Original Research Article

Microbial, Physicochemical and Shelf-life Evaluation of Stored Sugarcane Jaggery in Different Packaging Materials

Abstract

The main problems associated with Jaggery storage are liquefaction and deterioration of properties. The packaging with different packing materials revealed that there was a drastic increase in moisture (15-22%) of Jaggery packed in HDP, while no significant change occurred in % moisture of Jaggery stored under aluminium pouch and LDP environment when compared with fresh Jaggery. The Jaggery stored in glass jars and in HDP, got deteriorated after six months of storage while Jaggery packed under aluminium pouch environment sustained the sucrose, moisture, reducing sugars, titratable acidity, pore space, total microbial count levels as that of fresh Jaggery at room temperature and remained distinctly superior in its overall acceptability. The physico-chemical properties and shelf life of Jaggery under aluminium pouch and LDP were at par with fresh Jaggery samples but the major limitation turned out to be its hardness and consequent lesser acceptability.

Objectives: The present study was undertaken with an objective of evaluating Jaggery's shelf life at room temperatures by packaging under different packing materials to find out that which packing material is better for long storage of Jaggery at room temperature with preserved properties and comparable with fresh Jaggery.

Methodology: Jaggery samples were prepared from sugarcane juice obtained from four certified varieties ('Co 0237', 'Co 0238', 'CoS 767' and 'CoJ 64') in April 2022 and packed under aluminium pouch (AP), Low density polythene (LDP), High Density Polythene (HDP) and glass jars (GJ). The samples were analyzed after six months of storage for their physico-chemical, microbial properties and overall acceptability. Microbial counts for bacteria, mould and yeasts was evaluated using nutrient agar (NAM) and potato dextrose agar (PDA) medium.

Results and Concussions: The traditional way of storage was compared with future storage ways with improved preservation of properties with an eye on better trade practices. It, is suggested that the Jaggery packed in aluminium pouch will have better preserved properties for sale in the market.

Key words: Jaggery, Shelf life, aluminium pouch Packaging, HDP, LDP, microbial evaluation

1. Introduction

Jaggery is a natural sweetener with high content of minerals that has been used for a very long time in traditional medicine. It is sometimes referred to as unprocessed sugar or non-centrifugal sugar (NCS) (Rao and Singh, 2022; Zidan & Azlan, 2022). Jaggery has a long history in the Indian traditional medical system and is used to treat many ailments (Nayaka et al., 2009; Nath et al., 2015). It has significant nutritional properties including antioxidant, and therapeutic qualities and is also used as a functional food. It is rich in protein, minerals, vitamins, carbohydrates, phenolic acid, and other vital nutrients (Iqbal et al., 2017; Sahu & Paul, 1998). Depending on the magnesium content, Jaggery is utilized to help promote the relaxation of muscles and nerves by improving their functioning to reduce weariness (Kumar and Singh, 2020).

The knowledge that Jaggery has many health benefits and is not just a source of sugar has led to a rise in the use and demand for it. Its richness in mineral and vitamin content has increased its export potentials. The issue with Jaggery manufacturing, though, is that it loses texture and colour with time. In current Indian storage conditions, Jaggery to loses its quality (Singh, 2013), especially its crystalline structure, colour, and flavour even when stored properly at room temperature. The microbiological and chemical alterations are linked to the original texture, colour, and flavour loss, which degrade the quality of Jaggery and cause a massive loss for this industry.

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The right packing material should be chosen to protect Jaggery from contamination and moisture gain during storage and transportation in order to prolong the product's shelf life. Due to its low processing, Jaggery has a short shelf life and requires certain storage conditions (Sharifi-Rad, 2023). The shelf life study of Jaggery packaged under specified packaging is important because it identifies the type of packaging that effectively extends the product's shelf life without loss of its quality.

Furthermore, studying storage behaviour of Jaggery in different kinds of packaging materials could reveal elements that contribute to its quick deterioration and, ultimately, provide ideal conditions for storage. Thus, the purpose of this study is to assess the microbiological, physico-chemical, and shelf life of Jaggery in relation to different packaging materials and duration of storage.

2. Materials and methods

2.1 Sample collection, Packaging and storage

Fresh Jaggery samples were prepared from four different certified varieties of sugarcane (‘Co 0237’, ‘Co 0238’, ‘CoS 767’ and ‘CoJ 64’), procured from local small scale Jaggery manufacturing units situated in surrounding areas of Muzaffarnagar, India, a district known for its quality of sugar industry. Jaggery was packed in different packing materials, stored and evaluated for its quality, shelf life and overall acceptability. The fresh Jaggery was analyzed for its physico-chemical and microbial parameters. Initial analysis of Jaggery was carried out in April 2022 and later after six months of storage in September 2022. Samples were packaged at 250 g per packaging material and designated various treatments as: Jaggery packed in Low Density Polyethylene (LDP), Jaggery packed in High Density Polyethylene (HDP), Jaggery packed in glass jar with cover (GJ), Jaggery packed in sealed aluminum pouch (AP) as shown in Fig 1. All samples were kept at ambient temperature and humidity for a period of six months. All treatments were done in triplicate.

Fig. 1: Storage of Jaggery under different packing materials

2.2 Physio-Chemical analysis

The fresh and stored (after six months of storage) Jaggery samples were analyzed for their physico-chemical properties *viz.* % moisture, % sucrose, purity, total sugars, reducing sugars, colour (% transmittance) and pore space as per AOAC methods (1980).

The results are expressed on the dry weight basis (dwb) of Jaggery samples. The pH of aqueous Jaggery solution (0.5N) was measured using pH meter (Labman, India).

2.3 Microbiological analysis and sensory quality

The fresh and stored Jaggery samples were assayed for their Standard Plate Count, Yeast and Mould count as per Food Safety and Standards Authority of India (FSSAI, 2017) using Nutrient Agar medium (NAM) for bacteria and Potato Dextrose Agar (PDA) for mould while Yeast Agar medium was used for isolation of yeasts. The sensory qualities of fresh and stored Jaggery samples were assessed on 100 point scale allotting 20 points each for appearance, colour, texture, flavour, taste and overall acceptability as described by Okolki et al. 1988.

2.4 Statistical Analysis

All obtained data were analyzed using One-Way Analysis of Variance (ANOVA) for storage time at 5% level of significance with the aid of statistical software R.

3. Results and Discussion

Physico-chemical properties of fresh Jaggery

The physico-chemical properties of fresh Jaggery samples are given in Table 1. Sucrose and purity% of Jaggery were higher in samples of variety ‘CoS 767’ and ‘Co 0237’ than Jaggery from ‘Co 0238’ and ‘CoJ 64’ which were at par in terms of sucrose and purity% (Table 1). Per cent reducing sugars were found lesser in ‘CoS 767’ (7.3%) and higher in varieties ‘Co 0237’, ‘Co 0238’ and ‘CoJ 64’. These variations might be attributed to the genotypic differences (Uppal and Sharma, 1999). The transmittance % was highest in ‘CoS 767’ followed by ‘Co 0238’. The minimum transmittance was found in ‘CoJ 64’ (70.2 %). All Jaggery samples were attractive in colour and texture. The Jaggery of ‘CoS 767’ and ‘Co 0237’ was of golden yellow colour with highly crystalline texture while Jaggery from ‘Co 0238’ and ‘CoJ 64’ was of brown colour with less crystalline texture (Table 1, Fig 1).

Comment [DR2]: Provide the graph showing the wavelength as against the transmittance % for a better comparison.

Physico- chemical properties of Jaggery after six months storage

The physico-chemical properties of Jaggery from different genotypes under different packing materials are presented in Table 2. The Jaggery stored in glass jars turned blackish brown and had significantly lower % moisture content than the rest of packaging materials (Table 2, Fig 1). This finding indicates that glass containers are good packaging materials to produce stable Jaggery as moisture content is important determinant of shelf stability of a product (Saska and Kochergin, 2009). The Jaggery stored in HDP also turned dark brown incolour from the initial golden colour but remained free from the fungal growth. There was a drastic increase in % moisture (15-22%) of Jaggery from different genotypes and an increase of 22, 20, 16 and 15 % was recorded in ‘CoJ 64’, ‘Co 0237’, ‘Co 0238’ and ‘CoS 767’ respectively. The colour and texture of Jaggery stored under aluminium pouch and LDP were identical to fresh Jaggery. However, it was found that the Jaggery stored under LDP had turned very hard as compared to fresh Jaggery as well as that stored under the aluminium pouch environment. There was no significant difference in the transmittance% of Jaggery from all genotypes as compared to fresh Jaggery. Mild change, however, occurred in Jaggery of ‘CoJ 64’ (7.8%) under aluminium pouch and 8.8% under LDP. The sucrose content declined drastically (20-28%) in all Jaggery samples irrespective of genotypes. The maximum decline in sucrose content was in Jaggery from ‘Co 0238’ followed by ‘Co 0237’ (25%) and ‘CoS 767’ (22%) with least decline in Jaggery from ‘CoJ 64’. No significant change occurred in % moisture of Jaggery stored under aluminium pouch environment. However, under LDP there was significant decline in % moisture. It decreased by 5.5, 3.9, 3.8 and 3.5 % as compared to 7.3% in fresh Jaggery in ‘Co 0237’, ‘CoJ 64’, ‘CoS 767’ and ‘Co 0238’, respectively. Under LDP condition as the air is removed, the moisture also gets removed (Sharma et al. 2012). This thus helped in maintaining the moisture content and also inhibited the hydrolysis of Jaggery, enhancing its shelf life. The reduction in moisture content under LDP appeared to be responsible for contributing hardness to Jaggery. pH of Jaggery ranged from 6.5 - 6.9 (Table 1). The pH of Jaggery stored in glass jars and HDP turned acidic, however, no significant changes occurred in pH of Jaggery under aluminium pouch and LDP environments (Table 2). The reducing sugar contents in the fresh Jaggery samples were in the range of 5.3 - 8.5%. The reducing sugars increased after six months of storage in glass jars and HDP, which in turn showed maximum increase (Table 2). The reducing sugars content increased significantly in ranging from 12 -20%, the increase being 12.5, 16.2, 19.0 and 20.0 % in ‘CoJ 64’, ‘CoS 767’, ‘Co 0237’ and ‘Co 0238’, respectively. The increase in reducing sugars is attributed to the hydrolysis of sucrose that in turn gets triggered with increased moisture contents and pH. The increase in pH also leads to formation of several undesirable products (Uppal, 2002). Increased reducing sugars and undesirable by-products are responsible for the colour changes and significant reduction in transmittance% in stored Jaggery. The transmittance % in Jaggery declined by 18.0, 15.8, 15.0, and 13.3 % in ‘Co 0238’, ‘CoJ 64’, ‘CoS 767’, and ‘Co 0237’ respectively.

Purity of fresh Jaggery of ‘Co 0237’ was 86.03 %. It declined by 11% when stored in HDP for six months. However, purity% of Jaggery under aluminium pouch packaging

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remained at par with the fresh Jaggery. In Jaggery prepared from 'Co 0238', the initial purity was 85% which underwent a significant decline by 15% in HDP while fresh Jaggery from 'CoS 767' exhibited purity of 90% and declined by 17% in HDP. Jaggery from 'CoJ 64' had 85% purity at the initial stage but declined by 7% plastic bags. Similar changes were observed in % sucrose but no significant changes occurred in sucrose contents of Jaggery samples from all genotypes under aluminium pouch and LDP environments. However, a drastic decline was marked in all Jaggery samples stored in glass jars and HDP. The decline in sucrose contents ranged between 20 -28 %. The purity of Jaggery stored under aluminium pouch and LDP environment remained at par with purity% in fresh Jaggery irrespective of the genotypes. Similarly, no significant changes occurred in % sucrose, % reducing sugar and pH under aluminium pouch and LDP environments (Table 1).

Microbial properties and sensory scores of stored Jaggery

ThemicrobialprofileoffreshJaggerysampleshavebeen compared with that of Jaggerystored under different environmentsforaperiodofsixmonths(Table 3).Thetotal bacterial count increased significantly in Jaggery from all the genotypes but was maximum in 'CoJ 64' and 'Co 0238' (Table 3). The total fungal and ~~thermophillic~~thermophilic counts were also found to have increased significantly in the Jaggery packed in glass jars and HDP. No significant changes in total bacterial, fungal and ~~thermophillic~~thermophilic counts were found in Jaggery from all the genotypes under aluminium pouch and LDP environments as compared to that of fresh Jaggery. The sensory quality of Jaggery stored in different environments has been given in Table 4. The Jaggery stored under aluminium pouch was superior in terms of appearance, clarity of colour and texture followed by LDP. The overall acceptability of LDP stored Jaggery was at par for all the properties except texture as it had turned too hard. On basis of physico-chemical, microbial properties and sensory attributes, it was inferred that Jaggery can be best stored under aluminium pouch packaging. The packaging under glass jar with covers and polythene resulted in deterioration of Jaggery quality as compared with fresh Jaggery. Though under both aluminium pouch and LDP packaging, Jaggery shelf life was maintained for six months but overall acceptability of the aluminium pouch packed Jaggery was superior.

Comment [DR4]: Provide an evidence(citation) to support your assertion that sugar stored in an opaque material has a higher shelf life than in a transparent material.

Conclusions

It may safely be concluded that as long as the Jaggery is stored in a closed packaging material/container of any type, microorganisms have difficulty to survive. The longer the

Jaggery is stored, the more prone, it is for deterioration if the packaging material used cannot prevent entrance of moisture from the environment. Among physico-chemical properties, only sucrose content of Jaggery decreases with storage time. In storage, Jaggery uptakes more moisture, increases its water activity, color and reducing sugar thereby lowering its sucrose content. The most appropriate packaging materials for Jaggery storage are aluminum pouch and LDP plastic based on the evaluated microbial and physico-chemical across storage time. It is recommended to develop a flexible packaging material for Jaggery that has combined properties of aluminum pouch and LDP plastic (350 microns). It is suggested that the Jaggery packed in aluminium pouch will be accepted by consumers easily because of its better preserved properties and will have greater shelf life of storage.

Table1. Physico-chemicalpropertiesoffreshJaggery

Properties (%) / Samples	**'Co 0237'**	**'Co 0238'**	**'CoS 767'**	**'CoJ 64'**
Purity	85 ± 0.12	84 ± 0.11	89 ± 0.16	84 ± 0.13
Sucrose content	91.5 ± 0.15	88 ± 0.13	93.3 ±0.19	84.5 ± 0.09
Reducing sugar	7.4 ± 0.020	7.5 ± 0.02	5.7 ± 0.04	8.8 ± 0.07
Pore space	10 ± 0.16	11 ± 0.19	13 ± 0.11	11 ± 0.09
pH	6.8 ± 0.01	6.5 ± 0.01	6.6 ± 0.12	6.8 ± 0.11
Transmittance (color)	74.8 ± 0.21	75.8 ± 0.53	81.2 ± 0.51	71.3 ± 0.23
Moisture content	5.6 ± 0.09	6.5 ± 0.08	6.4± 0.08	6.9 ± 0.08

Thedatapresentedare mean±standard deviationofthree independent replicates

Table2 Physico-chemicalprofileofJaggeryaftersixmonthsofstorageundervaryingpackagingmaterial

Jaggery	**Packaging material**	**Purity (%)**	**Sucrose (%)**	**Reducing sugar (%)**	**Pore space (%)**	**pH**	**T (%)**	**% Moisture**
'Co 0237'	GJ	75 ±0.8	65±1.2	19±0.2	6.7±0.04	5.9±0.02	60.5±1.23	20±0.05
	HDP	78 ±0.7	69±0.9	17±0.1	6.8±0.07	5.6±0.01	65.5±1.6	2±0.06

	AP	84±0.02	88±0.9	15±0.1	11.6±0.06	6.8±0.03	73.8±0.93	5.5±0.06
	LDP	82±0.3	91±0.83	15.5±0.2	10.9±0.04	6.9±0.04	72±0.83	2.4±0.08
‘Co 0238’	GJ	70±1.35	60±0.89	20±0.06	2.3±0.06	5.48±0.23	55.8±1.25	26±0.74
	HDP	71±1.3	62±0.8	21±0.05	2.7±0.03	5.4±0.2	57.3±1.3	27±0.87
	AP	83±1.25	86±0.92	5.6±0.04	13.3±0.45	6.7±0.34	73.2±1.08	6±0.08
	LDP	81±1.01	81±0.84	18±0.78	12.3±0.04	6.5±0.12	72±1.06	3±0.03
‘CoS 767’	GJ	73±1.04	68±1.51	6.3±0.05	5.5±0.03	4.5±0.02	58.2±1.12	25±0.67
	HDP	74±1.02	66±1.2	6.4±0.01	5.8±0.04	4.7±0.06	57.4±1.16	23±0.61
	AP	89±1.13	90±1.78	7.2±0.06	11.9±0.04	6.9±0.03	78.2±1.04	5.5±0.06
	LDP	82±1.12	25±0.89	6.3±0.05	10.7±0.23	6.6±0.05	78±1.02	2.5±0.06
‘CoJ 64’	GJ	78±1.02	83±1.34	9.5±0.06	2.9±0.02	4.8±0.02	58±1.02	22±1.11
	HDP	77±1.1	84±1.3	9.6±0.05	2.5±0.06	5.1±0.02	60±1.2	20±1.3
	AP	81±1.03	80±0.97	9.3±0.05	10.7±0.04	6.3±0.04	66.6±1.11	5.3±0.96
	LDP	79±1.23	75±0.95	8.2±0.02	11.1±0.06	6.3±0.0	65±1.04	1.9±0.02

GJ=glass jar;HDP= High density polythene (350 microns); AP=aluminium pouch; LDP = low density polyethene (100 microns). Thedatapresentedare mean±standard deviationofthreereplicates

Table 3. Microbial profile of fresh and stored Jaggery samples

		After 6 months of storage			
(CFU/g)	**Packaging Material**	**Co 0237**	**Co 0238**	**CoS 767**	**CoJ 64**
Standard Plate Count	Fresh	$2.4x10^5$	$2.2x10^5$	$2.0x10^5$	$1.8x10^5$
	LDP	55	55	55	55
	HDP	100	155	120	203
	GJ	100	110	95	150
	AP	57	50	50	55
Mould Count	Fresh	11.67	12.58	13	14.50
	LDP	15.2	15	15	16.54
	HDP	10.67	9.76	8.4	10.67
	GJ	16.7	14.33	15	16.89
	AP	7.5	9.55	7.3	7
Yeast Count	Fresh	50	40	55	75
	LDP	0	0	5	5
	HDP	15	15	0	0
	GJ	50	55	55	80
	AP	15	15	10	10

Table 4. Sensory attributes of Jaggery stored for six months under different packaging

Sensory Attributes		Packed Jaggery (after 6 months)				CD (P<0.05)
	Fresh	**GJ**	**HDP**	**AP**	**LDP**	
Appearance	16	4	4.5	15	15	0.7
Clarity	15	4	4.5	19	17	1.3
Colour	16	6	6.5	15	15	1.9
Flavor	15	9	11.5	14	12	1.1
Taste	17	9	9	15	16	0.9
Texture	10	9	8	7	7	0.2

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