Assessment of Microbial, Physicochemical and Shelf-life of Sugarcane Jaggery Stored in Various Types of Packaging Materials

Abstract

The main problems associated with Jaggery storage are liquefaction and deterioration of properties. When compared to fresh Jaggery, the packaging using various packing materials showed that there was a marked increase in moisture (15–22%) in the Jaggery packed in HDP, but no discernible change in the percentage of moisture in the Jaggery stored in an aluminium pouch and LDP environment. After six months of storage, Jaggery kept in glass jars and HDP began to degrade, but Jaggery packed in aluminium pouches maintained levels of sucrose, moisture, reducing sugars, titratable acidity, pore space, and total microbial count comparable to fresh Jaggery at room temperature, and it continued to be significantly improved overall. The hardness of the Jaggery, which led to its lower acceptability, proved to be its main drawback. However, the physico-chemical characteristics and shelf life of the Jaggery under aluminium pouch and LDP were comparable with fresh Jaggery samples.

Objectives: The Jaggery industry is one of the largest and oldest in India, and the region in the north is known as the "sugar belt." However, small farmers face significant challenges in storing their Jaggery, which forces them to sell their product at a reduced price during the sugarcane season because it spoils quickly during rainy seasons. The goal of the current study was to evaluate the microbial, physicochemical, and shelf life of sugarcane Jaggery stored in various types of packaging material at room temperature. This was done to determine the impact of different packing materials with preserved properties comparable to fresh Jaggery, as the traditional method of storing Jaggery in villages reduces the product's market value and acceptability by causing microbial spoilage and bad odour.

Methodology: In April 2022, Jaggery samples were made using sugarcane juice from four certified genotypes (Co 0237, Co 0238, CoS 767, and CoJ 64). The samples were then packaged in glass jars (GJ), aluminium pouches (AP), and low- and high-density polythene (LDP) bags. After being stored for six months, the samples were examined for physicochemical, microbiological, and general acceptability characteristics. Using potato dextrose agar (PDA) and nutritional agar (NAM) medium, microbial counts for bacteria, mould, and yeasts were assessed.

Results and Conclusions: The traditional way of storage was compared with future storage ways with improved preservation of properties with an eye on better trade practices. It was found that the Jaggery packed in aluminium pouch showed better preserved properties comparable to fresh 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) [1,2]. Jaggery has a long history in the Indian traditional medical system and is used to treat many ailments [3,4]. It is utilised as a functional food and possesses important nutritional benefits, such as antioxidant and medicinal qualities. Protein, vitamins, minerals, carbs, phenolic acid, and other essential nutrients are abundant in it [5,6]. Jaggery is used to help encourage muscle and nerve relaxation by enhancing their functionality to lessen fatigue, depending on the amount of magnesium it contains [7].

The use and demand for Jaggery have increased as a result of the realisation that it offers numerous health benefits and is more than just a sugar substitute. Its potential for export has expanded due to its excellent mineral and vitamin content. The problem with Jaggery production, though, is that with time, its texture and colour fade. In current Indian storage conditions, Jaggery loses its quality [8], 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.

Farmers typically store Jaggery in the open, but within two to three months, microbial attack, moisture absorption, and unpleasant taste cause it to degrade. Farmers are forced to sell their stockpiled Jaggery when it is freshly made since its market value decreases. There are several techniques for storing food for an extended period of time. One popular technique is to utilise moisture and oxygen absorbers, but these are expensive and need the farmers to pay for the storage of Jaggery in three layers under vacuum [9].

As a result, food technologists are assessing several less expensive ways for farmers to store Jaggery for an extended period of time.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 [10]. 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. Therefore, the goal of this study is to evaluate the shelf life, physicochemicaland microbiological characterization of Jaggery in relation to various packaging options and storage times.

2. Materials and methods

2.1 Collecting, packing, and storing of samples

Four distinct certified sugarcane varieties (Co 0237, Co 0238, CoS 767, and CoJ 64) were used to prepare fresh Jaggery samples. These sugarcane varieties were purchased from nearby small-scale Jaggery manufacturing units in Muzaffarnagar, India, a district renowned for its high-quality sugar industry. Jaggery was kept, packed using various materials, and assessed for acceptability, quality, and shelf life. The physicochemical and microbiological characteristics of the fresh Jaggery were examined. After six months of storage, a second examination of Jaggery was conducted in September 2022, having first been conducted in April 2022.As illustrated in Fig. 1, samples were packaged at 250 g per packaging material and assigned different treatments, such as: Jaggery packed in glass jar with cover (GJ), Jaggery packed in sealed aluminium pouch (AP), and Jaggery packed in low density polyethylene (LDP), high density polyethylene (HDP), and Jaggery packed in HDP. For a duration of six months, all samples were maintained at room temperature and relative humidity.All treatments were studied in triplicates.

Fig. 1: Storage of Jaggery under different packing materials

2.2 Physio-Chemical analysis

According to AOAC methodology [11], the physicochemical parameters of the fresh and stored (after six months of storage) Jaggery samples were examined. These properties included moisture content, sucrose content, purity, total and reducing sugars, colour (% transmittance), and pore space. The dry weight basis (dwb) of the Jaggery samples is used to express the results. Using a pH metre (Labman, India), the pH of an aqueous Jaggery solution (0.5N) was determined.

2.3 Microbiological analysis and sensory quality

According to the Food Safety and Standards Authority of India [12], the fresh and stored Jaggery samples were analysed for their Standard Plate Count, Yeast, and Mould count using Nutrient Agar medium (NAM) for bacteria and Potato Dextrose Agar (PDA) for mould, while yeasts were isolated using Yeast Agar medium. According to Okolki *et al*. [13], the sensory attributes of fresh and preserved Jaggery samples were evaluated using a 100-point rating system, with 20 points awarded for each of the following categories: appearance, colour, texture, flavour, taste, and overall acceptability.

2.4 Statistical Analysis

With the use of statistical software R, all collected data were examined using One-Way Analysis of Variance (ANOVA) for storage duration at the 5% level of significance.

3. Results and Discussion

Small-scale farmers in India use Jaggery as a cash crop and it's an eco-friendly, natural sugar with many health benefits. However, storing Jaggery properly can be a major obstacle to selling it when demand increases. Any commodity's price is determined by the difference between supply and demand, and in northern India, sugarcane is harvested during the winter. The Jaggery is produced by small farmers who are forced to sell it in the neighbourhood market for less money. In order to help small farmers store Jaggery with better preserved qualities that are comparable to or similar to fresh Jaggery without losing its flavour, colour, or sugar content, a number of food technologists are developing improved preservation and storage techniques.

Physicochemical properties of fresh Jaggery

Table 1 lists the physicochemical characteristics of fresh Jaggery samples. Samples of the varieties "CoS 767" and "Co 0237" had higher percentages of sucrose and purity than samples of the varieties "Co 0238" and "CoJ 64," which had comparable percentages (Table 1). The percentage of reducing sugars was seen to be higher in cultivars CoJ 64, Co 0237, and Co 0238 and lower in CoS 767 (7.3%). The genotypic variances may be the cause of these variations [21]. "CoS 767" has the highest transmittance percentage (81.2 ± 0.51), followed by "Co 0238.""CoJ 64" (70.2%) had the lowest transmittance. Every sample of Jaggery had a pleasing hue and feel.While the Jaggery from "Co 0238" and "CoJ 64" was brown in colour and had a less crystalline texture, the Jaggery from "CoS 767" and "Co 0237" was golden yellow in colour.

Physicochemical properties of Jaggery after six months storage

Table 2 displays the physicochemical characteristics of Jaggery from various genotypes packed in various materials. When compared to the other packing materials, the Jaggery kept in glass jars turned blackish brown and had a substantially lower moisture content (Table 2, Fig 1). This research suggests that glass containers make excellent packaging materials for producing stable Jaggery since a product's moisture level plays a significant role in determining how long it will last on the shelf [14]. Though it still didn't have any fungal development, the Jaggery kept in HDP also transformed from its original golden colour to a dark brown one. Jaggery from several genotypes showed a sharp rise in moisture content (15–22%), and increases of 22, 20, 16, and 15% were noted in "CoJ 64,""Co 0237,""Co 0238," and "CoS 767," respectively. The texture and colour of the Jaggery kept in the aluminium pouch and LDP were exactly like those of the fresh Jaggery. But compared to fresh Jaggery and Jaggery kept in an aluminium pouch, it was discovered that the Jaggery kept under LDP had become extremely hard. When compared to fresh Jaggery, there was no discernible variation in the transmittance% of Jaggery from any genotype. However, Jaggery of "CoJ 64" under aluminium pouch changed somewhat (7.8%) and under LDP, slightly (8.8%).despite the genotype, the sucrose level fell sharply (20–28%) in all of the Jaggery samples. The Jaggery from "Co 0238" had the greatest decrease in sucrose content, followed by "Co 0237" (25%) and "CoS 767" (22%) with the least amount of reduction from "CoJ 64." The percentage of moisture in the Jaggery kept in the aluminium bag environment did not change significantly. Nonetheless, the percentage of moisture significantly decreased with LDP. In comparison to 7.3% in fresh Jaggery in "Co 0237,""CoJ 64,""CoS 767," and "Co 0238," it dropped by 5.5%, 3.9, 3.8, and 3.5%, respectively. Moisture is eliminated under LDP conditions together with the air [15].

As a result, the moisture content was preserved and the shelf life of the Jaggery was increased by inhibiting its hydrolysis. Hardness in Jaggery seemed to be influenced by a decrease in moisture content under LDP. The pH range of Jaggery was 6.9 to 6.5 (Table 1). Although the pH of the Jaggery in glass jars and HDP became acidic, the pH of the Jaggery in aluminium pouch and LDP environments did not significantly alter (Table 2). The fresh Jaggery samples had decreasing sugar levels ranging from 5.3 to 8.5%. After six months of storage in HDP and glass jars, the reducing sugars rose, exhibiting the highest rise (Table 2).The level of reducing sugars rose dramatically between 12 and 20 percent; the increases were 12.5, 16.2, 19.0, and 20.0% in the cases of "CoJ 64,""CoS 767,""Co 0237," and "Co 0238," respectively. The hydrolysis of sucrose, which is induced by higher pH and moisture concentrations, is thought to be the cause of the rise in reducing sugars. A number of unwanted compounds are also formed as pH rises [16]. The colour changes and marked decrease in transmittance percentage in stored Jaggery are caused by increased reducing sugars and unwanted by-products. In Jaggery, the transmittance percentage fell by 18.0, 15.8, 15.0, and 13.3% in the cases of "Co 0238,""CoJ 64,""CoS 767," and "Co 0237," respectively.

The fresh Jaggery from "Co 0237" had a purity of 86.03%. After six months of storage in HDP, it fell by 11%. Nonetheless, the percentage of pure Jaggery in aluminium pouch packing stayed consistent with that of fresh Jaggery. While fresh Jaggery from "CoS 767" showed a purity of 90% and fell by 17% in HDP, Jaggery prepared from "Co 0238" had an initial purity of 85% and had a considerable decline of 15% in HDP. At the beginning, the purity of the Jaggery from "CoJ 64" was 85%, but it decreased by 7% in plastic bags. Under aluminium pouch and LDP conditions, similar alterations were seen in the percentage of sucrose, but no significant changes were seen in the sucrose contents of Jaggery samples from all genotypes. Nonetheless, all of the Jaggery samples that were kept in glass jars and HDP showed a noticeable drop. The percentage of sugar content decreased by 20–28%. Regardless of genotype, the purity of Jaggery held in an LDP environment in an aluminium pouch remained equivalent to the purity percentage of fresh Jaggery. Likewise, in the aluminium pouch and LDP, there were no appreciable variations in the percentages of sucrose, reducing sugar, and pH (Table 1).

Microbial properties and sensory scores of stored Jaggery

Table 3 presents a comparison of the microbiological profile of fresh Jaggery samples with samples that were kept in various treatments for a duration of six months. From all genotypes, the overall bacterial count increased dramatically in Jaggery, with the highest count seen in "CoJ 64" and "Co 0238" (Table 3). Additionally, it was discovered that the Jaggery packaged in glass jars and HDP had much higher total fungal and thermophillic counts. When comparing the total bacterial, fungal, and thermophillic counts of fresh Jaggery to those from all genotypes in aluminium pouch and LDP, no discernible changes were observed. Table 4 lists the sensory quality of Jaggery that has been preserved in various treatments.The Jaggery that was kept in an aluminium pouch had a better look, more vibrant colour, and a smoother texture than LDP. With the exception of texture, which had become too hard, the general acceptability of LDP-stored Jaggery was comparable. Based on physicochemical, microbiological, and sensory characteristics, it was concluded that aluminium bag packaging is the most suitable for storing Jaggery. The utilisation of polythene and glass jars for packaging caused the quality of the Jaggery to decline in comparison to that of fresh Jaggery. While the shelf life of Jaggery was maintained for six months under both aluminium pouch and LDP packaging, the general acceptability of the Jaggery packaged in aluminium pouches was higher. Chandra Surya Rao *et al* [17] reported that storage of palmyrah Jaggery in low density polethene-50 (LDPE-50) in cold storage preserved the physiochemical properties and quality for a longer period. The storage at 2°C facilitated the better preservation of reducing sugars, soluble solids and phenolic content. Longer preservation of juice and gur without chemical preservatives is the requirement of health conscious people especially in post Covid-19 era and the storage of palm juice and gur in painted earthen pots extended the shelf life of gur while the storage of gur under open yielded high microbial activity [18]. Sankhla [19] found that the Jaggery packed in LDPE pouch and subjected with irradiation and stored at room temperature yielded no significant variations reducing sugars, sucrose, viable bacterial counts, yeasts and mold while the control samples showed high microbial activity and poor taste with foul smell. Chand et al [20] recommended the use of edible coatings active packaging to maintain dry conditions during long storage of Jaggery cubes. Uppal and Sharma [21] evaluated different methods of packaging of gur under subtropical conditions and observed that packaging in LDPE protect the Jaggery against the microbial spoilage and preserve better moisture content. Our results, thus, suggest that the packaging of Jaggery in aluminium pouch can enhance the shelf life of Jaggery with preserved properties comparable to fresh.

Conclusions

It is reasonable to say that bacteria struggle to survive when Jaggery is kept in any kind of closed container or packing material. The longer Jaggery is kept in storage, the more likely it is to deteriorate if the material used for packaging cannot keep moisture from the environment out. The sole physicochemical property of Jaggery that declines with storage time is its sucrose concentration. When Jaggery is stored, it absorbs more moisture, becomes more water-active, changes colour, and reduces sugar, which lowers the amount of sucrose it contains. Based on the assessed microbiological and physicochemical over storage duration, aluminium pouches and LDP plastic are the best packaging materials for Jaggery storage. It is suggested to create a flexible Jaggery packaging material with the qualities of an LDP plastic (350 microns) pouch mixed with aluminium properties. It is thought that because the Jaggery in the aluminium bag is better kept and has a longer shelf life, consumers will accept it more readily.

Table1. PhysicochemicalpropertiesoffreshJaggery

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 (%)	7.42 ± 0.2	7.55 ± 0.2	5.72 ± 0.4	8.80± 0.7
Porosity	10 ± 0.16	11 ± 0.19	13 ± 0.11	11 ± 0.09
pH	6.8 ± 0.1	6.5 ± 0.01	6.6 ± 0.12	6.8 ± 0.11
Color (%T)	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

Data is depicted as mean (m)±SD of three replicates

Table 2 Physico-chemical profile of Jaggery (after six months of storage) in various packaging material

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). Data is depicted as mean (m) ± SD of three replicates

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	2.41x10^5	2.23x10^5	2.04x10^5	1.81x10^5
	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 in various 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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