugarcane variety is producing the best jaggery in terms of its quality and recovery. This will enable farmers as well as cane growers to get proper benefit and encourage the cultivation of those sugarcane varieties, which are suitable and better for producing high quality jaggery, a healthier alternative to sugar. Also, in the present scenario, there is a need of value addition and thus making *jaggery* from sugarcane juice will definitely extend the scope of its marketing and export and will bring revenue for the country. Eventually, this study was conducted to prepare and evaluate nutritional and sensory quality of jaggery prepared from different early and mid-season sugarcane varieties.

MATERIALS AND METHODS

The research work was carried out in Regional Research Station (RRS), Karnal and Centre of Food Science and Technology, CCSHAU, Hisar. The detailed research work was undertaken as per the following steps given below:

Screening of different early and mid-season sugarcane varieties

The different sugarcane varieties of Regional Research Station, Uchani, Karnal were evaluated for jaggery quality. The five sugarcane varieties *viz.*, CoH 160, Co 0238, Co 89003 (Early varieties), CoH 119, CoH 167 (Mid season varieties) were planted in spring planting season during 2018-19 as per randomized block design (RBD) with three replications in the field at RRS, Karnal. These five sugarcane varieties were harvested at proper maturity, weighed and crushed to juice in November, January and March. The extracted juice was analyzed for various physico-chemical parameters.

Quality analysis of juice

The juice was extracted from these five sugarcane varieties (CoH 160, Co 0238, Co 89003, CoH 119, CoH 167) and analyzed for its quantitative characteristics like total soluble solids, pol, purity, commercial cane sugar and juice extraction percentage as per the methodology given below. Jaggery variants were prepared from these different sugarcane varieties. The juice extraction per cent was calculated by the formula as.

$$\text{Juice extraction (\%)} = \frac{\text{Juice weight (g)}}{\text{Sugarcane weight (g)}} \times 100$$

Total soluble solids (°Brix) was measured with hand refractometer (0-30%). Pol/Sucrose (%) was estimated by Horne's dry lead acetate clarification method (Iswaran, 1980). Purity (%) was determined by Spencer and Meade (1963). Commercial Cane Sugar (CCS) (%) was calculated by using the formula as. (Spencer and Meade, 1963).

CCS per cent =

Pol (sucrose) per cent × 0.73 × (1.4-0.4/Purity)

Jaggery production

The jaggery was produced from five different sugarcane varieties as per the methodology described in Gur Monograph (Roy, 1951). The jaggery was prepared using traditional open pan system in the pilot plant (Fig 2). All the five sugarcane varieties were collected from the RRS, Uchani, Karnal and the jaggery was prepared in pilot plant of CFST, CCSHAU, Hisar.

i) Physico-chemical analysis of jaggery

The jaggery prepared from different sugarcane varieties were physico-chemically analyzed for parameters such as moisture, sucrose, reducing sugars, total sugars, net rendement value, minerals (Fe, Ca and Zn) and hardness as described below. Moisture content (%) and crude ash content was estimated in final *jaggery* samples using AOAC (2000) method. Total and reducing sugars (%) were determined as per the method of Hulme and Narain (1931). Net rendement values were obtained by substituting the values in the formula as (Roy, 1951).

NR = (Sucrose %) - Reducing sugars % + (3.5 × Ash %)

The flow chart of jaggery manufacturing process involved the following steps as mentioned below (Fig 1). For mineral analysis, Iron (Fe), calcium (Ca) and zinc (Zn) in acid digested samples were determined by atomic absorption spectrophotometer according to method of Lindsay and Norvell (1978). A method developed by Kim and Zemel (1986) was used for finding the amount of calcium and zinc in the jaggery samples, while procedure of Rao and Prabhavathi (1978) was referred to find the available iron in jaggery samples. Texture analysis was done using

Sugarcane (10 kg)
↓
Harvesting
↓
Extraction of juice
(Juice extraction machine > 50% extraction)
↓
Filtration (Muslin cloth)
↓
Clarification (okra mucilage added @ 0.5% sugarcane juice)
↓
Formation of scum
↓
Removing scum and impurities (By using sieve)
↓
Preheating (75 to 80°C)
↓
Concentration (Till 75°Brix)
(By boiling at striking temperature 115-120°C)
↓
Cooling
(30-40°C temperature)
↓
Moulding
↓
Jaggery cubes
↓
Packaging and Storage

Fig 1: Flow sheet for preparation of jaggery from sugarcane varieties.

Texture analyzer Model TMS-Pro from Food Technology Corporation, U.S.A. having a load cell of 250 N. A 4 mm cylindrical probe was used for jaggery in conjunction with texture analyzer. The hardness of products was noted in Newton (N).

ii) Sensory evaluation

Sensory evaluation of jaggery samples was done by a panel of ten judges using 9-point hedonic scale as per the method described by Rangana (2017).

iii) Packaging

Different jaggery samples were vacuum packaged in LDPE (Low density polyethylene) bags and stored at room temperature.

iv) Statistical analysis

The data in the present investigation was subjected to analysis of variance (ANOVA) techniques and analyzed according to completely randomized design. The critical difference value at 5 per cent level was used for making comparison among different treatments during 60 days storage period. SAS (Statistical Analysis System) Software was used to statistically analyze the data generated in the study.

RESULTS AND DISCUSSION

The results are presented here with the goal of screening the different sugarcane varieties for jaggery production and evaluating the best jaggery prepared out of these varieties for assessing its overall acceptability in terms of quality.

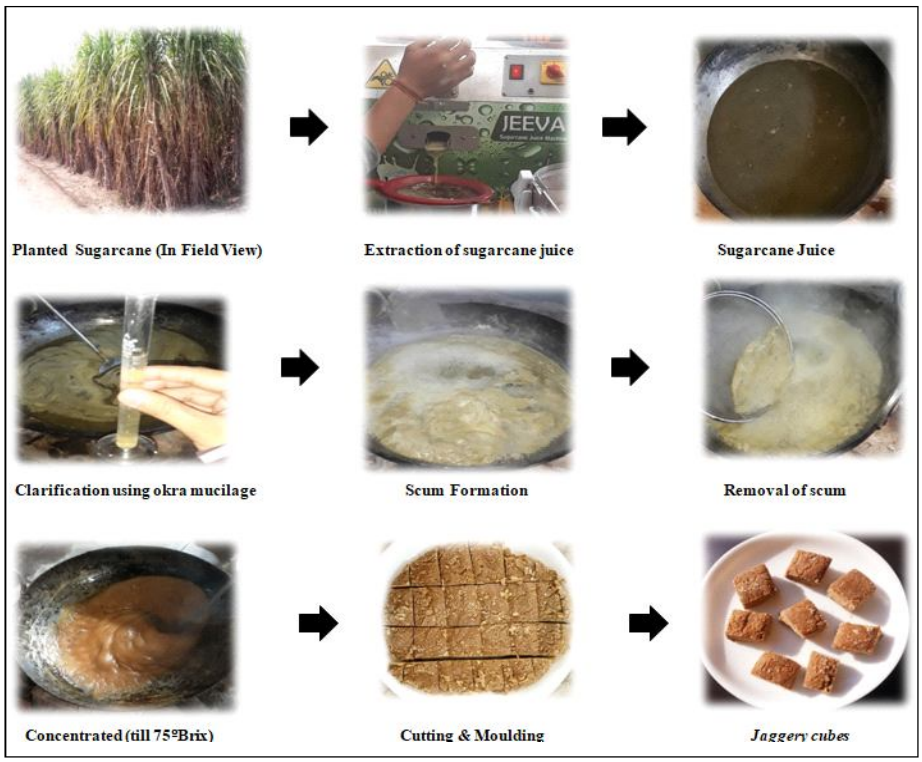

Fig 2: Pictorial representation of quality jaggery prepared from different sugarcane varieties.

Physico-chemical characteristics of the juice extracted from different sugarcane varieties harvested in November, January and March

In November, higher total soluble solids (TSS) were observed in the early sugarcane varieties CoH 160, CoH 238 and Co 89003 (20.5°Brix) (Table 1). Pol, purity and CCS per cent was also higher in the Co 89003 variety (18.46%, 0.89, 12.84%). In contrast a lower TSS, pol, purity and CCS percent was observed in the Mid-season sugarcane variety CoH 119 (20°Brix, 17.41%, 0.86, 11.99%). In January, higher total soluble solids (TSS) were observed in the varieties Co 89003, CoH 119 and CoH 167 (20.5°Brix). Pol, purity and CCS per cent was also higher in the Co 89003 variety (18.5%, 0.90, 12.94%). A lower TSS and pol per cent (19.2°Brix, 17.81%) was observed in CoH 238 variety whereas a lesser purity and CCS per cent was observed in CoH 119 (0.88, 12.38%) and CoH 167 (0.88, 12.63%) (Table 1). In March, higher total soluble solids (TSS) were observed in the mid-season sugarcane variety CoH 167 (22.3°Brix) whereas pol, purity and CCS per cent was observed to be more in CoH 160 (20.1%, 0.94, 14.34%) variety. In contrast a lower TSS, pol, purity and CCS per cent was observed in the early sugarcane varieties Co 89003 (19.7°Brix, 18.8%) and CoH 238 (0.92, 13.28%). A non-significant ($p>0.05$) difference was observed in the TSS, pol, purity and CCS per cent in different sugarcane varieties in all three months.

Xiao *et al*., 2017 reported a similar observation in sugarcane where in from the beginning of December to early January, the nutrients tend to accumulate causing TSS, purity, polarization and sucrose to increase. However, from January to mid-February, it got reversed and gradually leading to a loss in the accumulation of nutrients and by the end of March, reducing sugar formation slowly increase leading to the deterioration in sugarcane juice quality. Singh *et al*., 2018 also observed a similar range of pol per cent (sucrose content) in the early varieties and that was in the range of 20.1-21.2 per cent. In early maturing varieties, sucrose content ranged from 12.9 to 16.9% in October (early crushing period), which is the recommended month of harvest for early varieties. For late-maturing varieties, sucrose content was lower, ranging from 13.5 to 14.7% (Table 1). At the end of the crushing period (April), the sucrose content of early maturing varieties was 20.1- 21.2%, but for the late-maturing varieties, the range was 18.9-19.7%. High quality juice having low reducing sugars to sucrose ratio and high purity is considered to be good for *jaggery* manufacturing. At maturity, brix would be over 20-22% and 16-18% sucrose; harvest by about 20-30 days would cause a loss of about 1.0 to 1.5 tonnes of jaggery/ha. Net rendement value of jaggery was judged more by the juice sucrose content. The deterioration in juice quality manifests itself by a decrease in sucrose contents in juice by 5 to 25% and also through reduction in quantity and quality of jaggery (gur). The hardness and bright color of the jaggery was developed to the higher sucrose content in the juice. These results as mentioned above for the physico-chemical characteristics of sugarcane juice in the harvesting months of November, January and March are in agreement with the values reported earlier by Tripathi *et al.* (2017).

Physico-chemical evaluation of jaggery prepared from different sugarcane varieties harvested in November, January and March

In November, jaggery prepared from mid-late season sugarcane variety CoH 119 (8.66%) observed a higher reducing sugar per cent while a lower was in jaggery prepared from the early maturing variety CoH 160 (7.67%) (Table 2). A higher total sugar, sucrose, net rendement value and hardness was found to be in jaggery prepared from

Table 1: Physico-chemical evaluation of the juice extracted from different sugarcane varieties in November, January and March.

Variable	CoH 160	CoH 238	Co 89003	CoH 119	CoH 167	C.D. at 5%
			Sugarcane varieties harvested in November			
TSS (°Brix)	$20.5^{a}\pm0.57$	$20.5^{a}\pm1.29$	$20.5^{a}\pm1.29$	$20.0^{a}\pm1.15$	$20.2^{a}\pm0.50$	1.54
Pol %	$17.84^{a}\pm0.36$	$17.74^{a}\pm1.36$	$18.46^{a}\pm0.99$	$17.41^{a}\pm1.69$	$18.05^{a}\pm0.34$	1.64
Purity %	$87.0^{a}\pm0.01$	$87.0^{a}\pm0.02$	$89.0^{a}\pm0.03$	$86.0^{a}\pm0.03$	$88.0^{a}\pm0.03$	0.04
CCS %	$12.27^{a}\pm0.27$	$12.17^{a}\pm1.06$	$12.84^{a}\pm0.79$	$11.99^{a}\pm1.36$	$12.46^{a}\pm0.42$	1.32
			Sugarcane varieties harvested in January			
TSS (°Brix)	$20.0^{a}\pm0.81$	$19.2^{a}\pm0.50$	$20.5^{a}\pm1.00$	$20.5^{a}\pm1.29$	$20.5^{a}\pm0.57$	1.33
Pol %	$18.2^{a}\pm0.74$	$17.81^{a}\pm0.69$	$18.5^{a}\pm1.27$	$17.91^{a}\pm1.34$	$18.25^{a}\pm0.76$	1.51
Purity %	$90.0^{a}\pm0.02$	$90.0^{a}\pm0.02$	$90.0^{a}\pm0.01$	$88.0^{a}\pm0.04$	$88.0^{a}\pm0.01$	0.03
CCS %	$12.76^{a}\pm0.58$	$12.55^{a}\pm0.60$	$12.94^{a}\pm0.96$	$12.38^{a}\pm1.12$	$12.63^{a}\pm0.61$	1.21
			Sugarcane varieties harvested in March			
TSS (°Brix)	$21.5^{ab}\pm0.57$	$20.5^{bc}\pm0.57$	$19.7^{c}\pm0.50$	$21.2^{b}\pm0.95$	$22.3^{a}\pm0.75$	1.04
Pol %	$20.1^{a}\pm0.18$	$18.86^{c}\pm0.26$	$18.8^{c}\pm0.54$	$19.40^{bc}\pm0.59$	$19.84^{ab}\pm0.50$	0.67
Purity %	$94.0^{a}\pm0.02$	$92.0^{ab}\pm0.01$	$94.0^{a}\pm0.01$	$92.0^{ab}\pm0.03$	$89.0^{b}\pm0.04$	0.46
CCS %	$14.34^{a}\pm0.18$	$13.28^{b}\pm0.15$	$13.45^{b}\pm0.47$	$13.65^{b}\pm0.58$	$13.75^{ab}\pm0.59$	0.66

*Mean bearing different superscript differ significantly.

*The values are mean±S.D. of three replicates.

CoH 238 (83.88%, 72.43%, 76.26% and 361 N) followed by CoH 160 (83.11%, 65.34%, 73.10% and 357) variety. In contrast, a lower total sugar, net rendement value was observed in CoH 119 (79.02% and 70.88%) variety. As the per cent of reducing sugar was lesser in the early maturing varieties, it resulted in the production of better quality jaggery. In the early crushing month, a higher amount of sucrose, total sugars and net rendement value was observed as compared to the mid late season varieties which had lower amount of all these physico-chemical parameters and is also reported the same by Singh *et al.,* 2018. Among the minerals, maximum iron was observed in jaggery prepared from variety CoH 167 (11.98 mg/100 g) followed by Co 89003 (11.87 mg/100 g) and CoH 238 (11.67 mg/100 g) variety while minimum iron content was found to be in variety CoH 160 (11.40 mg/100 g). The calcium content was observed to be higher in variety CoH 238 (82.33 mg/100 g) while a lower was observed in jaggery prepared from variety Co 89003 (78.33 mg/100 g). The zinc content was higher in varieties CoH 238 (0.58 mg/100 g) and CoH 119 (0.58 mg/100 g) and lower in the varieties CoH 160 (0.33 mg/100 g) and CoH 167 (0.33 mg/100 g). Among all the six varieties the reducing sugar per cent in variety CoH 160 was found to be statistically different from all the other sugarcane varieties. The total sugar per cent was statistically similar in varieties CoH 160, Co89003 and CoH 167 however varieties CoH 238 and CoH 119 were statistically different. There was a non- significant ($p>0.05$) difference observed in sucrose percent, net rendement value and mineral content of the jaggery prepared from different sugarcane varieties in November (Table 2).

In January, jaggery prepared from sugarcane variety CoH 119 (8.83%) observed a higher reducing sugar per cent while a lower was in jaggery prepared from the variety CoH 160 (7.81%). A higher total sugar percent and net rendement value was found in *jaggery* prepared from CoH 238 (82.59% and 74.81%) and a lower total sugars, net rendement value was observed in variety CoH 119 (77.59% and 69.46%). A maximum sucrose and hardness was found in CoH 160 (78.95%, 352 N) variety and minimum sucrose content and hardness in CoH 167 (72.22%, 347.3 N) variety. Among the minerals, maximum iron was observed in jaggery prepared from variety CoH 167 (12 mg/100 g) followed by Co 89003 (11.95 mg/100 g) and CoH 119 (11.73 mg/100 g) while

Table 2: Physico-chemical evaluation of jaggery prepared from different sugarcane varieties in November, January and March.

Variable		CoH 160	CoH 238	Co 89003	CoH 119	CoH 167	C.D. at 5%
Sugarcane varieties harvested in November							
Reducing sugar (%)		7.67^{b}±0.14	8.56^{a}±0.48	8.42^{ab}±0.38	8.66^{a}±0.35	8.48^{a}±0.69	0.81
Total sugar (%)		83.11^{ab}±4.59	83.88^{a}±4.85	81.49^{ab}±4.51	79.02^{b}±2.56	79.61^{ab}±1.63	4.87
Sucrose (%)		65.34^{b}±3.96	72.43^{a}±2.49	64.82^{b}±6.46	68.18^{ab}±2.97	68.92^{ab}±0.27	6.93
Net rendement value (%)		73.10^{a}±4.52	76.26^{a}±2.36	73.49^{a}±4.40	70.88^{a}±2.66	71.21^{a}±1.93	5.93
Hardness (N)		357.0^{b}±2.00	361.0^{a}±1.00	355.0^{bc}±1.00	355.0^{bc}±2.00	353.3^{c}±1.52	2.85
Minerals (mg/100 g)	Fe	11.40^{a}±1.18	11.67^{a}±2.42	11.87^{a}±1.45	11.55^{a}±0.02	11.98^{a}±1.43	2.75
	Ca	81.66^{a}±1.43	82.33^{a}±1.17	78.33^{a}±1.40	80.16^{a}±2.65	80.33^{a}±5.53	3.52
	Zn	0.33^{a}±0.14	0.58^{a}±0.14	0.50^{a}±0.25	0.58^{a}±0.14	0.33^{a}±0.14	0.31
Sugarcane varieties harvested in January							
Reducing sugar (%)		7.81^{a}±0.35	8.72^{a}±0.34	8.26^{a}±0.66	8.83^{a}±0.24	8.69^{a}±1.04	1.10
Total sugar (%)		81.49^{ab}±4.5	82.59^{a}±4.74	79.90^{ab}±2.4	77.59^{b}±2.56	78.18^{ab}±0.8	4.87
Sucrose (%)		78.95^{a}±9.81	74.82^{a}±5.94	77.84^{a}±8.35	73.96^{a}±4.02	72.22^{a}±2.60	12.19
Net rendement value (%)		71.32^{ab}±4.5	74.81^{a}±2.36	72.20^{ab}±4.0	69.46^{b}±2.66	69.84^{b}±1.93	4.73
Hardness (N)		352.0^{b}±1.00	350.6^{a}±1.52	350.6^{b}±1.52	350.0^{b}±1.00	347.3^{c}±1.52	2.44
Minerals (mg/100 g)	Fe	11.60^{a}±0.95	11.20^{a}±0.02	11.95^{a}±1.45	11.73^{a}±0.13	12.00^{a}±1.51	2.41
	Ca	81.67^{a}±1.91	82.67^{a}±2.98	80.17^{a}±1.40	81.17^{a}±2.56	80.83^{a}±5.25	2.94
	Zn	$0.25±0.01^{b}$	0.30^{ab}±0.06	0.42^{ab}±0.08	0.50^{a}±0.25	$0.25±0.01^{ab}$	0.22
Sugarcane varieties harvested in March							
Reducing sugar (%)		7.67^{a}±0.14	8.54^{a}±0.11	8.43^{a}±0.49	8.66^{a}±0.35	8.69^{a}±1.04	0.99
Total sugar (%)		78.72^{a}±4.15	80.98^{a}±2.38	78.78^{a}±6.62	76.36^{a}±0.60	76.87^{a}±1.99	6.87
Sucrose (%)		71.05^{a}±4.02	72.43^{a}±2.49	70.35^{a}±7.05	68.12^{a}±0.27	68.18^{a}±2.97	7.32
Net rendement value (%)		69.99^{a}±4.36	70.57^{a}±2.11	68.85^{a}±6.16	66.56^{a}±5.27	65.84^{a}±5.52	8.90
Hardness (N)		310^{b}±1.00	309^{b}±2.08	319^{a}±5.29	319^{a}±3.78	323^{a}±2.64	6.01
Minerals (mg/100 g)	Fe	11.60^{a}±0.98	11.10^{a}±1.83	11.90^{a}±1.37	11.70^{a}±0.13	12.04^{a}±1.51	2.37
	Ca	80.60^{a}±2.43	82.10^{a}±1.32	79.80^{a}±1.80	79.80^{a}±2.27	80.33^{a}±2.53	2.99
	Zn	0.23^{bc}±0.01	0.18^{b}±0.01	0.35^{ab}±0.07	0.41^{a}±0.14	0.23^{bc}±0.02	0.13

*Mean bearing different superscript differ significantly ($p<0.05$).

*The values are mean±S.D. of three replicates.

minimum iron content was found to be in variety CoH 238 (11.20 mg/100 g). The calcium content was observed to be higher in variety CoH 238 (82.67 mg/100 g) while a lower was observed in jaggery prepared from variety Co 89003 (80.17 mg/100 g). The zinc content was higher in varieties CoH 119 (0.50 mg/100 g) and lower in the varieties CoH 160 (0.25 mg/100 g) and CoH 167 (0.25 mg/100 g). Among all the six varieties there was a non-statistical ($p>0.05$) difference in reducing sugar per cent in the prepared jaggery. However there was a statistical ($p<0.05$) difference in the total sugar, sucrose per cent in the CoH 238 and CoH 119 variety while CoH 160, Co 89003 and CoH 167 varieties were statistically comparable. In case of net rendement value, there was a statistical difference among the jaggery prepared from CoH 238 and CoH 119 varieties whereas CoH 160, Co 89003 varieties were statistically comparable. A statistical ($p<0.05$) difference was observed in the hardness among the jaggery prepared from varieties CoH 160, CoH 238 and CoH 167 whereas varieties CoH 160, Co89003 and CoH 119 were statistically comparable. There was non-significant ($p>0.05$) difference observed in iron and calcium content of the jaggery prepared from different sugarcane varieties in the harvesting month of January (Table 2). In contrast significant ($p<0.05$) difference was observed in the zinc content of the jaggery prepared from different sugarcane varieties.

In March, jaggery prepared from sugarcane variety CoH 167 (8.69%) observed a higher reducing sugar per cent while a lower was in jaggery prepared from CoH 160 (7.67%) variety. A higher total sugar per cent, sucrose per cent, net rendement value was found to be in jaggery prepared from CoH 238 (80.98%, 72.43%, 70.57%) and a lower total sugar and sucrose per cent was observed in CoH 119 (76.36%, 68.12%) variety. A lower net rendement value was observed in CoH 167 (65.84%). Higher hardness was reported in the jaggery prepared from CoH 167 (323 N) variety while lower in CoH 238 (309 N) variety. Among the minerals, maximum iron was observed in jaggery prepared from CoH 167 (12.04 mg/100 g) variety followed by Co 89003 (11.9 mg/100 g) and CoH 119 (11.7 mg/100 g) while minimum iron content was in CoH 238 (11.1 mg/100 g) variety. The calcium content was observed to be higher in variety CoH 238 (82.1 mg/100 g) while a lower was observed in jaggery prepared from variety Co 89003 (79.8 mg/100 g) and CoH 119 (79.8 mg/100 g). The zinc content was higher in variety CoH 119 (0.41 mg/100 g) and lower in the variety CoH 238 (0.18 mg/100 g). There was a non-significant ($p>0.05$) difference observed in reducing sugar, total sugar, sucrose percent, net rendement value of the jaggery prepared from different sugarcane varieties in March (Table 2). There was a non-significant ($p>0.05$) difference observed in iron and calcium content of the jaggery prepared from different sugarcane varieties however zinc content of CoH 119 is significantly ($p< 0.05$) different from the other sugarcane varieties like CoH 160, CoH 238 and CoH 167. The jaggery prepared from varieties Co 89003, CoH 119 and CoH 167 significantly differ in hardness from the other varieties CoH 160 and CoH 238.

The physico-chemical properties are important from commercial production point of view because they help to know the nature of developed product. Among all three months (November, January and March) maximum reducing sugar percent was observed in jaggery prepared from CoH 119 and CoH 167 variety while CoH 238 and CoH 160 varieties observed maximum total sugar per cent, sucrose percent, net rendement value and hardness. Similar results have been observed by Chand *et al.*, (2014). Among the minerals, maximum iron was found in jaggery prepared from CoH 167 variety followed by Co 89003 variety and the calcium and zinc content was higher in CoH 238 variety. Similar trends in minerals (Ca, Fe and Zn) content of jaggery was also reported by Singh *et al.* (2018). Singh *et al.*, (2018) evaluated calcium (40-100 mg), phosphorous (20-90 mg) and zinc (0.2-0.4 mg) in jaggery. Jambulingam *et al.*, (2001) estimated the mineral content *i.e.* Ca (80.2%), Fe (11.40%) and Zn (0.41%) per 100 g of jaggery. The similar results were observed by Sinha *et al.*, (2015).

Table 3: Jaggery quantitative analysis as per FSSAI.

Parameters (%)	Jaggery	Permissible limits (Source: FSSAI, 2017)
Moisture	8.50-10.70	7 (per cent by mass, max)
Sucrose	64.82-78.95	70 (per cent by mass, min)
Reducing sugar	7.67-8.83	20 (per cent by mass, max)
Ash	1.45-2.63	4 (per cent by mass, max)

Table 4: Sensory scores of jaggery prepared from different sugarcane varieties harvested in January.

Varieties	Sensory scores on 9 point hedonic scale				
	Color and appearance	Taste	Texture	Flavor	Overall acceptability
CoH 160	8.45^{b}±0.50	8.35^{a}±0.47	8.35^{a}±0.53	8.40^{a}±0.52	8.41^{a}±0.33
CoH 238	8.00^{b}±0.50	7.40^{b}±0.46	7.40^{b}±0.46	7.65^{b}±0.82	7.61^{b}±0.53
Co 89003	8.65^{a}±0.45	8.45^{a}±0.60	8.40^{a}±0.66	8.65^{a}±0.47	8.53^{a}±0.32
CoH 119	6.95^{c}±0.44	7.25^{b}±0.63	7.25^{b}±0.82	7.05^{c}±0.60	7.12^{c}±0.53
CoH 167	7.30^{c}±0.35	7.25^{b}±0.59	7.15^{b}±0.34	7.10^{c}±0.52	7.20^{c}±0.33
C.D. at 5%	0.47	0.50	2.01	0.54	0.37

*Mean bearing different superscript differ significantly.

*The values are mean±S.D. of three replicates.

Jaggery composition

Jaggery contained moisture (8.50-10.70%), ash (1.45-2.63%), reducing sugar (7.67-8.83%), total sugars (76.36-83.88%), sucrose (64.82-78.95%), net rendement value (65.84-76.26%), hardness (309-361 N), iron (11.10-12.04 mg/ 100 g), calcium (78.33-82.67 mg/100 g) and zinc (0.18-0.58 mg/ 100 g). As per the Food Safety and Standards Authority of India (FSSAI, 2017), the jaggery prepared in this study was found to contain all the three constituents namely sucrose, reducing sugar and ash well within the limits except the moisture content which was found to be higher (Table 3). This might be due to the high sucrose content which makes it hygroscopic in nature. However, there was no microbial growth observed in the jaggery samples and the jaggery was sensory acceptable in terms of the soft texture being provided due to the moisture. High moisture content (11.93%) in edible coated stored jaggery was observed by Chand *et al.,* 2014. The jaggery had sucrose (>70%) and reducing sugar (<20%) and could considered to be best in quality as is reported in the similar findings by Singh *et al.,* 2018. As per FSSAI, the reducing sugars can go maximum up to 20 per cent, however the jaggery prepared was found to have lesser amount of reducing sugar (7.57-8.83%) and thus making it more sensory acceptable in terms of its color and appearance as is observed in the similar finding by Kumar *et al.,* 2013.

Sensory characteristics of jaggery prepared from different sugarcane varieties

The jaggery prepared from five early and mid-late season sugarcane varieties (CoH 160, CoH 238, Co89003, CoH 119 and CoH 167) in January was most liked by the sensory panel and differ significantly from the jaggery prepared in November and March, as it was observed through the preliminary sensory trials. The jaggery prepared from Co 89003 had significantly highest sensory scores over jaggery made from all other varieties. Jaggery made from CoH 160 variety was comparable with that of Co89003 variety (Table 4).

CONCLUSION

A good quality jaggery was prepared from the different sugarcane varieties and finally it is concluded that early season sugarcane varieties like Co89003 and CoH 160 produces an excellent quality jaggery in terms of its sensory acceptability and other quantitative attributes. Also, the jaggery prepared from early season sugarcane varieties produces the desirable color and quality due to the lesser amount of reducing sugar and a higher sucrose content as compared to the mid-late season sugarcane varieties. The juice quality and jaggery recovery came out to be best in the harvesting month of January for producing jaggery. Moreover, it was also mostly liked by the sensory panel. It has been positively correlated with the higher brix, sucrose, purity values and also, due to lesser amount of reducing sugars in the formulated jaggery. Thus, an attempt will provide an open vista of researching and screening sugarcane varieties grown in Haryana for future feasibility studies related to jaggery production. It will also encourage farmers to cultivate those sugarcane varieties which results in producing excellent jaggery. Eventually, it will expand the horizons of value addition and marketing of jaggery for the potential young entrepreneurs.

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