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Sugar Industry: A Leader in Sustainable Development of India

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ABSTRACT

India's sugar industry is the most important contributor to India's economy. This research focuses on the active status of sugar factories, production of sugarcane and recovery rates, trends of sugar production and consumption, and the export-import of sugar. It examines the production of ethanol by the sugar industry, ethanol blending policies, and by-products resulting from the sugar industry. India is one of the largest sugar producers, sustainability challenges continue in terms of production efficiency, environmental concerns, and market fluctuations. This research paper highlights the growing role of ethanol production in India's energy sector and the potential for maximising by-product utilisation. The industry's contribution to India's sustainable development can be improved by adopting government policies and advanced technologies.

KEYWORDS

Sugar Industry**,** Sustainable Development, Production and recovery rate of Sugarcane, Production and Consumption of Sugar, Exports and Imports of Sugar, Production of Ethanol, Utilisation of By-products

INTRODUCTION

The sugar industry plays the prime and most significant role in the Agro-based industries in India, and this industry is deeply connected with the agricultural economy and rural livelihoods. This industry is a critical source of income for millions of farmers, laborers, and factory workers, who contribute substantially to employment generation, economic growth, and regional development. The industry is mainly focused on states like Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, and Gujarat. Because in these places climatic conditions and soil fertility favor sugarcane cultivation.
In the last few years, due to an increase in the number of sugar factories in this industry, sugarcane production has increased, due to which the recovery rate of sugar has also increased. On the other hand, Production efficiency and profitability are significantly impacted by factors such as climate change, fluctuating market prices, and policy interventions.

Sugar consumption in India is increasing due to the increased use of sugar in the food and beverage sector. Due to the excessive use of sugar, according to a report by the IDF (International Diabetes Federation), India has the second highest number of diabetic patients after China. Given the increasing use of sugar, this requires strategic planning to balance

domestic demand with export opportunities. Balancing exports and imports makes the balance of payment optimal, which is a good thing for the country's economy.

To the side from sugar production, the industry is playing a very important role in India's energy sector by producing ethanol. The government's move to blend ethanol with petrol is aimed at reducing India's dependence on imported crude oil, reducing carbon emissions and creating another source of income for sugar mills. For this, the government has also started a policy/program called 'Ethanol Blending Program'(EBP). Under this program, a target has been set for ethanol, which is to blend 20% ethanol by 2025. The sugar industry is being positioned as a key player in India's sustainable energy transition

This industry produces several valuable by-products such as bagasse, molasses, and press mud, which contribute to renewable energy, organic fertilizers, and alcohol production. Efficient utilisation of these by-products not only enhances cost-effectiveness but also aligns with sustainability goals by minimising industrial waste.

Despite contributing so much to this industry, it faces many challenges such as market stability, high water consumption and environmental pollution. Modernization of production facilities, sustainable agricultural practices are being promoted, and supportive strategies are also being implemented to bring sustainability to the industry. For example, now the sugar industry is not only focusing on the production of main products but also on the use of by-products.

This research paper intends to analyse the role of the sugar industry in India’s sustainable development by exploring key factors such as operational sugar factories, production trends, export and import trends, ethanol production, and by-product utilisation. By addressing these aspects, this study provides valuable insights into the industry's potential for economic growth, environmental sustainability, and energy security in India.

LITERATURE REVIEW

- **Diana Carolina Cedano et al., (2024)-** The study evaluates sustainable development in the Dominican Republic's sugar industry using life cycle assessment (LCA) to assess environmental and energy impacts. It identifies challenges and opportunities within sugar production and proposes tailored strategies to improve sustainability. The research aims to mitigate adverse effects by addressing these key areas while maximising social and economic benefits. The findings emphasise the importance of LCA in guiding environmentally friendly practices in Dominican sugar mills, reinforcing the need for strategic sustainability initiatives.

- **Mahalakshmi & Rajaram (2024) -** The study analyses the economic sustainability of hybrid solar-biomass systems in India's sugar industry, focusing on their potential to enhance sustainable development. Conducted in Tamil Nadu, it demonstrates that integrating this system significantly reduces both energy costs and greenhouse gas (GHG) emissions, making it economically viable and environmentally beneficial. The findings estimate the net present cost at $16 million, reinforcing the feasibility of this approach. The research concludes that

adopting hybrid solar-biomass systems is an effective strategy for promoting sustainability and long-term development in the sugar industry.

- **. P. Desai, D. M. Bongarde, et al., (2024)-** The study conducts a comparative analysis of environmental and social practices in the sugar industries of Brazil and Southern Maharashtra, India, highlighting their potential for sustainable development. It examines agricultural methods, social responsibility initiatives, and the utilization of byproducts like ethanol and biogas, showcasing their role in enhancing both environmental sustainability and economic impact. The findings reveal key differences in sustainability approaches between the two regions, emphasizing contrasts in farming techniques and corporate social responsibility efforts. The research provides insights into strategies that can promote sustainable practices in the global sugar industry.

- **Sneha Kumari, Bhupesh Gopal Chintamani, et al., (2024)-** The study examines the role of circular economy practices in the sugar industry, emphasizing sustainable development through enhanced mechanization, efficient waste management, and the repurposing of byproducts for construction materials. It highlights the potential of these strategies to reduce environmental impact and improve resource efficiency within the industrial ecosystem. The findings reveal that utilising sugar industry byproducts can reduce carbon emissions, though economic constraints remain a barrier to widespread adoption. The research concludes that financial investment is crucial for enabling a sustainable and circular economy within the sugar industry.

- **Ribadiya, C. V., & Desai, Y. (2024)-** The sugar industry plays a crucial role in India's economy, impacting multiple sectors and driving socio-economic progress. This study examines the financial performance of major sugar firms, assessing their profitability trends and strategic relevance between 2018-19 and 2022-23. The findings compare key financial indicators such as PBDIT and Net Profit Margin, offering insights into the firms' economic viability. The research concludes by providing an in-depth analysis of profitability trends, aiding stakeholders in making informed decisions and optimizing strategic planning within the industry.

- **Amin Sadeghi Sheshdeh, Mohammad Reza Sabour, et al. (2023)-** The study explores environmental sustainability in the sugar industry by evaluating supercritical water gasification (SCWG) technologies for managing sugarcane bagasse. It highlights the potential of transitioning to a circular economy by utilizing waste-to-energy solutions, optimizing energy recovery, and reducing reliance on fossil fuels. The findings indicate that SCWG is environmentally superior for hydrogen production, while direct combustion provides notable climate change mitigation benefits. The research emphasizes the role of advanced energy technologies in enhancing sustainability within the sugar industry.

- **Sahinujjaman. (2023)-** The sugar industry in India plays a significant role in the economy, producing around 30 to 33 million tons annually. However, it faces main challenges such as high production costs, low sugarcane prices, and irrigation difficulties, with Uttar Pradesh being the leading producer in terms of area and output. The study highlights issues like drought conditions and rising input costs, which impact sugarcane cultivation, while farmers struggle with fluctuating prices and unstable market conditions. The findings indicate that the Fair and Remunerative Price (FRP) for sugarcane has shown a steady increase from 2012-13 to 2021-22. The research concludes that government intervention is essential to balance FRP policies, ensuring fair benefits for both farmers and sugar producers.

- **Amjad, M. (2023)-** The sugar industry generates substantial waste from sugarcane production, posing serious environmental concerns. This study highlights the urgent need for effective waste management strategies to mitigate pollution and health risks associated with solid and liquid byproducts of sugar manufacturing. The findings highlight the environmental impact of the sugar industry waste and explore various wastewater treatment techniques. The research concludes that immediate action is necessary to enhance waste management practices, with a focus on implementing efficient wastewater treatment solutions to safeguard the environment.

- **Gangwar, D., & Misra, R. M. (2023)-** The sugar industry plays a vital role in India's economy, with Uttar Pradesh being a key production hub. This study examines the performance of cooperative and private sugar mills, highlighting the superior infrastructure, capacity, output, and social responsibility of private mills. The findings reveal that Dhampur, a private mill, outperforms the cooperative mill in multiple aspects, including revenue generation, while the cooperative mill lacks a power cogeneration unit. The research concludes that private mills demonstrate greater efficiency and financial strength, emphasising the need for policy interventions to enhance the performance of cooperative sugar mills.

- **Narendranath, M. (2023)-** The sugar industry is a key agro-based sector essential for economic growth, particularly in India. However, it faces challenges such as low sugarcane yield, high production costs, and outdated technology, necessitating process enhancements. This study examines improvements in sugar processing at The Andhra Sugars Ltd., focusing on optimizing production efficiency and minimizing losses. The findings emphasize the importance of upgrading processing techniques to ensure high-quality sugar production. The research concludes that advancements in processing methods at The Andhra Sugars Ltd. contribute to better product quality and reduced inefficiencies.

- **Jaiswal, K. K., Roy Chowdhury, et al. (2022)-** examine the role of renewable energy, specifically biofuels sourced from lignocellulosic biomass, in advancing sustainability within key sectors such as the sugar industry. Their research demonstrates that substituting fossil-based fuels with cleaner, renewable options can lead to substantial reductions in greenhouse gas emissions. The paper sheds light on the transformative potential of technologies like

biorefineries and bioreactors in converting biomass into high-value energy products, which, in turn, contribute to economic prosperity, ecological preservation, and social enhancement. Moreover, it illustrates the far-reaching effects of renewables in countering climate change and improving environmental outcomes. The authors argue that transitioning to renewable energy is not merely beneficial but necessary to address the drawbacks of conventional energy systems. They also stress that enabling this transition requires robust policy frameworks and active institutional participation to drive innovation and harness the complete benefits of clean energy for achieving integrated sustainability across environmental, economic, and societal domains.

- **Gondudey, S., & Chaudhari, P. K. (2020)-** investigate an enhanced approach to treating wastewater in the sugar industry, utilizing a dual-phase system that incorporates Sequential Batch Reactor (SBR) technology followed by electrocoagulation. Their findings reveal that, when operated under optimal parameters, the SBR method can achieve a substantial reduction in Chemical Oxygen Demand (COD)—up to 91.66%—thereby markedly decreasing pollutant concentrations in industrial effluent. The subsequent electrocoagulation step further reduces COD levels from an initial 640 mg/dm³ to as low as 77 mg/dm³, ensuring that the treated discharge meets regulatory standards. The study ultimately concludes that this integrated treatment strategy offers an efficient and reliable solution for managing sugar industry wastewater, aiding in environmental compliance and significantly mitigating ecological impact.

- **Meghana, M., & Shastri, Y. (2020)**-This research examines the sustainable management of waste in the sugar industry, with a focus on converting by-products into renewable energy and other value-added materials. The study underscores how these valorization strategies can cut down the industry's carbon emissions, boost economic potential through waste-to-energy innovations, and promote environmental protection via pollution reduction and resource efficiency. Socially, it supports job creation and greater community involvement in sustainability efforts. The findings explore the existing state of waste management and stress the promise of advanced methods like bioconversion for producing biofuels, bioplastics, and other products. However, the research also acknowledges significant barriers such as the financial practicality of these technologies, gaps in policy support, and the need for strong stakeholder collaboration. Ultimately, it argues that effective utilization of sugar industry waste can unlock both environmental and economic advantages, though this will depend on overcoming technical and regulatory hurdles to realize a truly circular economy.

- **Rajaeifar, M. A., Hemayati, et al. (2019)-** This study examines the environmental impact of the sugar beet industry, specifically focusing on how implementing waste-to-energy approaches can improve sustainability in sugar production. The research evaluates two sugar factories in Iran and finds that converting waste into renewable bioelectricity can significantly decrease negative impacts on human health by 14.11–15.41% and improve ecosystem quality

by 1.49–1.54%. The findings emphasize how these strategies help reduce environmental pressures while promoting cleaner energy sources within sugar manufacturing processes. The study concludes that the integration of waste-to-energy systems in sugar factories not only lessens environmental degradation but also enhances overall sustainability by reducing reliance on non-renewable power sources.

- **Chohan, M. (2019)-** This review examines the vulnerability of sugarcane cultivation to climate variability, focusing on how changing environmental conditions, particularly temperature and rainfall patterns, influence crop yield and quality. The study notes that global temperatures could rise by 3–5°C by the end of the century, which may significantly disrupt sugarcane growth cycles. It emphasizes the direct impact of climate stressors on sugarcane productivity without delving into the broader environmental, economic, or health-related implications of the sugar industry. The research concludes that climate change is a critical challenge for sugarcane farming and highlights the importance of developing climate-resilient sugarcane varieties along with adopting improved agricultural practices to sustain production in future climatic scenarios.

Objectives

The objectives of our research paper are as under-

- To study the production and recovery rate of sugarcane in India.
- To examine the pattern of India's current sugar production and domestic consumption.
- To study the import and export potential of the Indian sugar industry.
- To review the role of ethanol production from sugarcane.
- To recognise and appraise the utilisation of by-products of the sugar industry.

Research Methodology

The present study is **analytical in nature**, aiming to examine the role of the sugar industry in the sustainable development of India. The analysis focuses on key aspects such as the number of operational sugar factories, sugarcane production and recovery rate, sugar production and consumption, export and import of sugar, ethanol production and blending, and the contribution of sugar industry by-products.

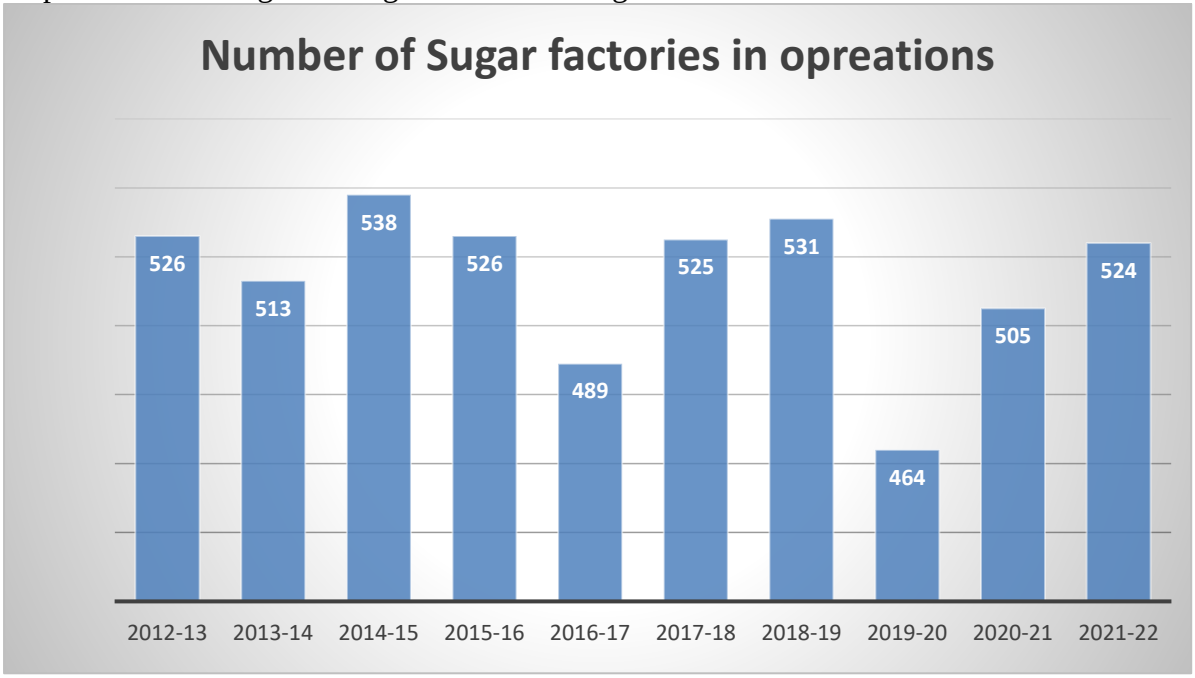
The research is based on **secondary data**, which has been collected from various **reliable and official sources**. These include government publications, research reports, and data available on the official websites related to the sugar and sugarcane industry in India, such as the Ministry of Consumer Affairs, Food and Public Distribution, Indian Sugar Mills Association (ISMA), and other relevant databases.

The **data covers a period of ten years**, allowing a comprehensive understanding of trends, growth patterns, and policy impacts within the industry. Various charts and statistical tools have been used to analyse the data and derive meaningful insights.

This methodology helps in understanding the performance and transformation of the sugar industry over the years, especially in its evolving role towards contributing to energy security, environmental sustainability, and rural development.

Data Collection & Analysis

The importance of the Indian sugar industry may be easily considered and observed with the help of the following and the given relevant diagrams:



Source: Directorate of Economics and Statistics, Ministry of Agriculture & Farmers' Welfare, New Delhi

This chart highlights the activities in the operational sugar mills across India over the years. The data shows fluctuations in the total number of working sugar mills, influenced by factors such as government policies, demand for sugar and ethanol, and the financial viability of mills. With India's increasing focus on ethanol production and sustainability, maintaining the stability of operational sugar mills is essential for the industry's long-term growth.

In recent years, the number of operational sugar mills has remained **above 500**, with variations due to new establishments, temporary shutdowns, or closures of financially unviable units. The increase in operational mills can be attributed to rising sugarcane production, government incentives, and the growing ethanol blending program. However, some mills face challenges such as financial distress, outdated technology, and inefficiencies, leading to periodic closures.

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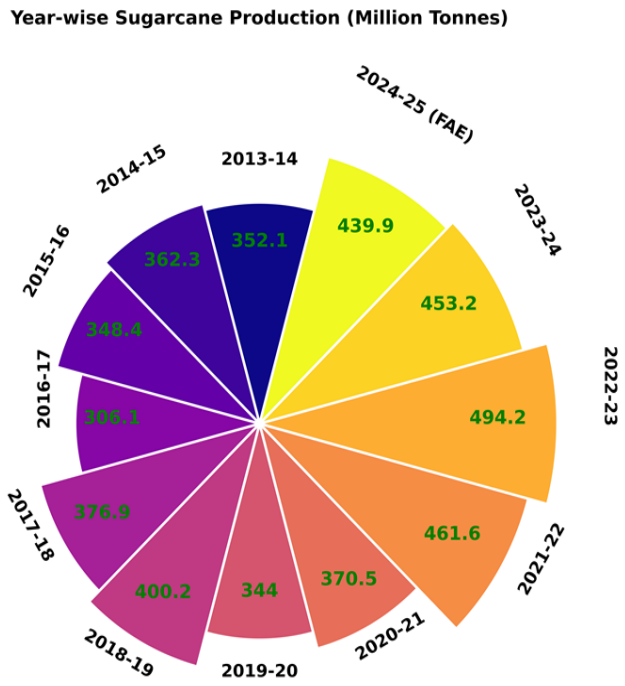
Trends in the production of sugarcane in India



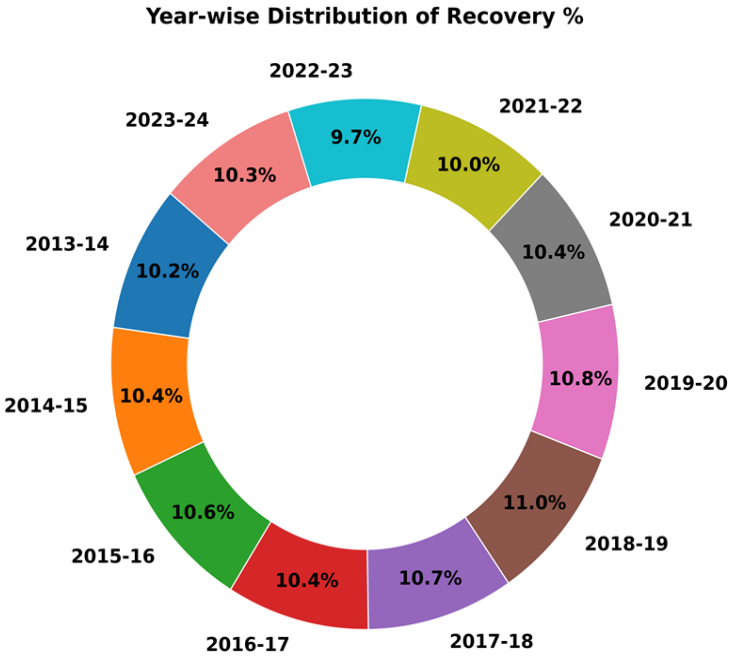
Year	Production (million tonnes)
2013-14	352.1
2014-15	362.3
2015-16	348.4
2016-17	306.1
2017-18	376.9
2018-19	400.2
2019-20	344.0
2020-21	370.5
2021-22	461.6
2022-23	494.2
2023-24	453.2
2024-25 (FAE)	439.9

SOURCE- https://sugarcane.icar.gov.in/index.php/sugarcane-statistics/

This chart highpoints the fluctuations in India's sugarcane production from 2013-14 to 2024-25. The data shows an initial variation, with production at 352.1 million tonnes in 2013-14, increasing to 362.3 million tonnes in 2014-15, but later dropping to 306.1 million tonnes in 2016-17. This decline may be due to unfavorable climatic conditions or reduced cultivation. However, production rebounded in subsequent years, reaching 400.2 million tonnes in 2018-19, reflecting improved agricultural practices and government support. A significant rise was observed in 2021-22, with production reaching 461.6 million tonnes, followed by the highest recorded production of 494.2 million tonnes in 2022-23. This growth can be related to advancements in farming techniques, better irrigation, and increased ethanol demand. However, a slight decline is noted in 2023-24 (453.2 million tonnes) and is projected to drop further to 439.9 million tonnes in 2024-25 (FAE), possibly due to changing climatic conditions and shifts in cultivation patterns.

The fluctuating trends in sugarcane production directly impact sugar output, ethanol production, and by-product utilisation. Sustaining high production levels requires continued technological improvements, policy support, and efficient resource management. With ethanol blending playing a vital role in India’s energy sector, stabilising sugarcane production is vital for both economic and sustainable development.

Annual percentage recovery rates of sugarcane in India



Year	Recovery (% cane)
2013-14	10.2
2014-15	10.4
2015-16	10.6
2016-17	10.4
2017-18	10.7
2018-19	11.0
2019-20	10.8
2020-21	10.4
2021-22	10.0
2022-23	9.7
2023-24	10.3

SOURCE- https://sugarcane.icar.gov.in/index.php/sugarcane-statistics/

This figure shows how much sugar is extracted from sugarcane in India, which is called the recovery rate. The data shows that the average sugar recovery rate in India stands at 10.25%, indicating the percentage of sugar obtained from crushed sugarcane. However, the recovery rate differs significantly across states due to differences in sugarcane varieties, differences in climate, and soil quality.

If we talk about the major sugarcane-producing states, Maharashtra records the highest recovery rate, which reflects favorable climatic conditions, improved agricultural practices, and efficient processing methods. In contrast, Tamil Nadu has the lowest recovery rate, which may be due to factors such as high moisture content in the cane, different harvesting practices, or lower sucrose content in the crop.
All these variations show that sugar recovery efficiency depends on both natural and technical factors.

The overall recovery rate plays an important role in determining the profitability of sugar mills and the sustainability of the industry. High recovery rate becomes an important factor in optimizing resources as sugar production increases without diverting the area of cultivation. With ongoing improvements in sugarcane breeding, processing technologies, and better irrigation practices, the recovery rate can be improved, contributing to higher efficiency in India's sugar industry.

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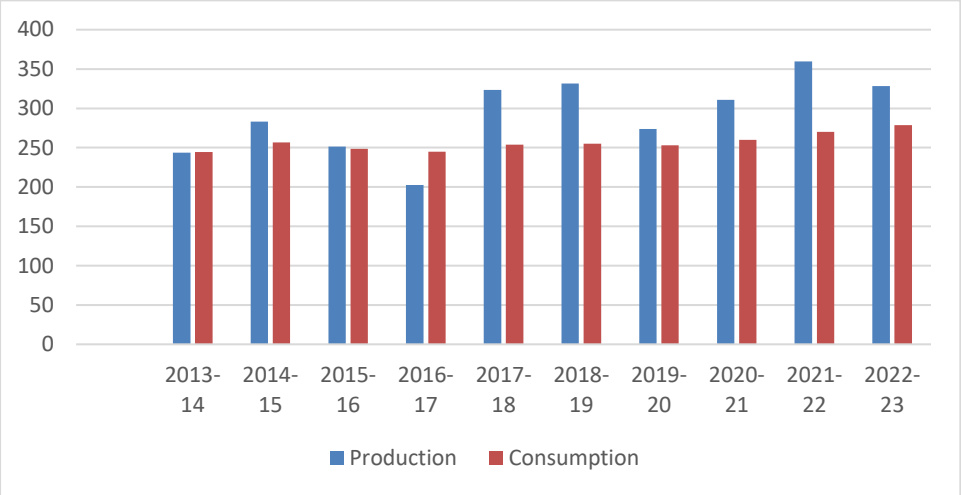
Production and Consumption of Sugar (in Lakh tonnes)

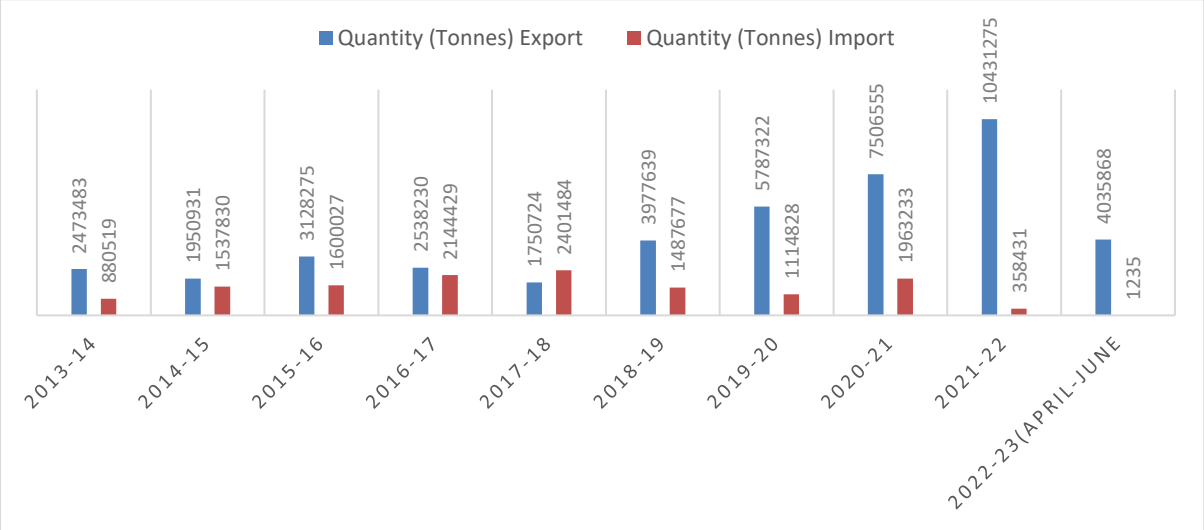


Source: Ministry of Commerce and Industry (Department of Commerce)

Production has reached its highest levels in the years 2017-18, 2020-21, and 2022-23, suggesting favourable conditions for sugarcane cultivation during these periods, such as adequate rainfall and favourable government policies. Consumption has also peaked in these same years, coinciding with the production peaks, including a strong correlation between production and consumption. This suggests that the domestic market is absorbing most of the produced sugar.

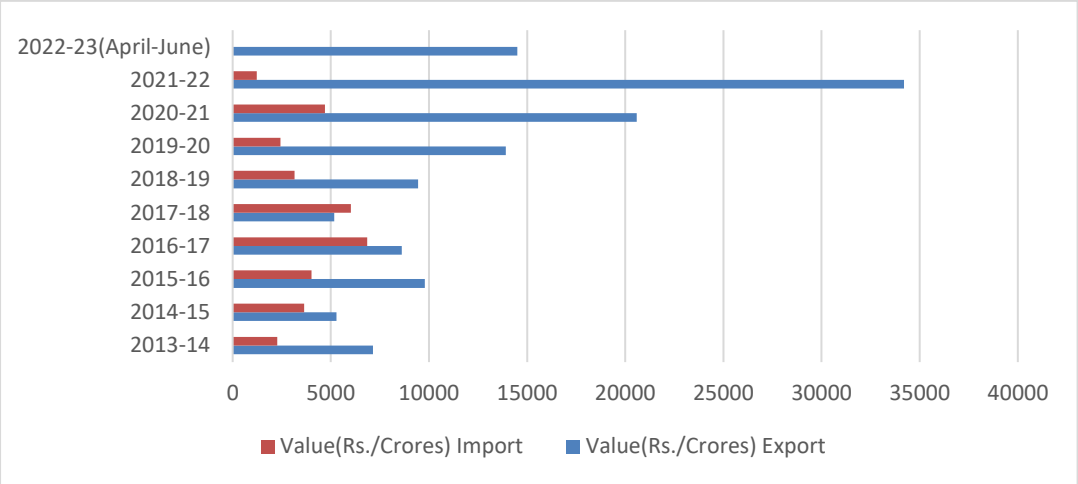
In some years, there is a noticeable gap between production and consumption. This could be due to factors such as exports, stockpiling, or losses during transportation and storage. Government policies related to sugarcane pricing, subsidies, and exports can significantly influence production and consumption trends. Any changes in these policies can lead to fluctuations in the market.

Exports and Imports of Sugar (In Tonnes)



Source - Ministry of Commerce and Industry (Department of Commerce)

India's sugar exports have reached significant peaks in the years 2020-21 and 2021-22, suggesting surplus production during these periods, likely due to favourable climatic conditions and government policies that encouraged exports. While exports have generally dominated, there have been occasional spikes in imports, which might be attributed to factors such as domestic shortage, higher international prices, or specific government policies.
There was a noticeable decline in sugar exports in 2022-23 compared to the previous two years. This could be due to factors like reduced production, increased domestic consumption, or changes in global market dynamics.
India's Export and Import of Sugar (in value)



Source - Ministry of Commerce and Industry (Department of Commerce)
This chart also shows the above-mentioned chart in value form. Its analysis is also similar

By-products of the Sugar Industry

The by-products of the sugar industry play an important role in sustainable development by promoting waste utilisation, renewable energy generation, and environmental conservation. The most important by-products include **molasses, bagasse, press mud, and ethanol**, each contributing to sustainability in different ways.

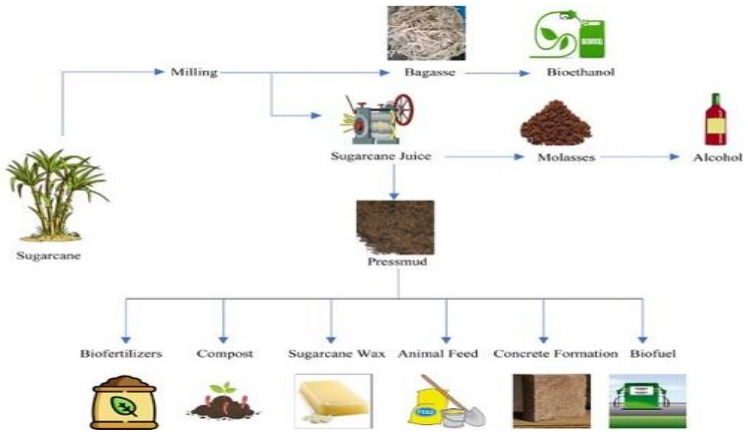
- **Molasses for Ethanol Production-** Molasses, a thick syrup obtained during sugar processing, is a key raw material for **ethanol production**. Ethanol is blended with petrol to reduce fossil fuel consumption, lower carbon emissions, and decrease India's dependence on crude oil imports. This supports the government's **ethanol blending program (EBP)**, which targets to achieve **20% ethanol blending (E20) by 2025**.
- **Bagasse for Renewable Energy**- Bagasse, the fibrous residue left after sugarcane crushing, is an excellent **biomass fuel** that contributes significantly to **renewable energy generation**. Sugar mills use bagasse to produce **electricity and steam**, making them self-sufficient in energy while also supplying surplus power to the national grid. This reduces dependence on **coal and other fossil fuels**, promoting **clean energy solutions** and reducing **carbon emissions**. Apart from energy production, **bagasse is also used to manufacture biodegradable tableware** such as **plates, bowls, cups, and food containers**. These **eco-friendly alternatives** to plastic and Styrofoam help reduce **plastic waste and pollution**, supporting environmental sustainability. As bagasse-based tableware is **compostable and biodegradable**, it offers a greener option for the food packaging industry, contributing to a

circular economy by turning agricultural waste into useful products. By utilizing bagasse for both **energy production and sustainable packaging**, the sugar industry plays a crucial role in **reducing environmental impact, promoting renewable energy, and supporting sustainable consumer products**.

Source- www.gogradable.com

- **Press Mud for Organic Fertilizers**

Press mud, a by-product of sugar refining, is rich in organic matter and nutrients. It is used to produce **bio-compost and organic fertilizers**, reducing the dependency on chemical fertilizers. This improves soil health, supports sustainable agriculture, and minimizes environmental pollution.



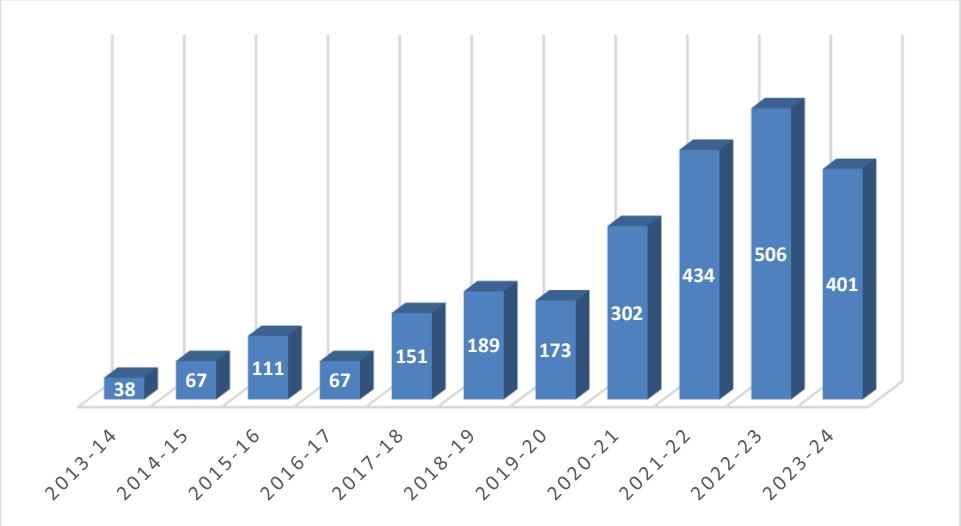
- **Ethanol and Biofuels**

Ethanol production from sugarcane and molasses helps in **reducing greenhouse gas**

emissions. Ethanol-blended fuel burns cleaner than conventional petrol, leading to **lower air pollution and carbon footprints**. The use of biofuels in transportation supports India's transition towards **sustainable energy solutions**.

By effectively utilizing these by-products, the sugar industry **reduces waste, lowers environmental impact, and supports a circular economy**. This contributes to India's goals of **sustainable agriculture, renewable energy production, and environmental conservation**, making the sugar industry a key player in sustainable development.

Production of Ethanol Through the Indian Sugar Industry (In Crore Liters)

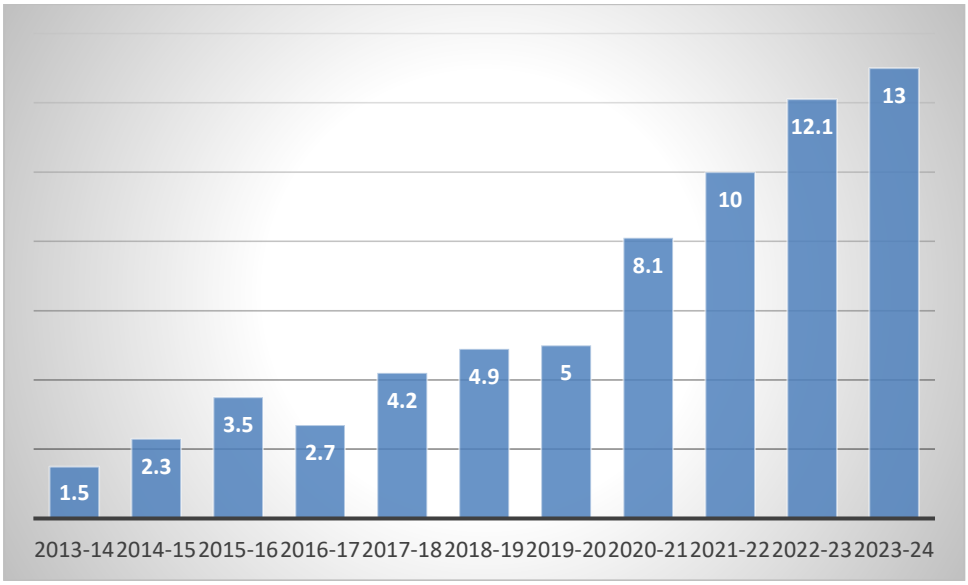


Source- chinimandi.com

(Figures in crore litres; Supply years are Dec-Nov, Dec-Oct for 2022-23 and Nov-Oct for 2023-24: Nov-June)

The Production of Ethanol Through the Indian Sugar Industry has witnessed significant growth in recent years, in performance a decisive role in India's energy sector and sustainability goals. Ethanol production reached 434 crore liters in 2021-22, motivated by the government's ambition for ethanol blending with petrol. Ethanol production helps in enhancing fuel security, reducing crude oil imports, and lowering carbon emissions, aligning with India's commitment to clean energy. The rise in ethanol production also benefits farmers by ensuring a stable demand for sugarcane, thus improving their income. With further investment in ethanol distilleries and infrastructure, India is well on track to achieve its target of 20% ethanol blending by 2025, consolidating both the sugar and energy industries.

Ethanol Blending in India (in percentage)



Source- chinimandi.com

The Ethanol Blending in India has gained momentum as part of the government's strategy to reduce dependence on fossil fuels and promote sustainable energy. In 2021-22, ethanol blending with petrol reached 10%, marking a significant milestone in India's biofuel program. This achievement is the result of increased ethanol production from sugarcane-based feedstocks, including sugarcane juice, B-heavy molasses, and C-heavy molasses.

The government has set an ambitious target of 20% ethanol blending by 2025, which will help lower fuel imports, reduce carbon emissions, and provide a stable market for sugarcane farmers. To achieve this, investments in ethanol distilleries, incentives for sugar mills, and streamlined supply chains are being prioritized. As ethanol blending progresses, it is expected to enhance energy security while supporting the sugar industry's long-term sustainability.

FINDINGS

The development trajectory of India's sugar industry reveals both substantial progress and persistent challenges in its contribution to sustainable growth. Sugarcane output in the country climbed to an impressive **494.2 million tonnes in 2022-23**; however, slight declines are anticipated due to evolving climate conditions, policy shifts, and shifting market needs. Despite these variables, the industry has maintained a steady base of approximately **524 operating mills**, illustrating its structural robustness. To safeguard its future, enhancements through technological upgrades and improved financial frameworks are critical. Regional variations in the average sugar recovery rate, which currently stands at **10.25%**, highlight disparities in efficiency. Elevating recovery percentages could significantly boost sugar yield without expanding the cultivation area. Meanwhile, ethanol production has seen notable growth, reaching **440 crore liters in 2021-22**, as an increasing share of sugarcane is allocated for fuel. This redirection has mitigated the issue of sugar oversupply and has bolstered the fiscal standing of mills, concurrently benefiting sugarcane farmers. Ethanol blending with petrol also achieved a **10% integration rate in 2021-22**, progressing toward the government's **20% target by 2025**. This policy not only strengthens India's energy autonomy but also aids in reducing emissions. The sector is gradually evolving into a multifaceted contributor to both

renewable energy and sustainable practices. Nonetheless, issues such as inconsistent crop yields, economic strain in processing units, and varying recovery metrics demand strategic interventions. Achieving balanced, long-term progress will hinge on supportive policy, innovation, and optimized use of natural and financial resources—factors essential for ensuring enduring prosperity for stakeholders and aligning with environmental goals.

CONCLUSION

The Indian sugar industry stands as a cornerstone of the nation's economy, intertwining with the agricultural and energy sectors while sustaining the livelihoods of millions of farmers and laborers. With more than 524 sugar mills currently operating, the sector not only bolsters rural development but also plays a pivotal role in driving agricultural innovation and job creation. Over recent years, improvements in sugarcane yield and recovery rates reflect notable progress in farming techniques and technological adoption. However, this growth is not without challenges—fluctuating market prices, surplus production, and environmental stressors all demand strategic, long-term solutions to safeguard the industry's future. Among the most transformative developments is the expansion of ethanol production. This shift addresses both the surplus sugar inventory and India's reliance on imported fossil fuels. The national ethanol blending initiative, targeting 20% integration by 2025, presents a valuable opportunity for sugar mills to diversify operations and boost profitability. Yet, achieving this vision hinges on robust policy support, modernized infrastructure, and significant investment in cutting-edge distillation methods. Equally vital are the industry's by-products—bagasse, molasses, and press mud—which offer untapped potential in bioenergy, fuel alternatives, and organic agriculture. Efficiently managing these outputs could reduce environmental strain while maximizing economic value. Embracing eco-conscious processing and effective waste management can further position the sugar sector as a model of sustainable industrial practice. Nevertheless, persistent issues such as high water use, pollution, and global price volatility must be addressed. Enhanced irrigation methods, environmentally responsible regulations, and balanced trade policies are critical for building resilience. In essence, the Indian sugar industry holds vast promise for fostering sustainable development by aligning growth with environmental stewardship and energy reform. Continued innovation, guided governance, and a commitment to responsible practices will be instrumental in ensuring the sector's enduring success and its contribution to India's broader sustainability ambitions.

REFERENCES

- M. S. Mahalakshmi, S. Rajaram (2024). *An Economic Sustainability Analysis of Hybrid Solar-Biomass System for Sugar Industries in India.*
  DOI: 10.34117/bjdv10n3-061

- Y. P. Desai, D. M. Bongarde, S. Khandekar (2024). *A Comparative Analysis of Environmental and Social Practices in the Sugar Industries of Brazil and Southern Maharashtra, India.*
  DOI: 10.9734/acri/2024/v24i11967

- Sneha Kumari, Bhupesh Gopal Chintamani, Shashikala Gurpur (2024). *Antecedents for Circular Economy in Sugar Industrial Ecology in Emerging Economy.*
  DOI: 10.18280/ijsdp.190602

- Ribadiya, C. V., & Desai, Y. (2024). *Assessing Profitability Trends: A Comparative Analysis of Leading Sugar Firms in India.*
  DOI: 10.21276/IERJ24172224843593

- Diana Carolina Cedano, Ruben Dario Ramos Ciprian, M. J. Cejudo Bastante, Rosario Viñoles (2024). *Sustainable Development Analysis in the Sugar Industry: Assessing Environmental Energy Impact in Sugar Production through Life Cycle Assessment.*

- Sahinujjaman. (2023). *An Overview on Sugarcane Industry in India.*
  DOI: 10.36713/epra13707

- Amjad, M. (2023). *A Perspective Review on Sugar Industry Wastes, Uses, and Treatment Techniques.*
  DOI: 10.23880/oajwx-16000186

- Gangwar, D., & Misra, R. M. (2023). *Problems and Prospects of Sugar Industry in India: Case Study of Bijnor District, Uttar Pradesh.*
DOI: 10.3126/ijssm.v10i1.50075

- Narendranath, M. (2023). *Process Improvements of a Cane Sugar Plant.*
  DOI: 10.36961/si29438

- Amin Sadeghi Sheshdeh, Mohammad Reza Sabour, Fateme Mohammadi, Jin Hui, Morten Birkved, Benyamin Khoshnevisan (2023). *Early Environmental Sustainability Guidance on Supercritical Water Gasification Technologies for Sugarcane Bagasse Management.*
  DOI: 10.1016/j.spc.2023.12.014

- Jaiswal, K. K., Roy Chowdhury, C., Yadav, D., Verma, R., Dutta, S., Jaiswal, K. S., Sangmesh, & Selvakumar, K. (2022). *Renewable and sustainable clean energy development and impact on social, economic, and environmental health.* Nexus, 100118. https://doi.org/10.1016/j.nexus.2022.100118

    - Meghana, M., & Shastri, Y. (2020). *Sustainable valorization of sugar industry waste: Status, opportunities, and challenges.* Bioresource Technology, 122929. https://doi.org/10.1016/j.biortech.2020.122929

- Gondudey, S., & Chaudhari, P. K. (2020). *Treatment of sugar industry effluent through SBR followed by electrocoagulation.*

- Chohan, M. (2019). *Impact of climate change on sugarcane crop and remedial measures – A review.*https://doi.org/10.35380/sugar.034.01.0141

- Rajaeifar, M. A., Hemayati, S. S., Tabatabaei, M., Aghbashlo, M., & Mahmoudi, S. B. (2019). *A review on beet sugar industry with a focus on implementation of waste-to-energy strategy for power supply.* Renewable and Sustainable Energy Reviews, 101, 540–551. https://doi.org/10.1016/j.rser.2018.12.056
- www.exportpotential.intracen.org
- www.statista.com
- https://icar.org.in