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Extracting the treasure of jaggery for enhancing human health through value-added products: A Review

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Abstract
Sugarcane *(Saccharum officinarum)* is a major cash crop, globally cultivated for its role in sugar production, contributing to 80% of the world's sugar supply. Jaggery, a non-centrifugal sugar derived from sugarcane juice, has gained attention as a healthier alternative to refined sugar due to its nutritional content, including essential minerals like iron, calcium, and potassium. Unlike white sugar, which is associated with various health issues, jaggery offers significant health benefits, including improved digestion, immunity, and the management of conditions such as anemia and hypertension.
This review focuses on the potential of value-added jaggery products, particularly when fortified with medicinal herbs, spices, and nuts, for enhanced health benefits. The fortification of jaggery with ingredients like pumpkin seeds, amaranth, and peanuts has resulted in the creation of energy bars, jams, and jaggery-based chocolates, providing both nutritional value and market potential. Comparative studies between sugar and jaggery based products reveal that jaggery-enriched formulations possess significantly higher mineral content, thereby offering a healthier alternative for nutritionally conscious consumers. Further, review studies evaluating the organoleptic qualities and physicochemical properties of jaggery-based products like mango jam and peanut energy bars highlight the high consumer acceptance of these items. The review also underscores the need for additional research into more value-added products, microbial safety and long-term storage viability of these products.

Keywords: Sugarcane, jaggery, value-added products, fortification, nutritional benefits, health, herbs & spices, fruits & vegetables

Introduction
Sugarcane (*Saccharum officinarum*), a member of the Poaceae family and Plantae kingdom, is an economically vital crop known for its role as a significant cash crop and its contribution to foreign exchange earnings. The juice extracted from sugarcane is processed into various sweeteners, including white sugar, brown sugar (khandsari), and jaggery (gur). This crop thrives in tropical and subtropical climates, preferring warm temperatures between 20-35 °C, well-distributed annual rainfall of 1000-1500 mm, and well-drained soils with a pH range of 6.5-7.5. It is well-suited to sandy loam, clay loam, and lateritic soils. The sugarcane industry also yields valuable by-products such as bagasse and molasses.
Globally, sugarcane is cultivated on a large scale, with Brazil and India being the top producers. It accounts for nearly 80% of the world's sugar production. In India, sugarcane was grown over an area of about 58.85 lakh hectares during 2022-23, producing approximately 4905.33 lakh tonnes (Annual Report, Department of Agriculture & Farmers Welfare, 2022-23). The primary sugarcane-producing states in India include Uttar Pradesh, Bihar, Assam, Haryana, Gujarat, Maharashtra, Karnataka, and Tamil Nadu. Among these, Maharashtra stands out for its substantial cultivation area and large number of operational sugar mills. The sugarcane sector plays a pivotal role in the socio-economic development of rural regions by generating employment, improving income levels, and mobilizing local resources.
Jaggery, also referred to as non-centrifugal sugar (NCS), is a traditional sweetener made by boiling sugarcane juice to remove water content. It is an unrefined blend of sugar and molasses, with sucrose levels ranging from 65% to 85%

The color of jaggery can vary from golden brown to dark brown, influenced by the method of preparation. It is nutritionally rich, providing essential minerals such as calcium (40-100 mg), magnesium (70-90 mg), potassium (1056 mg), phosphorus (20-90 mg), sodium (19-30 mg), iron (10-13 mg), manganese (0.2-0.5 mg), zinc (0.2-0.4 mg), copper (0.1-0.9 mg), and chloride (5.3 mg) per 100 grams. Additionally, jaggery contains several vitamins, including vitamin A (3.8 mg), B1 (0.01 mg), B2 (0.06 mg), B5 (0.01 mg), B6 (0.01 mg), C (7.00 mg), D2 (6.50 mg), E1 (11.30 mg), PP (7.00 mg), and protein (280 mg) per 100 grams (Shrivastava & Singh, 2020) [62].

As a high-calorie sweetener with natural contents like minerals, proteins, glucose, and fructose, jaggery is considered healthier than refined white sugar. High-quality jaggery typically contains over 70% sucrose, less than 10% glucose and fructose, below 5% minerals, and under 3% moisture. In India, jaggery is widely used in sweet and savory dishes and is also an important ingredient in herbal and traditional medicine systems. In Ayurveda, it is used as a remedy, blood purifier, and base for medicinal syrups.

The composition of jaggery varies with its physical form. Solid jaggery has lower moisture content (3-10%) and a higher energy value (383 kcal/100 g) compared to liquid jaggery, which contains 30-35% moisture and 300 kcal/100 g. Liquid jaggery also has higher reducing sugars (15-25%), whereas solid jaggery contains more non-reducing sugars (65-85%). Both types are low in protein (0.4-0.5%), fat (0.1%), and contain significant amounts of minerals (0.6-1%).

Table 1: General chemical composition of jaggery

Particulars	Chemical composition of different forms of jaggery	
	Solid	Liquid
Moisture content (%)	3-10	30-35
Reducing sugars (%)	9-15	15-25
Non-reducing sugars (%)	65-85	40-60
Protein (%)	0.4	0.5
Fat (%)	0.1	0.1
Total minerals (%)	0.6-1	0.75
Calorific value (Kcal)	383	300

Source: Baboo and Solomon (1995); Rao *et al*. (2007)

The regular and high consumption of refined white sugar is associated with several health problems, including dental issues, obesity, diabetes, and digestive disorders. White sugar is primarily composed of sucrose and lacks essential nutrients, making it a source of empty calories (Rao and Singh, 2022) [50]. In contrast, jaggery provides not only energy but also essential minerals, antioxidants, and vitamins, making it a more wholesome and nutritious sweetener. Jaggery is known to help in the prevention and management of various health conditions, such as anaemia, rheumatic diseases, bile disorders, and hypertension. It also aids in muscle and nerve relaxation, blood vessel health, and immune system support (Rao and Singh, 2022) [50].

Scientific studies have increasingly confirmed that non-centrifugal sugar (NCS) offers a range of health benefits**;** however, it remains largely overlooked in the current focus on functional foods and nutraceuticals**.** The most commonly reported benefit is its immunological effect (26%), followed by its anti-toxic and cytoprotective properties (22%), anticariogenic effects (15%), and its influence on diabetes and hypertension (11%). Some of these health benefits are attributed to the presence of iron (Fe) and chromium (Cr), while others are believed to result from the antioxidant compounds found in NCS.

Value-added jaggery products offer significant health benefits due to its rich content of amino acids, antioxidants, minerals, and vitamins, making it a healthier alternative to white sugar. Fortifying jaggery with medicinal herbs and spices can further enhance its nutritional value and introduce new flavours. With growing demand for healthy, convenient foods, fortified jaggery provides a versatile, nutritious sweetener option for daily use. Value-added jaggery products with enhanced health attributes and taste are gaining popularity, offering a promising solution for consumers seeking nutritious and functional foods (Rao and Singh, 2021) [64]. Value-added products from jaggery can be made by combining it with puffed rice, sesame, nuts (peanut, cashew, almond), and flavour enhancers like chocolate powder in different proportions. For instance, jaggery combined with 10% cocoa powder is well accepted as a chocolate substitute (Said *et al*., 2013) [57].

Peanut and jaggery mixtures also produce high-energy foods rich in bioactive molecules, vitamins, and minerals. Seeds like sesame, flaxseed, chia, and sunflower, rich in antioxidants, can be added to jaggery for fortified energy products (Said *et al.*, 2013) [57]. Commercial products include jaggery candies, cakes, flavoured alcoholic drinks, and jaggery enhanced with natural flavours (lemon, strawberry, chocolate), and nutritional supplements like protein and vitamins (Said *et al*., 2013) [57]. Popular traditional sweets such as rasgulla, Pedaand laddu made with puffed grains, almonds, and sesame are also value-added jaggery products.

Medicinal Benefits of Jaggery

Sugarcane contains a variety of beneficial phytochemicals, including phenolic compounds, plant sterols, and policosanols. Phenolic compounds help plants defend themselves against pests and diseases, while plant sterols and policosanols are essential components of plant waxes and oils. These compounds have attracted considerable scientific attention due to their antioxidant properties, cholesterol-lowering effects, and other potential health benefits. Numerous studies, both *in vivo* and *in vitro*, have highlighted the wide range of biological activities exhibited by sugarcane.

Antioxidant Properties

The production of Reactive Oxygen Species (ROS) can damage essential biomolecules like proteins, DNA, and lipids, leading to diseases such as atherosclerosis, diabetes, hypertension, aging, Alzheimer's disease, kidney disorders, and cancer. One of the most effective strategies to combat ROS is the use of dietary antioxidants. These are molecules capable of donating electrons to free radicals, thereby neutralizing them and preventing cellular damage. This protective action helps safeguard critical cellular components like nucleic acids, proteins, and lipids (Robert and Sindhu, 2009) [54].

Non-centrifugal sugar (NCS), such as jaggery, demonstrates strong antioxidant potential, primarily due to its high polyphenol content. Key antioxidants in NCS include phenolic acids and flavonoids. Noteworthy phenolic acids responsible for its antioxidant effects are caffeic acid, p-coumaric acid, ferulic acid, syringic acid, vanillic acid, and

chlorogenic acid. As a result, NCS can be used alone or alongside conventional therapies to help manage chronic diseases related to oxidative stress (Azlan *et al*., 2020; Cifuentes *et al*., 2021) [7, 13].

Anti-Inflammatory Properties

Inflammation is a natural immune response to triggers such as pathogens, toxins, or damaged cells. It can lead to either acute or chronic inflammation, potentially causing tissue damage or contributing to disease. Although research in this area is still emerging, some studies suggest that NCS may help reduce inflammation or promote the formation of anti-inflammatory compounds (Chen *et al*., 2018) [11].

A study by Singh *et al*. (2010) showed that mice exposed to arsenic-contaminated water experienced immune toxicity and elevated levels of pro-inflammatory cytokines, including interleukin-1 (IL-1), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α). However, when jaggery was administered alongside arsenic, it significantly lowered these cytokine levels, indicating its anti-inflammatory potential.

Anti-Obesity Effects

Obesity is a major factor contributing to metabolic syndrome (MetS). The anti-obesity effects of NCS have been examined in animal models. In one study, rats were fed a diet containing 15% NCS over a period of 42 days. The results showed a notable reduction in weight gain in comparison to rats that consumed a diet based on regular starch (RS), (Shamsi-Goushki *et al*., 2021) [61].

Antidiabetic Effects

For many years, researchers have studied the therapeutic potential of natural sweeteners in managing diabetes (Negai and Ito, 2013; Mejia and Pearlman, 2019) [39, 38]. While reducing sugars are quickly absorbed into the bloodstream and cause a rapid energy spike, making them unsuitable for diabetics, NCS is digested more slowly, leading to a gradual release of energy. This slower absorption makes NCS a healthier alternative for individuals with diabetes (Sanchez *et al*., 2019) [59]. Multiple studies are being conducted to further understand how NCS influences glucose metabolism and insulin resistance.

Different value-added product made from jaggery

- **Fruits and vegetable-basedproducts**

Jaggery-Based Fruit Bar

The popularity of snack bars is on the rise due to their convenience, appealing taste, affordability, and attractive appearance (Izzo and Niness, 2001) [24]. Regular consumption of fruits and vegetables contributes positively to overall health, as they are rich sources of micronutrients and antioxidants. In contrast, unhealthy junk foods are associated with negative effects, including a decline in cognitive and physical performance (Njike *et al*., 2016) [41]. Snack bars also tend to have a long shelf life due to their low moisture content, although they may undergo lipid peroxidation at room temperature, resulting in the formation of free fatty acids. Consumer appeal is often influenced by the sweetness and color of the bars (Meethal *et al*., 2017) [37]. A diet rich in vitamins, minerals, carbohydrates, proteins, and fats is essential for maintaining good health. Standardization refers to the process of repeated trials to refine a product until the desired quality and characteristics are achieved (Quadri and Rao, 2018) [47]. In developing jaggery-based bars, jaggery, groundnuts, oats, and pumpkin seeds were used as fixed ingredients across different formulations. All processed ingredients were mixed with jaggery syrup, spread on a greased surface, allowed to cool, and then cut into uniform bars.

Two formulations were developed, each with three different fruit combinations, and evaluated based on sensory characteristics. Among these, the bar containing 15% jaggery with a higher proportion of dates received the highest overall acceptability, followed by the bar made with pineapple, while the beetroot-based bar scored the lowest (Sree *et al*., 2020) [67].

Jaggery-Based Beetroot Jam

With rising consumer interest in healthier dietary choices, the demand for functional foods is growing. This study focused on developing a beetroot jam (BJ) sweetened with jaggery (a non-centrifugal sugar). The jam was formulated by partially replacing refined sugar with jaggery and evaluated for its sensory properties using the Compromised Acceptance Threshold (CAT) and Hedonic Rejection Threshold (HRT) methods (Dubey *et al*., 2023) [16, 17].

Beetroots were peeled, weighed using a CP-220 balance (Sartorius, Germany), pressure-cooked, and blended using a mixer grinder (MGAC75G4, Orient Electric Accord, 750 W). Various combinations of sugar-jaggery concentrations (40%, 45%, 50%, 55%, and 60% of total weight), pectin (1%, 1.2%, and 2% of beetroot weight), and citric acid (0.5%, 1%, and 1.5% w/w of beetroot) were tested using a one-factor-at-a-time (OFAT) approach to optimize ingredient levels. The most acceptable formulation contained 50% jaggery, 1.2% pectin, and 1% citric acid.

Five jam formulations were developed with different levels of sugar substitution by jaggery: 0% (BS), 25% (BJ25), 50% (BJ50), 75% (BJ75), and 100% (BJ100), (Dubey *et al*., 2023) [16, 17]. After optimizing the key ingredients, the flavor was further enhanced using cinnamon extract (100 µL/100 g of jam). The mixture of pulp, citric acid, pectin, sugar and/or jaggery was cooked in a non-stick pan over a low flame (180-190 °C) with constant stirring until it reached a Total Soluble Solids (TSS) content of 65° Brix, measured using a handheld refractometer (Erma, Tokyo, Japan). Once TSS reached 65-66%, the cinnamon extract was added. The hot jam was poured into sterilized 200 ml mason jars, sealed, and heat-treated (canned) to avoid microbial contamination. The jars were cooled at room temperature (28-30 °C), allowing the jam to set and reach a final TSS of 68%, and were then stored at 4°C for further analysis of physicochemical, nutritional, and nutraceutical properties (Dubey *et al*., 2023) [16, 17].

Star Fruit Jaggery Jelly

Star fruit, an underutilized fruit cultivated in India, China, the U.S., and parts of Africa, is known for its unique star shape and golden color. Rich in essential nutrients, it offers multiple health benefits. This study focused on developing a jaggery-based jelly with favorable physicochemical and textural properties using response surface methodology (RSM) for ingredient optimization (Chaurasia *et al*., 2023) [10]. Star fruit also has traditional medicinal uses for treating ailments like headaches, fever, and skin rashes due to its antioxidant, anti-inflammatory, and hypotensive effects (Dasgupta *et al*., 2013) [14].

The jelly was prepared using different levels of jaggery (33.2%, 40%, 50%, 60%, and 66.8%), citric acid (0.2% to 0.6%), and food-grade pectin (0.2% to 1%). All measurements were done with an analytical balance (MAC, India; Model: AB 600). Star fruit mass was kept constant at 100 g. After washing and slicing mature fruits, water was added and the mixture was boiled for 20-30 minutes. The juice was filtered using muslin cloth, transferred to a stainless-steel pan, and simmered. Jaggery was added and continuously stirred, followed by pectin and citric acid, with scum removal. The jelly was considered ready when it reached a TSS of 65-68° Brix, confirmed via sheet and drop tests. It was then poured into silicone molds (Panchal *et al*., 2018) [44].

Jaggery-Based RTS Beverage

Kagzi lime (*Citrus aurantifolia* L.) from the Rutaceae family is widely cultivated in India and ranks as the third most important citrus fruit after mandarin and sweet orange. Maharashtra is the leading producer, especially in the Vidarbha and Marathwada regions. There is strong potential for commercializing spiced Ready-To-Serve (RTS) beverages made with jaggery as a natural health drink. Lime-based drinks are gaining global popularity due to their health-promoting properties. This study aimed to standardize an RTS beverage using juice from Kagzi lime (cv. Sai Sharbati), jaggery syrup, and a blend of spice extracts (Walhekar *et al*., 2018) [70].

The ingredients included ginger, mint, cardamom, clove, cumin, jaggery, and potassium metabisulfite (KMS), all locally sourced. Lime juice was extracted and filtered through muslin cloth. Ginger and mint were juiced, while dry spices were ground, mixed with water, and filtered. The RTS drinks were formulated with varying spice concentrations:

- T_1 = 2.5% lime juice (no spices)
- T_2 = 2.5% lime juice + 0.5% spice extract
- T_3 = 2.5% lime juice + 0.7% spice extract
- T_4 = 2.5% lime juice + 0.9% spice extract
- T_5 = 2.5% lime juice + 1.1% spice extract
- T_6 = 2.5% lime juice + 1.3% spice extract

Each beverage included jaggery syrup and KMS at 750 ppm and was adjusted to 12° Brix TSS. The beverages were pasteurized at 60 °C for 30 minutes, cooled, bottled, and analyzed for physicochemical parameters following Ranganna (1986). The formulation with 2.5% lime juice and 0.9% spice extract (T_4) achieved optimal results with TSS of 12° Brix and acidity of 0.31%, and was rated best overall (Walhekar *et al*., 2018) [70].

Jaggery-Based Dates Pickle

Pickling, one of the oldest food preservation methods, uses salt or vinegar to preserve fruits and vegetables. This study successfully prepared a dates-based pickle using dates, jaggery, tamarind pulp, and spices. Both dates and jaggery are excellent sources of carbohydrates and iron. Three different formulations were tested, with the third trial (T_3) receiving the highest sensory evaluation score (Kokani *et al*., 2019) [30].

The formulations included varying proportions:-

- 50% dates: 30% jaggery: 5% tamarind pulp: 15% spices
- 40% dates: 40% jaggery: 5% tamarind pulp: 15% spices
- 40% dates: 30% jaggery: 15% tamarind pulp: 15% spices

Dried dates were deseeded and soaked in water for 24 hours. Tamarind pulp was prepared by soaking in 50 °C water for 30 minutes and strained. Spices were roasted, ground, and stored. For pickle preparation, jaggery was first heated with oil and tamarind pulp at 103 °C-106 °C for 5 minutes, followed by the addition of soaked dates and further cooking at 240 °C for 10 minutes. After cooling, spice powder and salt were added, and the pickle was stored in glass bottles at room temperature (Kokani *et al*., 2019) [30].

The final product was nutritionally rich, particularly in carbohydrates, proteins, and energy content. This value-added product contributes significantly as a nutritious energy source.

- **Dairy and Confectionery products**

Jaggery-Based Basundi

Basundi is a traditional Indian dessert typically sweetened with refined white sugar. Due to increasing health concerns associated with refined sugar, the trend of replacing it with jaggery is gaining momentum. The current study explored the preparation of buffalo milk-based basundi using chemically processed jaggery at concentrations of 5%, 6%, and 7%, labeled as T_1, T_2, and T_3, respectively (Ayare *et al*., 2020) [6].

Basundi is a thickened milk dessert characterized by a creamy texture, caramelized flavor, and a pleasant aroma. It is usually light to medium brown in color and is commonly enjoyed during festive occasions in states like Maharashtra, Gujarat, and Karnataka (Pagote, 2003) [43]. With rising popularity due to its taste, the demand for basundi is increasing. However, as refined sugar is linked to obesity, diabetes, and cardiovascular diseases, consumers are leaning toward healthier sweeteners like jaggery. India is the largest producer and consumer of jaggery, contributing over 70% of global production (Pravallika *et al*., 2018) [46]. Jaggery offers numerous health benefits, including lung protection as evidenced in animal studies (Sahu and Saxena, 1994) [56].

Basundi was prepared following the method described by Gaikwad and Hembade (2013) [18] with the only modification being the substitution of sugar with jaggery. Fresh buffalo milk was boiled in an iron pan with continuous stirring and scraping using a wooden ladle. Once the volume was reduced by half, jaggery was added at the prescribed concentrations. The mixture was gently heated until it reached a 2:1 concentration ratio. It was further boiled for 10 minutes, cooled, and stored at a low temperature until consumption.

Jaggery-Based Cold Extruded Products

Pravallika *et al*. (2018) [46] highlighted that solid jaggery can be made more nutritious by adding puffed rice, gram, sesame, cashews, almonds, vitamins, iron, and even chocolate powder, which can boost both nutritional value and consumer appeal.

The nutritional value and palatability of jaggery can be improved by combining it with ingredients like puffed rice, gram, groundnuts, wheat flour, or gram flour. Jaggery combined with 10% cocoa powder produced a highly acceptable chocolate alternative. The addition of jaggery to wheat-soy flour blends enhances taste and nutritional quality. Snacks extruded from such blends can fulfill

nutritional needs and serve as functional foods (Khan *et al*., 2012) [29]. Cold extruded jaggery products were prepared using a single-screw extruder. Multigrain flour, refined wheat flour (maida), and jaggery powder were mixed and kneaded for 45 minutes. The dough was shaped into forms like ribbed tubes and spirals using different dies. The extruded products were cooled with a fan, dried in a tray dryer, and stored (Pravallika *et al*., 2018) [46].

Jaggery-Based Bomboyson

Bomboyson is a traditional dairy-based sweet from eastern Nepal made with khoa, sugar, and ghee, and is commercially viable (Gartaula and Bhattarai, 2014). Since sugar lacks essential nutrients, jaggery a richer source of minerals and bioactive compounds is considered a healthier alternative. Jaggery contains 65-85% sucrose compared to sugar's 99.5%, and significantly more minerals (Nayaka *et al*., 2009) [40]. For preparation, 100 g of khoa was heated with varying levels of jaggery or sugar (20, 30, or 40 g), and the mixture was cooked to 116 °C for 15 minutes. Ghee (15, 20, or 25 g) was added during further cooking until the desired texture and color were achieved. The final product was poured into trays, allowed to cool, and packaged in polyethylene to preserve freshness.

Jaggery-Based Ice Cream

Ice cream is a highly nutritious frozen dairy dessert, enjoyed by all age groups for its rich flavor and texture (Soad *et al*., 2014; Adriano *et al*., 2009) [65, 1]. This study focused on creating a nutritious palmyra pulp-based ice cream enhanced with spices and jaggery.

Ratnasingam and Jayasinghe (2021) [52] added less bitter palmyra pulp before the overrun stage to enhance flavor and texture. One version used 25% pulp; another included 125 ppm of ginger for a spiced variation. Jaggery was added post-overrun to create a jaggery-ginger flavored ice cream. The result was a series of health-focused, flavor-rich ice creams.

Jaggery-Based Chikki

Chikki is a popular Indian traditional sweet, typically made using jaggery and roasted peanuts. Jaggery, derived from concentrated sugarcane juice, contains essential proteins, minerals, and vitamins, and is particularly rich in iron and copper (Manay and Swamy, 2001) [34].

According to Chetana and Sunkireddy (2010) [12], equal parts of jaggery and peanuts were used. Jaggery was made into syrup, filtered, and boiled to 145°C. Roasted peanuts were added and coated with syrup. The hot mixture was spread on an oiled surface, flattened, cut into pieces, cooled, and packed in polythene pouches.

Jaggery-Based Chocolate

Jaggery is richer in minerals and vitamins compared to refined or brown sugar, with 50 times more minerals than refined sugar (Gopalan *et al*., 1991) [20]. Traditional chocolates, often high in calories and low in nutritional value, can be improved by replacing sugar with jaggery (Kedari, 2005) [28].

Chand *et al*. (2011) [8] prepared jaggery chocolate by heating 400 g of liquid jaggery at 110 °C for 10 minutes, adding ingredients, and mixing at 80 rpm. The mix was poured into buttered molds, cooled for 24 hours, removed, and conditioned at 22 °C before drying.

Jaggery Energy Bar

Energy bars are convenient, nutrient-rich snacks, increasingly in demand due to their portability and health benefits (Ryland *et al*., 2010; Williams *et al*., 2006) [55, 71]. Jaggery, known for purifying blood and supporting liver function, is used as a key ingredient.

Bengal gram, flax seeds, and watermelon seeds were roasted at 150 °C for 4 minutes. Jaggery was heated to 120°C to form syrup, then mixed with the roasted ingredients. The mixture was spread on a greased tray, cooled, cut into bars, and packed (Ansari *et al*., 2019) [5].

Jaggery-Based Cookies

Cookies are a widely consumed snack but are usually made from refined flour and sugar, offering limited nutritional value (Rao and Singh, 2022). Replacing sugar with jaggery adds antioxidants, minerals, and vitamins, making the product more healthful (Kumar and Kumar, 2018) [31].

Dubey *et al*. (2023) [16, 17] created control cookies using sugar and refined flour, and test cookies by replacing 25-100% of sugar with jaggery. Whole wheat flour and finger millet flour were also used. The jaggery cookies showed high acceptability, especially those with finger millet.

Jaggery-Based Candy

Hard-boiled candies are popular worldwide. However, replacing sugar with jaggery often results in stickier and chewier textures (Sairagul *et al*., 2020) [58]. Jaggery, being rich in minerals, is a healthier sweetener compared to refined sugar (Chandrakanth *et al*., 2019) [9].

Kumar *et al*. (2022) [32] conducted trials using jaggery with gelling agents (gum acacia, guar gum, xanthan gum, and gelatin) at 0.25-1.0% concentrations. The control candy used equal parts sugar and glucose cooked to 140-142 °C. Jaggery-based variants were evaluated for texture, flavor, and process optimization.

Puran Poli

Puran Poli is a popular Maharashtrian festive dish, consisting of a sweet lentil filling encased in flatbread. Different varieties exist, but the version using Bengal gram is most common (Kadbhane and Giram, 2019) [27].

The filling (puran) is prepared by pressure-cooking 250 g Bengal gram dal for 15-18 minutes, mashing it, and cooking with jaggery and spices for 10 minutes. The dough is made from 100 g wheat flour, hot water, salt, and 10 g of MCT. Each poli is stuffed, rolled, and roasted with MCT until golden brown (Jadhav and Annapure, 2022) [25].

Adhirasam

Adhirasam is a traditional deep-fried sweet made with millet and jaggery. Kodo millet, native to India and Africa, is rich in fiber, antioxidants, and iron (Deshpande *et al*., 2015).

Kodo millet and rice flour (1:1) are mixed with water and rested for 4 hours. Jaggery syrup is prepared separately and mixed with the flour blend. The dough is fermented overnight, shaped into discs, and deep-fried until golden brown. The resulting sweet is rich in nutrients and easy to digest.

- **Jaggery Combined with Herbs & Spices**

According to Singh and Rao (2021) [64], the health-promoting qualities of jaggery have been recognized in ancient Indian texts. Unlike refined sugar, which is purely

composed of sucrose, jaggery contains a rich mix of sucrose, mineral salts, iron, and some dietary fiber. It is regarded as a healthier alternative because it generates heat and supplies instant energy. Hirpara *et al.* (2020) [23] emphasized jaggery's medicinal and nutritional properties, making it a suitable ingredient for a range of health-oriented products. Owing to its content of vital amino acids, vitamins, and minerals, jaggery is considered a nutraceutical.

Cardamom with Jaggery

Cardamom (*Elettaria cardamomum*) is rich in bioactive and phytochemical compounds such as α-terpinyl acetate, 4-terpineol, and geraniol. As per Singh and Rao (2021) [64], both jaggery and cardamom provide antioxidant, detoxifying, and diuretic benefits. This combination may help lower blood pressure, protect against chronic illnesses, and enhance cancer-fighting properties. Additionally, it supports digestive health and helps prevent ulcers. Consuming cardamom with jaggery, for example in tea, may aid digestion, freshen breath, and combat infections.

Dry Ginger with Jaggery

Dry ginger (*Zingiber officinale*) contains compounds like gingerols, shogaols, paradols, and oleoresin, known for their potent antioxidant and anti-inflammatory effects (Mao *et al*., 2019) [35]. When combined with jaggery rich in calcium, iron, phosphorus, amino acids, and vitamins the mixture helps relieve colds, improves digestion, supports weight loss, and aids in treating anemia, menstrual discomfort, and joint pain. The blend is also effective in lowering cholesterol and managing asthma or allergies. Incorporating sonth (dry ginger powder) and jaggery into foods like laddoos or cookies enhances these therapeutic effects (Singh and Rao, 2021) [64].

Holy Basil (Tulsi) with Jaggery

Holy basil (*Ocimum tenuiflorum*) contains compounds such as ursolic acid, rosmarinic acid, eugenol, and β-caryophyllene, making it highly antioxidant, antiviral, and antiseptic. Combined with jaggery which is rich in zinc and selenium, known antioxidants tulsi strengthens immunity, fights respiratory infections like colds and flu, and improves cardiovascular health.

Mint with Jaggery

Mint (*Mentha piperita*), commonly known as pudina, is renowned for its refreshing flavor and health-enhancing compounds such as menthol, menthone, and methyl acetate (Reddy *et al*., 2019) [53]. These components possess significant antimicrobial properties. When paired with jaggery, both ingredients offer minerals like iron, potassium, and manganese, which help increase hemoglobin and support cognitive functions. This combination also aids in healthy weight loss by preventing water retention and enhancing metabolism. Additionally, it improves lung health and alleviates respiratory issues such as asthma and coughs (Anonymous, 2018c; 2020) [2, 3].

Turmeric with Jaggery

Turmeric (*Curcuma longa*) contains *curcumin, turmerone*, and other curcuminoids, all of which have potent anti-inflammatory and antioxidant properties. These compounds are beneficial in preventing heart diseases, neurodegenerative disorders, and certain types of cancer (Hewlings and Kalman, 2017) [22]. A mixture of jaggery, dried ginger, and black pepper is known to relieve chronic coughs and throat irritation due to its soothing properties (Singh and Rao, 2021) [64].

Black Pepper with Jaggery

Black pepper (*Piper nigrum*) contains piperine, a compound that supports brain function, improves memory, and regulates blood sugar and cholesterol levels (Masood *et al*., 2013) [36]. Its antioxidant and anti-inflammatory properties are enhanced when combined with jaggery. This blend can also support weight loss, cleanse the digestive system, and aid in heart rate and blood pressure regulation due to the presence of vitamin B and potassium (Gupta *et al*., 2012) [21].

Cinnamon with Jaggery

Cinnamon (*Cinnamomum verum*) is rich in cinnamaldehyde, cinnamic acid, and polyphenols that have antimicrobial and antifungal actions. These bioactive elements help regulate blood sugar and reduce heart disease risks (Rao *et al*., 2014). When paired with jaggery, this combination supports heart health, boosts immunity, and helps manage digestive issues and respiratory infections (Singh and Rao, 2021) [64].

Conclusion

This review underscores the increasing relevance of jaggery as a functional and health-supportive sweetener. As a nutrient-rich substitute for refined sugar, jaggery offers a superior profile packed with vitamins, minerals, and antioxidants. Its therapeutic benefits include aiding digestion, reducing inflammation, and supporting the management of metabolic conditions like diabetes and obesity. Enhancing jaggery with herbs, spices, and nuts further amplifies its health benefits, paving the way for innovative products such as fortified sweets, energy bars, and functional confections. These products not only improve nutritional value but also align with consumer demands for natural and wholesome foods. Nonetheless, more research is essential to assess aspects like microbial safety, shelf stability, and sensory appeal to ensure wider market acceptance. Overall, jaggery holds strong potential as a nutraceutical, and its broader use could contribute to sustainable, health-forward food solutions benefiting both consumers and producers.

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