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Storage study of concentrated sugarcane juice

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Abstract
The study investigates the physicochemical and sensory changes in concentrated sugarcane juice (Liquid Jaggery) obtained at 104 °C strike point and stored at room temperature for 120 days. Parameters such as moisture content, turbidity, pH, total soluble solids (°Brix), reducing sugars, non-reducing sugars, and total viable bacterial count were analysed. The results revealed that moisture content and turbidity increased, while pH and total soluble solids declined, indicating chemical and microbial changes during storage. Reducing sugars increased due to sucrose hydrolysis, whereas non-reducing sugars decreased. Microbial growth was evident from the rising bacterial count. Sensory evaluation showed a gradual decline in colour and appearance, consistency, taste, flavour, and overall acceptability. These findings highlight the impact of storage conditions on liquid jaggery's quality, emphasizing the need for improved preservation strategies to maintain its physicochemical stability and sensory appeal.

Keywords: Liquid jaggery, physicochemical properties, sensory evaluation, storage

Introduction

Sugarcane is a member of the grass family's genus Saccharum and is used as a raw ingredient to make jaggery (Sankhla *et al.*, 2011) [15]. India ranks second globally in sugar production and consumption, following Brazil. According to the Directorate of Sugarcane Development's annual report for 2023–2024, sugarcane is cultivated on 56.48 lakh hectares in India. (Annon., 2024). Maharashtra is the state in India with the second-largest area under cultivation (14.00 lakh hectares in 2023–2024) of sugarcane. The states with the highest production per hectare are Tamil Nadu, Karnataka, Maharashtra, Telangana, Punjab, West Bengal and Haryana in close succession. Interestingly, Maharashtra produced 105.99 million tonnes of sugarcane on average in 2023–2024 (Annon., 2024).

Jaggery is a non-centrifugal sugar (NCS) made by evaporating water in sugarcane juice. It is known by various names including Gur in India, panela in Latin America, jaggery in South Asia and Japan, Hakura in Sri Lanka, Rapadura in Brazil, and Gur/Desi in Pakistan (Rao *et al.*, 2007) [14]. This traditional sweetener are a natural combination of sugar and molasses. When pure clarified sugarcane juice is cooked, the residue (which typically contains 65-85 percent sucrose) forms a jaggery. Khandsari sugar is a finely granulated, crystallized sugar that comprises 94-98% sucrose (Mungare *et al.*, 2000) [10].

There are three different kinds of jaggery: solid, liquid, and granular. India alone accounts for more than 70% of global jaggery production (Kumar *et al.*, 2021) [9]. Approximately 80% of the jaggery produced in India is in solid form and the remaining 20% being produced is in liquid and granular form. Liquid jaggery is also called as Kakawi in some regions in Maharashtra. (Nath *et al.*, 2015) [11] The substitute for honey is liquid jaggery. The initial stage in the production of liquid jaggery is the crushing of sugarcane. This intermediate product is gathered during the production of jaggery. Liquid jaggery is produced when the juice content reaches 60 to 70°B and its striking temperature typically varies between 103°C and 106°C, depending on the types of sugarcane utilized and agro-climatic zone (Singh *et al.*, 2013) [17]. A 100 grams of liquid jaggery has the following components: water (30–35 grams), invert sugar (15–25 grams), sucrose (40–60 grams), fat (0.1 grams), protein (0.5 grams), and total minerals (0.75). 300Kcal/100g is the calorific value of liquid jaggery. Adding preservatives such as 0.1% potassium meta bisulphate or 0.5% benzoic acid to liquid jaggery extends its shelf life and also used to check crystallization. Kerala, Tamilnadu, Gujarat, Andhra Pradesh and Maharashtra all use liquid jaggery as a sweetener in their daily food and also it has been used as sweetening agent in most food preparation, drinks and in traditional foods. Liquid jaggery is used as base sweetener in Pharmaceutical formulations like in ayurvedic medicines which are in the form of syrup (Halde *et al.*, 2019) [7].

In present study liquid jaggery at 104°C temperature is prepared and stored for storage period of 120 days at room temperature and its physicochemical characteristics analysed during storage.

Materials and methods

The variety Cv. Co-86032 was used to study the storage behaviour of liquid jaggery. Samples of liquid jaggery were prepared at 104°C and stored at room temperature (27°C) in pre-sterilized PET bottles and analysed for physicochemical properties at 30-day intervals over a period of 120 days with four replications.

Experimental site

The present study was conducted at the AICRP on Post-Harvest Engineering and Technology, Regional Sugarcane and Jaggery Research Station, Kolhapur, M.P.K.V., Rahuri.

Methods of analysis of quality parameters

Determination of pH

The pH was determined by using digital pH meter (AOAC, 2005) [5]. The electrode of the digital pH metre was dipped inside the beaker containing the sample (liquid jaggery) and recorded the pH value. Prior to measurement the pH meter was calibrated using pH 7 and pH 4 standard solutions (Patil and Anekar, 2014) [12].

Determination of Total Soluble solids (ºBrix)

The hand-held refractometer with 0 - 90° Brix scale (LC = 0.1% °Brix) was used for the determination of total soluble solids (TSS) of the liquid jaggery. In order to determine the TSS, the refractometer was initially set to zero followed by placing 1 to 2 drops of liquid jaggery on its screen and start pressed button. It directly gives the reading in percent or °Brix (Alarcon *et al.,* 2020) [1].

Determination of moisture content (%)

Moisture content was determined as per AOAC, 1990 [4] by using hot air oven method by putting known weight of the sample in a dish, keeping it in preheated oven maintained at a temperature of 110-120 C. After 1 hour the dish was removed and transferred to desiccator, allowed to cool and then weighed. The loss in the weight was reported as percentage of moisture content which can be calculated as per the following formula,

$$\text{Moisture content \% (m)} = [(W_1-W_2) / (W_1-W)] * 100$$

Where,
W = Weight of empty aluminium dish (g)
W_1 = Weight of aluminium dish + Sample before drying (g)
W_2 = Weight of aluminium dish + Sample after drying (g)

Determination of Turbidity (NTU)

Nephelometric turbidity of liquid jaggery was measured in a PC Compact Turbidimeter (Make: Labwan Model. LW-TM-901) in nephelos turbidity units (NTU), with an incident infrared light of 875 nm and a scattering angle of 90°. Samples of the jaggery were placed in a 15 ml cell, capped, and gently inverted twice to ensure even mixing. Secondary standards of 100 or 1000 NTU were used, depending on the sample. The range of this turbidity meter was 0 to 1000 NTU. (Benitez *et al.*, 2007) [6]

Determination of sugars

Reducing sugars and non- reducing sugars were determined by the method of Lane and Eynon, modified by Ranganna (2005) [13].

Microbial analysis

For estimating viable bacterial count in liquid jaggery sample dilution plate count method was followed. For bacterial estimation, plate count agar was used (Krishna kumar and Devadas, 2006) [8].

Sensory evaluation

The method given by Amerine *et al.* (1965) [2] was used for sensory evaluation. A panel of 10 judges using nine-point hedonic scale was used to judge the colour and appearance, taste, texture, flavour and overall acceptability of liquid jaggery.

Result and discussion

Chemical composition of liquid Jaggery

The chemical composition of liquid jaggery for variety Cv. Co-86032 was determined in Table 1. Fresh liquid jaggery prepared at 104°C was analysed for physico-chemical evaluation before storage. On estimation, liquid jaggery was found to contain 25.93 % moisture content, 106.18 NTU turbidity, 5.44 pH, 72.15 °Brix, 17.20 % reducing sugars, 43.40 % Non- reducing sugars and 2.6×10^3 cfu/ml total viable bacterial count.

Table 2: Effect of storage on physico-chemical properties of liquid jaggery at room temperature

Treatments	pH	TSS	Moisture	Reducing sugar	Non-reducing sugar	Turbidity
0	5.44^{a}	72.15^{a}	25.93	17.20^{c}	43.4^{a}	106.18^{e}
30	5.40^{a}	71.70^{ab}	26.00	18.48^{b}	42.75^{a}	107.85^{d}
60	5.31^{b}	71.18^{bc}	26.20	18.98^{b}	39.76^{b}	108.35^{c}
90	5.25^{bc}	70.27^{cd}	26.37	20.28^{a}	37.52^{c}	109.13^{b}
120	5.18^{c}	69.86^{d}	26.54	21.14^{a}	36.04^{d}	109.68^{a}
Mean	5.32	71.03	26.21	19.22	5.32	108.24
CD @5%	0.066	0.966	NS	0.917	1.382	0.253

Moisture content (%)

The moisture content of liquid jaggery increased from 25.93% on day 0 to 26.54% by day 120, showing a gradual increase over storage period. This may be due to the high-water vapour transmission rate of PET bottles due to which there was increase in moisture content of liquid jaggery. These findings align with the observations of Halde *et al.* (2019) [7] and Patil and Anekar (2014) [12], highlighting the impact of storage conditions on the quality of liquid jaggery.

Turbidity (NTU)

Turbidity of liquid jaggery increased steadily from 106.18 NTU on day 0 to 109.68 NTU on day 120. The rise in turbidity was linked to crystallization, insoluble complex formation, and microbial growth during storage. These findings align with the observations of Halde *et al.* (2019) [7].

pH

The pH of liquid jaggery dropped from 5.44 on day 0 to 5.18 on day 120, reflecting an increase in acidity over the storage period. This change is likely due to the production of organic acids from microbial or chemical activity. The findings align with previous studies by Halde *et al.* (2019) [7] and Patil and Anekar (2014) [12].

Total soluble solids (°Brix)
Total soluble solids of liquid jaggery decreased from 72.15°Brix on day 0 to 69.86°Brix on day 120. This decline suggests the utilization or transformation of soluble sugars and compounds during storage. This change likely due to moisture absorption and chemical changes during storage. The findings align with previous studies by Halde *et al.* (2019) [7] and Patil and Anekar (2014) [12].

Reducing sugars%
Reducing sugars of liquid jaggery increase significantly from 17.20% on day 0 to 21.14% on day 120. This increase was due to hydrolysis of sucrose into glucose and fructose, facilitated by moisture ingress during storage, which promotes the inversion process. The findings align with the studies of Halde *et al.* (2019) [7] and Patil and Anekar (2014) [12], highlighting the significant impact of storage on the sugar composition of liquid jaggery**.**

Non- reducing sugars%
Non-reducing sugars of liquid jaggery decreased from 43.40% on day 0 to 36.04% on day 120. This reduction was due to increase in reducing sugars, highlighting the enzymatic breakdown of sucrose. The findings align with the studies of Halde *et al.* (2019) [7].

Total viable bacterial count (cfu/ml)
The bacterial count of liquid jaggery rise from 2.6×10^3 cfu/ml on day 0 to 4.3×10^3 cfu/ml on day 120. With the advancement of the storage period, the microbial count was found to have increased for liquid jaggery. This was due to more moisture ingress in the liquid jaggery sample. The rise in moisture content was often associated with the growth of microbial flora (Singh *et al.*, 2007) [6]. This result was also in agreement with Halde *et al*. (2019) [7].

Sensory analysis
The data of effect of storage period on different organoleptic properties of liquid jaggery at room temperature was tabulated in Table.2. The obtained results showed that the sensory evaluation of liquid jaggery during storage revealed a consistent decline in all parameters over the 120-day storage period. Colour and appearance scores were dropped from 8.50 on day 0 to 7.63 on day 120, indicating a gradual loss in visual appeal. Similarly, consistency decreased from 8.75 to 7.63, reflecting changes in the product's texture, likely due to moisture and sugar dynamics. The taste score showed a notable decline from 8.63 to 7.13, suggesting a reduction in sweetness or the emergence of off-flavors over time. The flavour score starting at 8.75 on day 0 and reduced to 7.25 on day 120 highlighting the impact of prolonged storage on the product's sensory profile. Finally, overall acceptability scores declined from 8.66 on day 0 to 7.41 by day 120, indicating a general decline in consumer preference. These results suggest that the product remains acceptable initially while extended storage negatively impacts on its sensory attributes.

Table 2: Effect of storage period on different organoleptic properties of liquid jaggery at room temperature

Parameter	Storage period (days)				
	0	30	60	90	120
Colour and appearance	8.50	8.13	8.00	7.75	7.63
consistency	8.75	8.25	8.13	8.00	7.63
Taste	8.63	8.25	8.13	7.75	7.13
Flavour	8.75	8.00	7.75	7.63	7.25
overall acceptability	8.66	8.16	8.00	7.78	7.41

Conclusion
The study on the storage stability of liquid jaggery prepared at 104°C revealed significant changes in its physicochemical and sensory properties over a period of 120 days at room temperature hence there is need for optimization of the strike point temperature, process parameters and packaging as well as preservation strategies to maintain the quality, safety and sensory appeal of liquid jaggery during storage.

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