Jaggery Production and Comparative Analysis of Clarification Agents: A Review

Asfaq[1], Mohammed Haris Siddiqui[1,2*], Madipelli Nikhil[1], Thimmanolla Raghunath Reddy[1], Saba Siddiqui[1], Gazia Nasir[2], Khan Chand[3]

[1] Department of Agriculture, Integral Institute of Agricultural Science and Technology (IIAST), Integral University, Lucknow, U.P., India

[2] Department of Bioengineering, Faculty of Engineering & IT, Integral University, Lucknow, U.P., India

[3] Department of Agricultural Engineering, School of Agricultural Sciences, Nagaland University, Medziphema, Nagaland

[*] **Corresponding Author:** Mohammed Haris Siddiqui. Email: mohdharis.siddiqui@gmail.com

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ABSTRACT

Jaggery is a traditional, unrefined, non-centrifugal sugar widely consumed in Asia, Africa, and Latin America, particularly in India, which accounts for more than 70% of global production. It is valued for its rich nutritional profile, containing essential minerals, vitamins, and bioactive compounds that contribute to its health-promoting properties. The production of jaggery involves a series of unit operations including sugarcane juice extraction, filtration, clarification, concentration, moulding, and storage. Among these, clarification of sugarcane juice is a critical step that significantly influences the quality, color, texture, and shelf life of the final product. This review focuses on the processing techniques involved in jaggery production and provides a detailed analysis of various organic and inorganic clarifying agents used during juice clarification. Organic clarificants derived from plant mucilage, such as okra, aloe vera, and sukhlai, are gaining importance due to their eco-friendly nature and ability to improve product quality without compromising nutritional value. In contrast, inorganic clarificants like lime and sodium hydrosulphite enhance color and processing efficiency but may adversely affect nutritional quality and consumer health if used excessively. The manuscript also discusses different jaggery manufacturing systems, including single-pan, multi-pan, and improved furnace designs, highlighting their efficiencies and limitations. Comparative studies indicate that organic clarification methods not only improve jaggery quality but are also economically viable and environmentally sustainable. Therefore, the adoption of improved processing technologies along with natural clarificants is essential for enhancing productivity, quality, and market acceptability of jaggery.

Keywords: Jaggery, Clarification, Organic clarifying agents, Inorganic clarifying agents, Clarificants.

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1. Introduction

Jaggery is a conventional unrefined non-centrifugal sugar consumed in Asia, Africa, Latin America and the Caribbean. It contains all the minerals and vitamins present in sugarcane juice, so it is known as healthiest sugar in the world. India is one of the largest producer and consumer of jaggery in the world. Out of total world production, more than 70% is produced in India (Rao et al., 2007). In India, the production of sugarcane is about 300Mt. Of this 300 Mt of sugarcane produced, 53% is processed into white sugar, 36% into jaggery and khandsari, 3% for chewing as cane juice, and 8% as seed cane (Singh et al., 2011).

Jaggery, a product of sugarcane, is such a product which is rich in important minerals such as: 40–100 mg of Calcium, 70–90 mg of Magnesium, 1056 mg of Potassium, 20–90 mg of Phosphorus, 19–30 mg of Sodium, 10–13 mg of Iron, 0.2–0.5 mg of Manganese, 0.2–0.4 mg of Zinc, 0.1–0.9 mg of Copper, and 5.3 mg of Chloride per 100 g of jaggery, and vitamins such as: 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 (Singh et al., 2013). Jaggery contains micronutrients, which have the anti-toxic and anti-carcinogenic properties, if jaggery consume day to day diet than it can prevent the atmospheric pollution or air pollution related toxicity and prevent the risk of lungs cancer (Rao & Lakshminarayana, 1999).

In India, most the jaggery manufacturers use traditional methods to manufacture organic jaggery. The traditional jaggery making process has very low thermal efficiency. It requires high skill and more manual labour due to lengthy heating operation. Due to batch production, the traditional jaggery manufacturing process cannot be used for mass production (Mandal et al., 2006).

2. Steps Involved in Jaggery Production

The process of jaggery production involves various steps such as: harvesting, pre-cleaning and crushing of canes, filtration, clarification, heating, boiling and concentration of cane juice, cooling of concentrated cane juice (i.e., slurry), powder making, packaging, storage and marketing of jaggery (Handbook of Processing of Jaggery).

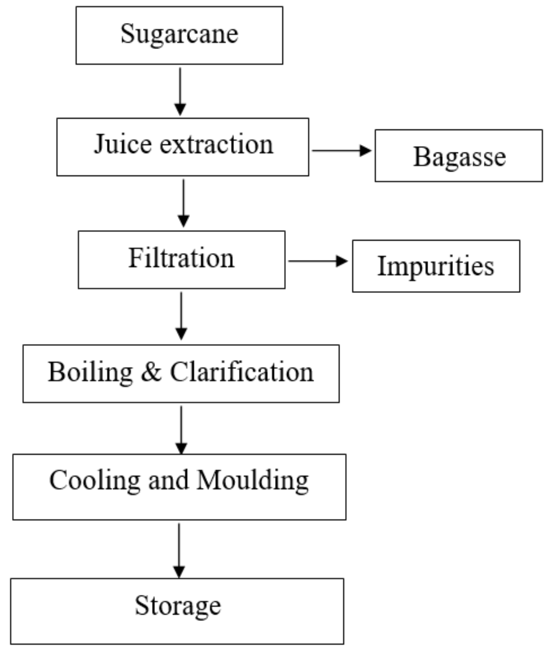

Figure1 Flow chart showing different steps involved in jaggery production

2.1. Sugarcane juice extraction

The first step involved in producing jaggery is weighing sugarcane and extraction of juice. The extraction process is done by crushing the sugarcanes in a crusher. The crushers can be classified into animal driven and engine driven crushers. Due to technological upgradation and high efficiency now a days engine driven crushers are used for this process. It is further classified into two types according to the orientation of crushing rollers, namely vertical crushers and horizontal crushers.

The efficiency of vertical crusher is about 50-55% and horizontal crusher is 55-60%. By using multiple crushers and hot water during crushing can boost crushing efficiency from 77% to 80%, however this is not possible in the case of traditional small jaggery facilities (Rao et al., 2007). After the extraction of sugarcane juice the remaining product is bagasse. In most of the jaggery making industries bagasse is used as fuel. Dry bagasse is sent to burning unit called furnace. According to calculations, 0.65 kg of bagasse is used to make 1 kg of jiggery (Shiralkar et al., 2013). Bagasse consists of fibers and sugar which has high calorific values. The calorific value of fiber in bagasse is about 19259 kJ/kg and sugar is about 16747 kJ/kg (Paturao, 1982).

Dry bagasse is used for producing thermal energy for boiling the sugarcane juice. This is achieved through thermochemical combustion process in fixed beds (Navarrete et al., 2017; Spliethoff, 2010). The industrial design of biomass burners needs a thorough understanding of the many processes that occur during the burning of biomass particles (heating, drying, pyrolysis, combustion of volatile particles and char combustion) (Spliethoff, 2010). The amount of bagasse in sugarcane varies from 23 to 37 percent, depending on the sugarcane variety (Agarwal & Maroo, 2013). According to reports, crushing 1000 kg of sugarcane yields 650 kg of juice and 350 kg of bagasse. Bagasse obtained immediately after extraction of juice contains about 50% moisture. The moisture content of bagasse can be reduced by various methods like sun drying, hot air oven method and microwave oven method. Sun drying reduces the moisture content from 50% to 20%. Out of all these drying methods the use of microwave oven method is more efficient and less time taking method (Rao et al., 2003).

2.2. Filtration and juice concentration

Filtration involves removal of large suspended impurities in the extracted sugarcane juice. The insoluble impurities are removed using a muslin cloth which has a mesh size about 100 μ (Pawar et al., 2017). Juice concentration is the method to remove light and heavy impure particles present in the juice. It is done by collecting extracted sugarcane juice into a masonry settling tank and then allowed it to rest for a few minutes. The clear juice is collected from settling tank through a middle port on it and conveyed it to a boiling tank, which is filled up to one-third of its full capacity (Rao et al., 2007).

2.3. Boiling and Clarification

In jaggery production, boiling is the second most important step. Usually boiling is done by burning the bagasse which is remained after extraction of sugarcane juice (Rao et al., 2007). Both the boiling and clarifying of sugarcane juice is done at the same time because overheating can cause the product to burn, which changes the color and flavor of final product (Kumar & Kumar, 2018).

The filtered sugarcane juice is boiled for about 20-30min at a temperature of 85^0-90^0C. A golden colored scum accumulates on the surface throughout this process, which should be removed. The sugarcane juice is currently partially unclarified (Singh et al., 2007). A clarifying agent is added to the sugarcane juice at this point which removes dissolved non-sugar impurities (Patil et al., 2005). If non-sugar impurities are not clarified, they will be carried to the next stage of processing, resulting in low-quality jaggery (Kumar et al., 2008). The clarification efficiency and type of clarificant used determines the quality of jaggery produced (Singh & Narain, 2002). The clarifying agents can be classified into two types and they are organic clarificants and inorganic clarificants.

The organic clarifying agents are made from mucilage of different plants and vegetables. Some of the organic clarifying agents are Deola (Hibiscus ficulneus), Bhendi (Hibiscus esculentus), Castor (Recinus communis), Groundnut (Arachis hypogea), Soybean (Glycine max), Phalsa (Grewia asiatica), and Sukhalai (Kydia calycina) (Shankunthala, 1985; Baboo, 1991; Baboo & Solomon, 1995; Singh & Gill, 1954; Laxmikantham, 1973; Jayamala et al., 2009). The inorganic clarificants are made up of different chemical compositions. These also function as bleaching agents, electrolyte or pH adjusting agent. Some of the inorganic clarificants are Hydros, Lime, Sodium carbonate, Sodium bicarbonate, Sajji, Super phosphate, Alum (Handbook of Processing of Jaggery). Most common clarificant used in sugarcane juice clarification is Lime (Calcium hydroxide). The addition of lime increases the acidic pH of the juice from 5.2-5.4 (depending on the variety of sugarcane) to around 6.0-6.4 (Chockalingam, 1985).

The addition of lime to sugarcane juice improves the consistency of jaggery by enhancing the crystallization of sucrose but too much lime might darken the color of final product (William et al., 2003). An optimum proportion of 60-70 ml of lime milk solution is added to every 100kg of juice (i.e., 1 kg of lime is combined with 4 liters of water) (Kuruba et al., 2020). During this process all the dissolved non-sugar impurities present in the sugarcane juice will float on top in the form of scum. The scum is removed for clear transparent juice with yellowish brown color.

The main goal of boiling is to concentrate the juice in order to make solid form jaggery or thick syrup (Liquid Jaggery) in order to extend the shelf life of the juice. The sugarcane juice undergoes several physical and chemical changes during this process. After adding the lime to balance the pH, the juice is boiled in a pan for around 2hours by skimming off the scum as needed from time to time. The boiling juice is continued for 3hours until the temperature reaches to 120^0C (Madhu, 2017).

2.4. Striking point

After the boiling and clarification, the sugarcane juice reaches to a temperature at which thickened cane juice slurry is modified into jaggery. This is called striking point or the end point. It is determined by dropping a small fraction of hot syrup into cold water and allow it to solidify. To prevent the frothing in the sugarcane juice, a small quantity of edible oil is added to it. The shaping of the syrup into various forms of jaggery is significantly influenced by temperature. The striking point varies depending on the product; for solid jaggery, it is 118^{o}C, for liquid jaggery, it is 106-107^{o}C, and for granular jaggery, it is 120-121^{o}C (Madhu, 2017; Vera-Gutiérrez et al., 2019).

2.5. Cooling and Moulding

The process of making hot syrup (Liquid jaggery) into different shapes is called moulding. The concentrated juice is taken out from boiling pan after it reaches to 92^o Brix. Hot syrup is transferred into wooden or aluminum moulds or earthen pots for solidification (Esther et al., 2013). The finished product is moulded in various shapes and sizes at the end of the jaggery production process, such as rectangular shape (0.250–1 kg), cubic shape (2.5 cm^3 and weight 20 g), bucket shape (10–20 kg), and trapezoidal shape (5 kg) (Tiwari et al., 2004).

2.6. Storage and packaging

The shelf life of jaggery is mainly determined by the humidity and temperature in the atmosphere. Jaggery consists of inverts of sugars and mineral salts which absorbs moisture especially during monsoon season due to the presence of high humidity that leads to spoilage [7]. The moisture content of jaggery should not exceed 6% for optimum consistency (Kumar et al., 2012). Sugarcane juice pretreated with nitric oxide results in improved color and sucrose content, extending the shelf life of jiggery (Hussain et al., 2012).

Jaggery is traditionally stored in earthen pots, wooden boxes and metal drums, however these changes from place to place. To keep the jaggery away from direct contact with moist air, jaggery is sometimes stored in the form of heap and covered with cane waste, bagasse, wheat straw, rice husk and other materials (Rai & Paul, 2007). The Figure 2 shows the several steps involved in jaggery manufacture.

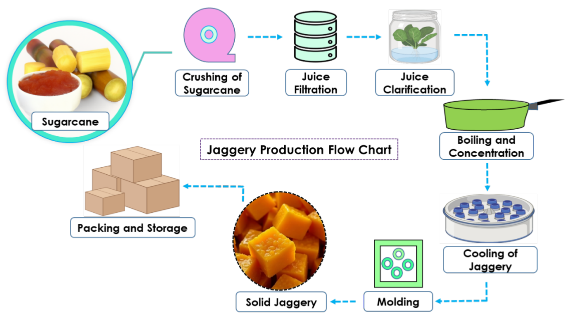

Figure 2 Steps involved in Jaggery Production

3. Overview of Jaggery Manufaturing Plants

In India, the jaggery manufacturing plants are mainly of three types and they are single-pan, two-pan, and multi-pan jaggery manufacturing plants.

1. Single-pan Plant:

In this type of plant, a furnace is made of a pit type which is dug into the ground. A wall of 10-15cm is built around the pit to maintain a flat surface to support the pan. The furnace can be made in a rectangular or round shape according to the type of pan used. The furnace is provided with two openings at positioned opposite each other. This allows to feed bagasse into furnace through one opening and other for exhaust smoke (Kumar & Kumar, 2018).

The pans that are used in jaggery manufacturing pants are usually in rectangular or hemispherical or cone shaped. The rectangular shaped pans have some drawbacks such as it does not allow even heating throughout the pan and this may cause burning of the product. The hemispherical and cone pans are expensive, and they have high maintenance (Kumar & Kumar, 2018). The conventional single pan jaggery plants consume a lot of bagasse i.e., around 3.85kg per kg of jaggery produced and it has a low thermal efficiency of 14.75% (Rao et al., 2003).

2. Two-pan Plant:

The two-pan plant was introduced by Indian Institute of Sugarcane Research Lucknow (IISR). It was designed to overcome the problem of low thermal efficiency in single pan plants. In this type of plant, a second pan is provided after boiling pan known as gutter pan. Before boiling sugarcane juice, the juice is preheated in the gutter pan and then transferred into the boiling pan to reach the temperature up to the striking point (Anwar, 1999). The efficiency of two pan furnaces for jaggery making is about 23.9% against the efficiency of single pan furnace which was about 16% to 19.7% (Singh et al., 2009).

3. Three-pan plant:

In a three-pan plant, the process of manufacturing jaggery is a continuous and time-consuming procedure that requires 7-8 skilled workers. The 3 pans of this plant are filled with sugarcane juice before boiling. Bagasse is used as fuel, and burning is done under pan-3; the temperature of the pan-3 is 1000^{0}C. The heat transmission for pan-3 is through convection and radiation whereas convection from hot flue gases is the mode of heat transfer for pan-1 and pan-2. Removal of scum and boiling is similar to single pan plant. The second batch of preheated juice from pan -2 is poured into pan boiling pan -3, and preheated cane juice from boiling pan -1 is poured into pan -2, after the juice in pan-3 has been turned to solid jaggery by evaporation. Fresh cane juice is pumped into boiling pan-1 via a pipe from the crusher (Arya et al., 2013).

4. Four-pan or multiple pan plant:

The four-pan plant is used for continues production where large quantity of jaggery is to be produced. In four-pan type, other than boiling pan and gutter pan there are two or more pans utilized. They are placed in a serial manner so that waste flue gases are extracted more heat. The first two pans are simply used to preheat the juice with the help of thermal energy of hot flue gases. The preheated juice is then transferred to the boiling pans which are at 1000^{0}C. The direction of juice transfer is the absolutely opposite to the motion of hot flue gases to make better use of the thermal energy contained in flue gases. The working and design of 4- pan jaggery plant is very similar to 2 or 3 pan system. The thermal efficiency of 4-pan plant is about 46% and the bagasse consumption is 1.44 kg per kg jaggery production (Shiralkar et al., 2013).

4. Clarification of Sugarcane Juice

In the jaggery making process clarification is the main step which helps in removal of non-sugar impurities from the sugarcane juice (Patil et al., 2005). If clarification is not done then the non-sugar impurities will be carried to the next step in processing and this will eventually result in low quality jaggery (Kumar et al., 2008).

Process of clarification: The juice extracted from sugarcane is first filtered to remove large sized impurities. Then the filtered sugarcane juice is boiled for 20–30 min at a temperature of 85–90°C. During this golden coloured scum forms on the surface and this should be removed. Now the sugarcane juice is partially unclarified (Singh et al., 2007). At this point a clarifying agent is added in the solution. Mostly lime (calcium hydroxide) is used as the clarifying agent (Handbook of Processing of Jaggery, n.d.). By adding lime, it also increases the acidic pH of juice, i.e., 5.2–5.4 (depending upon harvesting status, variety of the cane and soil condition) to around 6.0–6.4 (Chockalingam, 1985).

4.1 Clarifying Agents Used in Jaggery Production

The clarifying agents that are used in jaggery production can be classified into two types:

1. Organic clarifying agents
2. Inorganic or synthetic clarifying agents

4.1.1. Organic clarifying agents

These are the clarifying agents made from the mucilage of different vegetables. Now a days, the organic clarifying agents are highly encouraged and recommended. This is due to the problems that occurred while using chemical clarifying agents such as excessive use of chemicals for colour and storability (Handbook of Processing of Jaggery). This affects the health of the consumers. Some of the organic clarifying agents are Deola (Hibiscus ficulneus), Bhendi (Hibiscus esculentus), Castor (Ricinus communis), Groundnut (Arachis hypogea), Soybean (Glycine max), Phalsa (Grewia asiatica), and Sukhalai (Kydia calycina) which were found to improve the quality of jaggery (Shankunthala, 1985; Baboo, 1991; Baboo & Solomon, 1995; Singh & Gill, 1954; Laxmikantham, 1973; Jayamala et al., 2009).

4.1.2. Inorganic or synthetic clarifying agents

These are the clarifying agents made up of different chemical compositions. Chemical clarifying agents also function as bleaching agent, electrolyte or pH adjusting agent. Some of the inorganic clarifying agents are Hydros, Lime, Sodium carbonate, Sodium bicarbonate, Sajji, Super phosphate, Alum (Handbook of Processing of Jaggery).

Table-1. Organic clarifying agents (Handbook of Processing of Jaggery)

Common name	Plant part used	Methodology	Quantity per quintal juice	Remark
Deloa	Stem and root of green plant	Pound and extract in water. Use mucilaginous extract	40-50 g	
Bhindi	Stem and root of green plant	Pound and extract in water. Use mucilaginous	45-50 g	More effective in removing colouring matter

		extract		
Phalsa	Green bark of the tree	Pound and extract in water. Use mucilaginous extract	50-55 g	
Semul	Green bark of the tree	Pound and extract in water. Use mucilaginous extract	55-60 g	
Sukhlai (Kydia calycina)	Dry bark of the plant	Soak in water. Pound plant and rub in water. Use the extract	45-60 g	
Castor	Seed	Grind decorticated seed with water. Use milky liquid after straining	70-75 g	Good results with juice of immature waterlogged and infested canes
Groundnut	Seed	Grind decorticated seed with water. Use milky liquid after straining	70-75 g	Good results with juice of immature waterlogged and infested canes
Soybean	Seed	Flour	30-40 g	Good results with juice of immature waterlogged and infested canes

Table-2. Inorganic clarifying agents (Handbook of Processing of Jaggery).

Chemical	Action	Immediate effect on product	Effect on storability
Hydros (sodium hydrogen sulphite)	Colour bleaching	Brightens colour temporarily	Hastens darkening and process spoilage within a month
Lime	Remove	Liming to pH	Hard

(Calcium oxide)	s juice acidity. Helps in clarification	6.3-6.6 results in good quality. Useful in solidification of Gur from waterlogged lodged cane. Excess liming results in hard Gur of dark colour	Gur; stores better
Sodium carbonate	Reduces acidity	Helps in settling and improving Gur quality from inferior canes.	Hard Gur; stores better
Sodium bicarbonate	Colour bleaching	Brightens colour temporarily	Hastens process spoilage
Sajji(50% sodium carbonate, 6.4% sodium sulphate, 4.5% sodium chloride)	Partial neutralization of juice acidity, colour bleaching	Brightens colour temporarily, reduces the taste	Adverse effect on storage
Super phosphate	Increases natural acidity, improves colour	Reduces crystallization	Reduces shelf life
Alum	Improves clarification. Needs neutralization with lime / soda	Brightens colour temporarily	Reduces shelf life

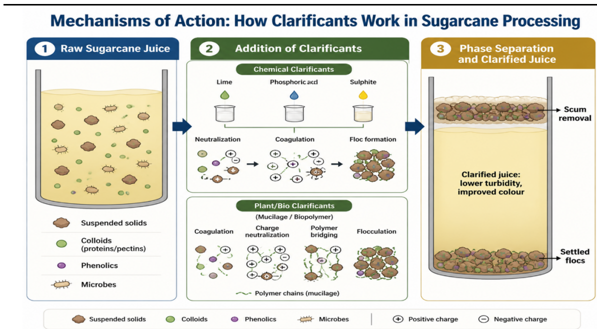

Figure 3 Mechanism of action of clarificants

5. Analysis of Different Organic and Inorganic Clarificants

Many scholars have done various research on the clarifying agents and their effect on the jaggery. Singh et al., (2021) developed a standard of jaggery by using some herbal clarifying agents. In this research, they used various clarifying agents such as Hibiscus esculentus (bhindi), Cadia celcina (sukalai), Bombax malabarium (semal bark) and combination of Shukhlai with semal. The table- shows the results of his research.

By this research they found that the organic Shukhlai to be the best clarifying agent among others. The Shukhlai used for his work was 2.960 kg/100 kg of sugarcane. The specified gravity of Shukhlai solution was 93.00 gm/100gm weight of standard solution. The scum recovery after the clarification process was 3.800 kg/100 kg of sugarcane. The recovery of sugarcane juice was 64.000 ±1 kg/100 kg sugarcane and recovery of bagasse was found to be 36.000 kg/100 kg sugarcane. Jaggery recovery was found for solid jaggery was about 11.67 to 13.467 kg/100 kg sugarcane, powder jaggery was 11.533 to 13.117 kg/100 kg sugar cane and liquid jaggery was 24.617 to 27.667 kg/100 kg sugarcane.

Table-3. Scum Recovery and Clarification results (Chikkappaiah et al., 2018)

Treatment	Mucilage of clarifying agent used (kg)	Clarifying agent specific gravity	scum recovery (kg)	Effect on clarification	Colour of final jaggery products
Shukhlai	2.960 ± 0.100	93.000 ± 0.500	3.800 ± 0.200	Complete clarification	Light yellow to red
bhindi plant	3.150 ± 0.150	95.000 ± 1.000	3.250 ± 0.250	Complete clarification	Dull yellow to red
semal	3.310 ± 0.100	95.500 ± 0.500	3.100 ± 0.100	Complete clarification	Bright red
Shukhlai + semal	3.050 ± 0.100	95.0000 ± 0.500	3.400 ± 0.200	Complete clarification	Yellow bright red

Chikkappaiah et al., (2017) conducted an experiment to produce jaggery from sugarcane variety Co86032 by using organic clarificants. He used 5 plant clarificants namely: Aloe vera, Flax seeds, Fenugreek, Purslane and Malabar spinach at three concentrations i.e., 0.1%, 0.2% and 0.4%.

By this research, they found that the jaggery prepared by using organic clarificants mucilage at a concentration of 0.4% to be more effective when compared to the concentrations 0.2% and 0.1%. Aloe vera at 0.4% removed maximum scum i.e., 4.07% and it took minimum processing time and recorded maximum jaggery yield of 10.92 kg. The highest to least efficiency of other organic clarificants are as following Fenugreek, Flax Seeds, Purslane and Malabar Spinach.

The organic clarificants used for the research found to be very effective. It removed maximum scum and also reduced the time of processing, and it also improved the yield of jaggery. He further stated that the selected plant mucilage increased the processing efficiency by the increase of concentration. He also stated that these clarificants can be used instead of chemical clarificants because of their natural origin, local availability and eco-friendly.

Hoi et.al., (1999) did research to find natural flocculant in cane juice clarification. They used seeds of drumstick tree (Moringa oleifera) and edible fruit of Cordia myxa for this research. The laboratory tests showed that when crushed seeds of Moringa oleifera, when applied at 0.16% on lime juice a solution clearer of 52% than without a flocculant and the mud produced was twice its volume. In case of Cordia myxa fruit mix, it was added between 0.016% and 0.04% on lime juice. This resulted in a clearer solution up to 42% with a 9% reduction in the mud volume. By this experiment they have concluded that the clarifying property of the seed of drumstick can be used in organic sugar production at rate of 0.16% on the juice, with a 0.05% of bentonite to help reduce the mud volume. The Cordia myxa has higher efficiency since its solution is added at a rate of 0.04% produces 42% clearer juice with 9% reduction in mud volume.

Chavan et.al., (2007) conducted an experiment to prepare white crude mucilage powder from fresh stems of mature lady's finger (Okra) plants. The yield of the mucilage powder was about 4%. The mucilage power was found to be highly efficient in clarifying the sugarcane juice in the jaggery production. The comparison of freshly prepared stem extract and mucilage powder solution was done in this experiment. The jaggery prepared by mucilage powder as a clarificant has shown similar properties as fresh stem extract. This experiment has indicated that the mucilage powder at 0.4% was similarly effective as clarificant to prepare good quality jaggery.

Malkunje et.al., (2017) did a cost-based analysis on usage of organic and inorganic clarificants in jaggery production in Kolhapur district of Maharashtra. By this study shows that the per unit resource use and their costs were about Rs. 679483.24 for organic jaggery units and Rs. 3240745.98 for inorganic jaggery units. Which was significantly higher in the case of inorganic jaggery plants, this was due to the crushing days of organic jaggery units was much less than the inorganic jaggery units. The use of hydrous powder was completely absent, and the use of phosphoric acid was very less in the case of organic jaggery. The quintal cost of jaggery production was Rs. 2768.97 for organic jaggery and Rs. 2834.32 for inorganic jaggery. The establishment cost per unit was Rs. 806120 for organic jaggery unit and Rs. 808509 for inorganic jaggery unit. The per quintal cost for jaggery processing was less in organic jaggery when compared to inorganic jaggery this was due to the less usage of chemicals.

Verma et.al., (2019) done research on chemical clarificant in jaggery production. To meet up the consumers requirements instead of traditional practices chemicals are used as clarificants. Sodium hydrosulphite (hydros) is a commonly used chemical in the jaggery processing industries. Hydros help to improve the colour of the jaggery. By this research, it is found that hydros-treated jaggery was brighter in colour. It had a lower browning index by 5-10. SO_2 content of this jaggery was more than 70ppm. The minerals, polyphenols and flavonoids were found to be less compared to organic jaggery. Therefore, compromising the overall quality of the final product.

Patel et al., (1990) did an experiment to make samples of jaggery from 3 sugarcane varieties. Co.775, Co.62175 and Co.6304 are the three varieties used in this experiment. The clarification was done with the following chemical clarificants: 5-20ml 0.01% Magna floc LT 22, 5-20ml 0.002% Magna floc LT 22 SP, 25ml of mucilaginous extract of Abelmoschus esculents + 1 ml of 0.01% H_3PO_4. After the experiment the 10 ml Magna floc LT 22 SP was found to be best in terms of colour, pol and purity. The best variety was found to be Co.62175.

6. Conclusion

As the demand for jaggery is increasing day by day there is a need to concentrate on advancing the jaggery making plants. The current jaggery producing industries should focus more on quality rather than quantity. There is need to focus on technological developments in jaggery processing units. Several research and scientists designed and developed new methods for jaggery producing plants. The local jaggery producers should also adopt these techniques to improve their overall productivity. More research should be done on increasing the thermal efficiency of furnaces, which will be very beneficial in the processing industry.

The clarification of sugarcane juice for jaggery production can be done with many organic and synthetic clarifying agents. But from all the above research it is found that the use of organic clarificants is best in terms of health, nutritional value, taste and economical. In terms of health, organic jaggery retains all the minerals and nutrients. Adapting organic jaggery making techniques is beneficial for both the producers and consumers. While in inorganic jaggery due to the high use of chemicals and sediments of chemicals nutritional values are lost and it can cause serious health issues to the consumers. The cost analysis shows that the net profit of organic jaggery is high when compared to inorganic jaggery due to the high chemical costs. Further research should be done on the preservation of organic clarificants.

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Declaration of competing interest

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Data availability

Data will be made available on request.

References

[1] Agarwal, A., & Maroo, V. (2013). Bagasse power in India: Meeting challenges of energy, environment and sustainable development. *International Journal of Recent Scientific Research*, 4, 1098–1102.

[2] Anwar, A. (1999). Industrial and policy issues including export potential of jaggery and khandsari. In *Proceedings of National Seminar on Status, Problems and Prospects of Jaggery and Khandsari Industry in India*. Indian Institute of Sugarcane Research, Lucknow, India.

[3] Arya, P., Jaiswal, U. K., & Kumar, S. (2013). Design based improvement in a three pan jaggery making plant for rural India. *International Journal of Engineering Research*, 2, 264–268.

[4] Baboo, B. (1991). PSO-SVM applied to SWASV studies for accurate detection of Cd (II). *Journal of Agricultural Engineering*.

[5] Baboo, B., & Solomon, S. (1995). Nutritive sweeteners from sugar crops: Development of jaggery, khandsari and syrup industries in India. In G. Singh & S. Solomon (Eds.), *Sugarcane agro-industrial alternatives*.

[6] Chavan, J. K., Dalvi, U. K., & Chavan, U. D. (2007). Isolation of lady's finger (okra) stem mucilage as clarificant in jaggery preparation. *Journal of Food Science and Technology*, 44, 59–61.

[7] Chikkappaiah, L., Nayaka, M., Mahadevaiah, & Prashanth, G. M. (2017). Preparation of plant mucilage clarificants and their effect on jaggery processing.

[8] Chikkappaiah, L., Nayaka, M., Mahadevaiah, & Prashanth, G. M. (2018). Effect of plant clarificants on scum removal and jaggery quality.

[9] Chockalingam, C. (1985). Gur manufacture in Tamil Nadu: A review. *Proceedings of National Seminar on Jaggery Manufacture and Storage*, Lucknow.

[10] Esther, M., Sharon, M., & Abirami, C. V. (2013). Energy losses in traditional jaggery processing. Thanjavur, Tamil Nadu, India.

[11] Handbook of processing of jaggery. Indian Institute of Food Processing Technology, Ministry of Food Processing Industries, Government of India.

[12] Hussain, Z., Islam, M., Mohammad, Z., Khan, K. M., Parveen, S., & Afzal, M. (2012). Effect of pre-treatment of juice on the properties and composition of jaggery. *Sugar Tech*, 14, 291–294.

[13] Jayamala, G. B., Chowde Gowda, M., Ramya, H. N., Shankar, M., & Krishnamma, P. N. (2009). Prospects of jaggery industry in Karnataka: A case study. *International Journal of Applied Agricultural Research*, 4, 203–214.

[14] Kumar, M., & Kumar, R. (2018). Upgradation of jaggery production and preservation technologies. *Renewable and Sustainable Energy Reviews*, 96.

[15] Kumar, V., Vijay, V. K., & Agarwal, U. S. (2008). Studies on centrifugal clarification of sugarcane juice: Possibilities and limitations. *Agricultural Engineering International: CIGR Journal*, 10, 6–29.

[16] Kumar, P. A., Kailappan, R., & Nirmala, R. (2012). Effect of different clarifying agents on the quality of jaggery. *Mysore Journal of Agricultural Sciences*, 46(4), 784–789.

[17] Kuruba, E., Rao, P., Khokhar, D., & Patel, S. (2020). Technologies for preparation of solid and granular jaggery: A review. *Current Journal of Applied Science and Technology*, 39, 105–113.

[18] Lakshmikantham, N. (1973). Importance of jaggery in Andhra Pradesh. Andhra Pradesh Agricultural University, Hyderabad, India.

[19] Malkunje, N. M., Lembhe, J. V., & Kharat, H. V. (2017). Economics of organic and inorganic jaggery production. *International Journal of Commerce and Business Management*, 10(2), 129–138.

[20] Mandal, D., Tudu, S., Mitra, S., & De, G. (2006). Effect of common packing materials on keeping quality of sugarcane jaggery during monsoon season. *Sugar Tech*, 8, 137–142.

[21] Madhu, B. (2017). Evaluation of edible coatings and packing methods on storage of solid jaggery. IGKV, Raipur.

[22] Navarrete, G., Curto, P., & Bizzo, W. (2017). Simplified model and simulation of biomass combustion. *Biomass and Bioenergy*, 99, 38–48.

[23] Patel, H. S., Mehta, N. J., Patel, U. N., & Patel, N. P. (1990). Impact of clarificants on jaggery quality. *Bharatiya Sugar*, 16(2), 73–74.

[24] Patil, J., Nevkar, G., & Singh, J. (2005). Clarification efficiency of synthetic and herbal clarificants in quality jaggery production. *Sugar Tech*, 7, 77–81.

[25] Paturao, J. M. (1982). *By-products of cane sugar industry*. Elsevier Scientific Publication.

[26] Pawar, D. A., Prakash, U., & Vivek, K. (2017). Studies on preparation of jaggery granules with nucleation technique. *International Journal of Agricultural Science and Research*, 7, 609–616.

[27] Rai, D. R., & Paul, S. (2007). Packaging requirements of highly respiring produce. *Journal of Food Science and Technology*, 44, 10–15.

[28] Rao, K. S. S., Sampathrajan, A., & Ramjani, S. A. (2003). Efficiency of traditional jaggery making furnace. *Madras Agricultural Journal*, 90, 184–185.

[29] Rao, V. K. J., Das, M., & Das, S. K. (2007). Jaggery: A traditional Indian sweetener. *Indian Journal of Traditional Knowledge*, 6, 95–102.

[30] Rao, V. K. J., Das, M., & Das, S. K. (2009). Changes in physical and thermo-physical properties of juices. *Journal of Food Engineering*, 90, 559–566.

[31] Rao, S. R., & Lakshminarayana, C. (1999). Cane jaggery in cube, powder, and liquid forms. Proceedings of National Seminar, Lucknow.

[32] Shankunthala, V. A. (1985). Proceedings of national seminar on jaggery manufacture and storage.

[33] Shiralkar, K., Kancharla, S., Shah, N., & Mahajani, S. (2013). Energy improvements in jaggery making processes. *Energy for Sustainable Development*, 18.

[34] Singh, H., & Gill, P. S. (1954). Comparative efficiency of organic clarificants in gur manufacture.

[35] Singh, J., & Narain, S. H. (2002). Jaggery and khandsari industry in India. *Indian Farming*, 57–68.

[36] Singh, J., Singh, R., Anwar, S., & Solomon, S. (2011). Alternative sweeteners production from sugarcane in India. *Sugar Tech*, 13.

[37] Singh, J., Solomon, S., & Kumar, D. (2013). Manufacturing jaggery as a health food. *Agrotechnology*.

[38] Singh, P., Shahi, H. N., & Suman, A. (2007). Improving sugarcane juice clarification. *Journal of Food Science and Technology*, 44, 315–318.

[39] Singh, R. D., Baboo, B., Singh, A. K., & Anwar, S. I. (2009). Performance evaluation of two pan furnaces.

[40] Spliethoff, H. (2010). *Power generation from solid fuels*. Springer.

[41] Tiwari, G., Kumar, S., & Prakash, O. (2004). Evaluation of convective mass transfer coefficient. *Journal of Food Engineering*, 63, 219–227.

[42] Vera-Gutiérrez, T., García-Muñoz, M. C., Otálvaro-Alvarez, A. M., & Mendieta-Menjura,

[43] O. (2019). Effect of processing technology on jaggery quality. *Heliyon*, 5, e02667.

[44] William, O. S. D., Christopher, M., Gorjian, S., Senogles, E., & Cheng, W. H. (2003). Flocculation and sedimentation of cane sugar juice particles. *Journal of Applied Polymer Science*, 90, 316–325.