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Exploring the nutritive sweetener liquid jaggery: Physicochemical characteristics and its application

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Abstract
India, a global food security contributor, harnesses its agricultural prowess to feed nearly 18% of the world's population. In the confectionery industry, as consumer preferences shift towards healthier options, liquid jaggery, a semi-solid derived from concentrated sugarcane juice, emerges as a nutritional alternative sweetener. This paper explores the physicochemical characteristics of liquid jaggery, a traditional sweetener with potential global applications. The research employs CO86032 variety sugarcane for analysis, evaluating physical, chemical, and phytochemical properties. Results reveal a high concentration of soluble solids (73° Brix), indicating its potency as a sweetening agent. The low percentage of insoluble solids suggests a smooth texture suitable for various food applications. Chemical analysis indicates a primarily sugary composition, with a moisture content of 21.32%, minimal fat (0.45%), and a slightly acidic pH (5.03). Mineral composition analysis demonstrates the presence of essential elements such as potassium, calcium, magnesium, iron, and zinc, contributing to overall nutritional value. Phytochemical analysis reveals significant levels of total phenols (4.46 mg GAE/gm), tannins (5.97 mg TAE/gm), and flavonoids (0.82 mg QE/ml), showcasing liquid jaggery's antioxidant properties. This comprehensive exploration of liquid jaggery's physicochemical characteristics provides valuable insights into its potential as a natural and organic sweetener with diverse applications, aligning with the global shift towards healthier dietary choices.

Keywords: Liquid jaggery, jaggery, minerals, sweetener, phytochemical

1. Introduction
India, with 2.4 percent of the world's land and 4 percent of its water resources, plays a remarkable role in global food security by successfully feeding nearly 18 percent of the world's population. This agricultural prowess results from ongoing reforms, progressive policies, and the integration of grassroots technology. India proudly holds the title of the world's largest producer of pulses, jute, and milk, and the second-largest producer of rice, wheat, sugarcane, cotton, and groundnuts (Saxena, 2022) [19]. In the diverse world of sugarcane-derived products, this research paper casts a spotlight on liquid jaggery.

Liquid jaggery, a semi-solid derived from concentrated sugarcane juice, is esteemed for its nutritional value, positioning itself as a viable alternative sweetener (Rao *et al*., 2007) [17]. Jaggery is known as "gur" in northern India and "velllum" or "bellam" in southern India, and has different names depending on its origin. Jaggery is a natural traditional sweetener produced by concentrating sugarcane juice or sap obtained from various palm trees (Deotale *et al*., 2019) [5]. Its title of healthiest sugar comes from its mineral and vitamin content, which is similar to sugar cane juice. The color of jaggery varies from golden to golden brown, and its quality is judged by characteristics such as color, texture, crystal structure, sweetness, and low impurities (Kumar *et al*., 2013) [9].

Jaggery is available in three forms in the market: solid, liquid and granular. While 80% of jaggery is solid, from sources including sugar cane, date palm, palmyra palm and coconut, the remaining 20% is liquid jaggery, known as 'Kakawi' in some Maharashtra regions (Vengaiah *et al*., 2013; Nath *et al*., 2015) [22, 13].

The process of preparation of liquid jaggery involves concentrating the sugarcane juice until its sugar content reaches around 60-70° Brix, corresponding to a temperature of 105-108 °C. Preservatives such as benzoic acid and citric acid need to be added during the preservation process to extend the shelf life and prevent crystallization (Hirpara *et al*., 2020) [8]. Notably, liquid jaggery not only finds a place in the diet but also serves as a sweetener in various food preparations, beverages and traditional foods.

Additionally, it is used as a base sweetener in pharmaceutical preparations, especially in Ayurvedic medicines available in the form of syrups. (Deotale *et al*., 2019) [5].

Growing global awareness of the negative impacts of current diets and sedentary lifestyles provides an opportunity for a revitalization of natural and organic products such as NCS. Jaggery, a traditional minimally processed sweetener, stands out for its unique flavor and aroma, not only for its sweetness but also for its nutritional value. This study aimed to comprehensively analyse the physicochemical properties of liquid jaggery and explore its diverse applications in the food industry. This study focuses on its importance in the Indian agricultural landscape and its potential as a global sweetener, helping to understand the role of liquid jaggery in health, nutrition and culinary applications.

2. Materials and Methods

From the different varieties of sugarcanes, CO86032 variety were selected for analysis and procured from sugarcane processing unit, near Parbhani district.

2.1 Physical Analysis of Liquid Jaggery

The total soluble solids of liquid jaggery was measured by using a handheld refractometer as per AOAC (2005) [2]. The specific gravity and the percent of insoluble solids present in liquid jaggery were measured by procedure given in the FSSAI Manual (2015) [6]. The viscosity of liquid jaggery was calculated in mili pascal per second using a viscometer as per the method suggested by Manzar and Singh (2018) [11].

2.2 Chemical Analysis of Liquid jaggery

The pH of liquid jaggery was determined by method described by Guerra and Mujica (2010) [7]. The proximate and mineral composition of liquid jaggery was analyzed by the methods given in AOAC (2005) [2]. The sugar profile of liquid jaggery was analyzed as per the procedures given in the FSSAI Manual (2015) [6].

2.3 Phytochemical analysis of liquid jaggery

Phytochemical analysis of liquid jaggery included determination of total phenolic, total tannin and total flavonoid content in liquid jaggery. The total phenolic content and tannin content of jaggery was determined spectrophotometrically using the Folin-Ciocalteu's method as described by Singleton *et al*. (1999) [21]. Using gallic acid as the standard, the total phenolic content was expressed in milligrams of gallic acid equivalents (GAE) per gram of sample similarly, using tannic acid as the standard, the total tannin content is expressed in milligrams of tannic acid equivalent (TAE) per gram of sample.

The total flavonoid content of jaggery was determined using the aluminum chloride method described by Nayaka *et al*. (2015) [15]. Using quercetin as the standard, the total flavonoid content was expressed in micrograms of quercetin equivalent per gram of sample.

3. Results and Discussion

Table 1: Physical analysis of liquid jaggery

Property	Value
Total Soluble Solids (°Brix)	73±1
Specific gravity	1.4±0.02
Insoluble solids (percent)	3.42±0.08
Viscosity (cp)	807.33±0.16

The observed °Brix value of 73±1 indicated a high concentration of soluble solids in the liquid jaggery. The high value suggests that the liquid jaggery is rich in sugars, thus making it a potent sweetening agent. The total soluble solids of liquid jaggery was in close agreements with the findings of Patil and Anekar (2014) [16]. Similarly, the presence of sugars in high concentration has resulted in this value of specific gravity of liquid jaggery. The low percentage of insoluble solids as in Table 1, suggests that the liquid jaggery has a smooth texture and can be used in different food applications. The obtained results for specific gravity and percent of insoluble solids were found comparable with the findings of Chikkappaiah *et al*., (2017) [4]. The Viscosity of liquid jaggery was 807.33±0.16 cp this suggests that liquid jaggery has dense and thick consistency which can be attributed to presence of soluble and insoluble sugars. This property is crucial parameter to determine the flow behavior and suitability for various applications in food industry.

Table 2: Chemical analysis of liquid jaggery

Property	percent
Moisture	21.32±0.50
Protein	0.87±0.05
Fat	0.45±0.06
Ash	1.07±0.14
pH	5.03±0.15
Titrable acidity	0.46±0.05
Total sugar	68.03±0.56
Reducing sugar	16.20±0.42
Non-reducing sugar	52.19±0.08

Table 2 gives brief idea about the nutrient's composition present in liquid jaggery. The observed moisture in liquid jaggery 21.32±0.50 percent. The similar results were reported by Deotale *et al*., (2019) [5] Chikkappaiah *et al*., (2017) [4] and Patil and Anekar (2014) [16]. The low-fat content of 0.45±0.06 percent indicates liquid jaggery is primarily sugary product. The protein content suggests that the liquid jaggery is a carbohydrate-focused sweetener and does not content much protein. Ash content provides insights about the mineral composition of liquid jaggery. The presence of minerals is important for overall nutritional value of the product. Similar results for fat, protein and ash content were reported by Hirpara *et al*., (2020) [8] and Rao *et al*., (2007) [17]. The slightly acidic pH value of 5.03±0.15 contributes to the overall taste of liquid jaggery and it may also contribute to the

liquid jaggery's preservation and storage quality of the jaggery. The results obtained are in close agreements with those reported by Guerra and Mujica (2010) [7] and Chikkappaiah *et al*., (2017) [4]. Titrable acidity of liquid jaggery was 0.46±0.05. The titrable acidity in liquid jaggery may play an important role in enhancing the taste and shelf life. The results for Titrable acidity of liquid jaggery are closely related to the results reported by Barad *et al*., (2021) [3]. The sugar profile of liquid jaggery reflects about the presence of complex sugars, Total sugar 68.03±0.56 percent, reducing sugar 16.20±0.42 percent and non-reducing 52.19±0.08 percent contributing to the overall sweetness and potentially influencing the product's mouthfeel. The results for reducing sugar are in close agreements with the results reported by Patil and Anekar (2014) [16].

Table 3: Mineral composition of liquid Jaggery

Mineral	(mg/100 gm)
Potassium	39.03±0.43
Calcium	26.64±0.57
Magnesium	16.50±0.38
Iron	7.22±0.32
Zinc	0.35±0.12

Table 3 gives brief idea about the mineral composition present in liquid jaggery. Potassium, the most abundant mineral at 39.03±0.43 mg, is pivotal for maintaining electrolyte balance, supporting nerve function, and regulating blood pressure, Magnesium, measuring 16.50±0.38 mg, plays a role in muscle and nerve function, blood glucose control, and bone health Singh *et al*. (2013) [9]. Similar results for Magnesium were reported by Manzar and Singh (2018) [11] Calcium 26.64±0.57 mg, is crucial for bone health, muscle function, and blood clotting. The presence of iron at 7.22±0.32 mg, as iron is essential for oxygen transport in the blood and helps relieve iron deficiency anemia Resmi *et al*. (2016). Zinc, though present in a smaller quantity at 0.35±0.12 mg, is vital. These results are closely related with the results reported by Hirpara *et al*. (2020) [8].

Table 4: Phytochemicals in liquid Jaggery

Liquid jaggery	Value
Total phenols (mg GAE/gm)	4.46±0.02
Total tannin (mg TAE/gm)	5.97±0.07
Total flavonoids (mg QE/ml)	0.82±0.05

Liquid jaggery as a promising dietary component, offering not only a sweetening agent but also a source of health-promoting phytochemicals. The total phenolic content of liquid jaggery was 4.46±0.02 mg GAE/gm. The total phenols and the phenolic constituents offer antioxidant properties to liquid jaggery. The tannin and flavonoid content of liquid jaggery was 5.97±0.07 mg TAE/gm and 0.82±0.05 mg QE/ml respectively. These values are in line with the results reported by the Alarcon *et al*., (2021) [1] for NCS syrup, similar results were reported by Nayaka *et al*., (2015) [15] for jaggery. These compounds confer antioxidant properties, crucial in mitigating oxidative stress-related cellular damage Nayaka *et al*., (2009) [7].

4. Application of jaggery

Liquid jaggery or jaggery renowned for its unique flavor and nutritional richness, finds diverse culinary applications across various cuisines. In traditional Indian sweets, such as kheer and halwa, liquid jaggery instead of jaggery can be used to give a natural sweetness and distinctive depth of flavor. Its versatility extends to baking, where it can enhance the taste of cakes, cookies, and muffins. As a topping for yogurt, and cereals, it adds a wholesome sweetness, replacing refined sugars. Jaggery's utility goes beyond desserts, serving as a key ingredient in chutneys, dips, and even savory dishes like curries and stews, providing a well-balanced flavor profile. Additionally, its application in Ayurvedic preparations showcases its integration into holistic and health-conscious culinary practices. With its culinary versatility and nutritional benefits, stands as a valuable and distinctive ingredient in the world of cooking. Lamdande *et al*., (2018) [10], Mohan & Agarwal (2020) [12].

5. Conclusions

The results of this study highlight the huge potential of liquid jaggery as a nutritional sweetener in the global food industry. Detailed physicochemical analysis of liquid jaggery, with its thick consistency, including high concentration of soluble solids, and rich mineral composition. In addition to its role as a potent sweetener, liquid jaggery also serves as a source of health-promoting phytochemicals. Liquid jaggery has its roots in India's agricultural landscape and is well-positioned to meet the changing needs of the confectionery market, especially as consumers increasingly seek healthier alternatives. Addressing contemporary dietary issues, this study highlights the dual benefits of liquid jaggery - sweetness and nutritional value. Further exploration of its applications in various food products and continued awareness of its unique qualities could drive wider recognition and adoption of liquid jaggery across the globe.

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