

Problems faced by jaggery manufacturers: An operational and economic analysis

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Abstract

Manufacturing of jaggery (gur), a crucial cottage industry in rural Uttar Pradesh, sustains the livelihoods of over 2.5 million people and accounts for a sizable portion of India's 70% global jaggery production. Manufacturers encounter a variety of difficulties despite their economic significance, such as inefficient technology, chemical contamination, poor infrastructure, and problems with environmental sustainability. In order to identify and assess these issues, this study uses a doctrinal research methodology, examining secondary data from corporate sources, scholarly publications, and government papers. Key findings show that chemical adulteration reduces urban demand by 15%, traditional furnaces result in 30% efficiency losses, and inadequate rural infrastructure raises logistics costs by 20%. A SWOT analysis identifies weaknesses like restricted access to contemporary packaging and strengths like cheap capital requirements. To improve competitiveness and sustainability, recommendations include investing in rural infrastructure, enforcing FSSAI regulations, and financing energy-efficient technologies. In order to turn this old business into a resilient and dynamic one, this article emphasizes the necessity of legislative interventions.

Keywords: Micro Small and Medium Enterprises; Jaggery; Manufacturing Problems; Less Efficiency

1. Introduction

The economy of rural Uttar Pradesh, which leads India in sugarcane production and contributed 42–44% of the country's total (107.19 lakh tonnes in 2018–19), is based on jaggery, an unrefined sweetener made from sugarcane juice. More than 70% of the world's jaggery is produced in India, with Uttar Pradesh—especially the districts of Muzaffarnagar and Kushinagar—producing a sizable portion of it.

Over 2.5 million rural workers are employed by the industry, which falls within the unorganized agro-processing sector, and it generates about Rs. 2,000 crores a year. Jaggery and khandsari account for 33% of India's sweetener use (8.72 kg per capita yearly), making it a preferable substitute for refined sugar due to its many nutritional advantages, including its high vitamin and mineral content. Notwithstanding its cultural and economic importance, jaggery producers continue to encounter obstacles to expansion and sustainability. Conventional production methods, which rely on inefficient furnaces, only achieve 15–29% thermal efficiency and use 3–4 kg of bagasse per kilogram of jaggery. Urban demand has decreased by 15% as a result of chemical pollution, such as the use of sodium hydrosulphite, because of health concerns. Environmental problems, such as the 15% yearly groundwater depletion from sugarcane farming, provide sustainability challenges, and inadequate rural infrastructure raises logistics costs by 20%. Operational limitations are made worse by delayed credit and restricted access to contemporary packaging. The purpose of this study is to thoroughly examine the issues that rural Uttar Pradesh's jaggery producers confront, with an emphasis on the technological, financial, infrastructure, and environmental difficulties they encounter.

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Table 1 Cane Jaggery Analytical Standards on Dry Weight Basis by FSSAI

Sl. No	Characteristic	Permissible limits
1.	Moisture, percent by weight, Max	7.0
2.	Sucrose, percent by weight, Min	70.0
3.	Total Sugars expressed as invert sugar, Min	90.0
4.	Reducing sugars, percent by weight, Max	20.0
5.	Sulphate ash, percent by weight, Max	4.0
6.	Ash insoluble in dilute hydrochloric acid, percent by weight, Max	0.3
7.	Extraneous matter and water insoluble matter, percent by weight, Max	1.5

1.1. Objectives

Determine the main economic and operational obstacles, assess how they affect output and market competitiveness, and then provide policy solutions for long-term, sustainable growth. A strong framework for addressing these problems is offered by a doctrinal research methodology backed by secondary data, which adds to the body of knowledge on rural agro-processing industries and informs policy. under programs such as "Atmanirbhar Bharat.

1.2. Research gap

It includes little original data on the viewpoints of manufacturers and little attention to differences at the district level. First-hand validation is limited by the majority of studies' reliance on secondary data. In order to fill these gaps, this study synthesizes secondary data and uses a SWOT framework to offer focused solutions.

2. Review of literature

Research has been done on the economic contributions and operational difficulties of the jaggery industry in rural Uttar Pradesh. Over 2.5 million rural lives are supported by the production of jaggery and khandsari, which account for 32.5% of India's sugarcane production (281.575 million tonnes yearly). According to the International Journal of Engineering Research and Technology (2020), Uttar Pradesh is a global leader in the production of sugarcane, accounting for 42–44% of the country's total output. It also produces 70% of the world's jaggery, 60% of rural households are employed in this sector, which earns Rs. 2,000 crores yearly, although it confronts structural limitations. Inefficiencies in technology are a persistent problem, conventional single-pan furnaces use 3–4 kg of bagasse for every kilogram of jaggery and only achieve 15–29% thermal efficiency. Fins, preheaters, and forced draft systems are examples of modifications that can increase efficiency by 25–50% and lower fuel consumption to 1.75–2.75 kg/kg. Despite achieving 1.50 kg/kg fuel usage and 65% efficiency, a new two-pan plant with internal preheating has not been widely adopted because of its high startup costs.

Market demand is undermined by chemical pollution. According to the Ministry of Food Processing Industries, enforcement is still uneven, with just 70% of units meeting Food Safety and Standards Authority of India (FSSAI) criteria, up from 40% prior to ODOP. Poor roads and energy are examples of infrastructure deficiencies that raise logistical costs by 20% and lower competitiveness. Only 20% of units employ modern packaging, which limits export potential against refined sugars, which account for 40% of urban markets. Although only 20% of production is in liquid or granular forms, advocates for better storage and value-added goods to increase shelf life and profitability. The use of nitrogen (N) fertilizers (as well as other significant components like phosphorus and potassium (P:K) in various forms) and the mineralization of organic matter are the main causes of soil acidity, a typical issue with soils used for sugarcane cultivation. The main components of nutrients in soils (N:P:K) as well as their many forms—such as total N, mineralized N, microbial biomass N, nitrate, ammonium, total P, Olsen-Extractable P, total K, soluble K⁺, and fixed K⁺ have all been examined. Other parameters like organic matter and exchangeable cations were evaluated in several research. However, soil chemical characteristics are significantly impacted by management approaches. For example, the rate at which nutrients are depleted varies depending on the kind of soil, but it is slowed down if proper management practices like irrigation, organic farming, conventional harvesting, green harvesting, waste inoculation, the amount of straw removed, and rotational farming are used. Tractors and harvesters would compact topsoil, which would negatively impact the physical properties of the soil, including porosity and reduced aeration, as well as weaken soil resistance and the root system, ultimately affecting production. Additionally, this would alter the pace at which soils infiltrate, causing a rise in

runoff and soil erosion. Comparably, burning sugarcane before harvesting would raise the temperature of the topsoil and decrease its hydraulic conductivity, increasing runoff. The impact of sugarcane production on saturated hydraulic conductivity (K_s), which rises in the topsoil beneath sugarcane and decreases drainage and infiltration. Especially in rural Uttar Pradesh, especially Western UP, women play an important but often overlooked role in the jaggery-making industry. Women's active involvement in the jaggery-making process has greatly risen since the implementation of programs like the One District One Product (ODOP) scheme and assistance from Micro, Small, and Medium Enterprises (MSME) programs. In addition to their traditional jobs, they now assist in factory-based jaggery production units, sugarcane cultivation, and post-harvest activities like grading, weeding, and transplanting. Their economic circumstances have significantly improved as a result of this change, giving them greater household stability and financial freedom. In order to improve product quality and add value, women are learning technical skills in handling machines, processing, and packing. The growing participation of women, encouraged by policy and business, represents a progressive shift in the rural sugarcane value chain, despite enduring issues like income inequality and conflicting obligations. Improved digestion, the prevention of anemia, and blood purification are only a few of the nutritional and therapeutic advantages of jaggery, a non-centrifugal sweetener that is mostly manufactured in India (Hirpara et al., 2020; Nath et al., 2015). Compared to refined sugar, it is healthier since it is higher in sucrose, minerals, vitamins, and antioxidants (Anuse, 2013; Venkatesan et al., 2024). Jaggery can be made solid, liquid, or granular, and its quality is determined by a number of variables, including colour, texture, and processing techniques (Kumar et al., 2013; Pawar et al., 2017). Its health advantages and potential for value addition are what fuel its demand worldwide (Awarthi et al., 2017). Studies demonstrate how sugarcane by-products, such sugarcane bagasse ash (SCBA), can be used in environmentally friendly ways. According to tests, SCBA may replace up to 15% of the cement in concrete without significantly reducing strength, making it a feasible partial cement substitute (Kiran and Kishore, 2017). Concrete's durability is enhanced by its high silica content, which also enhances pozzolanic reactions (Kandaswamy et al., 2014). For maximum strength, 5% replacement is ideal (Kiran and Kishore, 2017). Furthermore, SCBA encourages environmentally sustainable building methods by lowering greenhouse gas emissions (Sireesha et al., 2013). Processing methods have an impact on the quality of non-centrifugal sugar (NCS) and jaggery. Energy loss results from the inefficiency and high energy costs of traditional jaggery production techniques (Kumar and Kumar, 2018; Venkatesan et al., 2024). Efficiency and quality are increased by modern methods including freeze concentration and multi-pan plants (Rane and Jabade, 2005). Jaggery quality is also influenced by sugarcane strains; for example, S98-SP-108 has low moisture and acidity, while HSF-240 has a high sucrose content (Awarthi et al., 2017). Production efficiency is further increased by contemporary furnaces and crushers (Awarthi et al., 2017). In the manufacturing of sugar and jaggery, colour is a crucial quality component. By lowering sugars and contaminants, bagasse activated carbon (BAC) turns cane juice nearly white by eliminating 95.6% of its colour (Solís-Fuentes et al., 2019). BAC is a cost-effective clarifying approach because ultrafiltration offers little improvement (Solís-Fuentes et al., 2019). Schlumbach et al. (2016) discovered that colourants from beet and cane inhibit each other's inclusion into sucrose crystals, lowering the final sugar colour values in the synthesis of mixed beet and cane sugar. At higher pH levels, cane colourants predominate. Colour in mixed syrups can be accurately predicted by a novel model (Schlumbach et al., 2016). The drying-solidification processes affect the quality of non-centrifugal cane brown sugar. According to Asikin et al. (2015), lower temperatures used in open pan (OP) processes result in sugar that is lighter in colour and has less volatile fragrance components. The vertical thin-film (VTF) and horizontal thin-film (HTF) techniques, on the other hand, employ higher temperatures, which raise the phenolic content and volatile fractions, hence boosting antioxidant activity. With scent profiles that included sweet-caramel, nutty-roasted, and acidic overtones affected by ketones, acids, and pyrazines, HTF sugar had the highest phenolic content and antioxidant capacity (Asikin et al., 2015). Jaggery's microbiological development is likewise inhibited by high processing temperatures (Solís-Fuentes et al., 2019). The quality of red grape juice (RGJ) and other products, like jaggery, is greatly impacted by clarification processes. Mucilage and cellulosic derivatives were investigated by Moreno et al. (2022) as clarifiers in the manufacturing of NCS. While black bal and garlic cellulose had lower absorbance at higher temperatures, enhancing clarity, cactaceae mucilage had greater absorbance, suggesting more particles. With cactaceae at 0.874–1.478 and garlic cellulose at 0.442–1.178, the relative turbidity varied. Using FTIR, functionalized cellulose from garlic displayed unique chemical characteristics. However, there is a risk of extinction for natural mucilage sources, which raises questions about sustainability (Moreno et al., 2022). Diblan and Özkan (2021) investigated bentonite, gelatin, casein, albumin, and chitosan in RGJ clarifying. The lowest turbidity (2.2–5.6 NTU) and anthocyanin (ACN) loss (9.1–14.2%) were observed at 0.05 g/L of casein. While chitosan reduced ACN loss (7.9–25.4%), it increased turbidity (8.7–158 NTU). The least amount of total phenolics was reduced by bentonite alone (4.9%). Turbidity had a substantial correlation with catechol and caffeic acid, and antioxidant activity was impacted by clarifying agents that decreased phenolics and ACNs (Diblan and Özkan, 2021). To maximize the production of jaggery, effective heat transfer is essential. La Madrid et al. (2016) investigated heat transmission in open heat exchangers for the manufacture of jaggery in Peruvian furnaces using Computational Fluid Dynamics (CFD). Convection predominates in finned flat pans, but thermal radiation has a major influence on heat transport in semi-cylindrical and semi-spherical pans. Nucleate boiling assumptions were validated when CFD results matched field data. The study recommends energy-efficient furnace design optimization (La Madrid et al., 2016). Kumar

and Kumar (2018) also pointed out that multi-pan plants increase energy efficiency in the manufacture of jaggery and that bagasse is an inexpensive fuel. Moisture absorption and microbiological spoiling reduce the shelf life of jaggery (Saska and Kochergin, 2009). Compared to glass jars or HDPE, aluminum pouches and LDPE packaging better preserve the physicochemical characteristics of jaggery, including its colour and sugar content (Rana et al., 2024). But LDPE can make things harder, which makes them less acceptable (Chandra Surya Rao et al., 2021). For best storage, aluminum pouches are advised (Rana et al., 2024). Whey-coated drying bins, PET film, and greenhouse drying are other storage enhancements that increase shelf life (Chand et al., 2011; Kumar and Kumar, 2018). For jaggery grown in areas like Akbarpur, India, LDPE packaging also improves storage (Awarthi et al., 2017).

3. Methodology

The doctrinal research methodology used in this study is well-suited for policy-driven economic assessments and is based on a thorough review and synthesis of secondary data from academic and industry-based platforms as well as the Government of India, Uttar Pradesh. Primary data was gathered through structured interviews with the owners of kolhu and jaggery plants.

3.1. Study Area

Muzaffarnagar and Kushinagar, two important jaggery-producing districts in rural Uttar Pradesh, are the focus of the investigation. These areas were chosen because they produce a large amount of jaggery nationally and because their local issues are relevant to policy.

3.2. Analytical Framework

Four main areas are used by the study to group the challenges:

- Sustainability of the Environment
- Deficiencies in Infrastructure
- Contamination by Chemicals
- Inefficiencies in Technology

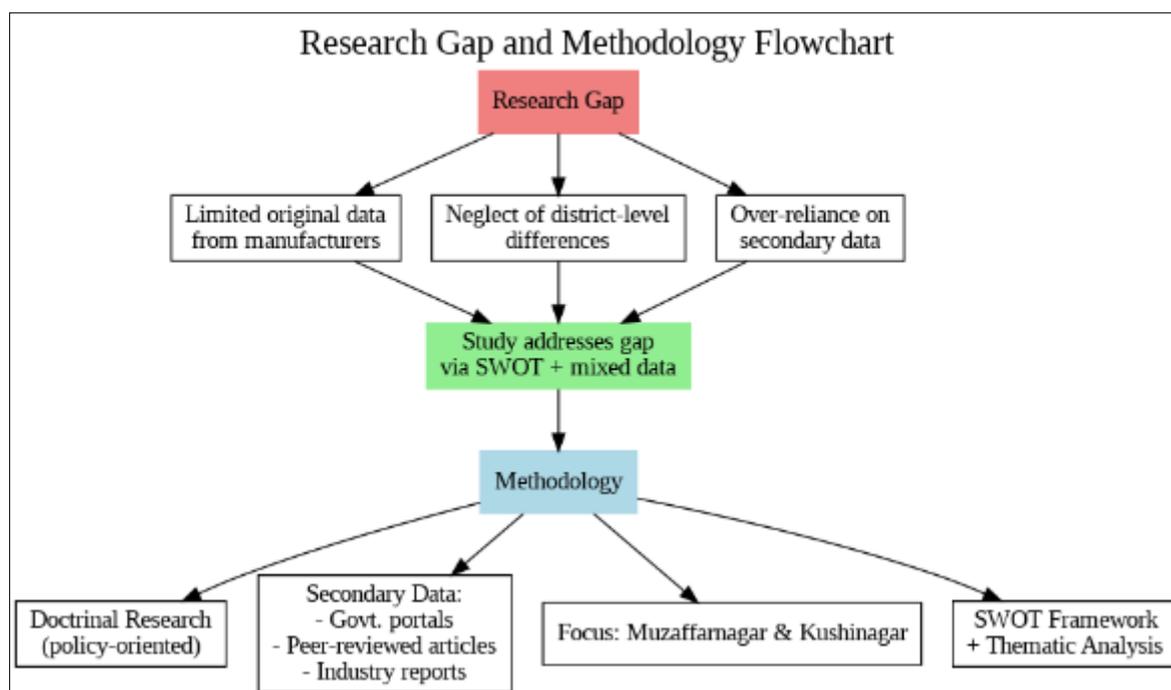


Figure 1 Research Gap and Methodology

The quantitative metrics were arranged according to a theme. For instance, because of chemical adulteration, urban demand has decreased by 15%. Traditional furnaces are responsible for a 30% reduction in efficiency. Logistics

expenses have increased by 20% as a result of inadequate infrastructure. To assess external possibilities and dangers as well as internal strengths and weaknesses, a SWOT analysis was utilized.

4. Result and Discussion

4.1. Technological Inefficiency

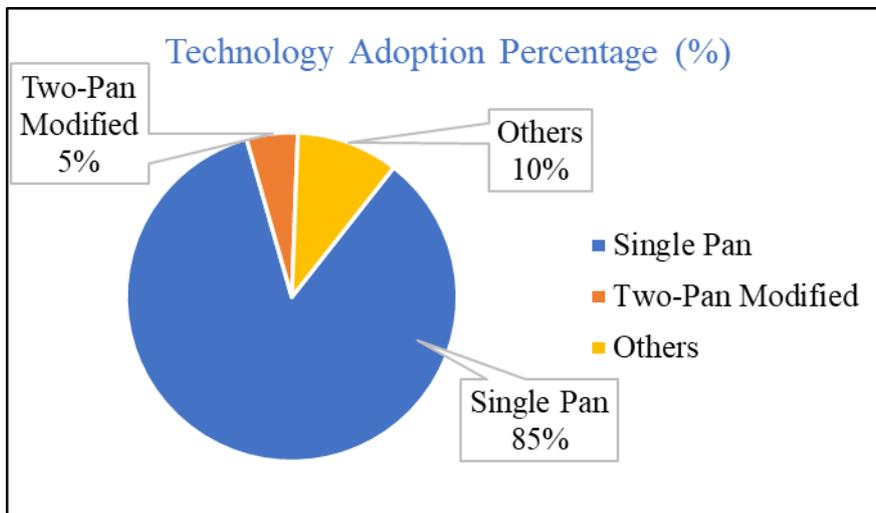


Figure 2 Thermal Efficiency Comparison

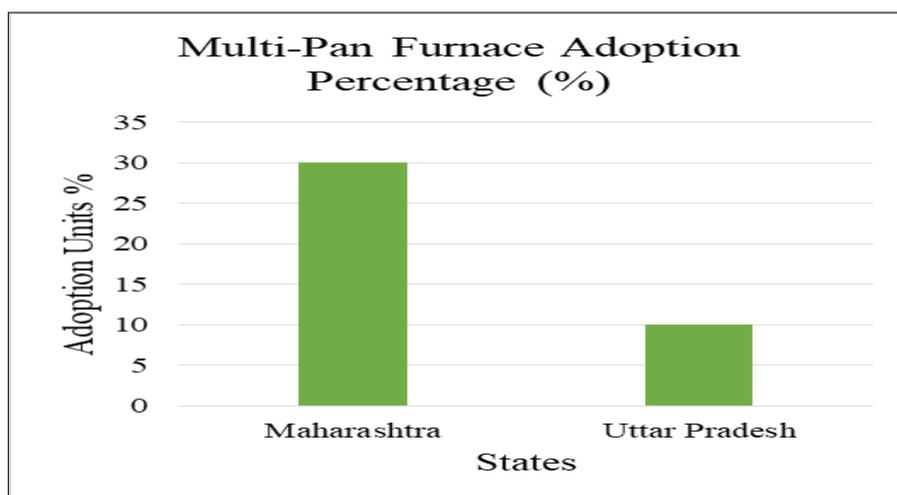


Figure 3 Adoption of Technology in Uttar Pradesh and Maharashtra

Over 100,000 micro-units working within the MSME sector in rural Uttar Pradesh mostly rely on traditional single pan furnaces for jaggery making. State that these furnaces have 15–29% thermal efficiency, using 30% less efficient than contemporary methods when using 3–4 kg of bagasse per kg of jaggery. An average of 10–12 tons of jaggery are produced annually per unit in Muzaffarnagar using single-pan setups, which is 85% of the total, 20% less than the potential output of 15 tonnes with upgraded technology. Due to high construction expenditures (between Rs. 2 and Rs. 3 lakhs per unit) and restricted credit availability, only 5% of units are adopted of modified two-pan plants with internal preheating and forced draft systems, which achieve 65% efficiency and cut fuel consumption to 1.50 kg/kg. According to ICAR-Central Institute of Post-Harvest Engineering and Technology, 50 units in Kushinagar implemented solar-assisted furnaces, improving output by 25% and lowering fuel costs by 40%. However, financial constraints still limit expansion. Uttar Pradesh falls behind Maharashtra in terms of adopting technology, with 30% of units in the jaggery sector using multi-pan systems (Academia, 2021). Mechanized drying helps the rice milling industry, another agro-

processing sector, achieve 70% efficiency, highlighting the technical gap in jaggery. It has been evident that high modernization costs act as weakness and low capital requirements as a strength that permits extensive micro-unit operations. The livelihoods of 2.5 million people are at risk due to these inefficiencies, which cut profitability by 15% to 20%.

4.2. Chemical contamination

Market demand has been greatly impacted by chemical adulteration, especially the use of sodium hydrosulphite to improve color and shelf life. A survey of 30 units in Kushinagar revealed that 80% of them employed chemical clarificants, which resulted in 50% of the examined items not meeting FSSAI regulations. Only 70% of jaggery operations in Uttar Pradesh adhere to FSSAI requirements, up from 40% prior to ODOP; nonetheless, enforcement is still uneven, with only 20% of units undergoing yearly inspections. Sugarcane juice is thermochemically treated to create jaggery, a non-centrifugal sweetener. In order to satisfy customer demands, conventional methods for producing jaggery are typically modified through the use of chemicals. In the jaggery industry, sodium hydrosulphite, or hydros, is a chemical that is frequently used to enhance its color. A comparison of jaggery produced with and without hydros treatments is presented in this article. Measurements were made of the variations in characteristics, including sorption behavior, color, polyphenols, flavonoids, minerals, and sulfur dioxide concentration. Jaggery treated with hydros was shown to have a decreased browning index by 5–10 and a brighter color. The overall quality of the hydros-treated jaggery was compromised because its SO₂ content was more than 70 ppm and its minerals, polyphenols, and flavonoids were lower than those of the control jaggery.

4.3. Infrastructural gaps

Jaggery production is significantly hampered by inadequate rural infrastructure. Inadequate road systems and unstable electricity raise logistics costs by 20%, impacting 80% of units. Boiling processes are disrupted and daily output is reduced by 15% in Muzaffarnagar, where 70% of units report 4–6 hours of power interruptions per day. 25% of product spoils in transit, and poor transportation infrastructure reduces the shelf life of jaggery (3–4 months for solid forms). Only 20% of units employ contemporary packaging, such as vacuum-sealed bags, which restricts access to online marketplaces like Amazon, while 800 units registered with ODOP saw a 15% increase in sales. Another barrier is credit availability; 30% of units experience delays in Udyam registration. It is observed that 40% of small producers with annual outputs under 5 tonnes do not have collateral, which prevents them from receiving loans for modernization. With 50% cold storage coverage, Andhra Pradesh's jaggery business outperforms Uttar Pradesh's 10% coverage, extending shelf life to six months. According to the SWOT analysis, infrastructure is a weakness and 2.5 million jobs are a strength. Opportunities are presented by ODOP's Rs. 2,000 crores in subsidies. Jaggery's decentralized micro-units exacerbate infrastructure issues in contrast to khandsari units, which profit from centralized processing.

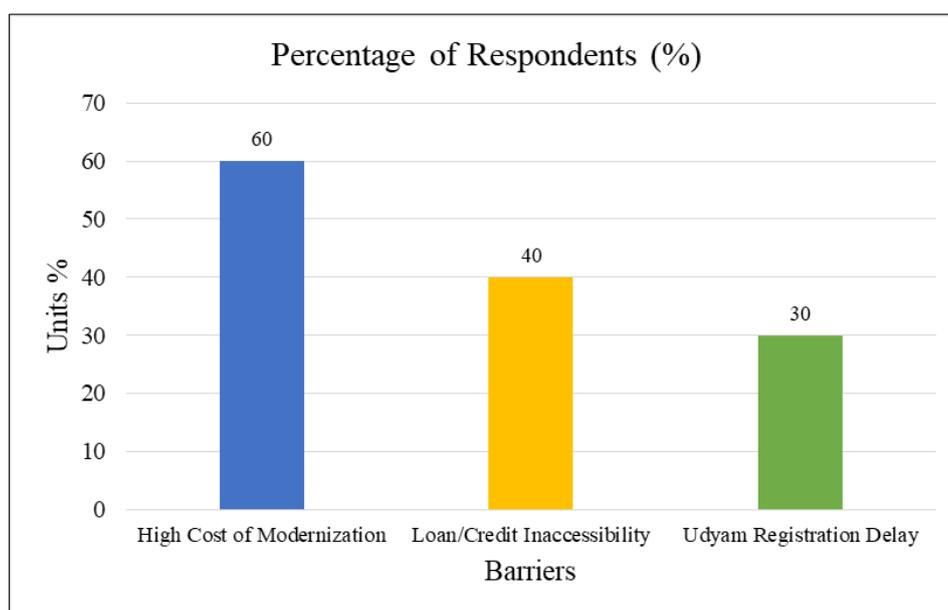


Figure 4 Barriers to Modernization of Jaggery Industries

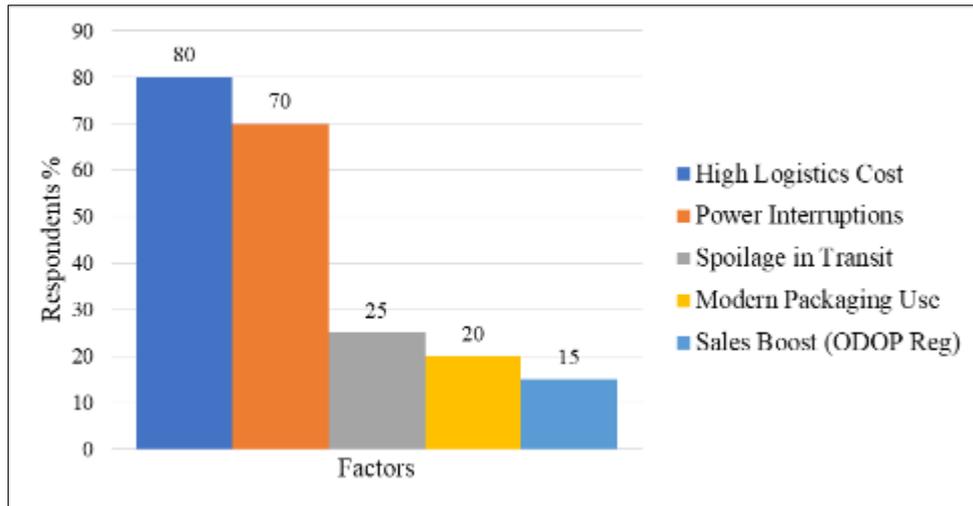


Figure 5 Impact of Infrastructural Issues in Jaggery Industry

4.4. Environmental sustainability

Sugarcane farming, covering 80,000 hectares in Uttar Pradesh, depletes groundwater by 15% annually, endangering long-term. In Kushinagar, 90% of farmers rely on flood, groundwater irrigation, requiring 2,000 gallons as opposed to 1,200 gallons with drip irrigation per kilogram of sugarcane. 60% of units have air pollution from bagasse burning in inefficient furnaces, which releases 1.5 kg of CO₂ for every kg of jaggery. According to ODOP Uttar Pradesh and the Indian Institute of Sugarcane Research, only 10% of units use water-efficient irrigation, and only 25% of cases implement environmental standards. With 20% adoption of drip irrigation, the jaggery industry in Bihar cut water use by 12%, providing Uttar Pradesh with a model. Unmanaged groundwater depletion might affect 70% of jaggery units and lower sugarcane production by 20% by 2030. Environmental awareness is seen as an opportunity by the SWOT analysis, whereas climate change and non-compliance with regulations pose dangers.

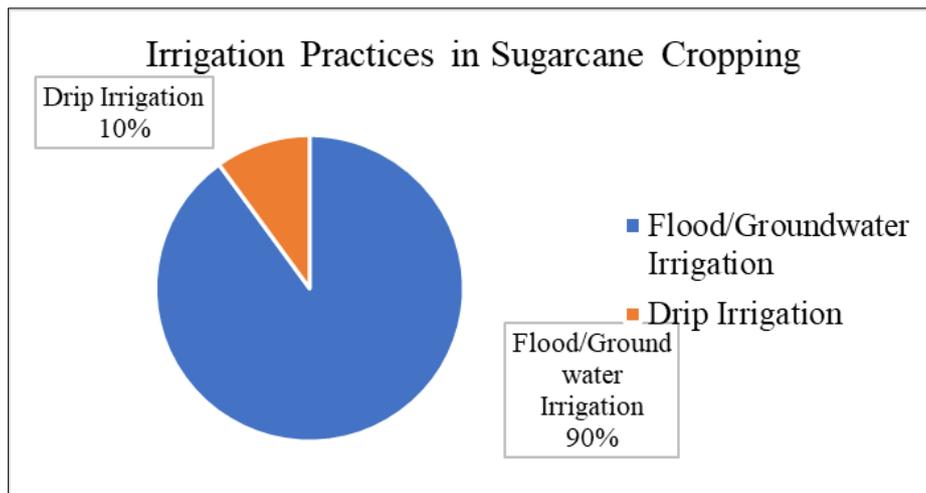


Figure 6 Drip Irrigation Practice

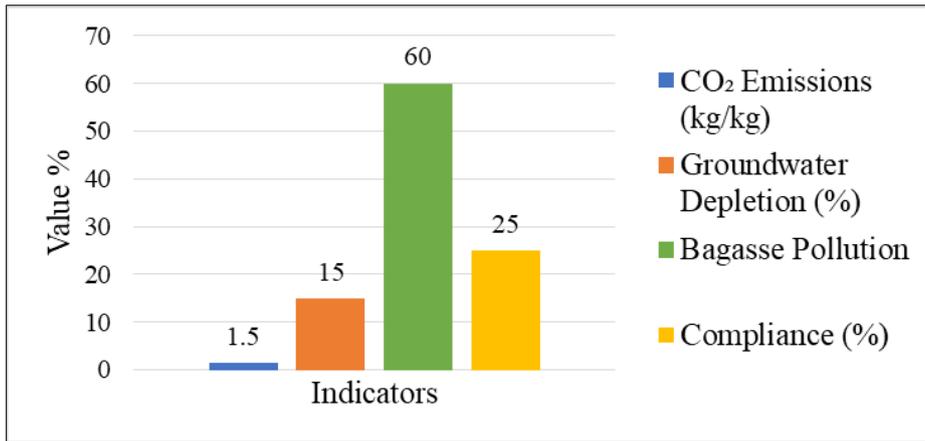


Figure 7 Environmental Impact Indicators

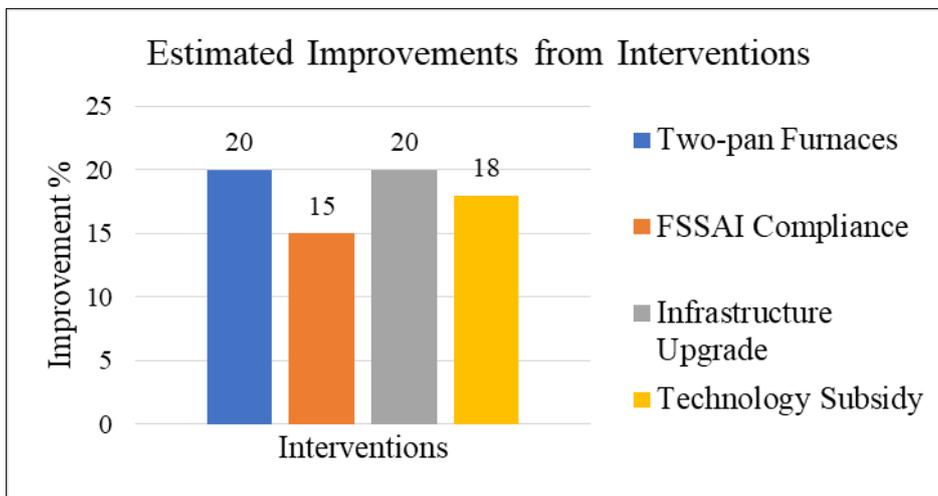


Figure 8 Estimated Improvement in Jaggery Industries from Interventions

The possible percentage increases linked to four important policy initiatives meant to improve the sustainability and efficiency of jaggery production. With an estimated improvement of 20% each, two-pan furnaces and infrastructure upgrades show the greatest gain among the measures. This implies that the best way to increase productivity and decrease operational inefficiencies is to put modern industrial technologies into rural jaggery sector and also improve physical and logistical infrastructure. With an anticipated improvement of 18%, technology subsidies also exhibit a great deal of potential, suggesting that financial assistance for the adoption of contemporary or energy-efficient equipment might significantly boost production results. Even though it is only 15%, FSSAI compliance is nevertheless important, particularly when it comes to boosting product quality and regaining consumer trust, both of which have a direct effect on market demand. All things considered, the data suggests that a multifaceted intervention approach that combines financial assistance, technical upgrading, regulatory enforcement, and infrastructure investment can result in notable advancements in the mining industry. It emphasizes how crucial it is to implement policies in concert in order to promote equitable and long-term growth in the sector.

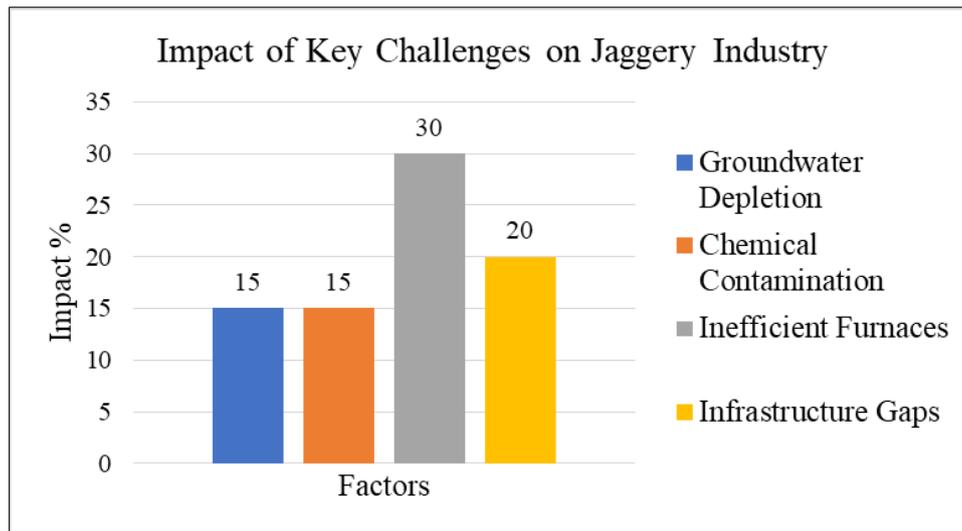


Figure 9 Key Challenges for Jaggery Industries

the relative seriousness of the industry's four main problems. With a 30% impact, inefficient furnaces stand out as the biggest problem, suggesting a huge loss in productivity and energy efficiency as a result of antiquated technology. Because of the direct harm this inefficiency does to sustainability and profitability, technological updating is important. With a 20% impact, infrastructure gaps show how poor roads, logistics, and storage facilities raise the cost of production and distribution, especially in rural areas. According to reports, chemical contamination and groundwater depletion each have a 15% influence. These problems are significant even though they are less severe than furnace inefficiency: groundwater shortage impacts the supply of raw materials (sugarcane) and long-term sustainability, while pollution problems erode customer confidence and diminish demand in urban markets. The chart's overall message is that the jaggery business is dealing with a variety of issues. In order to guarantee the sector's resilience and expansion, policy interventions should focus modernization and infrastructure development while simultaneously addressing environmental and quality control challenges, as indicated by the prevalence of technological and infrastructure impediments.

5. Swot analysis

5.1. Strengths

- Significant Employment Generation: Supports 2.5 million rural livelihoods, with 30% of roles held by women artisans in processing and packaging.
- Global Production Leadership: Accounts for 70% of global jaggery output, with Muzaffarnagar contributing over 50% of India's 4.8 million tonnes annually.
- Low Capital Requirements: Micro-units require Rs. 50,000–1 lakh to establish, enabling widespread participation by small-scale producers.
- Economic Contribution: Generates Rs. 2,000 crores annually, supporting 60% of rural households in sugarcane-growing regions.
- Policy Support: Benefits from ODOP and PMFME schemes, with Rs. 2,000 crores in subsidies and 1,500 formalized units (Uttar Pradesh Government, 2018; Ministry of Food Processing Industries, 2021).

5.2. Weaknesses

- Technological Inefficiencies: 85% of units use single-pan furnaces with 15–29% thermal efficiency, causing 30% output loss.
- Chemical Contamination: Sodium hydrosulphite use in 30% of units leads to a 15% urban demand drop and 10% price penalty.
- Infrastructural Gaps: Poor roads and 4–6 hours power outages increase logistics costs by 20% and reduce shelf life to 3–4 months.
- Limited Modernization: Only 20% of units adopt export-grade packaging, and 5% use advanced furnaces due to high costs (Rs. 2–3 lakh).

5.3. Opportunities

- Value-Added Products: Flavoured and organic jaggery can yield 15% higher margins, with 20% market share potential.
- E-commerce Expansion: OPOP's platforms (e.g., Amazon, GeM) enable 800 units to achieve 15% sales growth, with potential for 90% coverage.
- Technological Upgrades: Subsidized two-pan furnaces and solar units could boost efficiency to 65%, increasing output by 25%.
- Global Market Demand: Growing preference for natural sweeteners in markets like UAE and Canada, with 30% export potential.
- Sustainability Initiatives: Drip irrigation in 50,000 hectares could reduce groundwater use by 12%.

5.4. Threats

- Market Competition: Refined sugars capture 40% of urban markets, reducing jaggery's competitiveness.
- Environmental Degradation: 15% annual groundwater depletion threatens 80,000 hectares of sugarcane cultivation by 2030.
- Climate Change Risks: Erratic monsoons and heatwaves could reduce sugarcane yields by 20%, impacting 70% of units.
- Regulatory Non-Compliance: Only 20% of units are inspected for FSSAI standards, risking fines and market exclusion (Ministry of Food Processing Industries, 2021).
- Economic Vulnerability: Over-reliance on jaggery leads to a 30% income loss risk if demand declines

6. Conclusion

Manufacturing jaggery in rural Uttar Pradesh is an essential economic activity that sustains the livelihoods of 2.5 million people and accounts for 70% of global output. But manufacturers face many obstacles: groundwater depletion threatens sustainability, chemical contamination lowers demand by 15%, traditional furnaces reduce efficiency by 30%, and infrastructure gaps increase costs by 20%. With prospects in value-added products, the SWOT analysis identifies restricted packaging as a vulnerability and low capital requirements as a strength. Though it benefits from higher production quantities, Uttar Pradesh falls behind Punjab in terms of innovation in the export-driven jaggery sector. The results support the suggested actions, which include fostering diversification, improving sustainability, enforcing quality, improving infrastructure, subsidizing technology, and making loans easier to obtain. For example, FSSAI compliance might restore demand, while two-pan furnaces could increase output by 20%.

Recommendations and suggestions

The following suggestions are put forth in order to remedy the issues that have been identified: Incentives for Technological Improvements:

- Set aside Rs. 500 crores to cover half of the expenses for 10,000 units to switch to two-pan furnaces, which will increase efficiency to 65% and cut fuel consumption by 50%. To reduce pollution, test solar-powered equipment in Muzaffarnagar.
- Enforce Quality Standards: To guarantee complete compliance and get rid of chemical contamination, FSSAI inspections should be strengthened. The 15% decline in demand might be reversed by educating 20,000 craftsmen about natural clarificants.
- Improve Rural Infrastructure: To cut logistical expenses by 15%, invest Rs. 1,000 crores in roads and power. To increase shelf life to six months, expand cold storage in Kushinagar.
- Support Value-Added Products: Provide Rs. 100 crores for research and development of organic and flavoured jaggery with the goal of increasing market share by 20%. Encourage the production of high-profit goods by 5,000 women craftsmen.
- Improve Environmental Sustainability: Provide 50,000 hectares of drip irrigation subsidies to cut down on groundwater depletion by 10%. To reduce pollution by 30%, enforce emission standards for furnaces.
- Enable Credit Access: Simplify Udyam registration so that 90% of units can obtain credit totalling Rs. 500 crores, allowing for modernization. These strategies exploit the industry's strengths, such as 70% global production share, to solve operational and economic restrictions.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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