A Comprehensive Review on Jaggery: From Traditional Sweetener to Functional Food

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Abstract:

Particularly in South Asia, jaggery, a traditional unprocessed sweetener made from palm sap or sugarcane (Saccharum officinarum), is valuable in terms of culture, nutrition, and the economy. Because it preserves vital elements like iron, calcium, potassium, and magnesium, jaggery is a healthier option than refined sugar. Packed with phytochemicals and antioxidants, jaggery has several health advantages, such as better digestion, increased immunity, detoxification, and relief from respiratory conditions. In food processing, jaggery is becoming more popular as a means of creating goods that increase value and immunity in response to the growing demand for natural and functional foods. A superior choice for regulated energy release, its glycemic index is also lower than white sugar's. Nutraceuticals based on jaggery, flavored jaggery, and fortified jaggery have been the subject of recent innovations. But the production of jaggery is still quite disorganized, with issues with microbiological safety, shelf life, hygiene, and standardization. The nutritional profile, health advantages, processing technologies, commercial potential, and current research trends in the production and use of jaggery are all examined in this paper. Technological developments, quality enhancement, and potential future commercialization of jaggery as a functional food ingredient are also highlighted.

Keywords: Jaggery, Functional food, Nutritional benefits, Value addition.

Introduction:

Today, when consumers are caring more and more about their health and eating healthier and nutritious foods, the confectionery industry has to change completely. Consumers are more and more conscious of the harmful health consequences of the excessive intake of traditional confectionery containing a high amount of sugar, fat or otherwise additives. To meet this rising demand, with the increasingly interest in new sweeteners and combination with functional ingredients that contribute both flavour and health benefits. India, a leading global agricultural nation, significantly contributes to this shift in the industry. By optimizing land and water utilization, the country not only sustains a substantial part of the world's population but also emerges as a prominent producer of essential agricultural commodities such as sugarcane (Saxena, 2022).

Sugarcane (Saccharum officinarum L.) is a vital cash crop in the Indian subcontinent, abundant during its harvesting season. It serves as a rich source of sugar, minerals, and polyphenols. The juice of sugarcane is commonly used to produce liquid jaggery, a process that is popular in rural areas and has evolved into a profitable industry for farmers (Hossain & Singh, 2018). A natural and traditional sweetener, jaggery (also called gur) is manufactured by concentrating sugarcane juice. The Sanskrit name for "gur" indicates that it has been manufactured in India since the beginning of time and is currently used as a traditional sweetener in the rural cuisines of many countries (Mandal, 2006).

It is referred to as the healthiest sugar in the world since it contains all of the vitamins and minerals found in sugarcane juice. Jaggery is consumed worldwide and goes by several names; it is commonly referred to as jaggery in the majority of Asian and African nations. "Goda" in Sanskrit, "Gud/Gur" in India and Pakistan, "Bellam" in Telugu, "Bella" in Karnataka, and "Vellam" in Tamil and Malayalam, as well as "Hong Tang" in China, "Chancaca" in Chile, Peru, and Bolivia, "Panela" in Columbia, Ecuador, Guatemala, and other Central American nations, "Black sugar (Kurosato)/Kokuto" in Japan, and "Papelon/Panela" in Venezuela “Dulce/Tapa dulce” in (Costa Rica and Nicaragua), “Gula Java/Gula Merah” in (Indonesia), “Gula Melka” in

(Malaysia), “Raspadura” in (Panama), “Raw sugar” in (Europe, North America and United States) and “Unrefined muscovado” in (United Kingdom) (Guerra and Mujica, 2009; Kouhestani and Honarwar, 2021; Kumar et al., 2022).

Sugarcane juice is used to make jaggery. A large cottage industry, jaggery has long been regarded by the rural populace as a healthy sweetener. Jaggery is produced seasonally and typically preserved for six to eight months (Ramya et al., 2010). Jaggery is a traditional Indian sweetener made from sugarcane. Rural residents may easily obtain and consume jaggery, which is nutrient-dense. Unrefined sugar, jaggery is considered a "whole sweetener" due to its high nutritional content. Along with sucrose, sugarcane juice retains a variety of organic and inorganic components, making it more nutrient-dense than refined sugar (Kumar & Tiwari, 2006).

Because jaggery is made up of longer chains of sucrose than sugar, it is much more complex. Because it digests more slowly than sugar, it releases energy gradually rather than all at once, which is good for the body and does not make it safe for diabetics to eat. Because jaggery is made in iron vessels, a lot of ferrous salts (iron) are also produced during the manufacturing process, which is especially good for people who are anemic or lack iron. You may have noticed that jaggery leaves a somewhat salty taste on the tongue, but jaggery also contains minute amounts of mineral salts that are incredibly nutritious for the body. These salts are present in sugar cane juice and are absorbed from the soil. Jaggery works well as a cleaning agent as well. It cleanses the stomach, intestines, esophagus, and respiratory system. Consuming jaggery is highly recommended for people who deal with dust on a daily basis. Asthma, a cold or cough, chest congestion, and other conditions can be prevented by doing this.

Jaggery is well recognized for producing heat and giving the body instant vitality. Thus, it is customary in some parts of India to greet guests with a glass of water and jaggery. Aside from these applications, jaggery is used to make ayurvedic medicines, ayurvedic sura, ayurvedic nutritional supplements, cow feed, and a medicine manufacturing facility. At the moment, jaggery is becoming more and more popular as a candy. Workers in cement industries and coal mines are also given jaggery to help them avoid dust allergies. Furthermore, following major catastrophes, the district government purchases jaggery and distributes it to the victims as a health benefit (Nath et al., 2015).

A variety of Ayurvedic formulations, including Asava, Arishtas, Lehya, Gula, and others, are prepared using jaggery as a medium. Additionally, it serves as a channel for drug administration. According to Ghosh and Agrawal (1983), it contains up to 50% sucrose, up to 20% invert sugars, and other insoluble materials such ash, proteins, and bagasse fibers.

The exterior characteristics of jaggery, such as its color and texture, determine its quality and cost. The characteristics of high-quality jaggery include its distinct sweet flavor, firm texture, crystalline structure, golden yellow hue, low moisture content, and fewer impurities like molasses and some crystals. Numerous factors influence the quality of jaggery, including the type of sugarcane grown (conventionally or organically), the fertilizers used (natural or chemical), the water quality in a given soil region, the clarification method, processing time, storage conditions, and packaging techniques used. The physical and chemical quality parameters of jaggery, such as its sucrose content, reducing sugar, moisture, water-insoluble material, etc., are used to grade it (Kumar et. al., 2013).

Together with selenium, Kumar and Singh demonstrated the antioxidant qualities of jaggery. The potassium and low sodium content of jaggery aid in preserving the acid-base balance in bodily cells and in regulating blood pressure. One abundant source of iron that helps prevent anemia is jaggery. It relieves tension and treats asthma due to its anti-allergic qualities (Kumar, Singh, & Rai, 2013; Singh, Singh, Anwar, & Solomon, 2011).

In their work "Alternative sweeteners production from sugarcane in India: Lump Sugar (Jaggery)," the authors discuss the significance of jaggery in India. According to them, the primary sweetening agents added to beverages and meals to improve palatability are sugar and jaggery. Research and development efforts, as well as people's growing health consciousness, have had a significant impact on human eating habits over time. The jaggery business has thrived in several states across the nation, including Uttar Pradesh, Tamilnadu, Karnataka, Maharashtra, and Andhra Pradesh, despite the pressures of industrialization. Because of its nutritional and therapeutic benefits, jaggery is becoming more and more popular in rural regions, which makes it important to understand why people like it. Jaggery's nutritional and therapeutic qualities make it a valuable export commodity (Singh et al., 2013).

According to Ramaswamy et al., the production of jaggery is a traditional business in Tamil Nadu and is more lucrative for cane growers than it is for factories. However, price risk in jaggery is a countermeasure to increased profitability. Traditionally, cane growers use their own farms to produce jaggery. With the arrival of new businesspeople who purchase cane from cane growers and attempt to manufacture jaggery as a pure enterprise, the tendency has shifted. Due to the significantly higher price, instant payments for cane sales, failure to register with the factory in a timely manner, delays in cutting orders, and the intricate process of dealing with the factory, cane growers prefer to supply cane for the production of jaggery. Cane supply to the plant is primarily driven by the absence of price risk, labor shortages in the case of producing jaggery on one's own, and financial and technical support provided by the factory.

The market offers jaggery in three different forms: granular, liquid, and solid. Although sugar cane, date palm, palmyra palm, and coconut provide 80% of the solid jaggery, the remaining 20% is liquid jaggery, or "Kakawi" in specific Maharashtra districts (Vengaiah et al., 2013; Nath et al., 2015).

a) Solid jaggery:

Solid jaggery is cooked in a triple pan boiler with bagasse as fuel until it reaches its striking point temperature, which ranges from 116 to 120 °C. When it reaches its striking point, it is poured into molds of different shapes and sizes. In order to create light-colored jaggery, a natural clarifier (deola extracts at 45 g/100 kg juice) is used to remove impurities in suspension, colloidal, and coloring compounds by accumulation. (Anonymous, 2022, Hirpara et al., 2020; Nath et al., 2015; D. A. Pawar et al., 2017; Selvi et al., 2021). Solid jaggery has a moisture percentage of 5.0% to 7.0%, per the Bureau of India Standard.

b) Liquid jaggery:

Made by concentrating pure sugarcane juice, this intermediate product has a semi-liquid, syrup-like consistency. Liquid jaggery has both economic value and is a staple food in the majority of West Bengal and Maharashtra regions. The liquid jaggery is used as a sweetener in a number of Indian states, including Tamil Nadu, Kerala, West Bengal, Gujarat, Maharashtra, and Andhra Pradesh. The type of clarifiers employed, the volume and purity of

the cane juice, and the concentration temperatures of the juice all have a significant impact on the quality of liquid jaggery. When the concentrated juice reaches the striking point temperature, which varies from 103 to 106 degrees Celsius depending on the variety and agroclimatic zone (J. Singh, 2013; Nath et al., 2015), it is separated through the boiling pan. In liquid jaggery, citric acid is added at a rate of 0.04% (400 mg/kg) to prevent crystallization and to give it a beautiful hue.

c) **Granular jaggery**:

Powdered jaggery or granular Granular or powdered jaggery with a modest quantity of moisture (1–2% d.b.) has a shelf life advantage of up to two years because of its freely flowing characteristic, according to a study (Jagannadha Rao et al., 2007). [11]. There have been attempts to develop a method for producing jaggery particles, according to some researchers. The Regional Agricultural Research Station in Anakapalle and the Indian Institute of Sugarcane Research in Lucknow devised a technique for turning the solid into granules by scraping the concentrated syrup with a wooden scraper. (J. Singh, 2013; D. A. Pawar et al., 2017; Said and RC Pradhan, 2013) Adding lime to cane juice raised the pH between 6.0 and 6.2 with the striking point temperature of 120 °C, resulting in a superior granular jaggery with about 88.6% sugar percent, a low moisture content of 1.65%, and decent color, fragility, and crystallized texture . The concentrated slurry was scrubbed with a wooden scraper to create granules. The jaggery is cooled and then sieved into granules. Jaggery powder can range in color from bright yellow to a dark brown that looks like dark chocolate. The color of jaggery powder is determined by the main ingredient used in its production. With a rate of 0.1% (1 g/kg) or benzoic acid at 0.5% (5 g/kg), it is also softer and more amorphous than potassium metabisulphite. It is used to extend the shelf life of liquid jaggery without compromising its quality. The liquid jaggery is then allowed to settle for eight to ten days under normal conditions. After clarity, it is later precisely packed in a sterile container. According to Hirpara et al. (2020), J. Singh (2013), Nath et al. (2015), Selvi et al. (2021), the typical liquid jaggery contains 30 to 36 percent moisture, 40 to 60 percent sucrose, 15 to 25 percent inverted sugar, 0.30 percent calcium, 8.5 to 10 mg of iron per 100 grams, 5 mg of phosphorus, and 0.10 mg of protein per 100 grams. sugar. With its mineral-rich, easily digestible, sulfur-free organic constitution, ability to provide a unique flavor as a flavoring ingredient, ability to heal lung and throat infections, and ease of digestion, jaggery powder is a great option for a suggested, healthful substitute.

The government of India's Prevention of Food Adulteration Rules (PFA, 1955) states that "gur" or "jaggery" refers to the sugarcane juice derived by boiling or digesting sugarcane stalks. It must be free of contaminants harmful to health and able to pass some standard analysis on a dry weight basis i.e. Sucrose not less than 60% and total sugars not less than 90%, the water-insoluble extraneous matter is 2 per cent, total ash less than 6 per cent and less than 0.5% of ash is impermeable in hydrochloric and jaggery must not include more than 10% moisture if they are not liquid or semisolid varieties (D. A. Pawar et al., 2017)

Ayurveda's historical references to jaggery and sugarcane juice

In the ancient Indian medical system, sugarcane molasses has been utilized for ages to treat a variety of human ailments through the use of "Ayurvedic" medications. According to the Korampuran, the people of "Harivarsha" had a disease-free life for ten thousand years by eating sugarcane juice as a primary meal. They also shared the same hue as "Maharajatasnibha," which is silver. Ikshurus, or sugarcane juice, is regarded as the "best rasa" for body sustenance. A sweet, aromatic, and flavored "jaggery," the "best" sugar and sugar extracted from sugarcane, has been produced in our nation for centuries following a particularly notable point of heat concentration.

It describes the various uses of sugar (vinegar), including the pharmacological significance of ancient jaggery, sugarcane, and its juices, as well as the illnesses caused by these substances. Based on this, the Sushruta Samhita, a book that was written 560 years before Christ and is considered to be one of the three foundational books of Ayurveda, Brihadtrayi, is a treatise on medicine, surgery, and Ayurveda in ancient India. Thirteen cane species, sugarcane and its juices, the pharmacological characteristics of the disorders made from them, and their numerous applications in the treatment of various diseases in Uttaraantra are all mentioned in the book's predecessor, which is separated into two sections: the antipantra and the Uttaraantra (Srivastava and Singh, 2020).

Jaggery production and market scenario:

India has generated about 300 million metric tons of sugarcane in recent years. Of this amount, around 79.91% is used to make white sugar, 11.29% is used to make jaggery and khandsari, 8.80% is used to make cane juice, seed cane for the following harvest, etc. Jaggery (gur) recovery varies from 10–13%, depending on the variety, sugarcane quality, soil texture, irrigation facilities, crushing time, etc., while sugar recovery for various Indian states ranges from 8.89 to 11.26% on cane (MY 2018–19) (Narendra Mohan and Anushka Agarwal 2020).

Recent technologies in jaggery manufacturing process:

Current technologies in the production of jaggery: In India, three types of jaggery manufacturing plants have long been in use: single-pan, two-pan, and multi-pan (three or four pan) plants. Pans are usually hemispherical, cone-shaped, or rectangular with a flat surface in most jaggery production facilities. The type of pan used in the units has undergone a number of changes to improve heat efficiency. Schematic views of different jaggery making plants.

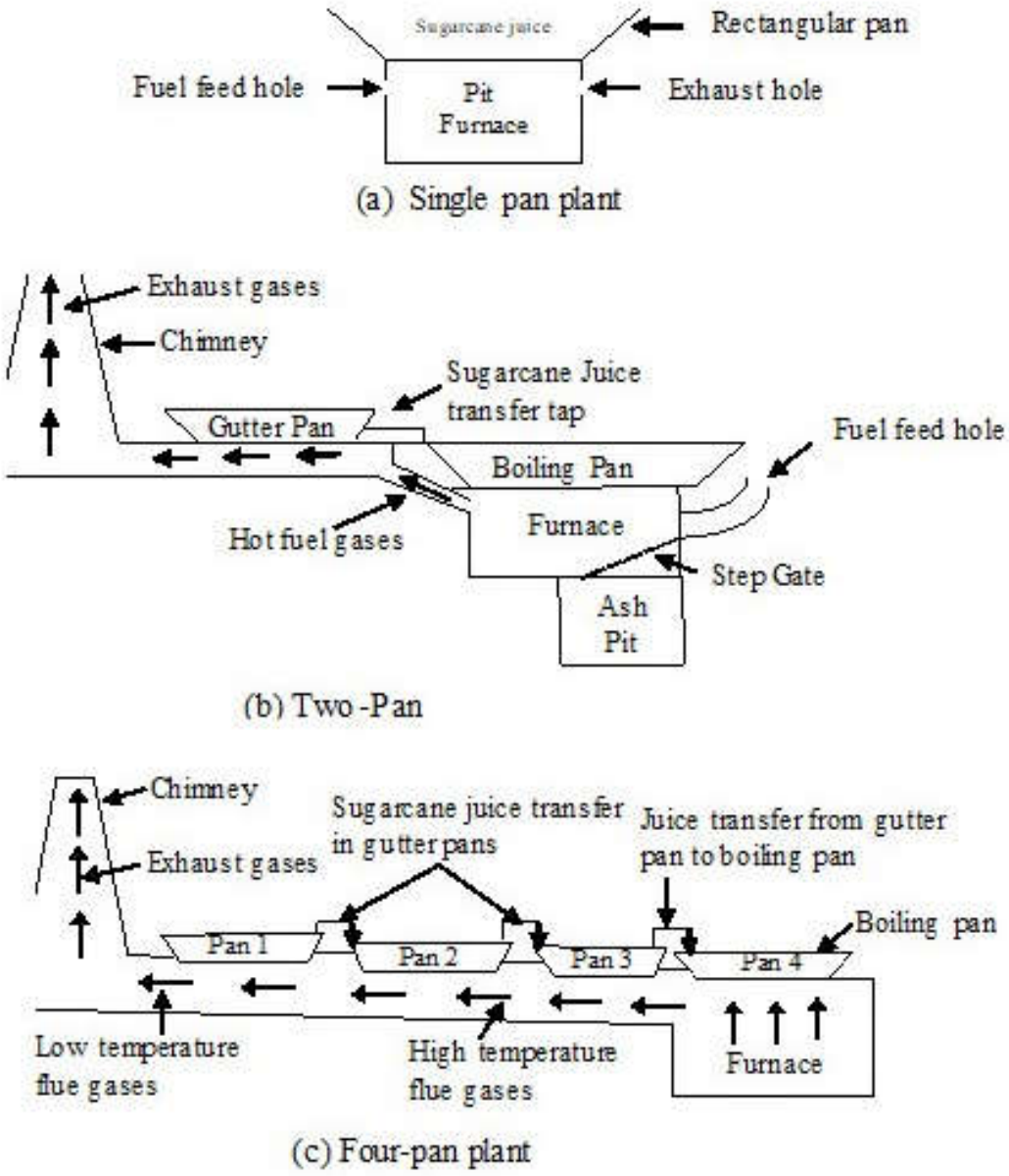

Figure 1 Schematic views of different jaggery making plants.

The schematic view of a two-pan jaggery making furnace is shown in Fig 3b. In addition to the gutter and boiling pans, one or two more pans will be fitted in a series manner in a multi-pan jaggery system. The sugarcane juice will be pre-heated in the first two pans before being moved to the boiling pan for actual heating. In the case of two pan jaggery making plants, two pans are

fitted at the top of the furnace: the first pan is the gutter pan, which is fixed as the first pan in which the sugarcane juice will be boiled.

The two pan jaggery producing model and the three or four pan model share comparable structural characteristics. Because more heat is generated in the three and four pan models, the jaggery-making plant performs better. However, using three or four pan types does not seem to result in a discernible improvement in thermal efficiency or a reduction in bagasse usage. Fig. 3c shows the schematic perspective of a four-pan jaggery-making plant.

Jaggery making using freeze pre-concentration of sugarcane juice

Making jaggery from sugarcane juice that has been frozen and pre-concentrated In 2005, Rane and Jabade introduced a novel concept for the concentration of sugarcane juice using a jaggery method: the heat pump dependent freeze concentration system (FCS). This technique uses selective freezing to obtain water from sugarcane juice as ice.

Figure 2 displays a schematic picture of the freeze concentration system utilized in a jaggery producing facility. This method creates concentrated juice and ice by selectively freezing and separating water from juice. After 20 to 40 minutes, the juice's freezing point drops from -1.5 to -4.6 degrees Celsius (Mathlouthi and Reiser, 1995).

This first 63% water removal saves bagasse, which may then be recycled for composting in the field. Low temperatures are used to generate concentrated juice. Using vegetable clarificants and a steam jacketed pan, this juice is further concentrated. Jaggery's color is improved overall, going from dark brown to golden yellow, which increases its market worth.

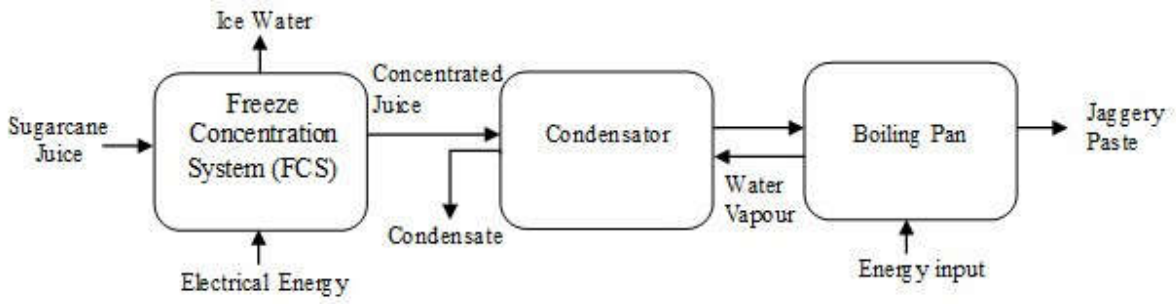

Figure 2 Schematic view of freeze concentration system.

The therapeutic benefits of jaggery

Although traditional sweeteners like jaggery are used worldwide, South Asia and Latin America are where they are most commonly utilized. A concentrated, unrefined sugar product is produced by extracting the water from date palm sap or sugarcane juice. Despite its many biological properties and potential health benefits, jaggery should only be used in moderation due to its high sugar content. The following are some of its biological traits and behaviors: Jaggery contains several essential elements, including Fe, Mg, and K. Among the fundamental bodily processes that rely on these minerals are the production of red blood cells and the maintenance of electrolyte balance. Phytochemicals and polyphenols, two types of antioxidants found in jaggery, may help minimize oxidative stress and reduce the risk of chronic diseases. Flavonoids, one of the components of jaggery, may have anti-inflammatory properties that help reduce inflammation in the body. Jaggery is claimed to help with digestion. By invigorating the digestive enzymes, it can lessen indigestion, constipation, and bloating. In many traditional medicinal systems, jaggery is given for respiratory ailments like coughing and colds. It is said to calm the throat and reduce respiratory discomfort. Iron-deficiency anemia may be prevented and treated with jaggery due to its high iron concentration. Only iron enables the oxygen-carrying protein in red blood cells, known as hemoglobin. As a naturally occurring source of carbohydrates, jaggery may help manage hormone imbalances, which is why some women take it to ease menstruation symptoms like mood swings and cramping in their stomachs. In many traditional practices, jaggery has been applied topically to wounds due to its potential antibacterial and wound-healing properties. Jaggery is often used in conjunction with other

herbal remedies to alleviate cold and cough symptoms. When coupled with herbs such as ginger and black pepper, it is believed to provide therapeutic effects for respiratory health.

A quick energy boost, it's popular among athletes and anyone who need a lot of energy. Because jaggery is heavy in calories and sugar, which can raise blood sugar levels, it should be used in moderation even though it may have some health benefits. Additionally, it's ideal to use organic and unprocessed jaggery because certain commercial varieties could contain additives or preservatives. Before making any dietary changes or additions, it's a good idea to consult a healthcare professional for specialized guidance, especially if you have underlying medical conditions like diabetes. For a number of reasons, jaggery is commonly referred to as "medicinal sugar" and used in both every day and pharmaceutical formulations (Hirpara et al., 2020; J. Singh, 2013; D. A. Pawar et al., 2017; Selvi et al., 2021).

1) Blood is purified by jaggery:

When taken consistently, jaggery helps to purify the blood and leave the body in a healthy state. It helps prevent a number of blood disorders and diseases by raising hemoglobin levels. Additionally, jaggery boosts immunity, which helps to avoid a number of blood-related problems.

2) Iron concentration:

Because it has a high iron and folate content, jaggery helps prevent anemia. Jaggery powder also prevents exhaustion and weakness by giving you rapid energy. In combination with vitamin C-rich foods, jaggery enhances the body's absorption of iron.

3) The amount of minerals:

Jaggery contains minerals and antioxidants, namely zinc and selenium, which help lower the risk of damage from free radicals. These minerals and antioxidants also help the body become more resistant to certain types of diseases.

4) Advantages for appearance:

Numerous natural properties of jaggery help to maintain the health of the skin for a very long time. It provides the skin with the nutrition it needs because of its high concentration of various minerals and vitamins.

5) Jaggery's digestive effects:

Digestion is sped up by jaggery, which encourages the release of digestive enzymes. A healthy digestive system helps regulate bowel motions and guards against issues including gas, stomach parasites, and constipation. This is highly beneficial for maintaining the proper operation of the digestive system. Intestinal issues are successfully avoided and dyspepsia is decreased when the digestive system is operating at peak efficiency.

6) Increased metabolism from jaggery:

Because of its high potassium concentration and powerful mineral content, jaggery helps people maintain their weight. This aids by reducing the body's capacity to retain more water. Jaggery's potassium boosts metabolism, maintains electrolyte balance, aids in muscular growth, and aids in weight loss.

7) Jaggery is used to cure water retention:

Common mild illnesses including colds, coughs, bloating, migraines, and water retention can be quickly cured with jaggery. For instant results, jaggery merely needs to be consumed with warm water or mixed into a beverage.

8) Jaggery aids with hormone regulation:

Jaggery has several positive benefits, especially for women who have mood fluctuations before their periods. Hormone fluctuations in the body are the cause of mood swings. Happy hormones called endorphins are released when you eat jaggery. Women feel better as a result of this physical relaxation.

9) Enhances cognitive abilities :

Additionally, jaggery helps prevent serious issues with the body's nervous system. It has many inherent characteristics that support the healthy operation of the nervous system. This allows people to continue living their normal, healthy lives.

10) Addresses respiratory issues :

Frequent jaggery consumption can protect against a number of respiratory disorders, such as asthma and bronchitis. Experts claim that eating jaggery, a naturally occurring sweetener, in the right amounts, together with sesamum seeds, benefits a person's respiratory system. Jaggery has properties that assist regulate body temperature, which is very beneficial for those with asthma. Additionally, keep in mind that jaggery contains anti-allergy properties.

11) Beneficial for joint discomfort

People who suffer from joint discomfort and aches may find that jaggery is a vital source of relief. Experts claim that mixing ginger and jaggery in a beverage can significantly lessen joint pain. Drinking a glass of milk with jaggery on a regular basis may help prevent bone and joint diseases like arthritis and strengthen bones.

The Nutritional Aspects of Jaggery:

Researchers have been examining functional foods in recent decades because of their potential to prevent and treat chronic diseases or their symptoms (Salehi et al., 2020; Sharifi-Rad, Dey, et al., 2021). Numerous authors have assessed the nutraceutical profile of jaggery, which is regarded as one of the world's most nutritious and healthful sugars (Singh, 2013) (Lamdande et al., 2018; Rao & Singh, 2022). P. V. Jagannadha Rao et al. (2010) documented the proximate composition of jaggery granules from palmyra, date, and sugarcane palms. The palmyra palm had the highest levels of protein (2.80%) and reducing sugar (12.41%), while sugar cane jaggery had the highest sucrose content (84.40%). Minerals such as iron, calcium, phosphorus, and magnesium were also found in jaggery granules, along with fat and protein (P. V. K. Jagannadha Rao et al., 2007; P. V. Jagannadha Rao et al., 2010).

Carbohydrates (sucrose: 72–78 g; fructose and glucose: 1.5–7 g), minerals (Ca: 40–100 mg; Mg: 70–90 mg; P: 20–90 mg; Na: 19–30 mg; Fe: 10–13 mg; Mn: 0.2–0.4 mg; Zn: 0.2–0.4 mg; Cl: 5.3–0.0 mg; 0.1–0.9 mg), vitamins (vitamin A: 3.8 mg; vitamin B2: 0.06 mg; vitamin B1, B5, and B6: 0.01 mg; vitamin C: 7.00 mg; vitamin D2: 650 mg; vitamin E: 111.30 mg), and protein (280 mg) were all found to be present in significant amounts in the nutritional composition of jaggery (100 g) made from sugar cane (Singh, 2013). Refined sugar had the highest amount of sucrose (99.70%–99.5%), while cane juice had the highest amounts of glucose (2%–4%), fructose (2%–4%), inorganic ash (2%–4%), organic ash (1%–3%), amino acids (0.5%–0.25%), and total polysaccharides (0.3%–0.6%).

Proximate composition	**Minimum–maximum range (%)**	
Ash	36	
Carbohydrate	83.90–97.2	
Reducing sugar	10.5	
Total sugar	87.5–95.4	
Sucrose	76.55−89.48	
Protein	1.7	
Fats	0.10	
Mineral content (per 100 g)	**Minimum–maximum range (µg/mL)**	
Iron	1.60–02.50	
Calcium	13.70–240.00	
Copper	0.17–8.50	Composition (Arif et al., 2019; Jaffé, 2015; Sahu and Saxena, 1994; Singh et al., 2011)
Chloride	5.30–250.00	
Iodine	0.01–0.01	
Chromium	11.90–16.00	
Phosphorus	2.00–125.00	
Sodium	15.50–79.00	
Potassium	14.00–1100.00	
Zinc	0.10–1.76	
Magnesium	31.00–120.00	
Cobalt	9.90–9.90	
Manganese	0.35–1.66	
Vitamins(per100g)	**Minimum–maximumrange(µg/mL)**	
VitaminA	0.00–3.8	
Bcarotene	0.00–16.15	

VitaminB1	0.01–0.05	
VitaminB2	0.04–0.11	
VitaminB3	0.08–7	
VitaminB5	0.01–1.38	
VitaminB6	0.01–0.72	
VitaminB9	0.00–10.00	
VitaminC	0.00–17.6	
VitaminD2	0.00–6.5	
VitaminE	0.00–55.65	
VitaminPP	7.00	

Chemical Composition:

Secondary metabolites or phytochemicals that are extracted from plant species have a variety of nutritional and medicinal uses (Amin et al., 2022; Salehi, Shetty, et al., 2019; Salehi,). Phenols, flavonoids, tannins, alkaloids, terpenoids, glycosides, and other types of organic chemicals make up these secondary metabolites (Salehi, Quispe, et al., 2021; Sharifi- Rad, Quispe, Herrera-Bravo, et al., 2021). The existence of different active chemicals in different varieties of jaggery is confirmed by multiple analyses of the chemical composition of jaggery (Mohan & Singh, 2020; Verma et al., 2019). The amount of phenolic acids and total phenols in jaggery, refined sugar, white sugar, and brown sugar were compared. Jaggery had the highest phenol concentration (3837 ± 154 µg gallic acid equivalent [GAE]/g), followed by refined sugar (26.5 ± 3.79 µg GAE/g), brown sugar (372 ± 1.44 µg GAE/g), and white sugar (31.5 ± 1.44 µg GAE/g). However, compared to other sugars, jaggery had the highest concentration of phenolic acids, including gentisic acid (130 ± 5.49 µg/g), gallic acid (122 ± 6.07 µg/g), protocatechuic acid (60.0 ± 3.47 µg/g), ferulic acid (34 ± 1.26 µg/g), 4 hydroxyphenyl acetic acid (29.5 ± 2.08 µg/g), and vanillic acid (25.6 ± 1.82 µg/g) (Harish Nayaka et al., 2009). Jaggery has 3285 µg GAE/g of phenol concentration, according to a different study on total phenol content (TPC) that

assessed TPC for molasses, refined sugar, raw sugar, and jaggery (Iqbal et al., 2017). The chemical makeup and colorimetric qualities of noncentrifugal cane sugar (conventional NCS bricks, granulated NCS, powdered NCS, and syrup of 50/70° Brix (S50)) produced using various processing techniques were examined by Alarcón et al. (2021) (Alarcón et al., 2021). Both the flavonoid and phenolic contents of NCS were found to be between 0.2% and 0.4% and 0.4% and 0.6%, respectively. For regular jaggery block, granulated sugar, light jaggery block, muscovado sugar, brown sugar, and cane honey, the HPLC result revealed the presence of chlorogenic acid, coumaric acid, caffeic acid, ferulic acid, flavones, tricin, and apigenin; however, luteolin was not found in cane sugar or brown sugar (Aynalem and Duraisamy, 2022; Barrera et al., 2020).

Chen et al. (2020) identified a total of 37 aromatic compounds including 4 alcohols, 8 carboxylic acids, 1 sulfur, 10 pyrazines, 3 esters, and 9 heterocyclic compounds in NCS by gas chromatography-olfactometry-mass spectrometry (GC-O-MS) analysis. Aromatic compounds like furfuryl alcohol, 2-ethyl-1-hexanol, 2,3-butanediol, 5-methyl furfuryl alcohol, phenylacetic acid, tetra decanoic acid, hexadecanoic acid, 3-phenyl-2-propenoic acid, dodecane-1-ol, hexanal, phenylacetic acid, 3-phenyl-2-propenoic acid, 2- methylpyrazine, 2,6-dimethylpyrazine, 2,5-dimethylpyrazine, 2,3-dimethylpyrazine, 2-ethyl-5-methylpyrazine, 2,3,5- trimethylpyrazine, 2-ethyl-6-methylpyrazine, 2-methyl-6- vinylpyrazine, 2-acetyl-6-methylpyrazine, 2,6-di-tert-butyl- pmethylphenol, 4-ethenyl-2-methoxyphenol, 2,4-di-tert- butylphenol, 4-ethenyl-2,6-dimethoxyphenol, 4-allyl-2,6- dimethoxyphenol, 2-methoxy-4-acetylphenol, 2-acetylfuran, 2-acetylpyrrole, 2-formylpyrrole, dibutyl phthalate, 1,3- dimethylbenzene, (+)-limonene, styrene, dimethyl sulfoxide were detected in NCS by GC-O-MS (Chen et al., 2020).

Phytochemicals	Type/content in jaggery	Reference
Phenolic acids	Gentisic acid (130 ± 5.49 µg/g), gallic acid (122 ± 6.07 µg/g) protocatechuic acid (60.0 ± 3.47 µg/g), ferulic acid (34 ± 1.26 µg/g, 4-hydroxyphenyl acetic acid (29.5 ± 2.08 µg/g), vanillic acid (25.6 ± 1.82 µg/g), syringic acid (1.08–2.80 µg/100 g), p-coumaric acid (0.69–1.35 µg/100 g)	Harish Nayaka et al. (2009); Alarcón et al. (2021)
Phenols	3285 µg GAE/g	Iqbal et al. (2017)

Flavonoids	0.2%–0.4%	Barrera et al. (2020)
Aromatic compounds	Furfuryl alcohol, 2-ethyl-1-hexanol, 2,3-butanediol, 5-methyl furfuryl alcohol, phenylacetic acid, tetra decanoic acid, hexadecanoic acid, 3-phenyl-2-propenoic acid, dodecane-1-ol, hexanal, phenylacetic acid, 3-phenyl-2-propenoic acid, 2-methylpyrazine, 2,6-dimethylpyrazine, 2,5-dimethylpyrazine, 2,3-dimethylpyrazine, 2-ethyl-5-methylpyrazine, 2,3,5-trimethylpyrazine, 2-ethyl-6- methylpyrazine, 2-methyl-6-vinylpyrazine, 2-acetyl-6-methylpyrazine, 2,6-di-tert- butyl-pmethylphenol, 4-ethenyl-2-methoxyphenol, 2,4-di-tert-butylphenol, 4-ethenyl-2,6-dimethoxyphenol, 4-allyl-2,6-dimethoxyphenol, 2-methoxy-4- acetylphenol, 2-acetylfuran, 2-acetylpyrrole, 2-formylpyrrole, dibutyl phthalate, 1,3-dimethylbenzene, (+)-limonene, styrene	Chen et al. (2020)