



Upgradation of jaggery production and preservation technologies

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ARTICLE INFO

Keywords:

Jaggery
Bagasse
Jaggery manufacturing plant
Jaggery preservation
Jaggery storage
Jaggery packaging

ABSTRACT

Jaggery is a traditional concentrated product of sugarcane juice which is easily and cheaply available to the Indian rural population. Several value added jaggery based products are also very popular in large section of population throughout the country. Jaggery is a good source of minerals and nutrients and also has various medicinal values. With the increasing demand of this nutritive sweetener, efforts are being made to develop a standard manufacturing package that will increase its productivity besides quality improvement in terms of hygiene, standardization of shape, size, and storability. The thermal and overall efficiencies of jaggery making plants are very low due to loss of thermal energy through flue gases and un-designed constructional parameters of plant. The storage of jaggery is also a major problem. Since, it is much influenced by the contents of invert sugars and mineral salts that are hygroscopic in nature. This intends us to study the technological upgradations used for the production and preservation of jaggery in order to prioritise the required advancements. This paper gives an overview of the technological upgradation of jaggery manufacturing plants and the preservation of jaggery by using different storage and packaging methods.

1. Introduction

Jaggery is the most popular traditional Indian sweetener produced by concentration of sugarcane juice without the separation of molasses. It is an unrefined, non-centrifugal whole cane sugar consumed all over the world. Organic jaggery is prepared without the use of any chemical/synthetic additives [1]. The color of jaggery varies from golden brown to dark brown but from market point of view light golden colored jaggery is very popular. Jaggery is produced all over the world under different names [2]. It is regularly consumed as a sweetener. It is also used as a main ingredient in number of traditional Indian dishes. Jaggery is a rich mixture of minerals and vitamins, thus it is the healthiest sugar from the group of sweeteners. The mineral contents in jaggery are approximately 50 times greater than refined sugar and 5 times more than brown sugar [3]. Jaggery is a good source of energy (383 kcal/100 g) and has various medicinal values [4,5]. In Ayurveda (5th Veda) it is considered as the best base material for the preparation of medicines [6,7]. In India, jaggery has been prepared since from Vedic-period as its reference is found in mythological texts and *Rig-Veda* [8].

Depending upon the end use mainly three types of commercial jaggery is available in the market, namely, solid jaggery, liquid jaggery, and granular jaggery [9]. To prepare solid jaggery the clarified sugar cane juice is boiled at its striking point temperature varying from 116 to 120 °C and then filled in to the molds of different shapes and sizes. The

moisture contents of solid jaggery lies in between 5% and 7% as per the Bureau of India Standard [10]. The liquid jaggery is semi liquid syrup made by boiling of sugarcane juice below striking point temperature varying from 105 to 108 °C [11]. It contains 30–36% water, 40–46% sucrose, 15–25% invert sugar and 0.30% calcium [12]. The granular jaggery is prepared by rubbing the concentrated product of sugarcane juice with wooden scrappers to form grains instead of molding [13]. The striking point temperature for granular jaggery ranges from 120 to 122 °C and it contains about 1.65% water and 88.6% sucrose [14]. About 80% of the total jaggery produced in India is prepared in solid form and remaining 20% is prepared in liquid as well as in granular form [15,16].

Among the major agro processing industries of India Jaggery/Khandsari is one of the oldest, largest, and most important industry. Jaggery making plants are placed in decentralized sectors in India. This industry is meeting about 40% of the total requirement of sweeteners and giving employment to 2.5 millions of people in rural areas with minimum capital investment [17]. It was estimated that about 50% of total sugarcane produced in India is used to manufacture 8–10 million tons of jaggery [18]. India is the largest producer and consumer of jaggery in the world. Out of total production in the world more than 70% of jaggery is produced in India [19]. The main cost of jaggery production is around 50% of total cost, which is followed by labor cost, material cost, marketing cost and interest [20]. The profitability of

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Table 1
Main findings on the elements of jaggery manufacturing plant.

Sr. No.	Researchers	Year	Description	Remarks
1.	Guddadamath et al. [27]	2013	Conducted an experiment on highly productive sugarcane hybrid clones for can yield, jaggery yield and quality parameters.	SNK 07337, SNK 0680 and Co 92005 are the excellent varieties of sugarcane for the color and quality parameters of jaggery.
2.	Soloman [28]	2011	Studied the by-products of sugarcane which can be used for the generation of secondary biofuels.	Sugarcane is one of the best available natural converters of solar energy into biomass (bagasse) and sugar.
3.	Ralph et al. [29]	2010	Overviewed the second generation biofuel technologies.	Bagasse can also be used to generate secondary biofuels like ethanol and n-butanol.
4.	Patel and Suryavanshi [30]	2012	Conducted a survey on techno-economic analysis of bagasse opportunities in jaggery industry.	Bagasse used as a fuel in all jaggery-manufacturing plants plays an important role in the economic development of rural areas.
5.	Singh and Singh [33].	1954	Compared the efficiency of some organic clarificants used in jaggery manufacturing process.	Vegetable based clarificants are more efficient to clarify raw sugarcane juice.

jaggery producer depends upon the efficient marketing. The marketing of jaggery through Cooperative Sangh is reported to be more profitable to the producers than the others [21]. The market value of jaggery is much affected by appearance parameters like color, texture, and smell of jaggery [22]. The jaggery marketing based on ID3 decision tree algorithm can provide a good marketing response on the basis of availability, price and season to the end-users [23]. Jaggery is exported from India to different countries like USA and UK. It is the best exportable sweetener produced at lowest cost which can be very helpful to earn valuable foreign money. The lack of infrastructural facilities and insufficient price distributions are the major factors, which affects the production and marketing of jaggery [24]. The jaggery has a good demand in domestic and foreign market. The values of nominal protection coefficient and domestic resource cost of jaggery were observed less than unity, which shows that it is a good exportable product and has high export competitiveness [25].

In India, all jaggery manufacturers use traditional methods to manufacture organic jaggery. The traditional jaggery making process has very low thermal efficiency. Since these units are generally designed by local artesian and large part of energy is wasted to the atmosphere in the form of flue gasses. It requires high skill and more manual labor due to lengthy heating operation. Due to batch production, the traditional jaggery manufacturing process cannot be used for mass production. In India, jaggery is manufactured during the winter and spring seasons and it is stored for rest of the year. The storage of jaggery is a major problem as it absorbs moisture from the air, which changes its properties. The traditional storage methods are not very efficient in all environmental conditions mainly in the rainy season. It has been estimated that more than 10% of jaggery produced in India worth US \$ 0.6 million is lost every year due to deterioration under normal storage process [26].

In order to overcome these problems and drawbacks many attempts have been made by various researchers to improve the efficiency of jaggery making plants and to enhance the shelf life of jaggery to store under different environmental conditions. The present paper is initiated to discuss the progress made towards the technological advancements in jaggery making process and preservation methods.

2. Elements and operations of jaggery manufacturing process

Jaggery manufacturing is a continuous heat and mass transfer process in which fresh sugarcane juice and bagasse are used as raw material and fuel respectively. The progressive heating and stirring of sugarcane juice in an open pan changes the sugarcane juice from liquid to semi-solid, which further becomes solid after cooling in an open earthen pan. The traditional jaggery manufacturing process involves a number of operations that are performed by skilled and semi-skilled persons.

2.1. Elements of traditional jaggery manufacturing process

The basic elements used in traditional jaggery manufacturing process are sugarcane juice, bagasse, and clarificants. Sugarcane juice is an opaque liquid available in different colors from gray dark green to light yellow depending upon the variety of canes used [15]. The different varieties of sugarcane hybrid clones cultivated in India are used to produce jaggery of good color and quality. Number of researches has been conducted in this area and it was found that sugarcane SNK 07337, SNK 0680 and Co 92005 are excellent on color and quality parameters of jaggery [27].

In all jaggery manufacturing plants fibrous part of sugarcane stalk remains after crushing named as bagasse is directly used as a fuel. In addition to this molasses is also a valuable byproduct of the jaggery manufacturing process that also serves as fuel. Thus this industry does not depend on additional fossil fuel for its production. Sugarcane is one of the best available natural converters of solar energy into biomass

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