International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(3): 410-416

Received: 09-03-2019
Accepted: 13-04-2019

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Study of traditional Indian sweetener 'Jaggery' and its storage behavior

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Abstract
Sugar cane juice (*S. officinarum*) based solid jaggery, jaggery obtained from sap of the palms like date palm (*Phoenix sylvestris* Roxb.), palmyra palm (*Borassus flabellifer* L.), coconut palm (*Cocos nucifera* L.) are consuming in India as a sweetener. Solid jaggery and liquid jaggery obtained from sugarcane juice (SJ), powder jaggery obtained from coconut palm (CP), date palm based solid jaggery (DP) and solid jaggery cubes obtained from palmyrah palm (PP) were kept at room temperature (23-25ºC) and at low temperature (6 to 8ºC) for determining their better shelf life. Moisture content, pH, and reducing sugars were estimated for shelf life study. Results revealed that solid jaggery (SJ) stored at low temperature was found more acceptable after storage of 1 year as compared to jaggery stored at room temperature. Liquid jaggery (SJ) stored in pet bottles at refrigerated conditions was found more acceptable after 4 months as compare to room temperature. DP based Jaggery stored at low temperature found acceptable after 8 months as compare to room temperature. Solid jaggery cubes obtained from PP stored at low temperature showing 2 month shelf life as compared to room temperature jaggery which shows deterioration after 20 days. Powder jaggery obtained from CP stored at low temperature found to be more acceptable after 6 months as compared to room temperature. With increase in storage time there is decrease in quality of jaggery; as compare to room temperature, jaggery stored at low temperature having a good shelf life.

Keywords: storage; different types of jaggery; jaggery; low storage temperature

Introduction
Jaggery is also known as gur in north India and velllum or bellam in soutn India. It is having different names in different location depending upon its sources (Table 1). Jaggery is a natural, traditional sweetener, prepared by concentrating the sugarcane juice, sap obtained from the coconut palm, date palm, palmyra palm or toddy palm. Jaggery is a traditional unrefined non centrifugal sugar mostly consumed in Asia, Africa, Latin America and the Caribbean. Because of its minerals and vitamins contents as present in sugarcane juice, it is known as healthiest sugar in the world. Generally its colour varies from golden yellow to golden brown. Jaggery prepared from sugarcane juice having lighter color comparing to other jaggeries obtained from sap. Mineral like magnesium present in jaggery strengthens human nervous system and helps to relax body muscles, gives relief from fatigue and takes care of blood vessels. It also acts as an antioxidant along with selenium, having property to scavenge free radicals from our body. Jaggery contains potassium and low amount of sodium which helps to maintain the acid balance in the body cells, and also combats acids and acetone and controls body blood pressure. Jaggery is called as rich source iron which helps to prevent anemia. Because of its anti-allergic properties it helps to relief tension and takes care of asthma (Kumar *et. al*., 2013, Singh *et. al*., 2011) [6, 16].

The quality and price of jaggery is depends upon its external features like color and texture. A best quality jaggery is judged by its features like golden yellow in color, hard in texture, crystalline structure, and its unique sweet taste, less in impurities like molasses and some crystals and low in moisture. The quality of jaggery is affected by many factors such as the variety of sugarcane grown (organically or conventionally), fertilizers used (natural or chemicals), quality of irrigation of water in particular soil region and the method of clarification (naturally available plant based clarifying agents or chemicals), processing time, storage condition and packaging methods adopted. For marketing point of view grading of jaggery is done as grade I jaggery and grade II jaggery based on its physical quality parameters like colour and texture, and chemical quality parameters like sucrose content, reducing sugar, moisture, water insoluble material, etc (Kumar *et. al*., 2013) [6].

Generally, in market jaggery is available in three forms such as solid jaggery, liquid jaggery and granular jaggery. In India, solid jaggery is prepared from sugar cane juice (*S. officinarum*), sap of the palms like date palm (*Phoenix sylvestris* Roxb.), palmyra palm (*Borassus flabellifer* L.), coconut palm (*Cocos nucifera* L.) etc. approximately 80 per cent of jaggery is prepared in the form of solid structure known as solid jaggery and remaining 20 per cent includes liquid jaggery and granular powder jaggery (Vengaiah *et. al*., 2013). Liquid jaggery is also called as 'Kakawi' in some regions of Maharashtra (Nath *et. al*., 2015) [8]. During concentrating the sugarcane juice, when solid content reaches around 60-70º Brix with a corresponding temperature of 105-108º C, the intermediate product is collected which is popularly known as liquid jaggery. The temperature and concentration is depends upon different varieties of cane and agro-climatic zones (environmental conditions in which cane grows). For the preservation of liquid jaggery preservatives like benzoic acid (0.1 %) and citric acids (0.5 %) are added which increase shelf life and also used to check crystallization. In most of the parts of Maharashtra, Gujarat, Kerala, Andhra Pradesh, West Bengal and Tamil Nadu liquid jaggery is used as a part of diet and also it has being 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. The powder or granular jaggery is also used as a sweetening agent particularly in rural regions. The granular jaggery is prepared from the sugarcane juice as well as the sap of date palm, coconut trees. During preparation of granular jaggery pH of juice or sap is adjusted to 6.0 – 6.2 by adding lime solution followed by boiling and clarification simultaneously using natural clarifying agent as deola (*H. ficulneus*) mucilage. The optimum temperature for manufacturing powder jaggery ranges between 120 and 122ºC (Rao *et. al*., 2007; Sridevi, 2008 and Singh *et. al*., 2011) [12, 19, 16]. The hot molten mass of jaggery is allowed to cool in the cooling pan for 5 -10 minutes without stirring for small crystal and slurry formation. The semi cooled mass containing seed crystals is then transferred from pan to aluminium tray and the mass is converted into granules by applying severe shearing action using wooden or stainless steel scrappers. Because of this shearing action the maximum surface get expose to atmosphere results in faster cooling rate and increase in moisture evaporation. For fine granular particle size the obtained mass is then dried to the moisture level of 1-2 % and after drying it is sieved through 3 mm size sieve. As it is hygroscopic in nature the powder jaggery is packed into moisture proof polyethylene-polyester laminates and PET bottles (Singh *et. al*., 2013) [6].

Need to preserve jaggery

The shelf life and keeping quality of jaggery mostly depends on the atmospheric humidity and temperature condition in which it is stored. In most of the cases Jaggery is spoiled due to higher humidity present in the atmosphere during monsoon season. Jaggery storage is difficult because of the presence of invert sugars and mineral salts which are hygroscopic in nature. The non-sucrose constituents present in jaggery such as glucose, fructose and protein, etc. generates hygroscopicity. For long term storage, moisture content of jaggery should not exceed 6% and relative humidity should be 43-61% (Mandal *et al*. 2006) [7]. In India near coastal region the atmospheric humidity is very high as well as the higher rainfall during monsoon, in such a climatic condition it is very difficult to store jaggery for long period. Because of such climatic condition about 5-10 % of stored jaggery get spoiled every year leading to a huge losses.

As the jaggery absorbs moisture from the environment it gives favourable conditions for growth of different types of bacteria and fungi which leads to the production of alcohols, organic acids and complex decomposition products. In fresh sugar cane juice yeast and contaminating microorganisms *viz*., *Leuconostoc mesentroides, Leuconostoc dextranicum, Aerobactor arogenes,* and *Bacillus mesenteries* have been identified (Owen, 1990, Singh *et. al*., 2009) [14]. Hence it is very important to take care of Jaggery manufacturing plant and post-harvest quality management of jaggery, because it is consumed in large scale by rural masses.

In India, the jaggery is stored in godowns at producer/ farmer level, household kitchens which are very poor storage systems where environmental conditions are unhygienic, which gives favourable conditions for growth of microorganisms, because of such conditions several pathogenic and non-pathogenic microorganisms get attracted. In India jaggery is kept as it is in room temperature or traditionally it stored in matka, gunny bags in the western and eastern region of country (Kumar & Kumar, 2018) [5]. In present study different types of jaggery is used to check their storage life at low temperature and at room temperature and its physiochemical characteristics analyzed during storage.

Materials and Method

In the present experiment storage study of different types of jaggery is done. Solid jaggery from sugar cane juice, sap of date palm, sap of Palmyra palm and powder jaggery from coconut palm sap are packed in a polyethylene pouches while fresh liquid jaggery filled in pet bottles. Samples are kept at room temperature (23-25º C) and at low temperature (6-8º C) in refrigerator with three replications.

SJ1 Sugarcane based solid jaggery stored at room temperature
SJ2 Sugarcane based solid jaggery stored at low temperature
LJ1 Sugarcane based liquid jaggery stored at room temperature
LJ2 Sugarcane based liquid jaggery stored at low temperature
DP1 Date palm based solid jaggery stored at room temperature
DP2 Date palm based solid jaggery stored at low temperature
PP1 Palmyra palm based solid jaggery stored at room temperature
PP2 Palmyra palm based solid jaggery stored at low temperature
CP1 Coconut palm based granular jaggery stored at room temperature
CP2 Coconut palm based granular jaggery stored at low temperature

The stored jaggery under different temperature was analyzed for parameters like moisture content, reducing sugar (glucose), non-reducing sugar (sucrose), microbial load and colour.

Analysis of quality parameters

The moisture content of the solid jaggery samples and granular jaggery was determined by using the method of AOAC (1990). For liquid jaggery sample moisture content was determined by vacuum oven method. A 10 g of the sample was weighed and placed into a pre–weighed crucible and then dried at 105ºC till the dryness occurs (Patil, 2014). Reducing sugars and sucrose content of all samples were determined by the method of Lane and Eynon (AOAC 1965).

For estimating viable bacterial, yeast and mold count in all jaggery samples dilution plate method was followed. For bacterial estimation, plate count agar was used and for yeast and mold potato dextrose agar was used (Krishnakumar and Devadas 2006) [4]. PH of N/2 jaggery solution was determined by glass electrode pH meter. By using colorimetry method colour of samples as % Transmittance of N/2 jaggery solution is recorded at 540 mm as given by Mandal and co-workers (Mandal *et al*. 2006) [7].

Sensory analysis

The effects of storage conditions on jaggery were assessed by a semi-trained panel comprised of faculty members and research scholars of 22-40 age group. Panelists evaluated the different types of jaggery samples based on the attributes of overall acceptance, colour, texture, hardness, taste, sweetness and after taste using 9-point hedonic scale (1- dislike extremely to 9 – like extremely). Samples were served in plates. Each sample was served in triplicate and rounded off mean scores were recorded. The scores of sensory attributes for different types of jaggery have been graphically represented with the help of radar chart (Nayaka *et. al*., 2015) [9].

Statistical analysis

The result obtained during the analysis was subjected to statistical analysis was done using IBM SPSS software version 20.0 (Armonk, NY: IBM Corp, 2011). The statistical analysis was done using Analysis of Variance (ANOVA) at significant level $p<0.05$.

Result and Discussion

Fresh jaggery obtained from different sources was analyzed for its physico-chemical, nutritional and microbiological properties before storage. During estimation the values for moisture content, pH, reducing and non-reducing sugars, colour, total viable bacterial, yeast and mold count are calculated for different types of jaggery (Table 2).

Moisture content and pH

The results revealed that moisture content of solid jaggery stored at room temperature (SJ1) significantly increased during the initial storage period of 120 days (September to January) due to the increase in relative humidity and decrease in temperature which causes the moisture migration into the sample from atmosphere. After 120 days as temperature increases there was decrease in relative humidity and film permeability so decrease in rate of moisture migration during 120-270 days (January to June) period of storage. After 270 days as the temperature decreases, moisture migration increases during July to September. Same phenomenon of moisture migration occurs with jaggery stored at low temperature (SJ2) but having good quality compared to SJ1. At low temperature rate of moisture migration significantly low compared to room temperature.

In case of liquid jaggery stored at room temperature (LJ1) there was significant ($P<0.05$) increase in moisture content from 19.5% to 20.79% during September to March. While in case of liquid jaggery stored at low temperature there was significant ($P<0.05$) increase in moisture content from 19.5% to 20.09% during September to March. Date Palm based jaggery revealed same results as solid jaggery when stored at room temperature, while palmyrah palm based jaggery shows deterioration after 2 months as it started liquefaction at room temperature. Coconut palm based powder jaggery stored at room temperature (CP1) revealed that there was significant ($P<0.05$) increase in moisture content from 2.34% to 3.09% during September to April. While CP2 shows less significant increase in moisture content from 2.34% to 2.85%. All results are tabulated in Table 3. The results revealed that there is significant ($P<0.05$) decrease in pH in all types of jaggery stored at room temperature as storage time increases (Table 3). While in case of jaggery stored at low temperature there was a slow decrease in pH compared to room temperature. It may be because of change in chemical composition in the jaggery during storage.

Reducing sugar and non-reducing sugar

The results revealed that there was significant ($P<0.05$) effect of storage conditions and storage period on reducing sugar of different types of stored jaggery. Jaggery stored at low temperature showed less significant increase in reducing sugar as compared to jaggery stored at room temperature. The maximum value of reducing sugar is observed as 18.5 % for SJ1 after 1 year storage. This is because of hydrolysis of sugars. Same results were observed for all types of jaggery (Table 4). While in case of powder jaggery the reducing sugar changed from 9.23 % to 14.5% at room temperature during 6 month storage. The jaggery packed in polyethylene bag prevents the inversion and running phenomenon or liquefaction of the jaggery (Mandal *et. al*., 2006, Shinde *et. al*., 1983) [7, 13]. Same observations observed during the study, there was less decrease in the non-reducing contents at low temperature compare to room temperature. It was observed that all samples kept at different storage conditions except in case of palmyrah palm based jaggery (Table 4). PP1 shows the running behaviour of jaggery after 20 days at room temperature and showed significant decrease in non-reducing sugar content within 1 month compared to PP2 jaggery stored at low temperature.

Colour

The results revealed that there was significant ($P<0.05$) effect of storage conditions and storage period on colour of different types of stored jaggery (Table 5). The jaggery stored at room temperature showed significant decrease in colour from 58.42% to 45.25% due to oxidation during 1 year of storage. While liquid jaggery (LJ1) stored at room temperature showed darker colour compare to LJ2 stored at low temperature. In case of CP2 result showed less significant decrease in colour compared to CP1.

Total viable bacterial count and total viable yeast and mold count

As the moisture content increases during the storage time it creates favorable conditions for microbial growth. In the solid jaggery SJ1 sample showed significant increase in total viable bacterial count from 2.16×10^6 cfu/g to 6.8×10^6 cfu/g during the storage period of 1 year. In case of liquid jaggery, date palm based jaggery and palmyrah palm based jaggery shows more value compared to solid jaggery (Table 6). While in case of coconut palm based granular jaggery (CP2) the results revealed that there was a significantly less total viable bacterial count from 0.54×10^6 cfu/g to 1.53×10^6 cfu/g compare to CP1.

The results revealed that there was significant ($P<0.05$) effect of storage conditions and storage period on total viable yeast and mold count of different types of stored jaggery. Maximum values observed in case of liquid jaggery, date palm based jaggery and palmyrah palm based jaggery. There

was a significant increase in total viable yeast and mould count in jaggery samples stored at room temperature compared to jaggery stored at low temperature (Chand & Kumar 2018) [3]. (Table 6).

Sensory analysis

Sensory analysis of jaggery showed that jaggery stored at low temperature scored more for texture, colour and taste compared to the jaggery stored at room temperature. Initially after two months of storage sensory analysis was done in that it was observed that all jaggeries scored well except Palmyra palm based solid jaggery due to its deterioration. Hence jaggery based on Palmyra palm did not consider for further analysis. For every 60 days interval sensory analysis was done, liquid jaggery scored less compared to other types of jaggery at the end of 120 days so it was discarded due to unacceptable sensory analysis. Coconut palm based granular jaggery stored at room temperature was scored less for sensory than coconut palm based granular jaggery stored at low temperature at the end of 180 days. Further after 240 days date palm based solid jaggery stored at low temperature shows better result for texture compared to date palm based solid jaggery stored at room temperature. Similar results were observed in case of sugarcane based solid jaggery stored at low temperature than sugarcane based solid jaggery stored at room temperature after 360 days (figure 1).

Table 1: Types of jaggery, its sources and common names in different region.

Sr. No.	Types of jaggery	Source	Common Names	Region
1	Solid jaggery	Sugarcane juice	Gur	North India
			Gul	Maharashtra
			Bella	Karnataka
			Vellum	Tamil Nadu, Malabar
			Bellam	Andhra Pradesh
			Akher Gur	Bengal
2	Liquid Jaggery	Sugarcane juice	Kakavi	Maharashtra
3	Palm Jaggery	sap of palm trees	Panam karkandu	Tamil Nadu
			Nalla bellam,	Andhra Pradesh
			Thaati bellam	
			Panam kalkandam,	Kerala
			Karippatti, Karipetti,	
			Karippotti	
			Ole Bella	Karnataka
4	Date palm jaggery	Sap of date palm	Khejurer gur	Bengal
			Khejura cini	Bangladesh
5	Coconut palm jaggery	Sap of coconut trees	Gula Melakha	Malaysia
			Gula Anau	
			Gula Merah	Indonesia

Source: https://en.wikipedia.org/wiki/Jaggery

Table 2: Physico-chemical characteristics of different types of jaggery before storage.

Parameter	sugarcane based solid jiggery SJ	Sugarcane based liquid jiggery LJ	Date palm based solid jiggery DP	Palmyra palm based solid jiggery PP	Coconut palm based granular jiggery CP
Moisture content %	11.2	19.5	13.2	16.54	2.34
pH	6.8	5.31	6.72	6.21	6.72
Reducing sugar %	11.67	13.72	12.45	13.2	9.23
Non-reducing sugar %	76.32	70.5	74.22	72.5	78.43
Colour (% transmittance at 540 nm)	58.42	51.5	62.34	61.67	42.34
Total viable bacterial count (cfu/g)	2.16×10^6	3.45×10^6	2.92×10^6	2.72×10^6	0.54×10^6
Total viable yeast and mold count (cfu/g)	3.25×10^3	4.5×10^3	3.12×10^3	3.5×10^3	00

Table 3: Effect of storage on moisture content and pH of different types of jaggery samples

Parameters	Storage (days)	SJ1	SJ2	LJ1	LJ2	DP1	DP2	PP1	PP2	CP1	CP2
Moisture content (%)	0	11.2	11.2	19.5	19.5	13.2	13.2	16.54	16.54	2.34	2.34
	30	11.45±0.05	11.2±0.02	19.62±0.06	19.5±0.02	13.77±0.32	13.29±0.12	18.70±0.44	16.67±0.1	2.59±0.06	2.32±0.01
	60	11.72±0.05	11.28±0.06	19.74±0.16	19.61±0.03	14.36±0.4	13.47±0.09	19.68±0.19	17.10±0.11	2.85±0.28	2.35±0.01
	90	12.12±0.16	11.32±0.01	19.79±0.08	19.67±0.04	14.99±0.17	13.57±0.09	-	-	3.04±0.23	2.43±0.01
	120	12.68±0.16	11.43±0.03	20.05±0.1	19.8±0.03	15.53±0.21	13.72±0.05	-	-	3.44±0.29	2.58±0.05
	150	12.64±0.19	11.46±0.03	20.58±0.24	19.84±0.03	17.11±0.22	14.09±0.2	-	-	3.81±0.22	2.72±0.07
	180	11.81±0.34	11.75±0.07	20.79±0.02	20.09±0.21	15.1±0.68	14.19±0.08	-	-	3.55±0.29	2.71±0.06
	210	10.58±0.16	11.88±0.03	-	-	14.09±0.03	14.20±0.05	-	-	3.09±0.03	2.85±0.11
	240	10.38±0.29	11.88±0.09	-	-	15.12±0.33	14.29±0.05	-	-	2.42±0.072	2.92±0.17
	270	9.57±0.22	12.15±0.2	-	-	16.48±0.62	14.21±0.1	-	-	-	-
	300	11.24±0.33	12.39±0.15	-	-	-	-	-	-	-	-
	330	12.6±0.23	12.52±0.04	-	-	-	-	-	-	-	-
	360	15.16±0.18	12.68±0.107	-	-	-	-	-	-	-	-
	F value	**	**	**	**	**	**	**	**	**	**
pH	0	6.8	6.8	5.31	5.31	6.72	6.72	6.21	6.21	6.72	6.72

	30	6.75±0.04	6.78±0.02	5.25±0.07	5.29±0.006	6.70±0.015	6.71±0.01	4.51±0.18	5.32±0.34	6.71±0.01	6.69±0.03
	60	6.73±0.01	6.78±0.02	5.24±0.08	5.29±0.01	6.67±0.03	6.70±0.01	3.15±0.07	4.47±0.24	6.68±0.03	6.61±0.14
	90	6.68±0.02	6.76±0.03	5.15±0.2	5.27±0.015	6.4±0.26	6.67±0.03	-	-	6.56±0.1	6.6±0.13
	120	6.66±0.04	6.74±0.02	5.1±0.16	5.25±0.026	6.37±0.19	6.66±0.05	-	-	6.49±0.23	6.47±0.18
	150	6.45±0.11	6.69±0.02	4.79±0.43	5.19±0.01	5.93±0.2	6.61±0.07	-	-	5.92±0.51	6.43±0.14
	180	6.34±0.14	6.69±0.03	4.78±0.39	5.13±0.03	5.4±0.55	6.57±0.06	-	-	5.47±0.28	6.25±0.34
	210	6.28±0.15	6.66±0.05	4.5±0.32	5.003±0.1	4.58±0.67	6.52±0.09	-	-	5.31±0.14	5.98±0.52
	240	6.18±0.27	6.65±0.04	-	-	4.51±0.51	6.3±0.18	-	-	4.65±0.41	5.78±0.37
	270	6.01±0.46	6.62±0.07	-	-	-	-	-	-	-	-
	300	6.03±0.33	6.61±0.06	-	-	-	-	-	-	-	-
	330	5.94±0.32	6.59±0.08	-	-	-	-	-	-	-	-
	360	5.8±0.3	6.55±0.08	-	-	-	-	-	-	-	-
	F value	**	**	**	**	**	**	**	**	**	**

Mean value ± S.D Values shown in table average of triplicates **-**: Not determined further as sample was unacceptable due to liquefaction
** Significant at 0.05% level of significance

Table 4: Effect of storage on reducing sugar and non-reducing sugar of different types of jaggery samples

Parameters	Storage (days)	SJ1	SJ2	LJ1	LJ2	DP1	DP2	PP1	PP2	CP1	CP2
Reducing sugar (%)	0	11.67	11.67	13.72	13.72	12.45	12.45	13.2	13.2	9.23	9.23
	30	11.76±0.09	11.7±0.03	14.81±0.27	13.76±0.05	12.72±0.14	12.53±0.07	16.14±0.29	14.98±0.2	9.84±0.28	9.47±0.03
	60	12.01±0.28	11.73±0.04	15.69±0.28	13.81±0.03	12.87±0.1	12.58±0.1	18.22±0.26	16.85±0.5	10.21±0.56	9.64±0.05
	90	12.29±0.33	11.83±0.08	17.02±0.2	14.16±0.27	13.22±0.27	12.86±0.06	-	-	10.74±0.48	9.67±0.06
	120	12.67±0.1	12.00±0.29	17.92±0.24	14.57±0.32	13.74±0.26	13.04±0.19	-	-	11.34±0.61	9.84±0.07
	150	13.11±0.39	12.13±0.21	18.25±0.29	15.00±0.18	14.47±0.47	13.47±0.21	-	-	12.03±1.33	10.15±0.06
	180	14.25±0.44	12.48±0.09	-	-	15.92±0.18	13.74±0.08	-	-	13.70±0.46	10.45±0.3
	210	14.7±0.67	12.74±0.07	-	-	16.74±0.07	14.13±0.18	-	-	14.5±0.26	10.62±0.11
	240	15.66±0.51	12.97±0.14	-	-	17.97±0.11	14.47±0.32	-	-	-	-
	270	17.04±0.4	13.57±0.36	-	-	-	-	-	-	-	-
	300	17.55±0.21	14.22±0.4	-	-	-	-	-	-	-	-
	330	18.1±0.16	14.54±0.3	-	-	-	-	-	-	-	-
	360	18.5±0.2	15.1±0.15	-	-	-	-	-	-	-	-
	F value	**	**	**	**	**	**	**	**	**	**
Non reducing sugar (%)	0	76.32	76.32	70.5	70.5	74.22	74.22	72.54	72.54	78.43	78.43
	30	75.5±0.61	75.89±0.37	68.09±0.69	69.8±0.34	73.05±0.32	73.72±0.39	64.88±0.84	70.7±0.85	77.76±0.51	78.14±0.16
	60	75.03±0.6	75.69±0.42	65.95±0.58	68.18±0.32	71.22±0.66	73.29±0.45	62.99±0.89	69.27±0.94	77.45±0.48	78.04±0.07
	90	74.59±0.61	75.26±0.55	64.43±0.81	66.02±0.75	69.83±0.59	72.4±0.71	-	-	76.81±0.58	77.86±0.17
	120	73.64±0.55	74.85±0.78	61.78±0.41	64.15±0.25	69.21±0.85	71.49±0.53	-	-	76.42±0.52	77.67±0.12
	150	73.26±0.55	74.4±0.56	58.86±0.50	62.75±0.91	67.62±0.71	70.65±0.48	-	-	75.98±0.89	77.50±0.13
	180	71.53±0.96	73.52±0.65	-	-	65.84±0.58	69.83±0.51	-	-	75.64±0.58	77.12±0.12
	210	68.32±0.99	73.45±0.95	-	-	64.33±0.49	69.29±0.45	-	-	-	-
	240	66.07±0.79	71.55±0.67	-	-	62.93±0.19	68.58±0.67	-	-	-	-
	270	62.91±0.59	69.77±0.39	-	-	-	-	-	-	-	-
	300	61.84±0.64	68.3±0.29	-	-	-	-	-	-	-	-
	330	60.63±0.48	67.4±0.56	-	-	-	-	-	-	-	-
	360	59.91±0.51	67.73±0.46	-	-	-	-	-	-	-	-
	F value	**	**	**	**	**	**	**	**	**	**

Mean value ± S.D Values shown in table average of triplicates **-**: Not determined further as sample was unacceptable due to liquefaction ** Significant at 0.05% level of significance

Table 5: Effect of storage on color of different types of jaggery samples

Storage (days)	SJ1	SJ2	LJ1	LJ2	DP1	DP2	PP1	PP2	CP1	CP2
0	58.42	58.42	51.5	51.5	62.34	62.34	61.67	61.67	42.34	42.34
30	57.74±0.46	57.89±0.22	52.28±0.37	51.67±0.12	61.33±0.88	61.63±0.55	57.76±0.68	60.43±0.52	42.07±0.06	42.29±0.05
60	57.26±0.45	57.78±0.19	55.83±2.28	51.62±0.07	60.74±0.56	61.25±0.47	56.58±0.66	59.81±0.33	41.81±0.42	42.24±0.10
90	56.44±0.97	56.89±0.61	60.21±1.9	50.99±0.29	59.96±0.28	60.97±0.37	-	-	41.63±0.55	42.17±0.15
120	54.69±0.99	56.53±0.46	64.95±0.55	50.59±0.34	57.98±0.58	60.36±0.45	-	-	41.52±0.47	42.07±0.07
150	52.89±0.44	55.47±0.50	-	-	55.10±0.11	58.78±0.48	-	-	41.37±0.39	41.93±0.06
180	51.02±0.74	55.26±0.48	-	-	54.36±0.45	58.05±0.29	-	-	40.62±0.54	41.73±0.36
210	49.52±0.81	53.96±0.16	-	-	47.51±0.71	56.73±0.36	-	-	-	-
240	47.96±0.73	52.94±0.86	-	-	44.58±0.55	56.19±0.24	-	-	-	-
270	46.46±0.41	50.91±0.61	-	-	-	-	-	-	-	-
300	46.06±0.79	49.92±0.33	-	-	-	-	-	-	-	-
330	45.6±0.52	48.15±0.13	-	-	-	-	-	-	-	-
360	45.25±0.54	47.78±0.49	-	-	-	-	-	-	-	-
F value	**	**	**	**	**	**	**	**	**	**

Mean value ± S.D Values shown in table average of triplicates **-**: Not determined further as sample was unacceptable due to liquefaction ** Significant at 0.05% level of significance

Table 6: Effect of storage on total viable bacterial count (x 10^6 cfu/g) and viable yeast and mold count (x 10^3 cfu/g) of different types of jaggery samples

Parameters	Storage (days)	SJ1	SJ2	LJ1	LJ2	DP1	DP2	PP1	PP2	CP1	CP2
Total viable bacterial count (x 10^6 cfu/g)	0	2.16	2.16	3.45	3.45	2.92	2.92	2.72	2.72	0.54	0.54
	30	2.38±0.02	2.24±0.06	5.14±0.29	4.27±0.3	3.83±0.38	3.11±0.11	7.08±0.22	4.08±0.37	0.99±0.18	0.59±0.02
	60	2.62±0.13	2.49±0.06	6.76±0.6	5.29±0.41	5.15±0.17	3.32±0.12	8.95±0.16	5.02±0.58	1.24±0.34	0.88±0.02
	90	2.69±0.23	2.72±0.19	8.06±0.65	6.28±0.38	6.8±0.31	3.69±0.05	-	-	1.5±0.33	0.96±0.04
	120	3.05±0.12	2.91±0.09	9.19±0.57	7.27±0.25	9.1±0.22	3.88±0.14	-	-	1.74±0.23	1.10±0.1
	150	3.66±0.2	3.1±0.13	-	-	11.13±0.59	4.68±0.18	-	-	2.26±0.45	1.29±0.02
	180	4.02±0.27	3.57±0.19	-	-	12.27±0.57	5.05±0.11	-	-	2.99±0.19	1.53±0.06
	210	4.77±0.97	3.85±0.17	-	-	14.83±0.62	5.48±0.17	-	-	-	-
	240	5.08±0.81	4.1±0.18	-	-	15.73±0.11	5.79±0.2	-	-	-	-
	270	5.51±0.53	4.37±0.27	-	-	-	-	-	-	-	-
	300	6.15±0.55	4.82±0.07	-	-	-	-	-	-	-	-
	330	6.51±0.53	5.08±0.07	-	-	-	-	-	-	-	-
	360	6.8±0.37	5.35±0.08	-	-	-	-	-	-	-	-
	F value	**	**	**	**	**	**	**	**	**	**
Viable yeast and mold count (x 10^3 cfu/g)	0	3.25	3.25	4.5	4.5	3.12	3.12	3.5	3.5	00	00
	30	3.55±0.18	3.36±0.09	6.68±0.42	5.88±0.25	3.74±0.48	3.42±0.23	8.00±0.11	6.16±0.34	0.43±0.08	0.03±0.06
	60	3.74±0.25	3.48±0.03	9.32±0.48	6.96±0.26	4.73±0.64	3.98±0.52	12.03±0.16	7.94±0.41	0.68±0.12	0.19±0.16
	90	4.38±0.33	3.69±0.16	11.16±0.27	7.66±0.15	5.61±0.99	4.52±0.46	-	-	1.58±0.07	0.36±0.05
	120	4.97±0.05	3.84±0.14	13.07±0.47	8.55±0.38	7.03±0.07	4.87±0.33	-	-	1.91±0.10	0.49±0.05
	150	5.67±0.17	3.99±0.12	-	-	8.00±0.11	5.38±0.38	-	-	2.82±0.16	0.85±0.17
	180	5.98±0.14	4.18±0.29	-	-	9.19±0.56	5.83±0.15	-	-	3.90±0.11	1.21±0.20
	210	7.00±0.43	4.52±0.50	-	-	10.55±0.45	6.26±0.38	-	-	-	-
	240	7.61±0.53	4.69±0.51	-	-	13.06±0.18	6.81±0.71	-	-	-	-
	270	8.22±0.11	5.07±0.60	-	-	-	-	-	-	-	-
	300	9.26±0.44	5.43±0.50	-	-	-	-	-	-	-	-
	330	10.27±0.25	5.75±0.55	-	-	-	-	-	-	-	-
	360	10.94±0.41	6.66±0.69	-	-	-	-	-	-	-	-
	F value	**	**	**	**	**	**	**	**	**	**

Mean value ± S.D Values shown in table average of triplicates -: Not determined further as sample was unacceptable due to liquefaction ** Significant at 0.05% level of significance

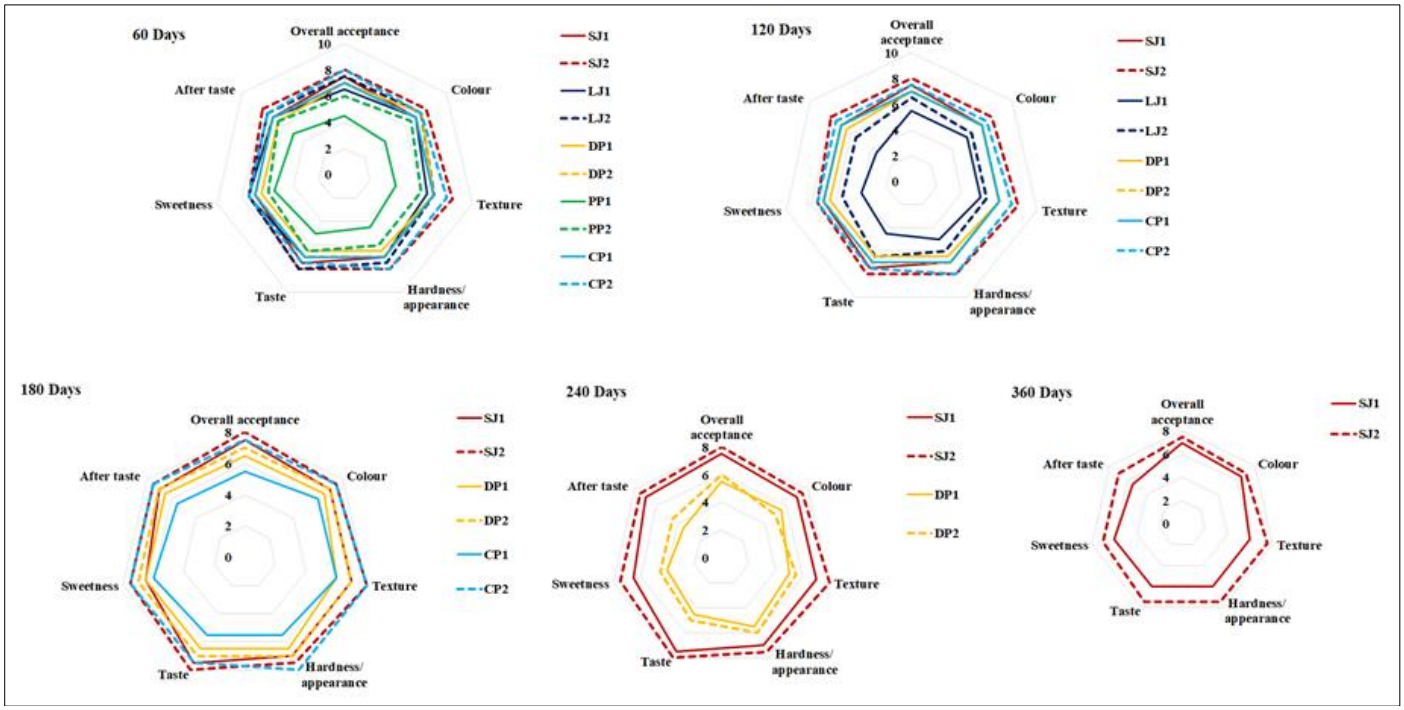

Fig 1: Sensory analysis of different types of jaggery at the end of 60, 120, 180, 240, 360 days

Conclusion

It can be concluded from the facts stated in this research that solid jaggery can be stored at low temperature for more than one year. The quality and colour are the important properties which determine the consumer acceptability towards jaggery. In case of jaggery stored at low temperature, quality and colour are good and acceptable compare to solid jaggery stored at room temperature. During the study, liquid jaggery showed deterioration after 4 months stored at room temperature. While in case of low temperature it was showing

good result than room temperature. In case of jaggery obtained from date palm can be stay longer than 8 months at low temperature which showed little effect on colour but found more acceptable than DP1. Palmyrah palm based jaggery showed very different behaviour than other types of jaggery. At room temperature it showed liquefaction effect after 20 days of storage as increase in moisture content and same effect shown by PP2 after 2 months. From results it can be concluded that palmyrah palm based jaggery can be stay good for a period of 2 months if stored at low temperature. In case of powder jaggery, CP2 showing good quality parameters after 6 months compared to CP1. From the results obtained during study, low temperature helps to extend the shelf life of all kinds of jaggery without adding any preservatives. This can prevent the losses happen during the storage of jaggery. This study can be helpful for the farmers for keeping jaggery quality suitable for consumption as well as for increasing its market value. Further research can be done on the suitable packaging material for increasing shelf life of jaggery.

Acknowledgement: Authors are thankful to Paawak Foods, Mumbai for providing Jaggery for the study.

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