

REVIEW

Non Centrifugal Sugar (NCS): a review of its production, nutritional composition, health benefits and industrial applications

R. Venkatesh^{a*} and Dhani Babu Talakala^b

^a*Agro-Processing and Technology Division, CSIR-National Institute for Interdisciplinary Science and Technology, Pappanamcode, Thiruvananthapuram-695019*

^b*Environmental Technology Division, CSIR-National Institute for Interdisciplinary Science and Technology, Pappanamcode, Thiruvananthapuram-695019*

*Corresponding author : Email: rvenkatesh@niist.res.in

Received: 25 April 2024 ; accepted: 28 May 2024

Abstract

Jaggery, a traditional sweetener derived from sugarcane juice, holds a significant place in the Indian diet and various cultures worldwide. Despite being less processed than white sugar, it retains essential phytochemicals like polyphenols, contributing to its high nutritive value and potential health benefits. However, challenges such as its dark appearance, limited shelf life, and chemical clarificants during processing have impacted its consumer preference. This review delves into the production, processing, storage conditions, nutritional composition, health benefits, and industrial status of jaggery, emphasising its cultural significance and potential for innovation. India, being the second-largest sugarcane producer globally, contributes significantly to jaggery production, which remains a vital part of rural economies and traditional diets. The traditional jaggery-making process, involving extraction, clarification, boiling, and moulding, has seen substantial technological advancements. Modern methods, including energy-efficient boilers, continuous flow pans, advanced filtration, and automated packaging, have improved the efficiency, quality, and safety of jaggery production. These advancements ensure better product consistency, extended shelf life, and adherence to international quality standards. The review also underscores jaggery's health benefits, such as detoxification, improved digestive health, enhanced immunity, and the potential to combat oxidative stress-induced diseases.

Keywords: Non Centrifugal Sugar (NCS); Value-added products; Storage; Health benefits

Introduction

Jaggery, a traditional Indian sweetener, is a concentrated product of sugarcane juice that holds an important place in the common Indian diet (Lamdande et al. 2018). It is a known ancient sweetening agent used in the rural areas of many countries and has been considered by many Ayurveda practitioners as wholesome sugar for its high nutritive value (Ahuja et al. 2008). Jaggery is the least processed sugar and hence contains phytochemicals like Polyphenols that are present in sugarcane juice (Nayaka et al. 2009). Sugar and Jaggery are the well-known sweetening agents added to beverages and foods for increasing

palatability. Sugar and jaggery are sweeteners obtained from the same plant, sugarcane (Abidin et al. 2019). Jaggery has been the least preference for consumers because of its dark appearance and spoilage during longer storage in contrast to white sugar (Krell 1996). Jaggery can be called by different names, in India and South Africa it is called "jaggery"; in Japan, "black sugar"; in Indonesia, "gula-java"; and in Malaysia, Pakistan, and Brazil, it is referred to as "gula-mala," "gur," and "rapadura," respectively (Jaffe 2012). In addition to that, jaggery can be prepared from the stalks of several palm trees, such as wild date-palm (*Phoenix sylvestris* L.), coconut palm (*Cocos*

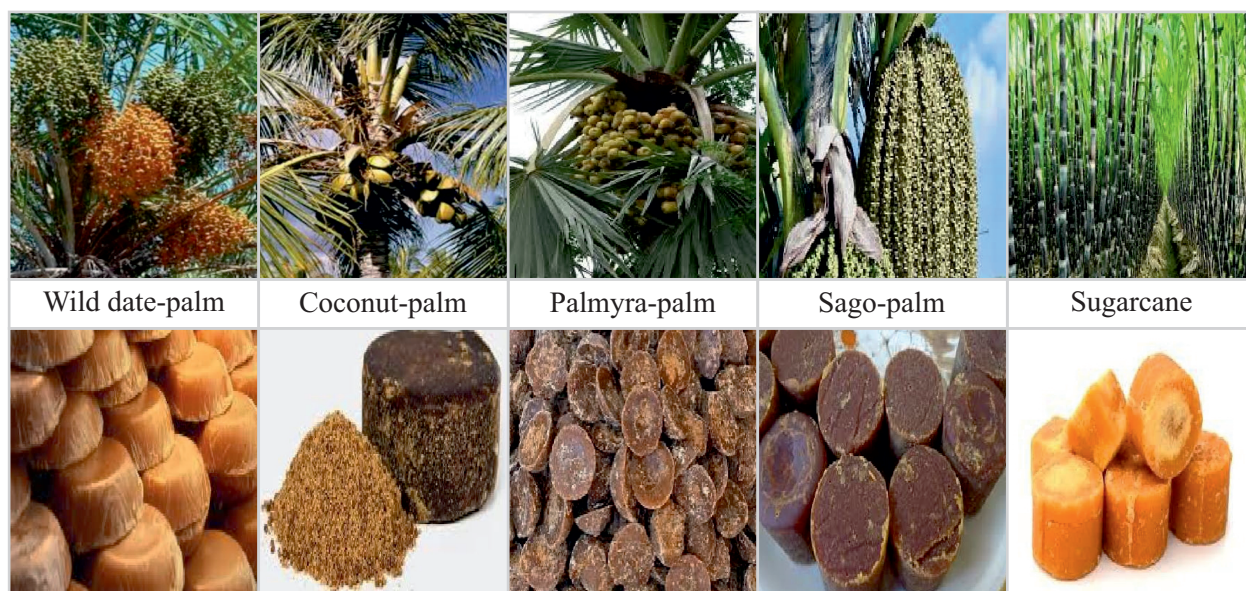


Figure 1. Different varieties of Jaggery

nucifera L.), Palmyra palm (*Borassus flabellifer* L.), and sago palm (*Caryotaurens* L.) (Dalibard 1999) (Fig. 1).

Jaggery is the least processed sweetener because it preserves many of the phytochemicals present in sugarcane juice, contains bioactive compounds, and provides health benefits (Arif et al. 2019). Indian Ayurveda medicine considers jaggery to be beneficial in treating throat and lung infections (Saxena et al. 2010). In recent years, plants and their products have been the main focus in the search for nutraceuticals to combat oxidative stress-induced diseases (Lobo et al. 2010). Free radicals are generated during normal cellular metabolism, and their effect is neutralized by antioxidant molecules present in the body (Sen et al. 2010). However, this balance between the oxidants and antioxidant molecules is disturbed by free radicals derived from exogenous sources like ozone, exposure to UV radiation, and cigarette smoke. Certain toxic redox-cycling compounds, such as drugs and carbon tetrachloride, can significantly increase free radical production in cells. Importantly, the main biomolecules like

DNA, lipids, and proteins are vulnerable to free radical damage resulting in cell destruction (Nayaka et al. 2009; Iqbal et al. 2017).

Sugarcane production

India, producing 376.90 million metric tonnes of sugarcane annually, is the second largest sugarcane-producing country in the world, after Brazil, which produces 739.30 million metric tonnes. Together, India and Brazil account for 59% of the world's total sugarcane production. The top ten sugarcane-producing countries are Brazil, India, China, Thailand, Pakistan, Mexico, Indonesia, Colombia, the Philippines, and Vietnam.

In India, sugar cane is grown in tropical and subtropical climates (Lapola et al. 2009). The top ten sugarcane-producing states in India are Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Bihar, Haryana, Punjab, Andhra Pradesh, and Uttarakhand (National Horticultural Board, 2018). The processing of sugarcane gives many valuable products such as jaggery, brown sugar, molasses, table sugar, and syrup (Khare 2007). The

sugarcane yield can be varied based on the texture of the soil, type of irrigation, climatic condition, and also the variety of sugarcane, (Leal et al. 2013). Co 419, Co 453, Co 740, Co 997, Co 1148, Co 62175, Co 6304 and Co 6806 are the major varieties of sugarcane (ICAR-SBI). The chemical constituents of sugarcane juice are, Sugars (sucrose -81-87 reducing sugar -3-6 oligosaccharides -0.06-0.6 polysaccharides including gums and dextrans -0.2-0.8), Salts (inorganic salts 1.5-3.7), Organic non-sugars (organic acids -0.7-1.3, aminoacids -0.5-2.5, dextrans -0.1-0.6, starch -0.11-0.5, gums-0.02-0.05, waxes, fat, phospholipids-0.05-0.15, colourants-0.1), Insolubles (sand, bagasse, etc. 0.15-1.0) (Walford 1996).

Preparation of Non Centrifugal Sugar (Jaggery)

The art of making jaggery is varied from region to region. Jaggery preparation from sugarcane juice involves mainly four unit operations, namely, extraction, clarification, boiling, and moulding (Ghosh et al. 1998). In the extraction process, crushing the sugar cane (Fig. 2) within one day after harvesting to avoid the inversion of sucrose



Figure 2 Sugarcane Crusher (Electric)

into glucose and fructose and other harmful substance formation (Saxena et al. 2010). A horizontal three or five-rollers electric-powered crusher is used to extract juice from sugarcane; it's more efficient than the vertical sugarcane crusher (Singh et al. 2011). The obtained juice was filtered via muslin cloth to remove the extraneous materials and small bagasse in the juice (Khare et al. 2012). The jaggery is produced in various types, such as solid, liquid, or granular form (Solomon 2014).

The acceptability, quality, and storability are defined by the clarity of the juice used for jaggery preparation (Said et al. 2013). The main aspect of juice clarification is to prevent the formation of non-sugars while heating due to the acidity of juice; it can be done by using vegetative or chemical clarificants or both (Umesh et al. 2015). The solidification of jaggery is difficult in acidic conditions because it will invert the sucrose and also result in the development of dark jaggery. Hence, adjusting the pH of the juice before boiling by using lime (which helps to the formation of scum during boiling of juice) improves the jaggery consistency (Rao et al. 2007). Proper care should be taken to correct the neutralization of the acidity of the juice, to obtain good color and hardness. The excess of liming leads to the hard and dark color of jaggery. The amount of lime added depends upon the quality of lime (Panda 2011).

The vegetative clarificants like Bhendi (*Abelmoschus esculents*), Chikani (*Sida caroinitolia*), Castor (*Ricinus communis*), Peanut seed (*Arachis hypogaea*), Soybean seed (*Glycine max*), tamarind seed (*Tamarindus indica*), Deola (*Hibiscus ficulneus*), and roots of Kasturi (*Hibiscus ablemoschus*) showed excellent clarificant property (Patil et al. 2005). Plenty of chemicals are used in the preparation of jaggery for good texture and color. Hydrous (Sodium hydrosulphate) gives

a bright yellow color to the jaggery, and act as a bleaching agent. Hydrous has many disadvantages as it imparts temporary color to jaggery leading to its rapid deterioration of jaggery (Chikkappaiah et al. 2017). As per the PFA rules 1995, the sulfur dioxide (SO₂) content was limited to 70 ppm. Apart from that the other chemical clarificants superphosphates, phosphoric acid, chemiflocks, and alum are also used in the manufacturing of jaggery (Said et al. 2013). In addition to the above, tetrazine and erythrosine along with hydrous also used as colouring agents. For a better set of non-sugar impurities and mud, flocculants are used (Thai et al. 2013). The use of chemical clarificants during the preparation of jaggery can result in numerous health complications (Kumar 2008).

The concentration of juice by boiling, after the clarification processes, removes the scum completely and boils the juice till it reaches the temperature of 118°C and gets thick concentrated syrup. A small amount of coconut oil was used to avoid excess frothing, charring of jaggery syrup, and easy transfer of hot syrup to the desired shape (Babu 1990). After solidification, the contents were transferred to wooden or aluminium moulds. The shape of the solid jaggery is varied like a square, round, rectangular, bucket or trapezoidal, etc. the irregular shape of the jaggery leads to many problems in moulding, drying, packaging, and distribution (Sharon et al. 2013).

Storage conditions

The demand for jaggery is throughout the year, but jaggery is produced during winter, and it is necessary to store it during the off-season. The main concern during storage is to preserve without affecting the taste, quality, hardness, colour, flavour, adequate temperature, and humidity. Metal drums, wooden boxes, and earthen pots have been used for storing jaggery, and they vary from region to region. Sometimes, it can be covered with cane

trash, bagasse, furnace, ash, cotton, wheat straw, rice husk, and Palmyra leaf, etc., to protect from ambient humidity (Sharon et al. 2013). Jaggery deteriorates rapidly due to the presence of high moisture, sugar, and hygroscopic nature, which includes non-sucrose constituents like glucose, fructose, protein, etc. Jaggery can be stored for longer periods when its moisture content is within 6% and placed at a relative humidity of 43-61%. It is very difficult to store jaggery during monsoon seasons especially in coastal areas of high rainfall and humidity. It is estimated that about 5-10% of stored jaggery gets spoiled every year. Cold storage warehouses have been used in a few states of India (Rao et al. 2007).

Nutritional Composition of NCS (Jaggery)

Carbohydrates, also called saccharides, are the main source of energy. One gram of carbohydrates provides four kilocalories of energy, and they are quickly absorbed into the bloodstream as glucose (Bloemendal et al. 2012). Jaggery has a more complex structure than sugar because of the long chain of sucrose, resulting in longer digestion, slow energy release, and a nonspontaneous process. Jaggery absorbs some amount of iron in the form of ferrous salts during preparation, as it is typically prepared in iron vessels, making it beneficial for those with iron deficiency. Besides, jaggery has cleansing action, clearing respiratory tracts, lungs, esophagus, stomach, and intestines. The composition of jaggery is 50 % sucrose, 20 % invert sugar, 20 % moisture, and insoluble matter such as bagasse, ash, and protein. Jaggery contains an adequate amount of carbohydrates such as sucrose 72-78 g, fructose 1.5-7 g, and glucose 1.5-7g/100 g (Singh et al. 2013). Magnesium enhances the strength of the nervous system, plays an important role in the relaxation of muscles, and keeps our blood vessels healthy (Faryadi 2012). In addition to this, selenium exhibits antioxidant

properties to scavenge free radicals from the human body. The potassium and sodium present in jaggery in smaller amounts help to maintain the acid balance in the body's cells (Adnaik et al. 2020). Iron in the body helps to maintain a normal hemoglobin level and prevent anemia. Apart from these, it also exhibits anti-allergic properties (Breymann 2015). Jaggery is a concentrated product of sugar cane juice containing sucrose, fructose, glucose, calcium (40-100 mg), magnesium (70-90 mg), potassium (1056 mg), phosphorous (20-90 mg), sodium (19-30 mg), iron (10 – 13 mg), manganese (0.2-0.5 mg), zinc (0.2-0.4 mg), chloride (5.3 mg), copper (0.1-0.9 mg), vitamins: A (3.8 mg) D2 (6.5 mg) E (11.3 mg), B1 (0.01 mg), B2 (0.06 mg), B5 (0.01 mg), B6 (0.01 mg), C (7.0 mg), and protein (280 mg) (Singh et al. 2011; Jagannadha Rao et al. 2007).

Sugar and NCS (Jaggery)

From time archaic, food custom of humans comprised natural sweeteners whose priority is perceived in Indian diets as well to make their food delightful. Sugar and Jaggery are the common sweetening agents added to beverages and foods for rising palatability (Barclay et al. 2014). Sugarcane (*Saccharum sp.*), sugar beet (*Beta vulgaris*), and sugar maple (*Acer saccharum*) are the important sugar sources (Ghosh et al. 1998). Seventy-five percent of sugar production in the world is from sugarcane and the remaining 25% is from sugar beet (Goldemberg et al., 2008). Asia and Europe hold first and second place respectively in the sugar cane production in the world. Besides, India holds a second place next to Brazil. A significant portion of Indian population consumes raw cane chewing it to extract juice (Galloway et al. 2005). The per capita consumption of sugar is 19.6 kg annually, while jaggery and khandsari sugar together amount to 3.1 kg per annum. It can be increased to 19.6 kg/annum by increasing the

standard of living. Apart from that, the darker color of jaggery, less shelf life, and usage of chemicals during manufacture have also contributed to the decline in jaggery consumption (Hunsigi 2001).

Non-centrifugal sugar (Jaggery) based products

Jaggery can be used for making sweet as well as savoury dishes across the country. A pinch of jaggery was used in the preparation of *sambar*, *rasam*, and other staple foods (Raghuvanshi et al. 2009). Besides, jaggery is used for making Bengali cuisine and Gujarati cuisine as a sweetener for balancing spicy, salty, and sour components (O'Brien 2013). Maharashtra is the largest consumer and producer of jaggery in India. They are traditionally using jaggery for making *tilgul* dessert during the Sankranti festival. In rural Maharashtra, a chunk of jaggery was added to drinking water for cooling purposes (Lara 2019). Jaggery was used in making the dish *Chakkari Pongal* during the Pongal festival, which is celebrated at the beginning of the harvesting season in Tamil Nadu (Ramaswamy 2017). In Bengal, jaggery is used for the preparation of dishes such as *laddu*, *Patishapta*, and *candy*. *Til-pitha*, a popular Assamese sweet, is made by mixing rice powder, sesame, and jaggery. Additionally, in rural areas of Assam, jaggery is used for making licking tea (Wangpan et al. 2019). In Karnataka, which produces both sugar and palm-based jaggery, the latter is traditionally used for making dishes like *payasa* and *obattu*. Moreover, a pinch of jaggery is often added to *sambar* and *rasam* (George 2018).

Health benefits of Non-Centrifugal Sugar (Jaggery)

Jaggery, a concentrated product of sugar cane, it is having several medicinal benefits and plays a major role in Indian Ayurveda medicine. Jaggery

aids in detoxifying the liver by helping to flush out harmful toxins from the body. It also promotes digestive health by stimulating digestive enzymes and alleviating constipation, making it an effective natural remedy for improving digestion (Choudhary et al. 2020). The antioxidant properties of jaggery, primarily due to its phenolic compounds, help combat oxidative stress. This action reduces the risk of chronic diseases such as heart disease, diabetes, and cancer. The antioxidants in jaggery neutralize free radicals, thereby protecting cells from damage (Kumar et al. 2021). Jaggery is noted for its ability to enhance the immune system. Its high content of essential micronutrients supports the body's defense mechanisms, helping to fight infections and boost overall immunity (Rao et al. 2019).

Traditionally, jaggery has been used to treat respiratory issues such as bronchitis and asthma. Its natural anti-allergic properties help alleviate symptoms and improve lung function, making it a beneficial component in managing respiratory ailments (Sharma et al. 2018). Research indicates that jaggery can help regulate blood pressure and improve cardiovascular health due to its balanced potassium and sodium content. This balance helps in maintaining proper heart function and reducing the risk of hypertension (Patil et al. 2021). Iron-rich jaggery plays a crucial role in synthesizing hemoglobin and facilitating oxygen transport to cells. This is particularly beneficial in preventing anemia and enhancing overall energy levels (Goswami et al. 2015).

The magnesium present in jaggery helps in relieving muscle fatigue, nerve tension, and symptoms associated with asthma, migraine, and headaches. Magnesium acts as a natural relaxant, easing muscle soreness and improving overall physical comfort (Vasey 2020). Jaggery is a good source of manganese and selenium, both of which

play important roles in antioxidant defense and enzymatic reactions. These minerals act as cofactors for various enzymes, enhancing metabolic processes and protecting against oxidative damage (Toufektsian et al. 2000). Jaggery is a good source of other minerals and vitamins such as calcium, phosphorous, zinc, Niacin, and vitamin B6 which are essential cofactors for enzymatic activity (Uppal 2018).

Present status of NCS (jaggery) industries in India

Jaggery industry is one of the major agro-processing industries in India. In the total production of sugarcane, approximately 20-30% is used for jaggery manufacturing (7 million tons) (Kachru 2010). The jaggery industry creates an employment opportunity for around 2.5 million people (Sandeesh 2009). Therefore, the development of the jaggery industry is very helpful in uplifting the rural economy (Swaminathan, 1991). Jaggery has been used traditionally in the preparation of many dishes like *chikki*, *reori*, *ramdan*, etc. In several regions of India, liquid jaggery has become a staple in daily dietary practices, particularly prominent in Maharashtra, gaining significant industrial importance (Vivek et al. 2019). Sugar and jaggery are commonly incorporated into various foods and beverages to enhance palatability. However, evolving research and development endeavors have fostered a heightened awareness among individuals regarding their dietary choices. Consequently, the jaggery industry has flourished across multiple states in India, including Karnataka, Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Telangana, and Maharashtra, despite encountering pressures from industrialization (Asif 2009).

In rural areas, people utilize jaggery owing to its significant nutritional and medicinal attributes. Consequently, the production of value-added

products from jaggery emerges as a more lucrative venture. However, further studies are imperative to facilitate large-scale production (Nath et al. 2015). Price dissemination and inadequate infrastructural facilities have been faced by jaggery producers in India. As per the reviews, Uttar Pradesh has many jaggery manufacturing industries; they follow conventional methods for jaggery production (Ramaraao 2011). More than half of the people from this region depend on these jaggery manufacturing units. However, they do not receive any research and development assistance or proper marketing support because the manufacturers primarily produce local liquor products and distillates, not items for common consumption (Dwivedi 2010). The study revealed that only medium and large-scale jaggery industries can cover their expenses at a remarkable level but small units are earning marginal income. This profit is very low when compared to the other two scales. People in the jaggery manufacturing industry are not interested in developing new jaggery-based products as they earn more from jaggery itself (Kumar 2010).

Innovation in the NCS (Jaggery) process

Crushing is the primary method for extraction of sugarcane juice in a fuzzy analytical hierarchical process with vertical crushers that run on electrical power, horizontal crushers that run on electrical power, horizontal crushers that run on diesel engines, multi-horizontal crushers that run on electrical power, multi-horizontal crushers that run on electrical power with hot water application is studied. Single horizontal crushers power-operated equipment shown to be the most suitable and sustainable crushing method (Srinivas et al. 2020). Clarification with membrane filtration, electrocoagulation, plant mucilage, the combined effect of centrifuge, and activated carbon with a multicriteria evaluation technique is studied. Clarifying with plant mucilage has shown to be a

sustainable clarification method (Beeram et al. 2020).

The jaggery-making process is used in the open pan systems to concentrate the cane juice, which will take place in a single-pan or multiple-pan. The efficiency of energy utilization in single pan systems is 14.7% - 24.36%; a conventional open pan system with a heat exchanger and thermic fluid heater reduces the losses and improved efficiency by 96.49%, and process time reduces to 13%-27% (Abhijeet et al. 2023). The pan system was studied by considering jaggery production, bagasse consumption, emissions, and exhaust gas temperature. There is better performance in 12% of bagasse consumption reduction and 23% of jaggery production increase, along with less emission and lower exhaust (Pankaj et al. 2013).

A two-pan jaggery manufacturing plant is studied to improve the rate of heat for preheating the bulk sugarcane juice pan modified with the gutter internal fitting of copper tubes. Modified system performance in terms of the thermal efficiency of 72.34%, along with the low bagasse consumption and reasonable rate of jaggery production (Rakesh Kumar et al. 2021).

Conclusion

Jaggery production is one of the major enterprises in sugarcane-producing areas in India. These days, farmers make jaggery on their farms, and they sell the sugar cane directly due to the scarcity of labor and skilled workers, rate depletion, lack of financial and technical assistance, complex transaction procedures, delay in cutting, and missing in-time registration from sugar factories. Jaggery, an indigenous concentrated product of cane juice, is used for the preparation of traditional foods. Jaggery exhibits numerous health benefits, yet its widespread acceptance is hindered by its dark appearance and shorter shelf life. Developing

highly acceptable, chemical-free jaggery could lead to a decrease in the consumption of white sugar, thereby helping to prevent various health complications such as coronary thrombosis, dental caries, and heart-related problems. This initiative may contribute to maintaining a healthy society and also create employment opportunities for rural people to sustain their economic stability. Additionally, promoting jaggery industries to produce various jaggery-based products at affordable prices for the general population is another way to encourage consumption. The integration of sustainable practices and biotechnological interventions reflects a dynamic shift towards more efficient and eco-friendly jaggery production, positioning it as a modern and evolving industry. Further research and development are essential to explore value-added products and innovative processing techniques, ensuring the continued growth and modernization of the jaggery industry.

Acknowledgment

Authors would like to convey their sincere thanks to the Agro-Processing and Technology Division and Environmental Technology Division, CSIR-National Institute for Interdisciplinary Science and Technology, for their support of this work.

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