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REVIEW ARTICLE

Alternative Sweeteners Production from Sugarcane in India: Lump Sugar (Jaggery)

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Abstract Importance of sweeteners has long been recognized in Indian diets. Sweetness and flavour are very important as regards consumers' acceptability. The sugar and jaggery are the main sweetening agents which are added to beverages and foods for increasing palatability. Over the years, food habits of human beings have been greatly influenced by research and developmental activities and also due to their health consciousness. Despite witnessing pressure of industrialization, the jaggery industry has flourished in different states of the country viz; Uttar Pradesh, Tamilnadu, Karnataka, Maharashtra and Andhra Pradesh. The increasing trend of their production is of much significance to learn about peoples' liking towards jaggery in rural areas mainly due to it's nutritional and medicinal values. About 25-30% of sugarcane produced in the country is utilized for production of jaggery and *khandsari* and this industry serves as very important means of subsistence and livelihood for masses. The technology and equipment for production of quality jaggery and its value added products have been developed. Due to its nutritional and medicinal values, the jaggery has great export potential in the world.

Keywords Jaggery · Nutritional · Medicinal · Furnace · Clarificants · Storage

Introduction

In India, sugarcane is being processed for making jaggery (*gur*), *rab* (concentrated sugarcane juice), sugar and *khandsari*. *Of these,* jaggery is considered as a food material, as it contains a large quantity of minerals in addition to energy and is consumed directly as sweetener, and also in different preparations including animal feed mixtures (Singh 2001). It is used in Ayurvedic medicines and is considered to be the best of all sugarcane preparations. It has properties of cooling, diuretic, aperient, refreshing, and improving throat conditions and also acts as tonic. It is a natural sweetener of rural areas.

Sugarcane contributes about 90 per cent of the sweeteners' production. About 32 per cent demand of total sweeteners' consumption in the country is met out with jaggery and *khandsari*, mostly in the rural areas. In 2008-09, about 37.2 percent of the total sugarcane produced was processed for making jaggery and *khandsari* (Table 1) (Anonymous 2011).

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Art of Making Jaggery in India

Unit Operations Involved

Jaggery making from sugarcane involves mainly four unit operations viz. extraction of juice, heating and clarification of juice, boiling/concentration of juice and moulding. These operations are described below:

Extraction of Juice

For juice extraction, sugarcane is normally crushed in power operated (engine/electric) vertical/horizontal crushers. These crushers have 3–5 rollers and extract 60–65 per cent juice (cane basis). Crushing of cane yields juice and bagasse. Horizontal roller crushers yield 2–4% more juice compared to vertical roller crushers. Juice extraction

Table 1 Sugarcane production, its utilization for jaggery and *khandsari* in India

Year	Average cane production (million tonnes)	% Utilized for jaggery and *khandsari*
1971–1980	140.09	55.81
1981–1990	185.66	46.31
1991–2000	265.45	37.07
2001–2010	291.37	25.29

depends upon crusher settings, crop parameters and operating conditions.

Heating and Clarification of Juice

The extracted juice is collected through underground PVC pipeline into a juice settling tank covered with thick muslin cloth for removal of trash and bagasse particles. Settling helps in removal of heavy impurities. Clean juice is then pumped into open pan on the furnace for concentration.

The juice is heated in open pan furnace and vegetative clarificants are added into it for its' clarification. These clarificants help in formation of thick froth having colloidal impurities on juice surface, which is removed using strainer. Out of various vegetative clarificants Deola (*Hibiscus ficulneus*) was found to be the most effective (Singh 1998; Banerji 2008). The removed scum is poured in scum settling tank, which helps in recovery of juice going as waste with scum. Introduction of this tank into the prevalent juice clarification process improves jaggery recovery by 0.4% (Baboo 1994) besides light colour and crystalline texture.

Boiling/Concentration of Juice

After clarification, juice is boiled vigorously over the furnace. A little quantity of mustard/coconut oil is added to check excess frothing. Based on requirements of jaggery production, the furnace may have single, two, three, four or five pans. Indian Institute of Sugarcane Research (IISR), Lucknow has developed improved/efficient two-pan (Singh et al. 2009) and three-pan furnaces (Singh 2009) which save bagasse. To further improve the efficiency; pans of two-pan furnace have been modified providing fins to their bottoms which resulted in saving of fuel (28%) and juice processing time (17%) (Anwar 2010; Anwar et al. 2009).

Extra pans are also provided in jaggery making furnaces to further improve the efficiency by trapping waste heat going along flue gases through chimney and are utilized for pre-heating of juice. The triple pan furnace developed at IISR Lucknow possesses these special features which had 34.3% heat utilization efficiency (Singh 2009).

Moulding

The concentrated juice with appropriate consistency is transferred into a wooden tray and puddled using ladle. The concentrate (slurry) is then transferred into the moulds, dried, packed, stored and marketed. The jaggery manufacturing system developed at IISR is shown in Fig. 1. Earlier, jaggery used to be produced by different traditional methods in different shapes and sizes in India which ranged from 15 to 20 kg bucket shape to irregular shapes and varied from place to place. Some of these shapes posed problems in moulding, drying, packaging and distribution etc. To overcome these problems, IISR Lucknow developed moulding frames and the techniques for moulding jaggery into different desired shapes and sizes viz; brick (500 and 250 g), cubes (25 mm cube, weighing 20–22 g each; Fig. 2) and rectangular shapes (25 × 25 × 12.6 mm, weighing about 10–11 g each). Of these, 25 mm jaggery cubes packed in attractive packages are hygienic, helpful in distribution and has become very popular among consumers.

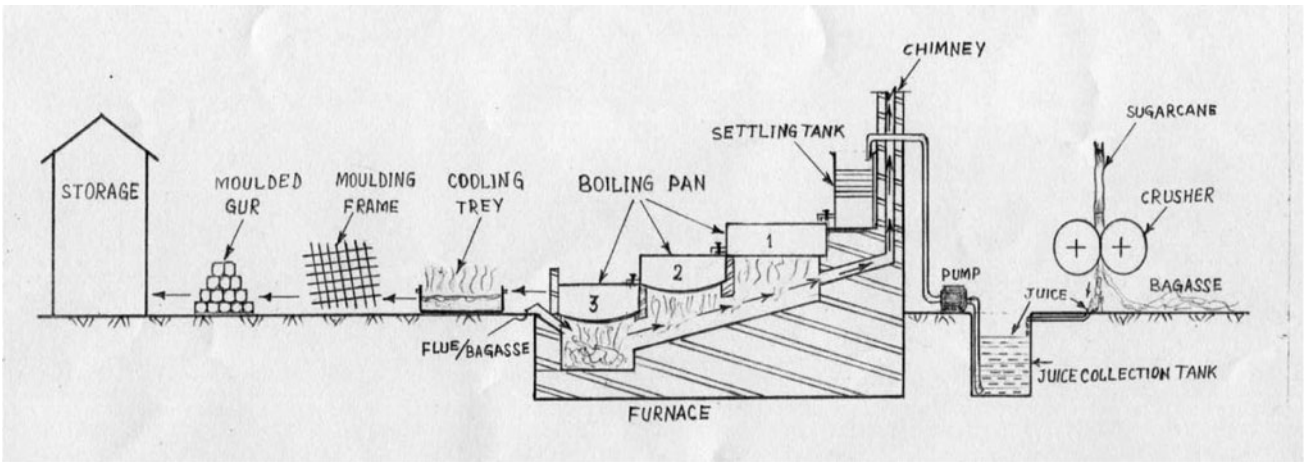

Fig. 1 Jaggery manufacturing system developed at IISR Lucknow

Fig. 2 Jaggery cubes

Storage of Jaggery

While jaggery is produced during winter and autumn, its' demand is throughout the year necessitating its storage during off season. Like other commodities jaggery storage is also done to prevent market glut, uniformity of supply and fetching higher prices. Most important aspect of storage is to preserve the quality of jaggery without affecting taste, flavour, hardness and colour under adequate temperature and humidity conditions. IISR developed an improved drying-cum-storage bin of 100 kg capacity and also a godown of 06 tonnes capacity which have been found suitable for almost all the regions in India. Chand et al. (2011) reported that jaggery stored in IISR jaggery drying-cum-storage bin showed less reduction in quality parameters. Techno economic analysis of cold storage of jaggery revealed that establishment of new cold storage exclusively for jaggery was not feasible economically (Narain and Kulshrestha 2001). However, cold storage made for different produces, if used for storing jaggery was found feasible techno-economically.

Grading of Jaggery

The colour, hardness and texture are important physical characteristics which affect marketing of jaggery. In general, light golden colored jaggery is preferred. But in the market, traders give higher prices to white coloured jaggery prepared using chemical clarificants such as sodium hydrosulfite. Some of the important chemical characteristics of jaggery are taste, flavour, sucrose content, reducing sugars, and moisture content, based on which different systems of jaggery grading have been in vogue. Indian standard for jaggery grading is given in Table 2.

Packaging of Jaggery

Jaggery packed with hessian cloth lined with polyethylene sheet alone or packed with tin foil covered with polyethylene

Table 2 Indian standard for jaggery

Characteristics	Unit	Grade I	Grade II
Sucrose	%, (db), min	80	70
Reducing sugar	%, (db), max	10	20
Moisture	%, (db), max	5	7
Water insoluble matter	%, (db), max	1.5	2.0
Sulphated ash	%, (db), max	3.5	5.0
Sulphur dioxide	ppm (db), max	50	50
Ash insoluble in dilute HCl	%, (db), max	0.3	0.3

IS 12923: 1990

or hessian cloth was found better than wooden and card board boxes, thick gunny bags, plastic containers and earthen pots. Three ply (PET/Al.FOIL/POLY) packaging material helped more in checking the inversion rate. The lowest inversion of 4.35 and 2.67% was recorded with three ply followed by four ply packaging material (4.53 and 3.43%) in Lump (*bheli*) and brick shaped jaggery respectively Singh and Singh (2008). The effect of different packaging materials on keeping quality of jaggery is given in (Table 3, Singh 2008). Similarly the moisture ingress was lowest in three ply (4.70–2.15%) packaging treatment. The opaqueness of three ply packaging material helped in maintaining colour intensity during storage. The three ply packaging material was superior because of higher strength low water vapour transpiration rate (0.14 g/m^2/24 h) and least oxygen transmission rate (207.0 ml/m^2/24 h). Thus, three ply packaging (PET/A1 FOIL/POLY) was found suitable as quality packaging material for solid jaggery and also checked the deterioration during storage. Gupta et al. (2002) observed that nitrogen packaging of solid jaggery maintained freshness for longer period compared to vacuum packaging which hardened the jaggery samples.

Jaggery from Other Sources

Jaggery is also prepared from other sources viz; palm and sweet sorghum. In case of palm jaggery, palm juice is collected, and heated in the pans to 40°C, delimed to neutrality and clarified by adding phosphoric acid or triple super phosphate solution slowly and stirring with ladle. The temperature is then allowed to go to 100° C. At this stage, deliming is complete and juice is collected in the bucket and transferred on to a stretched filter cloth where filtration takes place rapidly and precipitate of calcium diphosphate settles on cloth in the form of thick sediment. As boiling proceeds, the froth/foam is removed from surface with a perforated ladle. As juice concentrates/thickens, the fire is judiciously controlled to prevent it from caramelization. Correct stirring temperature of about 118–120°C is judged by putting a small mass in the water and rolling it into a ball shape. If ball forms into hard one, the strike is over and the mass is removed and poured into moulds.

Table 3 Effect of different packaging materials on keeping quality of jaggery during storage

Sr. No.	Treatment	Reducing sugar (%)		Non reducing Sugars (%)		pH (6.5% soln)		Colour intensity		Moisture content (%WB)	
		Bheli (Lump)	Brick	*Bheli*	Brick	*Bheli*	Brick	*Bheli*	Brick	*Bheli*	Brick
	Initial jaggery analysis	7.14	6.32	80.55	80.51	6.31	6.42	40.08	45.71	5.10	5.10
1.	Jaggery analysis during storage control (without wrapping)	9.78	8.66	69.71 (13.45)	68.86 (14.47)	5.94	5.33	59.83	59.25	12.70	12.10
2.	Linear low density polyethylene (LLDPE-20 μ)	7.95	7.47	75.09	75.08	5.89	5.86	51.33	50.83	6.26	6.17
3.	Low density polythylene (LDPE-37.5 μ)	7.96	7.40	73.94	76.64	6.03	6.02	50.83	53.16	5.92	5.80
4.	Low density polyethylene (LDPE-50 μ)	7.61	7.19	71.34	73.04	6.07	5.79	51.50	54.16	5.90	5.76
5.	Poly propylene (PP-100 μ)	9.12	7.12	70.37	74.80	6.03	5.58	55.00	57.16	6.00	5.86
6.	Low density/high density/linear low density (LD/HD/LLD-150 μ)	7.60	7.14	75.57	76.57	6.07	5.92	55.16	53.83	5.83	5.78
7.	Bioriented poly propylene (BOPP 25 μ)	7.72	6.81	73.21	73.80	5.98	5.91	57.00	55.38	6.13	6.05
8.	PET/.A FOIL/POLY (3 Ply)	7.31	6.58	77.04 (4.35)	78.36 (2.67)	6.01	6.04	50.58	49.16	5.34	5.21
9.	PET/.A FOIL/POLY (4 Ply)	7.61	7.12	76.90 (4.53)	77.82 (3.34)	5.96	5.75	53.00	50.83	5.41	5.30
	SE±	0.10	0.19	0.43	0.38	0.025	0.019	0.23	0.53	0.19	0.18
	CD at 5%	0.31	0.58	1.29	1.15	0.074	0.059	0.69	1.60	0.57	1.29

NB Figure in parenthesis indicates per cent inversion

Fig. 3 Liquid jaggery

In case of sweet sorghum, Coleman (1970) reported about production of syrup/jaggery from this crop using open pan type evaporators for clarification, evaporation and finishing the syrup. The minimum temperature for characteristic flavour development was 106°C. The sorghum

Fig. 4 Granular jaggery

syrup is often finished at 110°C to meet the specific gravity requirement of high quality. In India, Nimbkar Agricultural Research Institute (NARI) at Phaltan (Maharashtra) has developed *Madhura* syrup. Studies carried out at All India Co-ordinated Sorghum Improvement Project, Mahatma Phule Agricultural University Rahuri (India) to screen sorghum cultivars for syrup and jaggery have shown that variety SSV-108 produced a superior quality syrup and jaggery (Baboo and Solomon 1995). Research work carried out at IISR Lucknow showed that jaggery prepared from sweet sorghum was found to be as good as prepared from the juice of the sugarcane (Singh and Singh 1986).

Other Forms of Jaggery

Most of the jaggery produced in India is in solid form. However, in some of the places it is also produced in liquid and granular forms as briefly discussed below:

Liquid Jaggery

It is an intermediate product collected during jaggery making process. Its striking point temperature lies between 105 and 108°C depending upon cane varieties and agro-climatic zones (Nevkar 2008). The liquid jaggery free from impurities is filled in sterilized bottles (Fig. 3). Benzoic acid and citric acids are added as preservatives and also to check crystallization. It is utilized as sweetening agent in food and drinks in Maharashtra, Gujarat, Kerala, Andhra Pradesh and Tamilnadu.

Granular Jaggery

For making quality crystalline granular jaggery, juice pH is adjusted to 6.0 – 6.2 by adding lime solution and juice is boiled and clarified simultaneously using Deola (*H. ficulneus*) mucilage as clarificant. The striking point temperature for powder jaggery ranges between 120 and 122°C (Sridevi 2008). The hot mass is cooled in the cooling pan with thorough puddling and left without stirring for a few minutes for crystal and slurry formation (Fig. 4). At this solidifying stage, the mass is made in granular form by shearing action between the wooden scrapers and palm, dried to the moisture level of 1–2% and sieved through 3 mm size sieve to get uniform sized granules. It is then packed into moisture proof polyethylene–polyester laminates and PET bottles.

Fig. 5 Value added (vitamin C rich) jaggery

Value Added Jaggery

To make jaggery more nutritious, it is fortified with cleaned, shredded/grated and dried natural source of vitamin C (Fig. 5) viz; Indian gooseberry (Aonla–*Emblica officinalis* L.) using IISR jaggery moulding frames (Anwar and Singh 2010) .

Export of Jaggery

Presently, jaggery and alternative sweeteners worth more than Rupees 2,000 crore are being exported to different

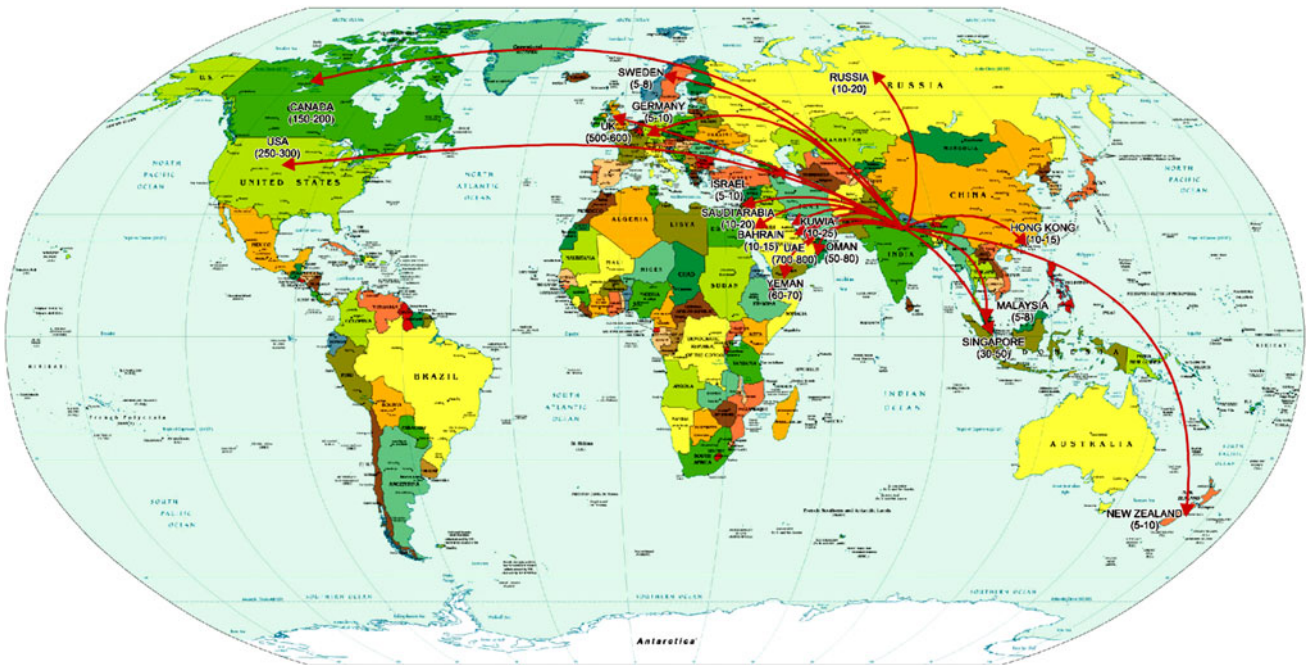

Fig. 6 Export of jaggery to different countries

countries viz; U.S.A., Canada, U.K., U.A.E., Kuwait, Oman, USSR (former), Philippines, Bangladesh, etc. as shown in Fig. 6.

The production of sugarcane is increasing rapidly and nearly 25–30 percent of raw material will be available for making alternative sweeteners which is more nutritional and health friendly compared to white sugar. These alternative sweeteners are liked by rural population and therefore there is a great scope to produce and market them in the developing countries. However, jaggery making is so far on the traditional lines and development of an automated process system with hygienic control is the need of the hour.

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