International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(1): 692-701
www.biochemjournal.com
Received: 16-11-2023
Accepted: 17-12-2023

Er. PD Ukey
1) Research Scholar, Department of Processing and Food Engineering, Faculty of Agricultural Engineering, D. Y. Patil Agriculture & Technical University, Talsande, Maharashtra, India.
2) Assistant Professor, Department of Processing and Food Engineering, Dr. D. Y. Patil College of Agricultural Engineering and Technology, Talsande, Maharashtra, India.

Dr. VM Ingale
Assistant Professor, Department of Food Technology, D. Y. Patil Agriculture & Technical University, Talsande, Maharashtra, India

Dr. SB Wategaonkar
Assistant Professor, Department of Chemistry, Kisan Veer Mahavidyalaya, Wai 412803, Maharashtra, India.

Dr. Jong Pil Park
Professor, Basic Research Laboratory, Department of Food Science and Technology, Chung-Ang University, Anseong 17546, Republic of Korea

Prathapan K Pillai
Vice-Chancellor, D. Y. Patil Agriculture & Technical University, Talsande, Maharashtra, India

Dr. JS Ghatge
Associate Dean, Faculty of Agricultural Engineering, D. Y. Patil Agriculture & Technical University, Talsande, Maharashtra, India

Dr. SB Patil
Principal, Dr. D. Y. Patil College of Agricultural Engineering and Technology, Talsande, 416 112 Maharashtra, India

Dr. JA Khot
Registrar, D. Y. Patil Agriculture & Technical University, Talsande, 416 112 Maharashtra, India

Corresponding Author:
Er. PD Ukey
1) Research Scholar, Department of Processing and Food Engineering, Faculty of Agricultural Engineering, D. Y. Patil Agriculture & Technical University, Talsande, Maharashtra, India.
2) Assistant Professor, Department of Processing and Food Engineering, Dr. D. Y. Patil College of Agricultural Engineering and Technology, Talsande, Maharashtra, India.

Jaggery making reforms, value addition and preservation: A comprehensive review

Er. PD Ukey, VM Ingale, SB Wategaonkar, Jong Pil Park, Prathapan K Pillai, JS Ghatge, SB Patil and JA Khot

DOI: https://doi.org/10.33545/26174693.2024.v8.i1i.480

Abstract
Jaggery is a popular conventional Indian sweetener. It is prepared without the use of chemicals by uniformly heating and condensing clear sugarcane juice. Now a day's people are very conscious of food-related health issues and the quality of food is the focus of consumers. Jaggery is one of the products rich in nutrients including protein, vitamins and minerals. Jaggery can be utilized for various medicinal purposes like blood purification, regulating digestion, beauty treatment, improving metabolism, prevention of different respiratory issues, etc. Due to technological limitations in the processing and storage of its export grade, the jaggery sector is remains at the rural level. The percentage in sugarcane used for the manufacturing of jaggery and khandsari has significantly decreased. This is leading to a decline in annual production of jaggery. There is a need to improve the quality of jaggery and also reduce the production costs so that the jaggery industry can get a boost. New concepts of improving nutritional value by fortification and modification in the design of jaggery processing plant are some of the concepts that can help in achieving the goals. With the addition of nutritional additives, value-added jaggery has a significant export potential and may attract high market prices. To maintain future profitability in the jaggery trade, the manufacturing of various value-added produces and its profitable accessibility are essential. Various Institutes, researchers, and scientists are working on technological development in jaggery processing, preservation, storage, and packaging. The paper presents a comprehensive review of the processing, value addition and preservation of jaggery.

Keywords: Jaggery, sugarcane, sweetener, clarification, value addition, preservation

1. Introduction
A cash crop that is extensively cultivated for commercial purposes worldwide is sugarcane (*Saccharum officinarum*) (Selvi *et al*., 2021; Venkatesan *et al*., 2022) [28, 34]. Sugarcane is also used to make jaggery and khandsari in addition to producing sugar (Barad *et al*., 2021; Kumar *et al*., 2022; Said and RC Pradhan, 2013; Singh *et al*., 2021) [3, 13, 27, 31]. Sugarcane is the primary source of sugar in India and it is grown in an area of about 5.15 million hectares (2018-19) (Quadri *et al*., 2022) [25].

The sugar industry is India's second largest agro-based industry, contributing to the rural population's socioeconomic development (Chougule *et al*., 2021) [5]. It provides direct employment to over 0.5 million skilled and semi-skilled workers and supports 50 million farmers and their families. Currently, India produces 27.7 million metric tonnes of sugar and 6.6 million metric tonnes of jaggery (Bashir and Yousuf, 2022; Jagannadha Rao *et al*., 2007) [4,11]. Sugarcane constitutes approximately 90% of global sweetener production. About 70 per cent of the worldwide sugarcane crop cultivation is utilized in the production of jaggery (D. A. Pawar *et al*., 2017) [24]. Maharashtra is top in sugar production (107.14 LMT) and sugar recovery (10%) and second in sugarcane acreage (11.63 lakh hectares) just after Uttar Pradesh. However, Maharashtra's productivity (79.50 tonnes/ha) is poor and the state ranked sixth in productivity in the country during 2018-19 (sugarcane.icar.gov.in) Chougule *et al*., 2021) [5].

300 million tonnes of sugarcane are produced in India each year, of which 53 per cent has been converted in granulated sugar, 36 per cent in jaggery and khandsari, 3 per cent into cane juice for chewing, and 8 per cent into seed cane

(Hirpara *et al*., 2020; I. Rajendran, 2020; Dilip Pawar *et al*., 2017) [9, 26, 22]. Jaggery has different regional names such as Gur (Jaggery) in India, Desi in Pakistan, Panela in Mexico and South America, Jaggery in Burma and other African nations, Hakuru in Sri Lanka, and Naam Taanoi in Thailand are all used to refer to jaggery (A. K. Thakur, 1999; Madhu *et al*., 2018; D Pawar *et al*., 2017; P Verma *et al.*, 2019; Pankaj Verma *et al.*, 2019; W R Jaffe, 2015) [33,16,24,36,10]. Making jaggery is a common practice in sugarcane growing areas. Jaggery is a golden brown, unrefined, non-centrifugal sugar and natural sweetener made by evaporating sugarcane juice to a specific striking point temperature (Kumar and Kumar, 2022) [13] and then crystallizing it in molds. Over 70 percent of the jaggery consumed worldwide is produced in India (Kumar *et al*., 2021) [12].

In several Asian and South American nations, jaggery is a common non-centrifugal sweetener. By concentrating sugarcane juice, it is commonly manufactured in small cottage industries. The concentrated syrup is typically poured into molds to create solid jaggery in a variety of sizes and forms (T. Deokate, 2013; Pankaj Verma *et al*., 2019) [7,37]. Clarified sugarcane juice is concentrated during the jaggery manufacturing process. The concentrated syrup is spun for a while before being placed into molds for solidification. The Conventional solid blocks can be formed by gently stirring for 10 to 15 minutes, then settling and molding. On the other hand, jaggery is not allowed to crystallize in bulk when making powder jaggery, which requires rapidly stirring the concentrated syrup continuously.

According to the Food Safety and Standards Authority of India (FSSAI), cane jaggery is a by-product of boiling or processing sugarcane juice. Jaggery is generally referred to as "medicinal sugar" due to its use in Ayurveda and its similarity to honey. It is extremely high in minerals, protein, and vitamins. "Jaggery," is used as a functional food and is high in protein, minerals, vitamins, carbohydrates, phenolic acid, and other nutrients, as well as antioxidant and medicinal properties. Jaggery is a type of nutritious food which contains enough carbohydrates (sucrose, fructose, and glucose), minerals (calcium, potassium, sodium, iron, zinc, magnesium, and so on), and vitamins (B, C, D, E) for normal human growth and function (Custódio *et al*., 2023) [6].

In Indian cuisine, jaggery is either consumed directly or used to prepare a variety of sweet-based dishes. Sugarcane farmers produce jaggery with minimal capital investment and several researchers have attempted to replace sugar in low-calorie and sugar-free muffins. Jaggery and khandsari were produced in the early 1930s using roughly two-thirds of the sugarcane produced at the time. The demand for sweeteners has moved to white sugar, which includes just sucrose (99.7%), due to the creation of sugar factories and its numerous developments, improved level of comfort, and increased income per person. Consequently, manufacturing of khandsari and jaggery suffered considerable setbacks (D Pawar *et al*., 2017) [24]. The percentage of sugarcane used to produce jaggery and khandsari includes significantly decreased, reducing compared to 37.20 percent in 2008–2009 to roughly 12 percent during the year 2017-2018. This implies that quality research is required in the jaggery industry to develop high-quality jaggery and consequently improve the current scenario (Anonymous, 2022) [1].

In India, jaggery is consumed at various formation: solid (lumped), liquid, and granular or powder. Production of powder jaggery is also common in various regions, especially in northern India. Although powder jaggery has a higher market value on a national and international level, few producers are involved in this industry because it requires more effort to manufacture. In general, solid jaggery is simpler to mold, pack, and transport than powder. Powder jaggery is progressively increasing in popularity among consumers and traders due to its ease of use in handling and family cooking, whereas powdered jaggery dissolves quickly due to its small particle size and wide surface area, while solid jaggery lumps need more effort to handle and are difficult to cut into small pieces (Pankaj Verma *et al*., 2019) [37]. Liquid jaggery is a staple part of the diet throughout the majority Maharashtra and West Bengal, and its commercial importance is growing. At Tamil Nadu, Gujarat, Kerala, Andhra Pradesh, West Bengal, and Maharashtra, liquid jaggery are frequently used as a sweetening additive in food and beverages (Anonymous, 2022) [1].

According to the existing literature, this study provides an overview of the numerous jaggery production processes, including medicinal use, value addition and preservation. It will assist in locating the area for additional study to produce jaggery in its many forms efficiently.

2. Importance of jaggery

Since jaggery is composed of longer chains of sucrose than sugar, it is far more complicated. As it digests more slowly than sugar, it releases energy gradually rather than instantly. This gives off energy for a longer period and is healthy for the body. But as it is ultimately sugar, this does not make it safe for diabetics to consume.

Jaggery is manufactured in iron vessels, hence a significant amount of ferrous salts (iron) are also generated during this process. For those who lack iron or anemic, this iron is especially beneficial to their health. You may have noticed that jaggery leaves a slightly salty taste on the tongue, but jaggery also contains minute amounts of mineral salts that are extremely healthy for the body. These salts are absorbed from the soil and are found in the juice of sugar cane. Jaggery also functions well as a cleaning agent. It purifies the respiratory system, as well as the stomach, intestines and esophagus. It is strongly advised that those who deal with dust daily need to consume jaggery. This can protect people from things like asthma, a cough or cold, chest congestion, etc.

Jaggery is known for generating heat and supplying immediate energy to the human body. Therefore, in some regions of India, it is tradition to welcome people with a glass of water and jaggery. In addition to these uses, Jaggery is employed in the production of cattle feed, medicine manufacturing unit, distillery, ayurveda medications, ayurvedic sura, and ayurveda nutritional supplements. Currently, Jaggery is growing in popularity into sweets. Additionally, jaggery is given to the workers in coal mines and cement factories to prevent them from dust allergies. In addition, the district authority buys jaggery during catastrophic disasters and gives it to the sufferers as a health benefit (Nath *et al*., 2015) [19].

3. Composition of jaggery: Jaggery is appropriate healthy and nutritious foodstuff that serves as the primary sweetener

for rural as well as urban residents. It includes approximately 5–15% glucose and fructose, 60–85% sucrose, 0.4% protein, and 0.1g of fat. Proteins, lipids, vitamins (B-complex and folic acid), and minerals (Ca, Fe, P, Mg, K, and trace amounts of Zn, Cu, etc.) all contained at jaggery, which are essential components that are absent in sugar. Jaggery is a healthier alternative to khandsari. Iron (11 mg), calcium (0.4%), magnesium, and phosphorous (0.045%) are significant minerals, which make up 0.6% to 10% of the total mineral content. In addition to reducing sugars, jaggery also contains protein (0.25%), fat (0.05%), and sugars such as glucose and fructose (10–15%) (Jagannadha Rao *et al*., 2007; D. A. Pawar *et al*., 2017) [11,22]. The use of Jaggery regularly could lengthen human life. Diabetes is reported to occur less frequently in areas that consume jaggery than sugar. Jaggery is consumed either directly or used to prepare a variety of sweet-based meals in Indian cuisine.

The composition of different forms of jaggery and sugar (per 100 g of product) is given in Table 1 (J. Singh, 1998; Venkatesh *et al*., 2023)**.** According to Rao *et al*. (2007) (Jagannadha Rao *et al*., 2007) [11] and D. A. Pawar *et. al*., (2017) [24] assessment, jaggery is a healthy diet that provides 0.6 to 1.0 percent minerals, including 11.4 percent Fe, 8 percent Ca, and 4 percent each of Mg and P and other significant minerals. Additionally, it contains lowering sugar, which includes 0.50% protein, 0.40% fat, and 10-15% glucose and fructose.

Jaggery, a sugarcane product, is one such food that contains significant amounts of essential substances included in jaggery per 100 g comprise 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), along with chloride (5.3 mg). It also contains Vitamins (namely, vitamin A-3.8 mg, vitamin B1-0.01 mg, vitamin B2-0.06 mg, vitamin B5-0.01 mg, vitamin B6-0.01 mg, vitamin C-7.00 mg, vitamin D2-6.50 mg, vitamin E-111.30 mg, vitamin PP-7.00 mg), and protein-280 mg per 100 g of jaggery, it may be provided for the general population helping in resolving issues of starvation and under nutrition (J. Singh, 2013; Mohan *et al*., 2020; Pathak *et al*, 2019) [30,18,20]. The microelements available in jaggery offer antitoxin and antitumour effects (Nath *et al*., 2015; Selvi *et al*., 2021) [19,28].

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) [24].

Table 1: Composition of various forms of jaggery and sugar (per 100 g of product) (J. Singh, 1998; D. A. Pawar *et al*., 2017; Venkatesh *et al*., 2023) [29, 24, 35].

Composition	Forms of Jaggery			Centrifugal sugar	Non-centrifugal sugar	
	Solid Jaggery	Liquid Jaggery	Granular Jaggery	Sugar	Sulphur processed khandsari	Non-sulphur processed khandsari
Water (g)	3-10	30-35	1-2	0.2-0.5	0.3	0.5
Sucrose (g)	65-85	40-60	80-90	99.5	97.5	96.0
Reducing sugars (g)	9-15	15-25	5-9	-	-	-
Protein (g)	0.4	0.5	0.4	-	-	-
Fat (g)	0.1	0.1	0.1	-	-	-
Total minerals	0.6-1.0	0.75	0.6-1.0	0.05	0.05	0.2
Calcium (mg)	8.0	300	9.0	-	100	100
Phosphorous (mg)	4.0	3.0	4.0	-	-	-
Iron (mg)	11.4	8.5-11	12	-	-	-
Energy (Kcal)	383	300	383	398	395	388

4. Medicinal properties of jaggery

Traditional sweeteners like jaggery are used all around the world, but they are most popular in South Asia and Latin America. By removing the water from sugarcane juice or date palm sap, a concentrated, unrefined sugar product is left behind. Due to its high sugar content, jaggery should only be consumed in moderation despite its many biological qualities and possible health benefits. Its biological characteristics and actions include the following:

Fe, Mg, and K are among the vital elements found in jaggery. The synthesis of red blood cells and the preservation of electrolyte balance are just two of the basic functions in the body that depend on these minerals. Antioxidants included in jaggery, such as phytochemicals and polyphenols, may help prevent oxidative stress and lower the chance of developing chronic illnesses. Certain components found in jaggery, like flavonoids, might possess anti-inflammatory qualities that can aid in lowering bodily inflammation. Digestion is said to be aided by jaggery. It can help reduce bloating, indigestion, and constipation by stimulating the digestive enzymes. For respiratory conditions including colds and coughing, jaggery is prescribed in several traditional medical systems. It is thought to ease respiratory irritation and soothe the throat. Jaggery's iron content makes it a potential treatment and prevention for iron-deficiency anaemia. The protein in red blood cells called haemoglobin, which carries oxygen, is made possible only by iron. Because jaggery is a naturally occurring source of carbohydrates, which offer because jaggery may be able to manage hormone imbalances, some women use it to relieve menstrual symptoms like mood swings and stomach cramps. Because of its possible antibacterial and wound-healing qualities, jaggery has been topically administered to wounds in several ancient practises. When combined with other herbal medicines, jaggery is frequently used to ease the symptoms of colds and coughs. It is said to provide therapeutic effects for respiratory health when combined with herbs like black pepper and ginger. A rapid energy boost, athletes and those with high energy needs tend to favour it.

Although jaggery has some possible health benefits, it must be consumed in moderation because it is high in calories and has a high sugar content that might elevate blood sugar levels. Additionally, since some commercial types may contain preservatives or additives, it is best to select unprocessed and organic jaggery. It's a good idea to speak with a healthcare provider for specific advice before making any dietary additions or adjustments, particularly if you have underlying medical issues like diabetes.

Jaggery is frequently stated as "medicinal sugar" and utilized for daily use as well as pharmaceutical formulations for several advantages (Hirpara *et al*., 2020; J. Singh, 2013; D. A. Pawar *et al*., 2017; Selvi *et al*., 2021) [9, 30, 24, 28].

4.1 Jaggery purifies blood

Jaggery helps to cleanse the blood and leave the body healthy when consumed regularly. By increasing haemoglobin levels, it helps in the prevention of several blood illnesses and diseases. Jaggery also strengthens immunity, resulting in the prevention of several blood-related issues.

4.2 Iron content

Jaggery contributes to the prevention of anemia because it contains a significant amount of iron and folate. Additionally, jaggery powder provides quick energy, preventing body weakness and fatigue. Jaggery improves the body's ability to absorb iron when consumed along with meals that are high in vitamin C.

4.3 Mineral content

Minerals and antioxidants namely Se and Zn, which are present within jaggery, contribute to reducing the risk of free radical damage. Additionally, these antioxidants and minerals support the body's improved resistance to various infections.

4.4 Cosmetic benefits

Jaggery offers plenty of natural qualities that ensure the skin's health for a very long period. Due to its significant concentration of different minerals and vitamins, it supplies the skin with the necessary nutrition.

4.5 Digestive effects of Jaggery

Jaggery promotes to release of enzymes used for digestion, accelerating the process of digestion. Proper digestion improves in controlling bowel movements and protects against problems including gas, stomach parasites as well as constipation. This is very helpful to preserve the digestive system's function smoothly. A perfectly effective system of digestion means that intestinal problems are effectively prevented while dyspepsia is reduced.

4.6 Jaggery increases metabolism

Jaggery's potent mineral content and high quantities of potassium contribute to weight management. This helps by minimizing the body's ability to keep additional water. The potassium in jaggery improves metabolism, preserves electrolyte balance and helps to build muscle, along with helping in weight loss.

4.7 Jaggery treats water retention

With the use of jaggery, persons can quickly treat typical minor diseases including water retention, migraines, bloating, coughs, and colds. The only thing essential for getting instant benefits is jaggery taken with warm water or included in drink.

4.8 Jaggery balances hormone levels

Jaggery has many positive effects, especially for women who suffer changes in their moods before their periods. Changing hormone levels in the body are the root cause of mood swings. Endorphins are pleasant hormones that are released when jaggery is consumed. This helps women feel better by relaxing the body.

4.9 Strengthens brain function

Jaggery is additionally helpful in avoiding severe problems within the body's nerve process. It has plenty of natural qualities that help to maintain the nervous system's proper functioning. People can maintain their natural, healthy lives as a result of this.

4.10 Treats respiratory problems

Regular use of jaggery is helpful in the protection from several inhaling conditions including bronchial and asthmatic conditions. According to specialists, consuming jaggery as a naturally occurring sweetness in the correct proportion including sesamum seeds has an advantageous effect on a person's respiratory system. Jaggery provides characteristics that help to maintain body temperature, which is extremely advantageous for asthma sufferers. It's also important to remember that jaggery has anti-allergy benefits.

4.11 Useful in joint pain

Jaggery can provide crucial relief for people who have joint pain and aches. According to experts, combining ginger and jaggery in a drink can do wonders for reducing joint discomfort. Regularly consuming a glass of milk with jaggery may help strengthen the bones and the prevention of joint and bone conditions like arthritis.

5. Types of jaggery

Jaggery is primarily accessible in various formations: solid (lumped), liquid, and granular. In India, from the total production of jaggery, approximately 80% is prepared in the format of solid lumps also 20% in liquid and granular format (Fig. 1).

5.1 Solid jaggery

Filtered and clarified cane juice is pumped into pans which are boiled at its striking point temperature varying from 116 to 120 °C in a triple pan boiler using bagasse as fuel. After reaching its striking point, it is poured into molding of various sizes and shapes. To produce light-colored jaggery by removing contaminants in suspension, colloidal, and coloring compounds by accumulation, juice is clarified using a natural clarifier (deola extracts at 45 g/100 kg juice). (Anonymous, 2022, Hirpara *et al*., 2020; Nath *et al*., 2015; D. A. Pawar *et al*., 2017; Selvi *et al*., 2021) [1, 9, 19, 24, 28]. According to the Bureau of India Standard, the moisture content of solid jaggery ranges from 5.0% to 7.0%.

5.2 Liquid jaggery

It is a semi-liquid, syrup-like intermediate produce obtained while concentration of pure sugarcane juice used for making the jaggery. In most of West Bengal and Maharashtra regions, liquid jaggery accounts for an important component

of the diet and provides commercial value. In several states of India like Maharashtra, Kerala, West Bengal, Gujarat, Andhra Pradesh, and Tamil Nadu, the liquid jaggery is used as a sweetener in dishes and beverages. Liquid jaggery's quality is greatly influenced by the type of clarifiers used, the content and purity of the cane juice, as well as the juice's concentration temperatures. The concentrated juice is separated through the boiling pan when it touches the striking point temperature, which depends on the variety and agroclimatic zone and ranges from 103 to 106 degrees Celsius (J. Singh, 2013; Nath *et al*., 2015) [30, 19]. Citric acid is mixed in liquid jaggery at a rate of 0.04% (400 mg/kg) to avoid crystallization also to give it a pleasing color, whereas potassium metabisulphite at a rate of 0.1% (1 g/kg) or benzoic acid according to 0.5% (5 g/kg) is utilized to improve the life span of liquid jaggery without lowering its quality. After that, liquid jaggery is permitted to settle in ambient conditions about 8 to10 days. It is accurately packed in sterile container later, after clarification. The usual liquid jaggery contains 30 to 36 per cent moisture, 40 to 60 per cent sucrose, 15 to 25 per cent inverted sugar, 0.30 per cent calcium, 8.5 to 10 mg of iron per 100 grams, 5 mg of phosphorus, and 0.10 mg of protein per 100 grams (Hirpara *et al*., 2020; J. Singh, 2013; Nath *et al*., 2015; Selvi *et al*., 2021) [9, 30, 19, 28].

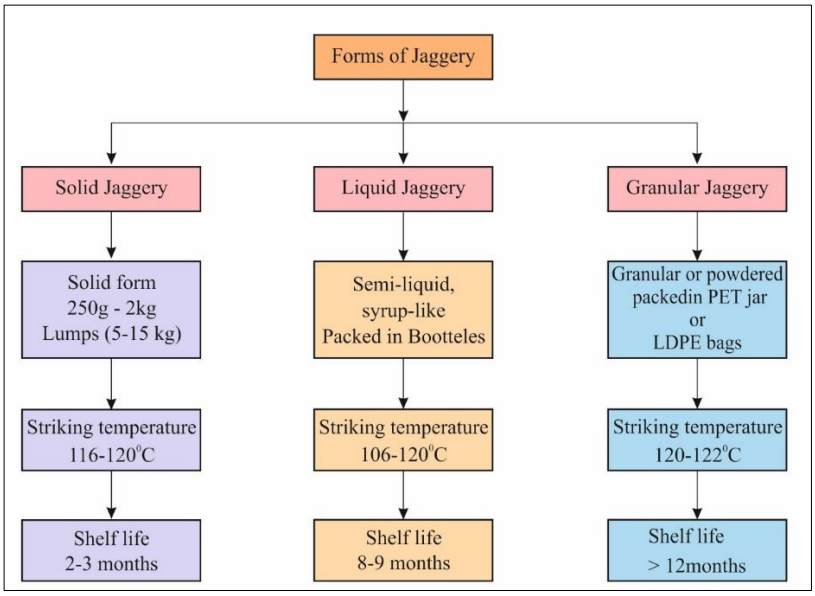

Fig 1: Forms of jaggery with major findings

5.3 Granular or powder jaggery

According to a study, granular or powdered jaggery with small amount of moisture (1-2% d.b.) has a shelf life advantage for maximum two years due to its flowing freely characteristic (Jagannadha Rao *et al*., 2007) [11]. Some researchers reported some efforts to invent a technique for making jaggery particles. The Indian Institute of Sugarcane Research, Lucknow and Regional Agricultural Research Station, Anakapalle developed a method of rubbing the concentrated syrup using wooden scraper to transform the solid into granules. A superior granular jaggery with approximately 88.6% sugar percent, a low moisture content of 1.65%, and decent color, fragility, and crystallised texture was found to be produced by adding lime to cane juice to raise the pH between 6.0-6.2 with the striking point temperature of 120 °C (J. Singh, 2013; D. A. Pawar *et al*., 2017; Said and RC Pradhan, 2013) [30, 24, 27]. A wooden scraper was utilized to scrub the concentrating slurry to develop granules. After cooling, the jaggery is sieved into granules. For making excellent granular jaggery, smaller crystals, less than 3 mm, are preferred. Jaggery may be preserved for an extended period of time (above 2 years), throughout the rainy season, without affecting quality when it is at granular form (around 3 mm sieved), sun-dried and packaged in polypropylene bags or polymer bottles. The colour of jaggery powder may vary from golden yellow to a dark brown colour that resembles dark chocolate. The primary substance used for producing jaggery powder determines the color. It is also amorphous and softer than sugar. Jaggery powder is filled with mineral, easily digestible, generates a distinct flavour as a flavouring agent, recovers lung and throat infections, is readily digested and regulates the level of sugar deficit, sulfur-free organic constitution, a perfect choice as a recommended healthy replacement.

6. Processing of jaggery

There are two types of jaggery processing methods, one is the traditional method and another is the improved or modern method. Jaggery processing depends on the color of the cane, sugarcane juice can range in color from grey to dark green to pale yellow. It is an opaque liquid. It contains numerous nutritious components as well as mud, wax and other soluble and insoluble contaminants. All of these unwanted soluble and insoluble fractions in jaggery should be removed to preserve proper quality. State to state, within a state from one district to another, and occasionally even within a district, the procedure varies widely.

6.1 Traditional method of jaggery processing

The unit operations of jaggery processing in the traditional method include Juice extraction, juice clarity, boiling to concentrate juice, cooling concentrated juice, drying, powdering, packing, and storing (Sharon *et al*., 2013) [8].

6.1.1 Juice extraction

Extraction of sugarcane juice by crushing is the initial step in jaggery manufacturing process. The juice is extracted

using a 2-5 roller crusher, a vertical three roller crusher or a horizontal three roller crusher (power operated or animal). The efficiency of juice recovery for a horizontal crusher is 55–60% and 50–55% for a vertical three-roller crusher. Therefore, it is recommended to use a horizontal three-roll crusher to extract the juice (Anonymous, 2022; Said and RC Pradhan, 2013) [1,27].

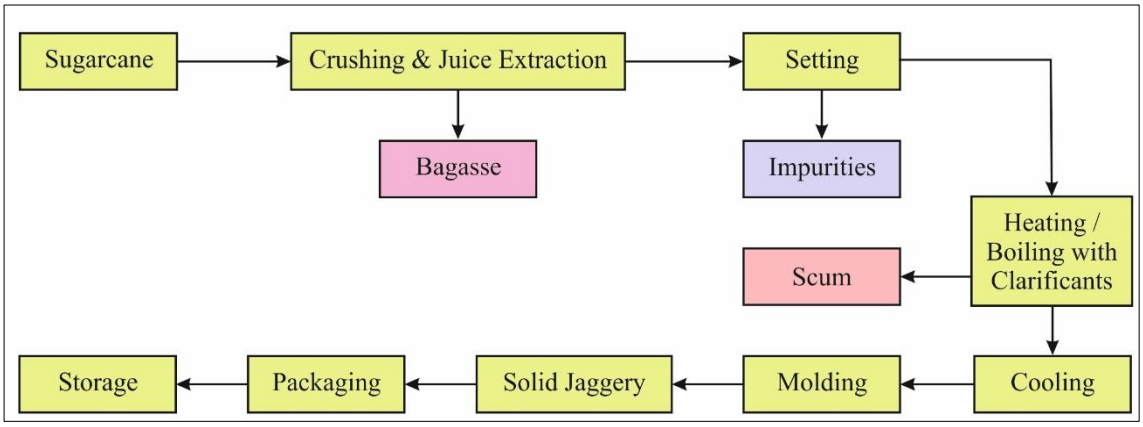

Fig 2: Process flow chart for manufacturing of solid jaggery

6.1.2 Juice clarification

Clarification of the juice to remove chemical impurities is one of the most important steps in the production of jaggery. However, the insolvable contaminants are separated using technical processes like setting or filters through muslin cloth. Usually, the juice clarity used for preparing jaggery determines its quality, storability, and acceptability. For the most effective scum removal, better color retention, higher jaggery recovery, and support for preserving jaggery quality, several clarifying agents (chemical or natural clarificants) are utilized. Application of chemical clarificants including hydros (sodium hydrosulfite), lime, sodium carbonate, super phosphate, di-ammonium phosphate, and alum are utilized due to their accessibility. The use of herbal clarificants in place of chemical clarificants is now becoming more popular. Depending on availability, a variety of plant extracts include deola (*Hibiscus ficilenues*), bark of semal (Bomboxmalabarieum), extracts of groundnut (Arachis hypogea) and caster (Ricinuscomunis), guar gum powder as well as bhendi powder are commonly utilized. When differentiated to jaggery produced with deola and hydrous gum, the quality of jaggery produced with guar gum powder was excellent, growing popularity, and conserved over 6 months at 27°C (Said and RC Pradhan, 2013) [27]. Application of synthetic clarificants, such as bhendi plant at a rate of 2 kg per 100 liters of sugarcane juice and SN2 at a rate of 2 mg/liter (2 ppm) was found more beneficial than the control treatment in terms of increasing NRS, color, jaggery recovery, and maximum scum removal, suggesting a greater effect on jaggery quality (Patil *et al*., 2005; Said and RC Pradhan, 2013) [21, 27].

6.1.3 Juice concentration

In the conventional process, jaggery was made with a knowledgeable and experienced trained person. The second essential process in the production of jaggery is the boiling of sugarcane juice at the striking point of temperature ranges in between 118 ^{O}C to 123 ^{O}C (Shankar Kumbhar, 2016) [15]. The primary purpose of heating is concentrating liquid into solid, granular, or thick liquid jaggery to extend its shelf life. Temperature is the key factor during the forming of the liquid into various types of jaggery. The excessive heating may result to dark colour products with a bitter taste. A trained person closely monitors the numerous physical and chemical changes that take place during boiling. Juice is continuously boiled in a regulated period of time greater than 2.5 to 3 hours until the concentrated syrup reaches the striking point of 118 ^{O}C. Traditionally, the endpoint or striking point is selected physically by simply adding a lesser quantity of boiling syrup to a container of cold water that has been shaped with fingers. For the production of solid jaggery, the striking point is 118 °C (Said and RC Pradhan, 2013) [27]. A lesser volume of groundnut or mustard seed oil is sprayed to stop extreme foaming while boiling, which facilitates the flow of hot syrup when transferring it between containers. Since the juice is heated for a extended period at a high temperatures, the furnace's thermal efficiency is as low as 14.75 percent. The conventional type furnaces used by farmers have very low overall heat utilization efficiency and require significant improvement. The Indian Institute of Sugarcane Research (IISR) in Lucknow invented more effective two and three-pan furnaces that minimize bagasse (R D Singh, 2009) [32]. In addition to using dried bagasse as fuel, burning wood, agricultural waste, and tires are also used even used or old tires.

6.1.4 Cooling, molding and packaging

After attaining the striking point, the pan which includes the hot mass is taken off the fire and transferred into the tray for 10 to 15 minutes. The heated lump is vigorously agitated with a flat wooden beater during that period for consistent cooling of the hot mass by fresh air (Anonymous) [1]. The concentrate is then poured into the appropriate shape mold for shaping. The shape of jaggery varies from region to region; some common shapes that are selected in various regions of the country include, rectangular (250 gm – 1 kg), bucket-shaped (10-20 kg), trapezoidal lumps (5 kg), etc. (Said and RC Pradhan, 2013) [27]. After solidification, the moisture content of solid jaggery decreases to 10–12% (d.b.). After that, storage and packaging are applied to the finished product. The many traditional packing techniques used around the world include blankets made of wheat straw, plastic canisters, clothing lined with polyethylene

sheets, clay pots, aluminum foil, and jute bags (Venkatesh *et al*., 2023) [35].

6.2 Improved/Modern method

In the traditional process of jaggery preparation, because of uncontrolled heating normally occurring enzymes including other substances in the liquid from sugarcane generates a variety of complex dark-colored molecules. Also due to the high temperatures, the sugars in juice caramelise to produce compounds that are black in color. In the end, overuse of lime and iron draining from pans additionally contributes to darker colour, which lowers the quality of the jaggery. Due to outdated technology and a lower market price for jaggery, several jaggery factories are on the verge of closing. The flue gases emit dangerous compounds that are hazardous and cause workers respiratory issues. Therefore, the jaggery producers should use innovative technological advances to generate high-quality jaggery at reasonable prices. Jaggery is produced using this process in incredibly hygienic neat tidy, and clean surroundings. The tools and machinery needed to produce jaggery are kept sterile and clean. The efficiency of NCS production is increased by 2.5–3 times when a steam-jacketed kettle is used in place of an open pan evaporator in modern NCS manufacturing machines (Venkatesh *et al*., 2023) [35]. Insects, ants, flies, bacteria, fungi, etc. cannot grow on the jaggery unit's cement floor. For the clarification of cane juice, herbal clarifying agents are utilized instead of dangerous and expensive chemicals. This method of making jaggery contains several stages, including cane harvesting, pre-cleaning and crushing, filtration, clarification, heating, boiling and concentration, cooling, packaging and storage (Anonymous,2022) [1].

Fully ripened canes are selected; stalks are properly washed using high-pressure water pistols to remove any waxes, insects, and other impurities. After pre-cleaning, extract the sugarcane juice with a sugarcane crusher and collect it into sterilised stainless steel or food-grade plastic jars. After extraction, cane juice is filtered and settled for approximately 20 minutes in a settling tank for the removal of contaminants like bagasse, leaves, dust, and other waste.

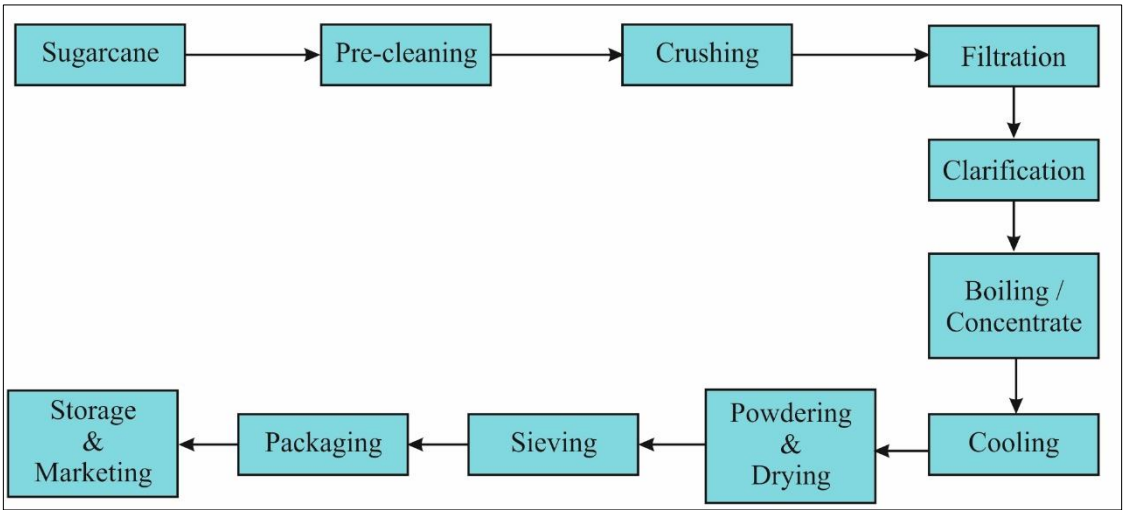

Fig 3: flow process chart for production of jaggery

Cane juice should be strained using naturally clarifying solutions in place of chemical clarificants. For clarification, the cane juice is supplemented with the mucilaginous extracted using vegetative clearing chemicals, such as Doela (wild okra), okra, falsa, or semal (40 to 60 gm of stem and roots of green plant per quintal of cane juice), 70 to 75 gm of caster or groundnut, or 30 to 40 gm of soybean seeds every quintal of cane juice. Maintain the juice pH between 6.0-6.2 to improve the quality of jaggery. Boil the sugarcane juice up to 80 °C and remove all impurities floating up during boiling. The cane juice is condensed up to the striking point of temperature ranging between 120-122 °C (for solid Jaggery) based on the varieties, paddling, and cooling procedures. The purified juice might get heated inside multistage, cost effective evaporators powered by steam. The generation of dark-colored compounds is reduced as a result of the regulated heating of juice in stainless steel evaporators. The juice is progressively condensed in a second concentrator to make jaggery, until it reaches its ultimate constancy. In several phases of the multiple-effect evaporator, pre-heater, and air-cooled condenser, water that evaporates during the boiling of the juice is recovered through condensation.

After reaching the striking point, the concentrated can of juice was transferred into the tray and cooled for some time. Then the concentrate is poured into the appropriate shape's mold for shaping or converted into granules using a wooden or stainless steel scraper. After making the jaggery powder, it is dried from 9-10% to 1-2% moisture content to improve the quality and shelf life up to 2 years. Granules ranging under 3 mm have been observed superior in quality. Jaggery can be packed attractively in a way that keeps it safe from handling and distribution hazards like insects, dust, and moisture. To obtain maximum benefits during the winter season, jaggery should be preserved in dry and cold areas to prevent direct contact with moisture as bacteria indicated the highest growth at a moisture content of 10% and a temperature of 30 °C. In modern technology of jaggery production, the advantages include, without physical handling or processing (aside from placing sugarcane in the crusher), shelf life improvement up to 18 to 24 months, chemical-free, sulfur-free, and hygienic processes, reliable product quality, small plant includes edges made of food-grade stainless steel, continuously generating technique and the produce fetches higher price to farmers and producers.

7. Value addition of jaggery

Jaggery is known as a "medicinal sugar" due to its high content of minerals and nutritional value. It quality could be upgraded through adding constituents such as cocoa powder which is rich in proteins, vitamins, and minerals, aonla pulp, whey, cashew, almond, and groundnuts. This will boost the jaggery's nutritious value in addition to raising market prices, which will increase its export capacity (D. A. Pawar *et al*., 2017; Said and RC Pradhan, 2013) [24, 27]. Jaggery can be combined with a variety of natural flavorings (such as black pepper, cardamom, ginger, lemon, etc.), nutritional ingredients (such as protein, amino acids, vitamins, and phytochemicals), additives that improve texture, and flavor enhancers (such as nuts, cereal, spices, and pulses). Natha *et al*. (2015) [19] and Anwar *et al*. (2011) [2] created a jaggery powder that is vitamin C fortified. He added a natural supply, namely, tiny bits from amla fruits, and observed that 10 per cent moisture content seemed ideal (Hirpara *et al*., 2020; Nath *et al*., 2015) [9,19].

8. Storage

The stowing time of jaggery is based on the temperature and moisture of the surrounding air. Mostly jaggery is spoiled during the monsoon season due to the higher humidity in the air. The combination of inverted sugars and mineral salts, that are deliquesce in nature creates major challenges for jaggery storage, especially during the rainy period when surrounding humidity is more and spoiling occurs (Selvi *et al*., 2021; Venkatesan *et al*., 2022) [28,34]. Jaggery should be maintained at a relative humidity of 43-61% and with a moisture content of not more than 6% for the most effective storage quality (D. A. Pawar *et al*., 2017; Said and RC Pradhan, 2013) [24, 27]. On an average, it is observed that more than 10% of jaggery produced in the country worth Rs. 40 crore is lost every year due to deterioration (Mandal *et al*., 2006; Venkatesan *et al*., 2022) [17, 34].

Jaggery was traditionally preserved in gunny sacks, earthen pots, wooden boxes, metal drums or other readily available materials like plant leaves, as well as in godowns, home kitchens, and inexpensive storage units where hygienic conditions are not carefully maintained therefore it attracts a variety of pathogenic and non-pathogenic bacteria, therefore it could not preserve the quality of the jaggery for a long period. Therefore, to maintain the quality and improve the shelf life of jaggery, Indian Institute of Sugarcane Research, Lucknow had established a drying cum storage bin. The deterioration of quality in bins is less as compared to polythene bags and open storage. The utilization about some advanced technology i.e. irradiation, and modified atmospheric packaging was found to improve the storage period of jaggery (D. A. Pawar *et al*., 2017) [23].

9. Challenges and future prospectus of jaggery

Many places still use labour-intensive, traditional ways for producing jaggery. The adoption of technology and the development of skills are challenges associated with the shift to more automated and efficient procedures. It's difficult to maintain constant safety and quality requirements in the jaggery industry. The final product may be impacted by changes in raw materials, processing techniques, and cleanliness. The production of jaggery may have an impact on the environment through water use and deforestation for fuel. It's difficult to strike a balance between environmental practices and the demand for jaggery. Larger marketplaces are generally inaccessible to small-scale jaggery producers because of information and infrastructure gaps. This restricts their ability to expand and make money. There are many different kinds of sweeteners and sugar alternatives accessible in the competitive jaggery industry. It's difficult to remain competitive in this setting. Adherence to food safety and quality standards is vital; but, small-scale producers may find it difficult to comply due to their limited resources and lack of expertise.

Incorporating contemporary technology, such as upgraded vacuum evaporators and sugar cane crushers, can improve jaggery production quality and productivity. Utilizing sustainable practices, such as resource efficiency, organic farming techniques, and renewable energy sources, can improve the environmental impact of jaggery production. Gaining a wider range of customers and making more money can be achieved by adding jaggery to beverages, confections, and health foods. The skills and knowledge of jaggery producers about best practices in jaggery production and quality control can be enhanced by funding training programmes and educational initiatives. Small-scale producers can compete more successfully and reach larger markets with the support of improved market access and transportation infrastructure. To improve the market reputation of jaggery products, quality control methods should be put in place and certifications such as organic or fair trade should be obtained. The growth of the jaggery business can be accelerated by government regulations and incentives, such as subsidies for organic farming and advanced equipment. Jaggery, with its natural and unrefined qualities, has a potential future in the health-conscious market as customers look for healthier substitutes for refined sugar. The market reach and profitability of the jaggery and associated goods industry can be increased by investigating foreign markets.

In conclusion, there are encouraging opportunities for the reform and expansion of the jaggery industry despite the numerous obstacles it faces. By prioritizing sustainability, technology, education, and quality, the jaggery sector has the potential to capitalize on evolving consumer tastes and achieve unprecedented success in the coming years. Realizing these opportunities will require coordinated efforts from all parties involved as well as government backing.

10. Conclusion

Jaggery is also known as "medicinal sugar" and can be utilised for both daily life and pharmaceutical formulations for a variety of health benefits. The largest unorganised sector and one of the oldest and most significant rural cottage industries in India is the jaggery industry. To make the jaggery industry profitable there is a need to concentrate on the improvement of high-quality and hygienic jaggery by practicing advanced methods starting from extraction, cleaning, clarification, cooling, molding, and packaging process. The quality of jaggery making can also be improved by making various forms of solid, liquid, and granular jaggery from various sources. Through the development of new technology, it is now possible to make crystallized jaggery of high quality by adjusting factors like pH, clarifying techniques and striking point temperature. The use of herbal clarificants in place of chemical clarificants is now becoming more popular. Granular jaggery offers more advantages than lumped jaggery due to

their lesser moisture content and free-flowing tendency. Though, the technique is still not developed commercially available. With adding of nutritional additives, value-added jaggery has a significant export potential and may hence attract high market prices. Growers and processors can earn more profit by improving their quality using added value, packaging, preparation of jaggery and jaggery-based products with technological advances.

10. References

1. Anonymous. Handbook of Processing of Jaggery. Available at: https://5.imimg.com/data5/SELLER/Doc/2022/12/SB/DK/NP/145967076/natural-jaggery-powder.pdf
2. Anwar SI, Singh RD, Singh J. Process Development of Production of Jaggery (Gur) with Aonla as a Natural Source of Vitamin C. Journal of the Institution of Engineers (India). 2011;92:33-35.
3. Barad TH, Chandegara VK, Rathod PJ, Mori MR. Quality Evaluation of a Jaggery Prepared from Developed Three Pan Jaggery Making Furnace. International Journal of Chemical Studies. 20219;(1):907-913.
4. Bashir N, Yousuf O. Jaggery as a Potential Source of Nutraceutical in Food Products. Emerging Trend in Nutraceutical. 2022;1(3):30-55. doi: http://dx.doi.org/10.18782/2583-4606.118
5. Chougule SB, Shike VS, Bhanage SB, Giri PR. Constraints Encountered by Jaggery Producing Sugarcane Growers Regarding Jaggery Marketing. The Pharma Innovation Journal. 2021;SP-10(9):795-797.
6. Custodia L, Duarte CV, Cebeci F, Ozcelik B, Sharopov F, Gurer ES, *et al*. Natural Products of Relevance in the Management of Attention Deficit Hyperactivity Disorder. eFood. 2022;4:e57-1-11. https://doi.org/10.1002/EFD2.57
7. Deokate T, Bandgar D, Mali B. Marketing and Export of Jaggery. 1st ed. Saarbrücken, Germany: Scholars' Press (Chapter 1); c2013.
8. Esther Magdalene Sharon M, Kavitha Abirami CV, Alagusundaram K. Energy Losses in Traditional Jaggery Processing. Indian Food Industry Magazine. 2013;32(3):22-25.
9. Hirpara P, Thakare N, Kele VD, Patel D. Jaggery: A Natural Sweetener. Journal of Pharmacognosy and Phytochemistry. 2020;9(5):3145-3148.
10. Jaffe WR. Nutritional and Functional Components of Non-Centrifugal Cane Sugar: A Compilation of the Data from the Analytical Literature. Journal of Food Composition and Analysis. 2015;43:194–202.
11. Jagannadha Rao PVK, Das M, Das SK. Jaggery – A Traditional Indian Sweetener. Indian Journal of Traditional Knowledge. 2007;6(1):95-102.
12. Kumar R, Kumar M. Issues, Problems and Amelioration in Jaggery Making Process and Plants. International Conference on Recent Intelligent Technologies in Science, Engineering, Humanities and Management; c2021. p. 344-349.
13. Kumar R, Kumar M. Technological Upgradation in Jaggery Making Plants. Materials Today: Proceedings. 2022;56(5):2478-2483. https://doi.org/10.1016/j.matpr.2021.08.240
14. Kumar S, D Kumar, Markam SK, Patel A. Heat and Mass Balance of IISR Three Pan Jaggery Furnace: A Review. The Pharma Innovation Journal. 2022;SP-11(12):331-335.
15. Kumbhar YS. Study on Gur (Jaggery) Industry in Kolhapur. International Research Journal of Engineering and Technology. 2016;3(2):590-594.
16. Madhu B, Patel S, Jagannadha Rao PVK, Sreedevi P. Use of Edible Coatings to Increase the Shelf Life of Jaggery: A Review. International Journal of Current Microbiology and Applied Sciences. 2018;7(6):2466-2479.
17. Mandal D, Tudu S, Mitra SR, De GC. Effect of Common Packaging Materials on Keeping Quality of Sugarcane Jaggery During Monsoon Season. Sugar Technology. 2006;8(23):137-142. https://doi.org/10.1007/BF02943648
18. Mohan N, Agarwal A. New Ventures of Value Addition in Jaggery Processing for a Dynamic Sugar Industry. International Journal of Engineering Research and Technology, 2020, 9(01).
19. Natha A, Dutt D, Kumar P, Singh JP. Review on Recent Advances in Value Addition of Jaggery Based Products. Journal of Food Processing and Technology. 2015;6(4):1000440. https://doi.org/10.4172/2157-7110.1000440
20. Pathak V, Dwivedi AK. Analytical Study of Different Samples of Guda (Jaggery). International Journal of Innovative Science and Research Technology. 2019;4(6):408-412.
21. Patil JP, Shinde US, Nevkar GS, Singh J. Clarification Efficiency of Synthetic and Herbal Clarificants in Quality Jaggery Production. Sugar Technology. 2005;7(2&3):77-81. https://doi.org/10.1007/BF02942535
22. Dilip P, Prakash U, Vivek K. Studies on Preparation of Jaggery Granules with Nucleation Technique. International Journal of Agricultural Science and Research. 2017;7(4):609-616.
23. Dilip P, Prakash U, Gajanan N. Development and Performance Evaluation of Crusher Cum Scraper for the Preparation of Jaggery Granules. International Journal of Agricultural Science and Research. 2017;7(3):93-102.
24. Pawar DA, Jadhav MS, Nimbalkar CA. Techniques and Advances in Jaggery Processing: A Review. Research Journal of Chemical and Environmental Sciences. 2017;5(2):14-20.
25. Quadri Md. H, Madhavi V, Navya A, Jayaprakash R, Rajender G, Swamy R. Development of Granular Jaggery and Jaggery Based Chocolates. The Pharma Innovation Journal. 2022;SP-11(5):1951-1956.
26. Rajendran I, Palaniswami C, Vennila A. Improved Method of Liquid Jaggery Preparation. Journal of Sugarcane Research. 2020;10:107-112.
27. Said PP, Pradhan RC. Preservation and Value Addition of Jaggery. International Journal of Agricultural Engineering. 2013;6(2):569–574.
28. Selvi VM, Mathialagan M, Mohan S. The Art and Science of Jaggery Making: A Review. Agricultural Reviews. 2021, 1-9. https://doi.org/10.18805/AG.R-2138
29. Singh J. Development of Proximate Composition of Indian Sweeteners. Jaggery Khandasari Res. Digest. 1998, 6.

30. Singh J, Solomon S, Kumar D. Manufacturing Jaggery, a Product of Sugarcane, As Health Food. Agrotechnology. 2013;S11:007 http://dx.doi.org/10.4172/2168-9881.S11-007
31. Singh K, Tomar A, Kumar V, Kumar A, Kumar M. Studies on Traditional Indian Sweetener Jaggery Processing with Selected Organic Clarifying Agents. The Pharma Innovation Journal. 2021;SP-10(12):293-296.
32. Singh RD, Baboo B, Singh AK, Anwar SI. Performance Evaluation of Two Pan Furnace for Jaggery Making. Journal of Institution Engineers (India). 2009;90(18):27-30.
33. Thakur AK. Potential of Jaggery Manufacturing in Punjab State. Proceedings of the National Seminar on Status, Problems and Prospects of Jaggery and Khandasari Industry in India, Indian Institute of Sugarcane Research, Lucknow, India; c1999.
34. Venkatesan MS, Lakshmanan C, Raman N. Jaggery Making Process and Preservation: A Review. 2022, 1-11.
35. Venkatesh T, NanduLal AM, Silpa V, Dharmalingam B, Padma Ishwarya S, Reshma MV, *et al*. Current Production Strategies and Sustainable Approaches Towards the Resurgence of Noncentrifugal Cane Sugar Production – A Review. Sustainable Food Technology, Royal Society of Chemistry. 2023;1:200-214.
36. Verma P, Shah NG, Mahajania SM. Effects of Acid Treatment in Jaggery Making. Food Chemistry. 2019;299:125094.
37. Verma P, Shah NG, SMahajania SM. Why Jaggery Powder is More Stable Than Solid Jaggery Blocks. LWT-Food Science and Technology. 2019;110:299-306. https://doi.org/10.1016/J.LWT.2019.04.093