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Innovative processing approaches for

producing chemical-free jaggery from sugarcane

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Jaggery production from sugarcane is vital for rural employment and value addition, yet conventional methods rely on chemical clarificants that compromise quality and safety. Under the ICAR-CIPHET's Farmer FIRST Programme, an improved, chemical-free, and energy-efficient jaggery-making system was introduced at Uppal Farm, Rahon (SBS Nagar). Using plant-based clarificants like okra mucilage and a multi-pan furnace burning sugarcane waste, the process enhances energy efficiency and product purity. The improved system enables production of both solid and granular jaggery, offering a sustainable, health-safe, and income-generating alternative for farmers.

Keywords: Energy-efficient processing, Farmer empowerment, Okra mucilage, Organic clarificants, Three-pan furnance, Value-addition

INDIA is the largest producer of jaggery, generating over 300 MMT of sugarcane annually, of which approximately 79.71%, 11.29%, and 8.80% are processed to produce white sugar, jaggery, and cane juice, respectively. The recovery and quality of jaggery primarily depend on sugarcane variety, fertilizer type and dose, irrigation, and crushing methods.

Jaggery or *gur*, is a traditional sweetener widely consumed in South Asia, Africa, and Latin America. It is known by various regional names, such as 'Gur' in India, 'Panela' in South America, and 'Jaggery' in South Asia. It is an unrefined, nutritional, non-centrifugal whole cane sugar consumed globally, and in Ayurveda, it is considered a therapeutic sugar for the treatment of lung and throat infections, possessing antioxidative and anticarcinogenic properties. Jaggery is generally prepared from sugarcane juice *(Saccharum officinarum)*, though it can also be made from palm and sweet sorghum. It contains 60–85% sucrose, 5–15% glucose and fructose, and various minerals. It is considered a healthy sugar due to its richness in minerals such as iron, magnesium, sodium, phosphorus, zinc, potassium, and vitamins.

The colour of jaggery typically ranges from brown to dark brown, while golden yellow jaggery is preferred in the market. Jaggery is available in three main forms: liquid, solid, and granular. Solid jaggery is produced by heating the concentrated juice to 116–128°C, followed by cooling and molding into rectangles or cubes using stainless steel or wooden molds. Liquid jaggery is a semi-solid product obtained by boiling sugarcane juice to 105–108°C. Granular jaggery is prepared by heating to 120–122°C, cooling, and scraping to form crystals. Traditional jaggery production often involves the use of chemicals, such as lime and hydros, to clarify the juice. While these chemicals improve shelf life and appearance, their residues in the final product can pose potential health risks to consumers. Growing awareness of chemical effects on health has increased the demand for organic and chemical-free jaggery that preserves nutritional value and health benefits.

ICAR-CIPHET has played a significant role in promoting chemical-free jaggery production by developing improved processing techniques, hygienic handling, and energy-efficient methods to maintain shelf life and purity. Adoption of these methods enables farmers to produce high-quality jaggery, ensuring that chemical-free jaggery reaches the market in good condition, thereby enhancing farmers' income and promoting employment-generating agricultural practices.

Processing stages in jaggery production

Jaggery production involves a series of operations to convert sugarcane juice to solid, granular jaggery. Each step plays an important role in maintaining the yield, colour and overall acceptability of the final product. The detailed process is given below:

Harvesting of sugarcane: Harvesting of mature sugarcane is crucial for achieving high sugar content,

maximum yield, and high-quality jaggery.

Juice extraction: Sugarcane juice is extracted using power operated vertical or horizontal crusher. Horizontal multi roller crusher is preferable due to its high juice extraction capacity (60–65%). The fibrous material remained after juice extraction is bagasse, dried and utilized as a biofuel to heat the juice during boiling stages.

Filtration and settling: After extraction, the juice is passed through a wire mesh or thick cloth to remove suspended impurities like bagasse and other plant debris. The filtered juice is collected into a stainless steel or aluminum tank through underground PVC pipes. The juice is allowed to left undisturbed for 10–15 min in covered tank to allow settling of heavy impurities at the bottom. The clear juice is then transferred to the furnaces pans for further concentration.

Boiling and clarification: The filtered juice is boiled in large iron vessels or open pans, heated by burning bagasse as biofuel. To clarify juice from the impurities like soil, wax, protein, gums, tannins, and colouring particles, clarifying agents (Sodium hydrosulphide, lime, sodium bicarbonate, or organic calrificants like deola or okra mucilage) are added to the heated juice at an optimum temperature of 70–80°C. The effectiveness of juice clarification greatly affects the quality of the jaggery. The efficiency of clarifying agents directly affect the colour, taste, texture, overall quality and acceptability of the jaggery.

Striking point: After clarification, the juice is continuously boiled to remove excess moisture and to concentrate the juice. The boiling process continues for 2–2.5 h until the temperature reaches to 116–118°C, knows as striking point. The end point can be determined by using an infrared thermometer or drop test, by dropping syrup in cold water, if it holds its shape, it is ready to remove from furnace. Adding a small amount of oil (groundnut, mustard, or coconut) can help to prevent excessive frothing, and pouring. The quality of jaggery largely depends on the composition of the sugarcane juice, the type of clarifying agents used, and the temperature at which the juice is concentrated.

Cooling and moulding: The hot concentrate is transferred into a wooden or aluminium troughs for settling and cooling. Once partially solidified, it is poured into moulds of desired shape and size like rectangular, round balls or cubes. For uniform packaging, cubes or rectangular shapes are popular due to convenience in packaging and distribution.

Packaging: Jaggery is traditionally packed in plastic bags, containers, wooden boxes, or cardboard boxes. To ensure hygienic conditions and better shelf life, it is recommended to pack jaggery in PET or polythene bags. Vacuum packaging can extend the shelf life of jaggery upto one year and reduce weight loss. Liquid jaggery can be packaged in PET bottles, while granular jaggery can be packaged in polyethylene pouches, PET jars or bottles. Information like the composition, net weight, manufacturing season, grade, manufacturer, manufacturing date, packaging date, and health benefits of jaggery can be printed on the packaging to promote its sales

Storage: Proper storage conditions are important to maintain the shelf life and quality of jaggery. Jaggery is most susceptible to spoilage due to high humid conditions during the rainy season. To prevent deterioration, the moisture content of jaggery should be between 5–7%. A relative humidity of 50–60% is ideal for storage. Sun drying or solar drying can reduce excess moisture in jaggery, though shade drying is preferred to prevent cracking and maintain a uniform texture.

The method of storing jaggery vary across regions and depends upon the local practices and infrastructure. Traditionally, it is stored in earthen pots, wooden boxes, metal drums, or simply covered with cane trash, bagasse, wheat straw, cotton seed, or rice husk to protect it from moisture. However, many small scale producers and farmers store jaggery in poorly maintained godowns, and kitchens, which can encourage the growth of harmful microorganisms and lead to spoilage.

Traditional method of jaggery production

Jaggery processing techniques vary widely, with traditional methods often relying on inefficient, single-pan furnaces that required higher mechanical and thermal energy to prepare jaggery. In conventional method, sugarcane juice is extracted by crushing the sugarcane using mechanical crusher followed by heating to prepare jaggery. The open pan heating system consists of three stages.

I Stage is raising the temperature of sugar cane juice to initiate boiling.

II Stage is supplying heat to boiling temperature to evaporate water from the sugarcane juice.

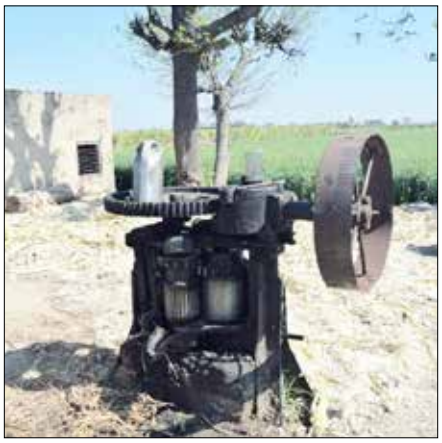
III stage is increasing heat to raise temperature from boiling point to striking point, the point when sugarcane juice converted to semi solid state and cooled as jaggery.

However, in traditional process, uncontrolled heat often leads to maillard reaction and sugar caramelization, resulting in dark coloured jaggery and quality deterioration of product. Chemical clarificants like lime, hydros and phosphoric acid are used to clarify the sugarcane juice, while the traces of clarificants remained in the end product which could pose harmful effect on human health.

Unit operation of jaggery manufacturing process

Improved modern chemical free jaggery processing method

Modern furnaces, designed for optimal heat utilization and operational efficiency through the use multiple pans and recover the waste heat to preheat incoming sugarcane juice. This design significantly improves energy efficiency and reduces processing time. ICAR-CIPHET has demonstrated improved three-pan furnaces that enhance thermal efficiency while saving fuel and processing time. The triple-pan furnace,



Traditional vertical crusher

Traditional method of jaggery concentration using single pan

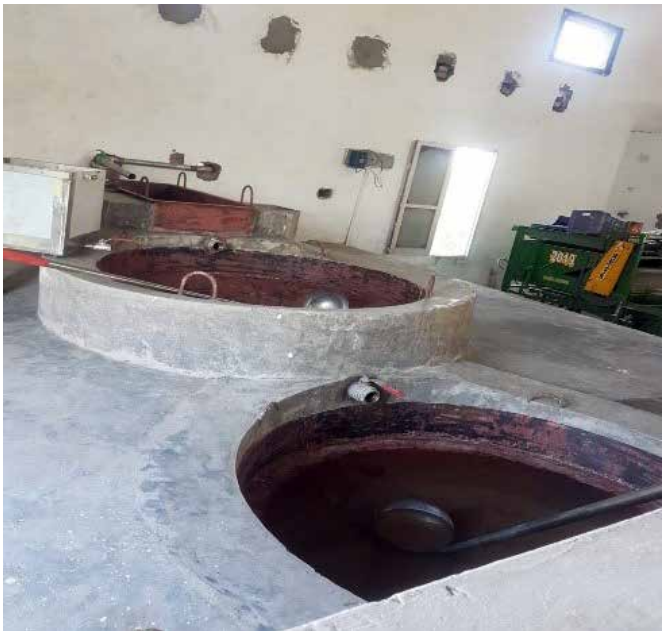
Jaggery round blocks

Traditional (one pan) method

in particular, utilizes the waste heat from the lower pans to preheat juice in the upper pans.

The jaggery making process in a three-pan system is continuous, and typically required 3-4 skilled workers. Sugarcane juice is filled into all three pans, with fuel combustion occurs beneath the bottom pan. The temperature is highest at the bottom pan and gradually decreases upward, facilitating effective heat transfer through convection and radiation. During processing, scum is removed continuously from the first two pans. As the juice in the bottom pan thickens and solidify into jaggery, the preheated juice from the middle pan moves downward, and the fresh juice enters to the top pan. This continuous process ensures controlled process, uniform evaporation, thermal efficiency and high-quality jaggery.

In addition to it, Jaggery is traditionally sold in large quantity and bulk packing is done in wooden boxes or cardboard boxes, which increase the risk of quality deterioration of jaggery due to moisture variation that lead to microbial attack. To address this issue, ICAR-CIPHET, recommended a packaging of jaggery in polythene bags or PET jars to ensure the longer shelf life of product which significantly preserve colour, texture and taste of the jaggery.



Modern (Three pan) method

The moulding of jaggery by silicon mould enables the farmers to prepare uniform sized jaggery cubes or candy shapes rather than irregular or round shapes. The uniformity in shape of the final jaggery cubes enhances the marketability, ease of handling, packaging convenience and consumer appeal, which improves the farmers income by 30%.

Establishment and impact of the chemical free jaggery processing plant by ICAR-CIPHET

Several key activities were undertaken during the establishment of the chemical-free jaggery production unit under ICAR-CIPHET.

Equipment installation: Equipment such as sugarcane crusher, collection tank, jaggery moulding frame, mould frame tray, and an open pan heating set were procured.

Table 1. Equipments for the establishment of the jaggery processing unit

Equipment	Application
Sugarcane crusher	Extract juice from harvested sugarcane
An open pan heating set up	Provide controlled heating for boiling of juice to concentrate
Collection tank	Collect and store juice temporarily before further processing
Jaggery mould frame	Shapes concentrated jaggery syrup into uniform blocks or cubes
Mould frame tray	Support moulds and ensure proper shaping and cooling of jaggery
Refractometer	Measure total soluble solids

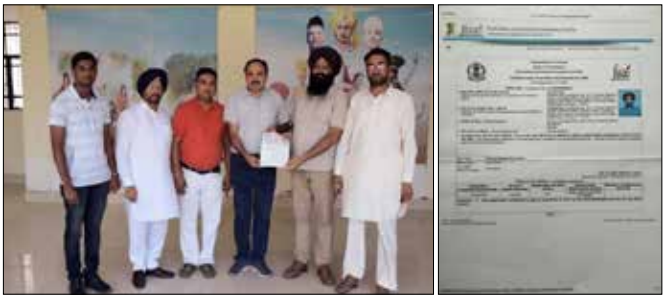
Technology dissemination and farmer training: The unit was handed over to farmers in Rahon, Nawanshahr. A sugarcane crusher and a three-pan heating system was installed. The participating farmers in the jaggery production plant were registered with FSSAI under the guidance of Farmer FIRST Programme team of ICAR-CIPHET.

Processing: The efficient crushing and concentration process enabled the plant to produce high-quality value added jaggery, both granular and solid. The organic clarificants, that is, okra mucilage, was used to clarify the juice.

***Moulding and packaging*:** Silicon moulds were provided to the farmers for production of cubical/candy shaped jaggery, which enhance marketability and consumer appeal of jaggery.

Profits and market value: The farmers sold their jaggery at attractive prices and earned profits. The solid and granular jaggery were sold at ₹ 100/kg and ₹ 120 /kg, respectively. In 2019, the farmers processed 300 quintals of solid jaggery and 100 quintals of granular jaggery, earning a profit of ₹5.5 lakh from the unit. Selling jaggery in addition to sugarcane helped the farmers increase their income by 30%.

Employment opportunities: This project created employment opportunities for local farmers and inspired other sugarcane farmers. Many farmers visited the unit and showed strong interest in establishment of their own chemical free jaggery production unit.



FSSAI registration certificate issued for the farmer of Farm Nation, Uppal Farm, Rahon, Nawanshahr

Installation of sugarcane crusher at Rahon, Nawanshahr

Installation of 3 pan heating system for sugarcane juice heating

Moulding of jaggery (candy/cubes) using silicon mould

Success Story: FFP intervention

Intervention: Establishment of modern chemical free jaggery production unit at Uppal Farm, Bharta Khurd, Rahon, SBS Nagar

Name : Shri Sohan Singh Uppal
Age : 50 years
Education : Graduate
Address : Uppal Farm, Rohan, SBS Nagar

Rationale of the intervention: Shri Sohan Singh Uppal, a farmer from Bharta Khurd, Rahon, SBS Nagar, Punjab, cultivates about 200 acres of land with crops mainly paddy, wheat, sugarcane, maize, and potato, in which sugarcane is cultivated on 60–70 acres of lands. Earlier, he sold sugarcane to nearby sugarcane mills and also produced jaggery for household use, by employing traditional method. The sugarcane growing farmers in the region were facing significant challenges due to delayed payment and inappropriate price of produce, from the mills. The price given by the mills could not cover cultivation cost. During field visit of FFP staff, the issues faced by the farmers were observed and FFP team advised the sugarcane growing farmers to start sugarcane processing at farm level instead of direct selling of sugarcane to the mills. Sri Uppal was motivated and guided to start his own jaggery processing plant using modern, energy efficient and chemical free technology. Under the guidance of ICAR-CIPHET, the training and practical exposure was provided to group of farmers to process sugarcane for the production of solid and granular jaggery. With the guidance of ICAR-CIPHET, Ludhiana, a chemical free jaggery unit was successfully established at Uppal Farm, Rahon, SBS Nagar under the Farmers FIRST Programme.

This jaggery processing unit is a semi-automatic plant, uses three-pan system to concentrate the juice. The unit setup includes a sugarcane crusher with a capacity of 1tonne/h), juice collection tank of capacity of 750 L, three open juice concentration pans, jaggery moulding frames, trays, etc. Using these frames, the concentrated jaggery can be moulded into unifrom cubical shapes (1″ × 1″ × 1″), which enhanced its market value. The higher crushing capacity of crusher and three pan setup ensures the higher processing and production efficiency of jaggery.

Outcome: The intervention helped the group of farmers to produce large quantity of solid and granular jaggery under hygienic conditions, at farm level. The uniform shape of jaggery improved selling price and consumer acceptance of jaggery in the market and thus, helped to earn good profits. This initiative also created a lot of employment opportunities. Processing and marketing of the jaggery in addition to sugarcane sale, increase the income of the farmers by nearly 30%. Successful operation of the setup also attracted 40–50

sugarcane farmers. They visited the plant and showed keen interest in the jaggery unit setup. Currently, Sri Uppal is producing solid and granular jaggery with a brand name "Farm Nation" and selling it in retail wholesale market. According to Shri Sohan Singh Uppal, if more farmers adopt this modern chemical free jaggery production method then they can significantly enhance their profitability in sugarcane farming.

Table 1. Economic analysis of jaggery processing unit

Capacity	55 q/day
Principal component cost (crusher, moulding frame, sieves, boiling pans, etc) (in lakhs)	9.75 L
Monetary benefits per annum (5-6 months) (₹in lakhs)	36.71 L
Saving over sugar cane selling (in lakhs)	17.96 L
Profit per ha (in lakhs)	3.06 L
Value addition (%)	204
Employment (Mandays)	15
Benefits-Cost ratio	1.6

SUMMARY

The traditional method uses one-pan system and chemical clarificants that affect the quality of product and human health. On the other hand, the modern method, chemical-free jaggery production process/developed by ICAR-CIPHET, Ludhiana under the Farmer FIRST Programme has significantly improved the quality, safety and market value of jaggery. The key features of chemical free Jaggery processing units are as follow:

- Adoption of three-pan system, is energy-efficient, ensure uniform heating and processing of jaggery, and it has optimal utilization of energy.
- Horizontal crusher increased the efficiency of juice extraction by 4–5% more juice than vertical crusher, which ultimately increases the finished product recovery. The reduced moisture content of bagasse inhances its improved burning efficiency thereby minimizing environment at pollution.
- Introduction of silicon mould to the farmer, enabled them to produce jaggery with uniform size and shape (Cube/ Candy), which improves the appearance, packaging convenience and market value (25–30% higher) of jaggery than the traditional round blocks. Diverse mould design are available to prepare jaggery cubes of different sizes (5–25 g) and shapes that helps to create market value.
- Adaptability of hygienic packaging material such a polythene pouches or PET jars, protected the jaggery from insect and moisture exchange, that could extend the shelf life of the jaggery upto one year.

Overall, the scientific intervention of ICAR-CIPHET empowered farmers through trainings and technical guidance, leading to an improvement in the value-addition of sugarcane to jaggery by 200%, contributing to high market demand, employment opportunities, and reduction in post-harvest losses for sugarcane farmers.

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