jpht
www.jpht.in

Journal of Postharvest Technology
2024, 12 (2): 14-21
https://doi.org/10.48165/jpht.2024.12.2.02
www.jpht.in

REVIEW ARTICLE

Innovations, difficulties, and constraints in the manufacturing of jaggery and jaggery manufacturing plants

P. D. Ukey[1], V. M. Ingale[2], G. B. Yenge[3], K. Prathapan[4], J. S. Ghatge[5], S. B. Patil[6] and J. A. Khot[7]

[1] Department of Processing and Food Engineering, Faculty of Agricultural Engineering, D. Y. Patil Agriculture & Technical University, Talsande, Kolhapur 416 112 Maharashtra, India
[2] Department of Food Technology, D. Y. Patil Agriculture & Technical University, Talsande, Kolhapur 416 112 Maharashtra, India
[3] Department of Processing and Food Engineering, Regional Sugarcane and Jaggery Research Station, Kolhapur 426 005 Maharashtra, India
[4] D. Y. Patil Agriculture & Technical University, Talsande, 416 112 Maharashtra, India.
[5] Faculty of Agricultural Engineering, D. Y. Patil Agriculture & Technical University, Talsande, 416 112. Maharashtra, India.
[6] Dr. D. Y. Patil College of Agricultural Engineering and Technology, Talsande, 416 112 Maharashtra, India.
[7] D. Y. Patil Agriculture & Technical University, Talsande, 416 112 Maharashtra, India.

ARTICLE INFO

Received : 08.02.2024
Accepted : 12.04.2024

ABSTRACT

In India, jaggery is a popular traditional sweetener. It is produced by continuously heating and condensing clear sugarcane juice without the use of chemicals. Currently, people are highly conscious of the health risks associated with eating and place greater importance on food quality. Jaggery is enriched with numerous nutrients, including vitamins, minerals, and protein. Jaggery offers various health benefits such as blood purification, digestion regulation, beauty treatment, improved metabolism, prevention of respiratory issues, and more.

The process of making jaggery involves constant heat and mass transfer, transforming fresh sugarcane juice into a concentrated product. The entire process includes various steps, from sugarcane harvesting to shaping the finished product into different sizes and forms depending on its intended use. The unit operations of jaggery processing include juice extraction, juice clarification, boiling to concentrate juice, cooling concentrated juice, molding/shaping, drying, powdering, packing, and storing. All of these practices, which have several drawbacks and difficulties, are employed in traditional jaggery-making plants. The main problems and challenges that manufacturers face today include the inferior crushing efficiency of the sugarcane crusher, the need for vast open space for bagasse drying, labor-intensive processes, the use of various chemical and natural clarifying agents to produce high-quality jaggery, shortened storage life, high fuel consumption, and poor thermal efficiency. This article addresses the different concerns and problems experienced by manufacturers and presents improvements to the plants and jaggery-making process suggested by researchers.

Keywords: Jaggery, sugarcane juice, sweetener, clarifying agents, bagasse, mechanization

Citation: Ukey, P. D., Ingale, V. M., Yenge, G. B., Prathapan, K., Ghatge, J. S., Patil, S. B., & Khot, J. A. (2024). Innovations, difficulties, and constraints in the manufacturing of jaggery and jaggery manufacturing plants. *Journal of Postharvest Technology*, **12**(2): 14-21.

* *For correspondence*: P. D. Ukey (Email: pravin.ukey1433@gmail.com), Dr. V. M. Ingale (Email: vingale03@gmail.com) **ISSN: 2348-4330**

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is a cash crop that is widely grown for commercial purposes all over the world (Selvi et al., 2021; Venkatesan et al., 2022). Apart from making sugar, sugarcane is also used to manufacture jaggery (Barad et al., 2021; Kumar et al., 2022; Said and Pradhan, 2013; Singh et al., 2021). In India, sugarcane is cultivated across an area of over 5.15 million hectares and is the primary source of sugar (2018-19) (Quadri et al., 2022).

The second-biggest agro-based sector in India is the sugar industry, which supports the socioeconomic advancement of the rural community (Chougule et al., 2021). In addition to supporting 50 million farmers and their families, it directly employs nearly 0.5 million trained and semi-skilled people. India presently produces 6.6 million metric tonnes of jaggery and 27.7 million metric tonnes of sugar (Bashir and Yousuf, 2022; Jagannadha Rao et al., 2007). Approximately 90 percent of the sweeteners produced worldwide are obtained from sugarcane. Jaggery is produced using approximately 70% of the sugarcane crop that is grown worldwide (Pawar et al., 2017). Maharashtra ranks second in terms of sugarcane acreage (11.63 lakh hectares), next to Uttar Pradesh, and first in terms of sugar production (107.14 LMT) and sugar recovery (10%). However, Maharashtra’s production (79.50 tonnes/ha) is low; in 2018–19, the state ranked sixth in the world for productivity (sugarcane.icar.gov.in) (Chougule et al., 2021).

India produces 300 million tonnes of sugarcane a year, of which 53% is turned into granulated sugar, 36% into jaggery and khandsari, 3% into cane juice for chewing, and 8% into seed cane (Hirpara et al., 2020; Rajendran, 2020; Pawar et al., 2017). Out of the total jaggery production in the world, 70% of the world’s jaggery production is produced in India (Agalave, 2015; Kumar et al., 2021). It has been reported that there are about one million jaggery manufacturing units working in India that come under the micro, small, and medium-sized enterprise (MSME) sector ministry (Baboo et al., 1994).

A wide range of regional names is used to refer to jaggery, including Gur (Jaggery) in India, Desi in Pakistan, Panela in Mexico and South America, Jaggery in Burma and other African countries, Hakuru in Sri Lanka, and NaamTaanoi in Thailand (Thakur, 1999; Madhu et al., 2018; Pawar et al., 2017; Verma et al., 2019; Verma et al., 2019; Jaffe, 2015). Growing jaggery is a common practice in regions where sugarcane is grown. Jaggery is a natural sweetener and golden brown, unprocessed, non-centrifugal sugar generated from boiling sugarcane juice when it attains a specific striking point temperature (Kumar and Kumar, 2022) and allowing it to crystallize in molds. In India, jaggery is consumed in three different forms: solid (lumped), liquid, and granular or powder. The powdered jaggery is also widely manufactured throughout the world, primarily in northern India. Due to the greater effort required in manufacturing, only a small number of producers are involved in this industry, in spite of powder jaggery’s higher market value both domestically and internationally. In general terms, it’s easier to mold, pack, and transport solid jaggery than powder. The popularity of powdered jaggery is steadily increasing due to its simplicity of use in handling, both for traders and consumers, whereas powdered jaggery dissolves quickly because of its small particle size and vast surface area. On the other hand, solid jaggery lumps need more work to handle and are challenging to cut into little pieces (Verma et al., 2019).

For the majority of people in Maharashtra and West Bengal, liquid jaggery is an essential component of their diet, and its market share is increasing a long with its importance in the marketplace. Liquid jaggery is widely used in Tamil Nadu, Gujarat, Kerala, Andhra Pradesh, West Bengal, and Maharashtra as a sweetening ingredient in food as well as beverages (Anonymous, 2022).

Jaggery is well renowned for its ability to generate heat and provide the body instant energy. Therefore, it is tradition in some parts of India to greet guests with a glass of water and jaggery. Among these applications, jaggery is used in the making of cattle feed, distilleries, medicine factories, ayurvedic medicines, ayurvedicsura, and ayurvedic nutritional supplements. Currently, jaggery is becoming more and more popular in sweets. In addition, workers in cement companies and coal mines are given jaggery to help avoid dust allergies. Moreover, when severe emergencies strike, the district authority purchases jaggery and distributes it to people affected as a health benefit (Natha et al., 2015). Since the method of manufacturing jaggery is indigenous, there are prospects for improvement in all of the various activities involved in its manufacturing, such as sugarcane harvesting and crushing, clarification, pre-heating, juice concentration, storage, and preservation. The process of manufacturing jaggery is indigenous, thus there are prospects for improvement in all of the various activities involved in its manufacturing, such as sugarcane harvesting and crushing, clarification, pre-heating, juice concentration, storage, and preservation. The traditional jaggery processing plants spend a large quantity of thermal energy into the atmosphere and are not fuel-self-sustaining due to their high bagasse consumption and low thermal efficiency. The inferior crushing efficiency of the sugarcane crusher, endless open space required for drying bagasse, labor-intensive processes, usage of various chemical and natural clarifying agents to produce high-quality jaggery, shortened storage life, high fuel consumption, and poor thermal efficiency are significant problems and difficulties that manufacturers face today. This paper includes a study of the different concerns and problems that manufacturers experience, as well as improvements to the plants and jaggery-making process that have been tested by researchers. This study will help new investigators understand the plants, the basic method for making jaggery, and the various issues and difficulties that the traditional industry suffers from.

PROCEDURES UTILIZED IN THE MANUFACTURING OF JAGGERY

The conventional method's unit operations for processing jaggery comprise juice extraction, juice clarification, boiling to concentrate juice, cooling concentrated juice, drying, powdering, packing, and storing (Sharon et al., 2013).

Figure 1 shows a schematic representation of the essential components of a conventional jaggery-producing plant. The entire process of jaggery manufacturing involves different kinds of steps, including sugarcane harvesting, shaping the finished product into various sizes and forms based on its intended use. The process of jaggery manufacturing starts from the harvesting of sugarcane and ends with the sending of the finished product for storage or marketing (Sharon et al., 2013). The flow diagram for the conventional jaggery manufacturing plant is represented in Fig. 2.

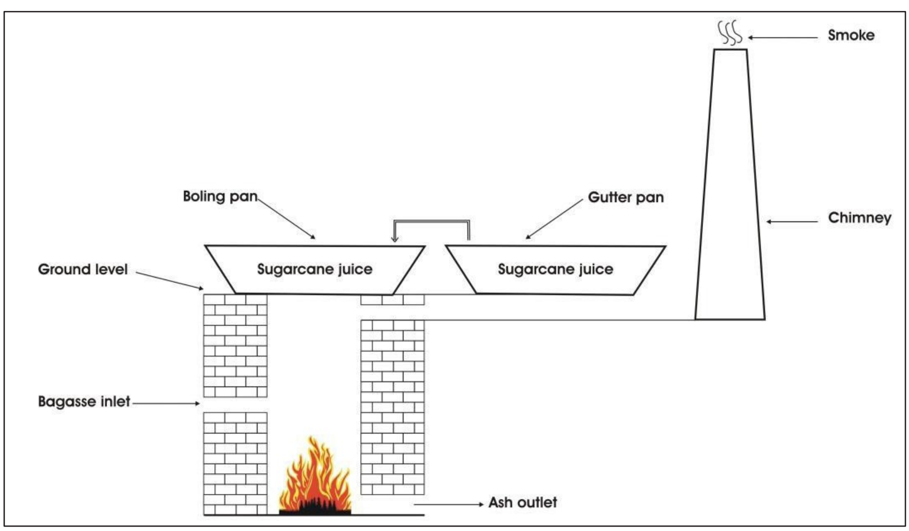

Fig. 1: View of conventional two-pan jaggery-making setup

Harvesting of sugarcane

Harvesting and weighing sugarcane is the initial stage in the production of jaggery. A crucial process for producing sugarcane juice is sugarcane harvesting. Timely harvesting of fully mature sugarcane is essential for producing sugarcane juice of superior quality and quantity. Sugarcane is traditionally harvested by hand, which is an extremely labor-intensive and difficult process. The main barrier to sugarcane harvesting is labor scarcity. Large-scale sugarcane harvesting is now also performed using harvesting equipment. Fortunately, currently available harvesting equipment is huge in size, making it unsuitable and unaffordable for farmers with relatively small holdings (Nagarjun et al., 2021).

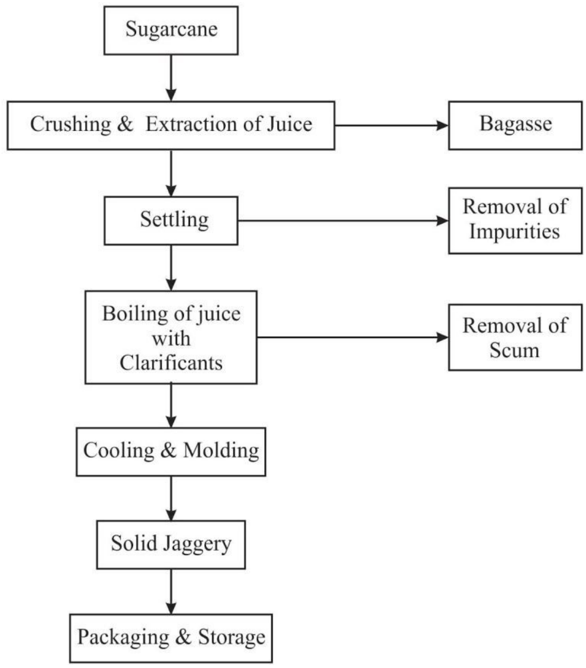

Fig. 2: Flow chart for manufacturing of solid jaggery

Juice extraction

The first step in the production of jaggery is the extraction of sugarcane juice through crushing. Previously, bullocks were used to operate these crushers for the extraction of juice, which is now modified by power-operated crushers. In India, various types of roller crushers, both horizontal and vertical, are employed for this work. 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, respectively, which can be improved from 77 to 80% by either applying hot water while crushing or by replacing them with multiple crushers (Anonymous, 2022; Gangadkar et al., 2017; Said and Pradhan, 2013). Traditional level crushers have very low crushing efficiencies due to their small size.

Drying of wet bagasse

Normally, bagasse is dried in the open sun, resulting in a 40% reduction in its moisture content. Various studies have been conducted to investigate the drying of bagasse in open air, inside closed cabinets, and by utilizing the thermal waste energy from jaggery-producing factories (Kumar et al., 2016; Kumar et al., 2016).

Dry bagasse supplied to the furnace

In all conventional jaggery manufacturing plants, bagasse is manually supplied to the furnace. According to the instructions provided by the most experienced worker, the amount and intensity of bagasse used in each sweep. The manual and unorganized bagasse feeding to the furnace result in excessive bagasse consumption and heat losses through the chimney. Therefore, secondary fuel is required to operate the jaggery processing plant. In order to conserve bagasse, which is essential for making the plant self-sustainable in terms of fuel, many studies have been conducted to reduce its consumption. These studies have found that different constructional and operational changes can reduce the bagasse consumption in traditional jaggery-making plants by 68.83%, 47.14%, and 27.62% in single-pan, two-pan, and multi-pan plants, respectively

(Kumar and Kumar, 2018). The traditionally used jaggery manufacturing plants have high fuel consumption and low heat utilization. The lack of technological advancements and low performance standards make jaggery manufacturing unprofitable for producers (Kumar and Kumar, 2018).

Juice clarification

One of the most crucial processes in the manufacturing of jaggery is the clarification of the juice to remove chemical impurities. However, the insoluble pollutants are separated using technical processes like settling or filters through muslin cloth. The quality, acceptability, and storability of jaggery often depend on the juice's clarity during preparation. There are many clarifying agents (chemical or natural clarificants) used for optimum scum removal, better color retention, more jaggery recovery, and support for maintaining jaggery quality. The employment of chemical clarifying agents such as hydros (sodium hydrosulfite), lime, sodium carbonate, super phosphate, di-ammonium phosphate, and alum is utilized because they are easily accessible. Now there is a growing acceptance of using herbal clarificants instead of chemical ones. A variety of plant extracts including 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 compared to jaggery made with hydrous gum and deola, the quality of jaggery made with guar gum powder was superior, it was becoming more and more popular, and it was preserved for six months at 27°C (Said and Pradhan, 2013). The application of 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 to be 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 Pradhan, 2013).

Juice concentration

In the traditional method, a skilled, knowledgeable worker manufactured the jaggery. The second important stage in the jaggery-making process is the boiling of sugarcane juice at the striking point of temperature ranges between 118°C to 123°C (Kumbhar, 2016).

To improve the shelf life of jaggery, boiling is mostly used to concentrate liquid into solid, granular, or thick liquid. The most important factor in the formation of the liquid into various types of jaggery is temperature. Excessive heating may result in dark-colored products with a bitter taste. The various physical and chemical changes that occur during boiling are carefully observed by an expert or a trained person. Juice is consistently boiled for a specified period of time, usually more than 2 to 3 hours, until the concentrated syrup reaches the striking point of 118°C. Traditionally, the striking point, or endpoint, is determined physically by simply adding a small quantity of boiling syrup to a container of cool water that has been molded with fingers. The striking point temperature for solid jaggery production is 118°C (Said and Pradhan, 2013).

To prevent excessive foaming while boiling, a small quantity of groundnut or mustard seed oil is sprayed, which facilitates the flow of hot syrup when transferring it between containers. The furnace's thermal efficiency is just 14.75% since the juice is heated at high temperatures for a prolonged period of time. 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 (Singh et al., 2009). In addition to using dried bagasse as fuel, burning wood, agricultural waste, and tires are also used, even used or old tires.

Cooling, molding and packaging

After the hot mass reaches the striking point, the pan is removed from the fire and placed in the tray to cool for a duration of 10 to 15 minutes. During that time, the heated lump is constantly smashed with a flat wooden beater to allow fresh air to continuously cool the hot mass (Anonymous, 2022). After that, the concentrate is put into the suitable shape mould 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 Pradhan, 2013). The moisture percentage of solid jaggery reduces to 10–12% (d.b.) after solidification. Following that, the finished good is packaged and stored. Throughout the world, a variety of ancient packaging methods are still in use, such as jute bags, clay pots, aluminium foil, plastic canisters, blankets made of wheat straw, and clothes packed with polyethylene sheets (Venkatesh et al., 2023).

JAGGERY MANUFACTURING PLANTS

In India, jaggery manufacturing units are small in size and operated by rural people at their own level without any technological advancements. Jaggery manufacturing units are made by local artisans and placed in decentralized sectors of India (Singh et al., 2013). Different types of traditional single, two, three-pan, and multi-pan jaggery manufacturing units are used according to the capacity of jaggery production. Normally, bagasse is used as fuel in pit-type furnaces.

In a single-pan plant, a single pan that is placed directly over the furnace is used for all heating, clarifying, and final concentration processes. Separate pans were utilized to heat and clarify the juice before its final concentration in two and multi-pan jaggery manufacturing units. These pans are placed to allow hot flue gases to pass through them after a boiling pan where the sugarcane juice is heated using the thermal energy of waste flue gases. The traditional jaggery manufacturing plants have low thermal efficiency and high bagasse consumption. Several investigations have been carried out to evaluate and improve the thermal efficiency of jaggery-producing plants.

The conventional single-pan plant‘s thermal efficiency was found to be approximately 15%, which is extremely low, leading to high bagasse consumption of 3.85 kg/kg of made jaggery (Rao et al., 2003). The constructional changes and the use of gutter pans to collect hot flue gases and use their thermal energy to heat sugarcane juice have increased the thermal efficiency of jaggery-making plants by up to 29% and decreased the consumption of bagasse, which has decreased the plant’s operating costs by 34.82% (Singh et al., 2009).

Investigation indicates that using multiple pans is an excellent way to increase the heat-use efficiency of plants that are frequently utilized to make jaggery (Shankar et al., 2009). Additionally, it was discovered that the controlled bagasse supplying into the furnace of the multi-pan jaggery manufacturing plant could lower the bagasse consumption of the generated jaggery from 2.39 kg/kg to 1.73 kg/kg (Sardeshpande et al., 2010).

CONCLUSION

From the review of research work conducted on the manufacturing of jaggery and jaggery making plants, it is concluded that different types and capacities of plants are being used by the farmers. The majority of these plants are situated in decentralized sectors of India and operated by poor rural people at their own level with limited investments. The researchers investigated the several processes involved in the production of jaggery, and they have proposed several changes to improve the productivity of these plants. However, additional research in this area is still required. Although the crushing efficiency of sugarcane crushers has increased by approximately 60% with the implementation of multi-roller crushers, there is still some juice in the bagasse that could be further extracted. The quality and shelf life of jaggery are significantly affected by the use of chemical and herbal clarificants. The researchers observed that the thermal efficiency of traditional jaggery-making plants was very low. They report that this has improved with the help of construction modifications in the plants, the use of multiple pans, and various heat recovery methods. However, a significant amount of thermal energy has still been wasted into the atmosphere. The amount of bagasse that these plants consume varies from 1.73 kg/kg to 3.85 kg/kg of produced jaggery, which appears to be significantly more than the amount that is readily available. Some other agricultural wastes are utilized as supplemental fuel to keep these plants operating well because bagasse is less available than is needed to run the plants. This paper will serve as an invaluable resource for researchers seeking to enhance the efficiency of currently operating jaggery manufacturing plants and to improve the process utilized in the manufacturing of jaggery. Additionally, it will assist new investigators in distinguishing between different kinds of jaggery manufacturing units and in understanding its numerous indicators of performance.

REFERENCES

Agalave, G. B. (2015). Performance improvement of single pan traditional jaggery making furnace by using fins and baffles. *International Journal of Advance Research in Science and Engineering, 4*(4), 85-89.

Anonymous. (2022). *Handbook of processing of jaggery*. Retrieved from https://5.imimg.com/data5/SELLER/Doc/2022/12/SB/DK/NP/145967076/natural-jaggery-powder.pdf

Baboo, B., & Anwar, S. I. (1994). Recent developments in jaggery (Gur) research. *Indian Institute of Sugarcane Research, Technical Bulletin No.IISR/JKS/94/9*, IISR, Lucknow (UP), India.

Barad, T. H., Chandegara, V. K., Rathod, P. J., & Mori, M. R. (2021). Quality evaluation of a jaggery prepared from developed three pan jaggery making furnace. International Journal of Chemical Studies, 9(1), 907-913.

Bashir, N., & Yousuf, O. (2022). Jaggery as a Potential Source of Nutraceutical in Food Products. *Emerging Trend in Nutraceutical, 1*(3), 50-55. doi: http://dx.doi.org/10.18782/2583-4606.118

Chougule, S. B., Shike, V. S., Bhanage, S. B., & Giri, P. R. (2021). Constraints encountered by jaggery producing sugarcane growers regarding jaggery marketing. *The Pharma Innovation Journal, SP-10*(9), 795-797.

Esther Magdalene Sharon, M., Kavitha Abirami, C. V., & Alagusundaram, K. (2013). Energy Losses in Traditional Jaggery Processing. *Indian Food Industry Mag, 32*(3), 22-25.

Gangadkar, P. N. R., Gowda, M. C., & Prasad, N. B. L. (2017). A Research on Traditionally Available Sugarcane Crushers. *International Journal of Engineering and Manufacturing Science, 7*, 77-85.

Hirpara, P., Thakare, N., Kele, V. D., & Patel, D. (2020). Jaggery: A natural sweetener. *Journal of Pharmacognosy and Phytochemistry, 9*(5), 3145-3148.

Jaffe, W. R. (2015). Nutritional and functional components of non-centrifugal cane sugar: A compilation of the data from the analytical literature. *Journal of Food Composition and Analysis, 43*, 194–202.

Jagannadha Rao, P. V. K., Das, M., & Das, S. K. (2007). Jaggery – A Traditional Indian Sweetener. *Indian Journal of Traditional Knowledge, 6*(1), 95-102.

Kumar, R., & Kumar, M. (2021). Issues, problems and amelioration in jaggery making process and plants. *International Conference on Recent Intelligent Technologies in Science, Engineering, Humanities and Management*, 344-349.

Kumar, R., & Kumar, M. (2022). Technological upgradation in jaggery making plants. *Materials Today: Proceedings, 56*(5), 2478-2483. https://doi.org/10.1016/j.matpr.2021.08.240

Kumar, R., Kumar, M., & Naveen. (2016). An experimental study to evaluate the calorific value of bagasse after open sun drying. *International Journal of Science, Engineering and Technology Research (IJSETR), 5*, 2153-2156.

Kumar, R., Kumar, M., & Amit. (2016). An experimental study to evaluate the calorific value of bagasse after solar cabinet drying. *International Journal on Recent and Innovation Trends in Computing and Communication, 4*, 239-241.

Kumar, R., & Kumar, M. (2018). Upgradation of jaggery production and preservation technologies. *Renewable and Sustainable Energy Reviews, 96*, 167-180. doi: 10.1016/j.rser.2018.07.053

Kumbhar, Y. S. (2016). Study on gur (jaggery) industry in *Kolhapur. International Research Journal of Engineering and Technology, 3*(2), 590-594.

Madhu, B., Patel, S., Jagannadha Rao, P. V. K., & Sreedevi, P. (2018). Use of edible coatings to increase the shelf life of jaggery: A review. *International Journal of Current Microbiology and Applied Sciences, 7*(6), 2466-2479.

Nagarjun, M.A., Mahendra, B.N.C., Manjunath, M. , & Ullegaddi. (2021). Design and development of a mini sugarcane harvester. *Recent Advances in Mechanical Engineering*, 427-439. https://doi.org/10.1007/978-981-15-7711-6_44

Natha, A., Dutt, D., Kumar, P., & Singh, J. P. (2015). Review on recent advances in value addition of jaggery based products. *Journal of Food Processing and Technology, 6*(4), 1000440. https://doi.org/10.4172/2157-7110.1000440

Patil, J. P., Shinde, U. S., Nevkar, G. S., & Singh, J. (2005). Clarification Efficiency of Synthetic and Herbal Clarificants in Quality Jaggery Production. *Sugar Technology, 7*(2&3), 77-81. https://doi.org/10.1007/BF02942535

Pawar, Dilip., Unde, Prakash., & Kanawade, Vivek. (2017). Studies on Preparation of jaggery granules with nucleation technique. *International Journal of Agricultural Science and Research, 7*(4), 609-616.

Pawar, D. A., Jadhav, M. S., & Nimbalkar, C. A. (2017). Techniques and advances in jaggery processing: A review. *Research Journal of Chemical and Environmental Sciences, 5*(2), 14-20.

Quadri, Md. H., Madhavi, V., Navya, A., Jayaprakash, R., Rajender, G., & Swamy, R. (2022). Development of granular jaggery and jaggery based chocolates. *The Pharma Innovation Journal, SP*-11(5), 1951-1956.

Rajendran, I., Palaniswami, C., & Vennila, A. (2020). Improved method of liquid jaggery preparation. *Journal of Sugarcane Research*, 10, 107-112.

Rao, K.S.S., Sathrajan, A., & Ramjani, S.A. (2003). Efficiency of traditional jaggery making furnace. *Madras Agriculture Journal, 90*(1–3), 184–5.

Said, P.P., & Pradhan, R. C. (2013). Preservation and value addition of jaggery. *International Journal of Agricultural Engineering, 6*(2), 569–574.

Sardeshpande, V.R., Shendage, D. J., & Pillai, I.R. (2010). Thermal performance evaluation of a four-pan jaggery processing furnace for improvement in energy utilization. *Energy, 35*(12), 4740–7.

Selvi, V. M., Mathialagan, M., & Mohan, S. (2021). The art and science of jaggery making: A Review, 1-9. *Agric. Rev*. https://doi.org/10.18805/AG.R-2138

Shankar, M., Ravindra, U., & Kalpana, B. (2009). Evaluation of multipan furnace over traditional pan furnaces used for jaggery production in Mandya district of Karnataka. *Environmental Ecology, 27*(1A), 316–9.

Singh, J., Solomon, S., & Kumar, D. (2013). Manufacturing jaggery, a product of sugarcane, as health food. *Journal of Agrotechnology, S11*, 1–3.

Singh, K., Tomar, A., Kumar, V., Kumar, A., & Kumar, M. (2021). Studies on traditional Indian sweetener jaggery processing with selected organic clarifying agents. *The Pharma Innovation Journal, SP*-10(12), 293-296.

Singh, R. D., Baboo, B., Singh, A. K., & Anwar, S. I. (2009). Performance evaluation of two pan furnace for jaggery making. *Journal of Institution Engineers (India), 90*(18), 27-30.

Thakur, A. K. (1999). Potential of Jaggery manufacturing in Punjab state. *Proceedings of the National Seminar on status, problems and prospectus of jaggery and khandasari industry in India*, Indian Institute of Sugarcane Research, Lucknow, India.

Venkatesan, M. S., Lakshmanan, C., & Raman, N. (2022). Jaggery Making Process and Preservation: A Review, 1-11.

Venkatesh, T., NanduLal, A. M., Silpa, V., Dharmalingam, B., Padma Ishwarya, S., Reshma, MV., Sajeev, MS., Pandiselvam, R., & Kothakota, A. (2023). Current production strategies and sustainable approaches towards the resurgence of noncentrifugal cane sugar production – a review. *Sustainable Food Technology, Royal Society of Chemistry, 1*, 200-214.

Verma, P., Shah, N. G., & Mahajania, S. M. (2019). Effects of acid treatment in jaggery making. *Food Chemistry, 299*, 125094.

Verma, P., Shah, N. G., & Mahajania, S. M. (2019). Why jaggery powder is more stable than solid jaggery blocks. *LWT-Food Science and Technology, 110*, 299-306. https://doi.org/10.1016/J.LWT.2019.04.093