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VOLUME-39

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From the Managing Director’s Desk

Munish Madaan
Managing Director
The Catalysts Group

India’s ethanol journey has reached an important turning point.

What began as an initiative to partially substitute petrol with a domestically produced renewable fuel has now evolved into a strategic national programme supporting energy security, rural prosperity, industrial growth and environmental sustainability.

The successful implementation of the Ethanol Blended Petrol Programme and the achievement of 20% ethanol blending demonstrate what can be accomplished when policy direction, industry investment, agricultural resources and technological capability work together toward a common objective.

However, E20 should not be viewed as the final destination. It is the foundation for the next phase of India’s biofuel journey.

The introduction of higher ethanol blends such as E85, together with the development of flex-fuel vehicles, has the potential to significantly expand ethanol consumption and create a stronger, more diversified domestic market for the distilling industry.

E85, containing approximately 80–85% ethanol, represents a major step beyond conventional ethanol-blended petrol. Unlike standard petrol vehicles, flex-fuel vehicles are engineered to operate on different combinations of petrol and ethanol, allowing consumers to use blends ranging from E20 to much higher ethanol concentrations.

The recent launch of the Maruti Suzuki WagonR Flex Fuel is therefore a landmark development for India’s mobility and ethanol sectors. Designed to adapt to ethanol-petrol blends from E20 to E100 and homologated for E85, the vehicle demonstrates that high-ethanol mobility is no longer limited to prototypes or policy discussions. It is beginning to enter the commercial market.

The simultaneous rollout of E85 fuel at selected retail outlets further strengthens this ecosystem. Vehicle availability and fuel infrastructure must progress together, and these developments indicate that India is gradually moving from an ethanol-blending programme towards a broader flex-fuel economy.

For the ethanol industry, this transition opens an important new growth opportunity.

As flex-fuel vehicle adoption increases, demand for ethanol could extend beyond the volumes required for E20. This can provide distilleries with greater market visibility, support the creation of additional production capacity and encourage investment in grain, molasses, sugarcane juice, syrup, agricultural residue and other approved feedstock-based ethanol pathways.

The benefits extend across the economy.

Higher domestic ethanol utilisation can reduce dependence on imported crude oil and conserve valuable foreign exchange. It can create additional demand for agricultural produce, strengthen farmer incomes and generate economic activity across rural supply chains. It can also support lower lifecycle greenhouse-gas emissions and contribute to India's transition towards cleaner and more self-reliant mobility.

However, expanding from E20 towards E85 and other higher blends will require more than additional distillation capacity.

The industry will need to ensure consistent ethanol quality, reliable feedstock availability, efficient fermentation, stronger process control and optimal utilisation of water and energy. As production volumes increase and feedstocks become more diverse, even small process inefficiencies can translate into substantial losses in yield, productivity and profitability.

This is where biotechnology and process expertise will play a critical role.

Advanced enzymes can improve starch conversion and increase the availability of fermentable sugars. Specialised yeast and nutrient solutions can support faster, healthier and more stable fermentation. Effective microbial control can reduce contamination-related losses, while analytical monitoring can help plants identify residual sugars, organic acids and other indicators of process inefficiency before they affect final recovery.

At The Catalysts Group, we believe the next phase of ethanol growth must be built not only on capacity, but also on efficiency.

Our objective is to help ethanol producers extract the maximum value from every tonne of feedstock, every fermentation cycle and every litre of installed capacity. Through biotechnology-driven solutions, on-site technical support, analytical diagnostics and continuous process optimisation, we work closely with plants to improve yield, reduce process losses and achieve more consistent operational performance.

The introduction of flex-fuel vehicles and E85 also sends a broader message to the industry: ethanol is no longer simply an additive to petrol. It is emerging as a mainstream mobility fuel with the potential to play a much larger role in India's energy mix.

Building this ecosystem will require close collaboration among policymakers, oil-marketing companies, vehicle manufacturers, ethanol producers, technology providers and the agricultural community. Fuel availability must expand, vehicle options must grow, consumers must be informed, and ethanol plants must remain prepared to meet rising demand efficiently and sustainably.

India has already demonstrated its ability to achieve ambitious ethanol targets ahead of schedule. The challenge before us now is to convert that momentum into a stable, scalable and commercially sustainable high-ethanol economy.

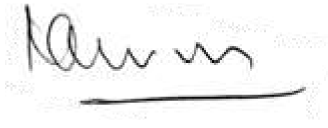
The journey from E20 to E85 represents more than an increase in the percentage of ethanol blended with petrol. It represents a transition towards greater energy independence, stronger rural value creation and a more resilient domestic bioeconomy.

For all of us associated with the ethanol and distilling industries, this is a defining opportunity. The decisions, investments and innovations we undertake today will determine how effectively India captures the full potential of ethanol tomorrow.

At The Catalysts Group, we remain committed to supporting this transition by combining science, process understanding and customer partnership to help the industry produce more efficiently, operate more sustainably and create measurable value.

The road ahead is increasingly powered by ethanol—and India is ready to move forward.

Warm regards,



Munish Madan

Process Hazards and Risk Management in Ethanol Plants

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Introduction

India's ethanol production capacity has expanded rapidly to 650 crore liters in 2024, targeting 1,350 crore liters by 2025-26 [1]. This growth brings significant process safety challenges: highly flammable liquid handling, explosive grain dust, asphyxiation risks from fermentation CO_2, confined spaces, and process upsets [2][3]. Recent Indian incidents storage tank fires, silo collapses, and molasses combustion demonstrate the critical need for structured risk management in ethanol plants.

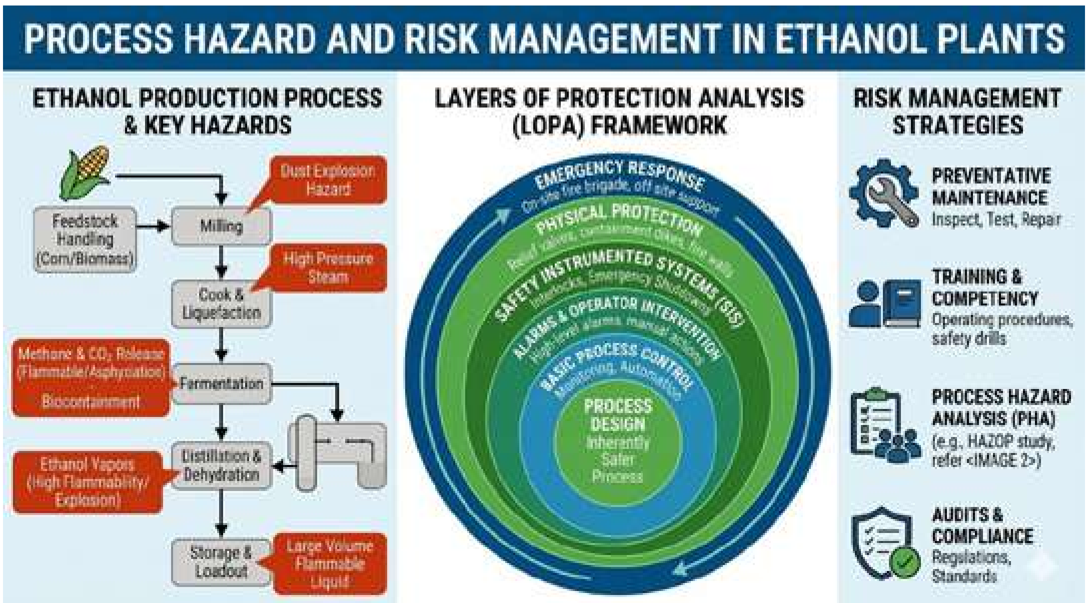

Figure. Hazard and Risk management in Ethanol plants

Major Process Hazards and Indian Case Studies

Flammable Vapours and Storage Tank Fires

Ethanol is highly flammable (flash point 13°C, flammable range 3.3–19% v/v) [4][5]. Vapour release occurs from fermentation vents, distillation systems, storage tank breathing, pump seals, and loading operations. Ignition sources include electrical equipment, static electricity, hot surfaces, mechanical sparks, and lightning [2][5].

Case Study 1: Oasis Ethanol Industries Tank Fire, Ambala (2024)

In May 2024, multiple ethanol storage tanks at Oasis Ethanol Industries, Naraingarh, caught fire with explosive ignition, killing one worker and consuming 250,000–300,000 liters of ethanol over 20 hours of firefighting [6][7][8]. Root causes included inadequate tank spacing, absence of fixed foam systems, and delayed emergency response.

Key controls: Tank spacing (≥1.5D), AR-AFFF foam deluge systems, lightning protection, hazardous area classification (Zone 0/1/2), emergency shutdown valves, dike containment (≥110% largest tank), and coordinated fire response plans [6][7]. At LHSF Distillery, Pilibhit, a similar fire destroyed 90,000 liters of ethanol; foam deployment and exposure cooling of adjacent tanks prevented escalation.

Grain Silo Hazards and Structural Failures

Grain dust is explosible (MEC 40–60 g/m^3, MIE <10 mJ), creating risks in elevators, silos, mills, and conveyors. Secondary dust explosions propagating through ducts often cause severe damage [3][9].

Case Study 2: Maize Silo Collapse, Sambhajinagar (2024)

A 15-year-old, 3,000-tonne maize silo at an ethanol plant collapsed during welding maintenance, killing 3–4 workers and injuring several others [10]. Root causes: structural degradation, corrosion, inadequate inspection, hot work on loaded silo without permit-to-work, and workers in collapse zone.

Key controls: Structural integrity assessment (ultrasonic testing, weld inspection) for assets >10 years, ageing-asset management, prohibition of hot work on loaded silos, strict permit-to-work systems, exclusion zones, and temperature/strain monitoring.

Molasses Spontaneous Combustion

Sugarcane molasses, the primary feedstock for many Indian ethanol plants, is a viscous byproduct containing 45–50% fermentable sugars, organic acids, minerals, and nitrogenous compounds. When stored at elevated temperature or for extended periods (>3 months), molasses undergoes microbial and chemical degradation, reducing sugar content and fermentation efficiency.

In extreme cases, exothermic decomposition reactions can cause spontaneous heating, foaming, frothing, and violent ejection of material from tank vents. If heat generation exceeds dissipation, molasses can char, producing carbonaceous residues and releasing flammable volatiles.

Case: Molasses Spontaneous Combustion in Indian Distilleries

Multiple documented incidents in Indian sugar mills and distilleries describe spontaneous combustion in molasses storage tanks. In one case, several thousand tonnes of molasses stored in vertical steel tanks underwent exothermic reactions that converted the liquid into charred, “charcoal-like” material. Operators observed foaming, bubbling, and temperature rise, and attempted emergency cooling by spraying water and introducing ice slabs into the tanks. Despite these efforts, short-duration fires or violent venting occurred in multiple tanks, resulting in total loss of feedstock and structural damage to tank roofs and vents. Insurance claims and legal proceedings documented the phenomenon as spontaneous combustion arising from prolonged storage under tropical ambient conditions without adequate temperature control or inventory turnover.

Typical safeguards (application):

- Temperature monitoring: Continuous thermocouple or RTD sensors at multiple tank levels with high-temperature alarms.
- Inventory rotation: Strict "first-in, first-out" (FIFO) protocol; maximum storage duration 60–90 days in tropical climates.
- Tank design: Insulated tanks or external spray cooling systems in regions with sustained high ambient temperature (>35°C).
- Periodic sampling and analysis: Total reducing sugars (TRS), pH, viscosity, and microbial contamination every 15–30 days.
- Dilution and mixing: Mechanical agitation or recirculation to prevent stratification and localised heating.
- Venting and pressure relief: Adequate vent sizing to relieve gases from decomposition; flame arrestors if flammable volatiles are possible.
- Emergency procedures: Defined actions for high-temperature alarms, including accelerated use, dilution, or emergency transfer to cooler storage.

Maize and Grain Storage Deterioration

Maize stored with moisture content above 14% or inadequate aeration is prone to fungal growth (Aspergillus, Fusarium, Penicillium), mycotoxin production (aflatoxins), self-heating, and quality loss. Biological respiration generates heat and moisture, creating hotspots that can ignite in the presence of oxygen. Caking, bridging, and compaction create mechanical hazards during silo discharge, including sudden collapse (avalanche) and engulfment of workers [3][9]. The Sambhajinagar silo collapse (Case Study 2) exemplifies catastrophic failure from combined structural, maintenance, and operational deficiencies.

Typical safeguards (application):

- Moisture control: Receive grain at ≤14% moisture; dry if necessary, using aeration or mechanical dryers.
- Silo aeration systems: Fans and perforated floors to maintain uniform temperature and prevent moisture migration.
- Temperature monitoring: Cable temperature sensors (thermometry cables) at multiple depths to detect hotspots early.
- Regular inspection: Visual checks for condensation, microbial spoilage, caking, and structural damage; olfactory checks for musty or fermented odours.
- Fumigation and pest control: Integrated pest management (IPM) using phosphine or controlled atmosphere (CA) storage.
- Safe entry procedures: Full confined-space protocols if silo entry is required; mechanical methods (augers, air lances) for de-bridging instead of manual entry.
- Structural integrity assessments: Periodic third-party engineering review of silo walls, hoppers, supports, and foundations.

Utilities and Auxiliary Systems

Cooling Water System Hazards

Cooling water is critical in ethanol plants for fermentation temperature control, distillation column condensers, molecular sieve regeneration gas coolers, and product coolers. Loss of cooling waterflow can trigger:

- Fermentation temperature runaway, yeast death, and batch loss
- Distillation column flooding or over-pressure from inadequate condensation
- Excessive vapour emissions to atmosphere from process vents

- Thermal damage to molecular sieve beds in dehydration units

Cooling tower systems face fouling, scaling, microbiological growth (Legionella risk), and chemical hazard exposure from biocides, corrosion inhibitors, and pH-adjustment chemicals [12].

Typical safeguards (application):
- Redundant cooling water pumps with automatic standby switchover on low-pressure or flow failure
- Uninterruptible power supply (UPS) or diesel generator backup for critical cooling circuits
- High-temperature and high-pressure alarms/interlocks on fermenters, reboilers, and condensers, triggering automatic load reduction or shutdown
- Water chemistry control: Continuous monitoring of pH, conductivity, oxidising biocide residual; automated dosing systems
- Preventive maintenance schedules for heat exchangers (cleaning, descaling), cooling tower fill replacement, and drift eliminator inspection
- Emergency operating procedures for cooling water loss: manual addition of chilled water, ice, or emergency batch dumping to save equipment.

Anaerobic Digester Failure and Inefficient Digestion

Many ethanol plants employ anaerobic digestion (AD) of stillage (spent wash) to generate biogas (methane-rich fuel gas) and reduce effluent biological oxygen demand (BOD). Digesters are sensitive biological reactors; common failure modes include:
- Organic overloading: Feeding too much COD too quickly overwhelms methanogen capacity, causing volatile fatty acid (VFA) accumulation, pH drop, and reactor souring.
- Temperature shocks: Abrupt temperature changes (±3°C) stress microbial communities, reducing biogas yield.
- Toxic/inhibitory compounds: Heavy metals, antibiotics, disinfectants, or high ammonia levels inhibit methanogens.
- Foaming and scum formation: Lipids, proteins, and fibrous solids create persistent foam that reduces working volume and can clog gas lines.
- Hydraulic overload or short-circuiting: Inadequate mixing or retention time causes washout of active biomass.
- pH imbalance: Optimal pH for methanogens is 6.8–7.2; deviation outside 6.5–7.5 inhibits activity.

Digester upset leads to reduced biogas production, odour complaints (H_2S, mercaptans), potential over-pressurization if gas relief is inadequate, and in severe cases, structural failure or gas release incidents.

Typical safeguards (application):
- Online process monitoring: pH, oxidation-reduction potential (ORP), temperature, biogas flow rate and composition (CH_4, CO_2, H_2S), VFA concentration.
- Controlled feeding strategies: Step-wise increase of organic loading rate (OLR), feed dilution during start-up, use of buffer tanks to dampen flow and concentration variations.
- Temperature control: Insulation, heating coils or jacket, and cooling provisions to maintain mesophilic (35–37°C) or thermophilic (50–55°C) range.
- Alkalinity supplementation: Sodium bicarbonate or lime dosing to maintain buffering capacity.
- Gas management: Pressure relief valves, flame arrestors on gas collection headers, biogas desulphurisation (iron oxide or biological H_2S scrubbing).
- Mixing systems: Mechanical agitators, gas recirculation, or hydraulic mixing to prevent stratification and scum layers.
- Standard operating procedures (SOPs) for start-up, normal operation, troubleshooting, and emergency shutdown.
- Operator training on microbial process fundamentals, alarm response, and digester chemistry.

Confined Spaces, Fermentation CO_2 and Occupational Risks

Confined Space Entry (CSE) Management

The fatality risk in confined spaces demands rigorous procedural controls. A comprehensive confined space program includes:

1. Identification and inventory of all confined spaces; classification as permit-required confined space (PRCS) if atmospheric, engulfment, configuration, or other serious hazards exist
2. Pre-entry atmospheric testing for oxygen (acceptable 19.5–23.5%), flammable gas/vapour (<10% LEL), and toxic gases (CO_2, H_2S, CO) using calibrated multi-gas detectors
3. Lockout–tagout (LOTO) of all energy sources: mechanical isolation of inlet and outlet lines, electrical lockout of agitators/pumps, blanking of steam and chemical feeds
4. Mechanical ventilation: Continuous forced-air ventilation during entry, with exhaust positioned to remove contaminants
5. Permit-to-work system: Written entry permit signed by authorized supervisor, valid for single entry/shift
6. Attendant: Dedicated person stationed outside the confined space, maintaining visual/voice contact, never entering
7. Rescue equipment: Retrieval harness and winch, self-contained breathing apparatus (SCBA) for emergency rescue team, communication devices
8. Training and drills: Annual training for entrants, attendants, supervisors; mock rescue drills every six months

Fermentation Gas and Vapour Control

Carbon dioxide from fermentation is a silent asphyxiant; concentrations above 5% cause dizziness and rapid breathing, above 10% cause unconsciousness within minutes. Ethanol vapour, if not captured, creates flammable zones around fermentation tanks and in building headspaces.

Typical safeguards (application):

- Adequate general ventilation in fermentation halls: natural (ridge vents, louvres) or mechanical (roof exhaust fans) to maintain air changes per hour (ACH) ≥6.
- Local exhaust ventilation (LEV): Dedicated duct systems capturing CO_2/ethanol vapour from fermenter vents and routing to condensers or thermal oxidisers.
- Gas detection: Fixed CO_2 and flammable gas (LEL) detectors with audible/visual alarms in fermentation areas, pump rooms, and tank farms.
- Electrical area classification: Hazardous area zoning per IS/IEC 60079 (Zone 0, 1, 2 for vapour; Zone 20, 21, 22 for dust) with appropriately certified (Ex) electrical equipment.
- Personnel safety: Portable gas detectors for workers entering low-lying or enclosed areas; training on CO_2 asphyxiation symptoms and emergency evacuation.

Risk Management Framework

Hazard Identification

Formal studies for ethanol plants include HAZOP (systematic deviation analysis using guide words), What-If/Checklist, FMEA (component failure analysis), and QRA (quantitative fire/explosion/toxic release modelling). Indian environmental clearances require risk assessment reports covering all process units, storage, effluent treatment, and utilities.

Layered Protection Strategy

- **Inherent safety:** Minimise ethanol inventory, substitute less hazardous materials, operate at lower temperature/pressure
- **Engineering controls:** Containment, isolation (double block-and-bleed), explosion vents/suppression, fire

detection/suppression (foam, UV/IR detectors), instrumented safety systems (SIL-rated), pressure relief
- **Administrative controls:** SOPs, permit-to-work (hot work, confined space), shift handover, competency management, safety audits
- **Inspection/maintenance:** Risk-based inspection, NDT (ultrasonic, radiography), predictive maintenance (vibration, thermography), functional testing of safety-critical equipment
- **Emergency planning:** On-site/off-site plans, evacuation drills, firefighting strategy, mutual aid, root cause analysis of incidents

Conclusion

Ethanol plants integrate complex hazards: flammable vapours, explosive dust, confined spaces, and biological process upsets. Recent Indian incidents—Oasis Ethanol tank fire (Ambala, 2024, 1 fatality, 250,000 L loss), maize silo collapse (Sambhajinagar, 2024, 3–4 fatalities), LHSF distillery fire (Pilibhit, 90,000 L loss), and molasses spontaneous combustion events—demonstrate the severe consequences of inadequate hazard management.

Effective risk management integrates inherent safety, engineering controls (foam systems, explosion protection, instrumented safety), administrative safeguards (permit-to-work, SOPs, MOC), proactive inspection/maintenance, and emergency preparedness. Structured hazard identification (HAZOP, QRA), layered protection, and strong safety culture enable safe, reliable ethanol operations supporting India's biofuel goals while protecting workers, communities, and the environment.

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Yeast: The Unsung Hero of Ethanol Production

Understanding strain selection, stress tolerance, and maintaining viability in high-gravity fermentation.




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Introduction

The increasing global demand for sustainable and environmentally friendly energy sources has intensified interest in bioethanol as a renewable biofuel. Bioethanol is widely recognized as a viable alternative to fossil fuels because it can reduce greenhouse gas emissions and contribute to energy security. It is primarily produced through the microbial fermentation of sugars derived from various biomass sources, including sugarcane, corn, wheat, and lignocellulosic feedstocks. The efficiency of this process largely depends on the metabolic capabilities and physiological stability of the fermenting microorganisms.

Among the diverse microorganisms capable of ethanol fermentation, the yeast Saccharomyces cerevisiae is considered the most efficient and widely used organism in industrial bioethanol production. Its popularity stems from several advantageous traits, including a rapid fermentation rate, high ethanol yield, and a relatively strong tolerance to ethanol. These characteristics enable S. cerevisiae to efficiently convert fermentable sugars into ethanol under anaerobic conditions. However, despite its robustness, industrial fermentation environments expose yeast cells to multiple stresses that can compromise their metabolic activity, viability, and overall fermentation performance.

To improve ethanol productivity, industries increasingly employ high-gravity (HG) and very-high-gravity (VHG) fermentation technologies, which utilize high concentrations of sugars to achieve higher ethanol yields. In VHG fermentation, sugar concentrations can exceed 250 g L^{-1}, resulting in ethanol levels above 15% (v/v). However, such conditions create severe osmotic and ethanol stress, which can reduce yeast cell proliferation and fermentation performance.

Although several yeast species are capable of fermenting monomeric sugars to ethanol, many strains exhibit limitations under industrial conditions. Common challenges include low tolerance to ethanol, sensitivity to toxic inhibitors generated during biomass pretreatment, and reduced performance in high-sugar environments. These constraints highlight the need for the development of more robust yeast strains capable of maintaining high productivity under stressful fermentation conditions.

Advances in biotechnology have provided multiple strategies to overcome these limitations through yeast strain improvement. Genetic and metabolic engineering approaches have been extensively explored to enhance ethanol tolerance, stress resistance, and fermentation efficiency. Techniques such as randomized mutagenesis, metabolic pathway modification, promoter engineering, protein engineering, genome editing, and quantitative trait locus (QTL) analysis have all been applied to improve yeast performance. In addition, whole-genome sequencing and resequencing technologies have enabled deeper insights into the genetic basis of desirable fermentation traits, facilitating more targeted strain development.

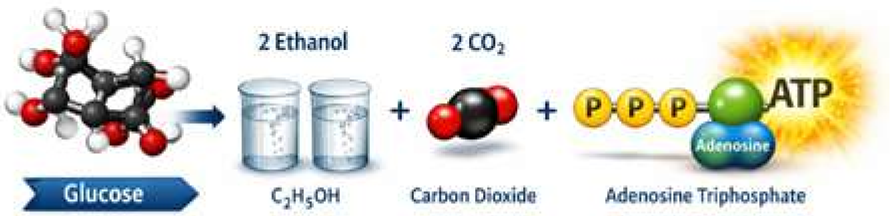
However, stress tolerance in S. cerevisiae is a complex phenotype controlled by multiple genes and regulatory networks, many of which remain poorly understood. This complexity makes the rational design of yeast strains with simultaneous resistance to multiple stresses particularly challenging. To address this issue, researchers have increasingly employed evolutionary engineering and adaptive laboratory evolution approaches. These methods rely on the natural selection of mutants under defined stress conditions, enabling the development of yeast strains with enhanced tolerance to osmotic pressure, ethanol toxicity, and other fermentation-related stresses. Such approaches are particularly valuable for improving traits that involve complex genetic interactions.

Yeast Metabolism and Ethanol Production

Yeast produces ethanol primarily through the process of alcoholic fermentation. In this pathway, glucose and other fermentable sugars are metabolized through glycolysis to produce pyruvate. Under anaerobic conditions, pyruvate is converted into ethanol and carbon dioxide.

The simplified reaction can be expressed as:

$$\text{Glucose} \rightarrow 2\ \text{Ethanol} + 2\ CO_2 + \text{Energy (ATP)}$$



This metabolic process allows yeast cells to regenerate NAD^+, which is essential for maintaining glycolysis under oxygen-limited conditions. The energy produced supports cellular maintenance and growth.

Although fermentation is a natural metabolic pathway, industrial ethanol production pushes yeast far beyond its natural environment. Fermentation tanks often contain extremely high concentrations of sugars and ethanol, which can inhibit cell growth and metabolic activity. Therefore, choosing the right yeast strain is critical for maintaining productivity.

Importance of Yeast Strain Selection

Yeast strain selection plays a crucial role in efficient ethanol production because different strains vary significantly in their fermentation performance. Even within the species Saccharomyces cerevisiae, strains show genetic and physiological differences that influence their growth rate, metabolic activity, stress tolerance, and ethanol productivity. Choosing the right strain helps ensure faster and more efficient fermentation, leading to higher ethanol yields and shorter processing times. An ideal industrial yeast strain must be able to tolerate challenging conditions such as high sugar concentrations, increasing ethanol levels, temperature fluctuations, and limited nutrient availability. In contrast, selecting an unsuitable strain can result in slow fermentation, reduced ethanol production, and decreased yeast viability. Therefore, careful selection and improvement of yeast strains are essential for maintaining consistent fermentation performance and maximizing ethanol production in industrial processes.

Key Characteristics of an Ideal Ethanol-Producing Yeast

An effective industrial yeast strain is characterized by several important traits that ensure efficient ethanol production. It should exhibit high ethanol productivity while maintaining strong tolerance to ethanol toxicity that builds up during fermentation. Additionally, the yeast must be able to grow and function in environments with high sugar concentrations and perform fermentation at a rapid rate to maximize production efficiency. Resistance to stresses such as osmotic stress from high sugar levels and thermal stress from high temperature during process, is also essential. Moreover, the strain should remain stable and maintain its performance over multiple fermentation cycles to ensure consistent industrial productivity.

Some industrial strains are specifically engineered or adapted to ferment not only glucose but also other sugars such as xylose or arabinose, particularly in lignocellulosic ethanol production. Strain improvement strategies include adaptive evolution, hybridization, mutagenesis, and genetic engineering. These approaches aim to enhance fermentation efficiency while increasing stress tolerance.

Stress Factors in Industrial Fermentation

During ethanol production, yeast cells are exposed to multiple stress factors that can significantly affect their performance.

Ethanol Stress: Ethanol itself is toxic to yeast cells at high concentrations. It disrupts cell membranes, affects protein stability, and interferes with metabolic pathways. As ethanol accumulates during fermentation, yeast growth slows down and eventually stops.

Osmotic Stress: High sugar concentrations at the beginning of fermentation create osmotic pressure around yeast cells. This can lead to dehydration of the cell and reduced metabolic activity.

Temperature Stress: Industrial fermentation tanks may experience temperature fluctuations due to metabolic heat production. Elevated temperatures can damage proteins and reduce enzyme activity within the cell which ultimately decreases yeast viability.

Nutrient Limitations: Yeast requires adequate nitrogen, vitamins, and minerals to synthesize essential cellular components such as nucleic acids and proteins, which are critical for proper growth and metabolic activity. A deficiency in these nutrients can limit yeast growth, resulting in sluggish fermentation and reduced ethanol yield. Together, these stress factors challenge yeast survival and productivity. Successful fermentation, therefore, depends on strains that can tolerate these harsh conditions.

High gravity fermentation

It is widely used in modern ethanol production due to its ability to enhance efficiency and reduce processing costs. In this approach, fermentation begins with a high concentration of fermentable sugars (typically above 200 g/L) from sources such as molasses or corn hydrolysates, resulting in higher ethanol production per batch. The increased final ethanol concentration lowers energy requirements during distillation and improves overall productivity. Additionally, this process requires less water, reduces wastewater generation, and allows better utilization of existing fermentation infrastructure, making it economically advantageous. Successful implementation, however, depends on the use of robust yeast strains along with proper nutrient supplementation, temperature regulation, and oxygen management.

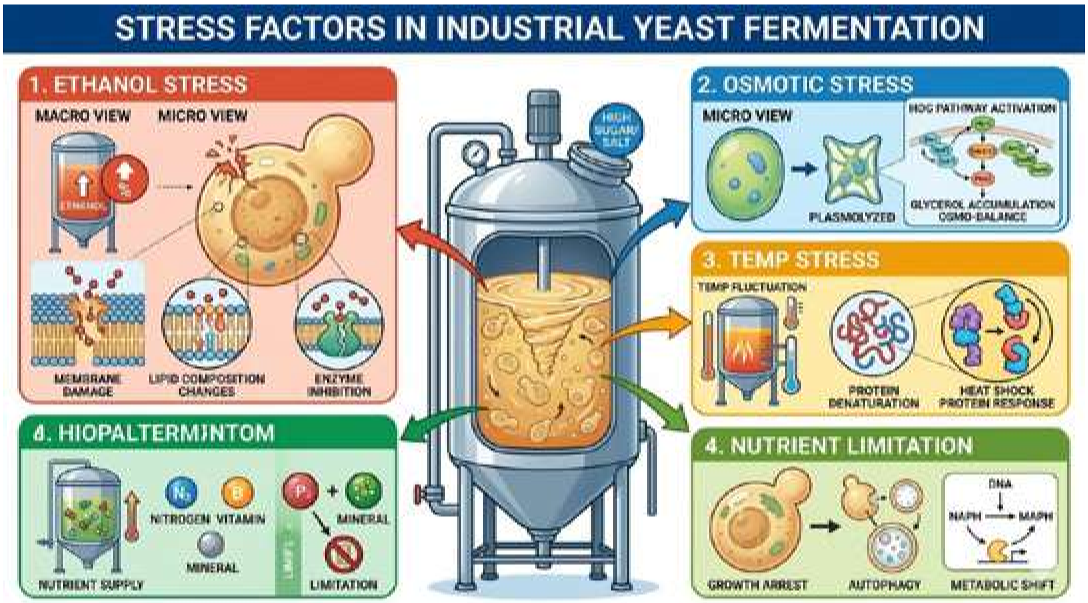
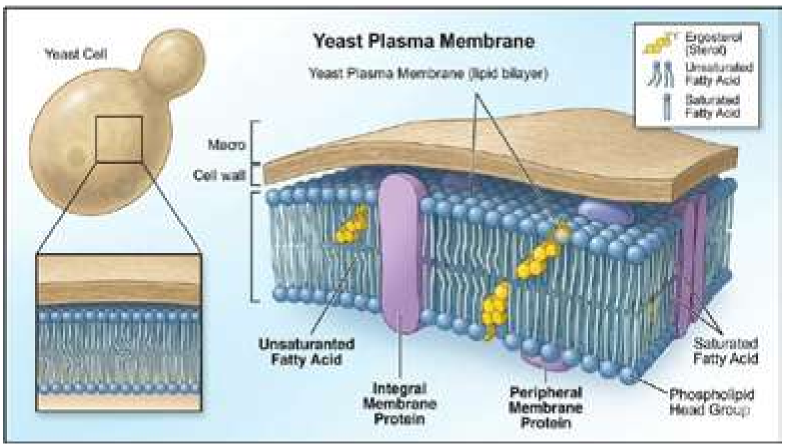


Figure. Factors affecting fermentation process in yeast cell.

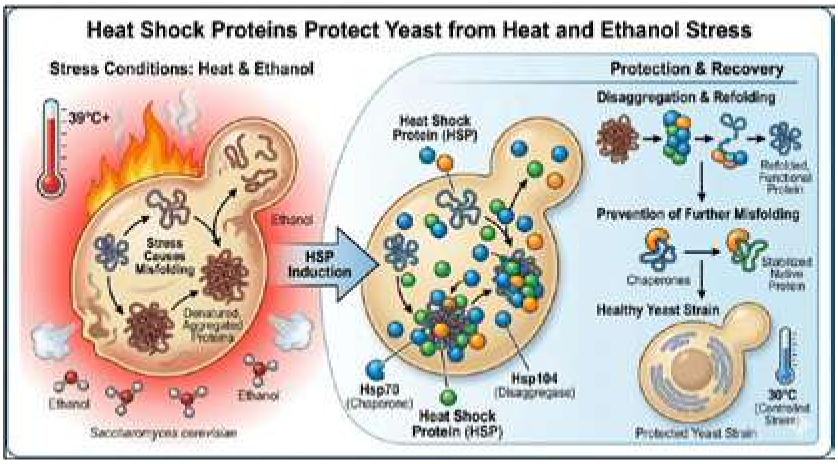
Despite its advantages, high gravity fermentation presents several challenges that can impact yeast performance and process efficiency. The high initial sugar concentration creates osmotic stress, which can inhibit yeast growth and metabolic activity. As fermentation progresses, accumulating ethanol exerts toxic effects on yeast cells, compromising membrane integrity and reducing viability. Furthermore, increased metabolic activity generates excess heat, leading to temperature stress, while potential nutrient limitations in high sugar environments can further slow fermentation. If not properly managed, these combined stresses can reduce yeast activity, resulting in lower fermentation efficiency and productivity.

Mechanism of Yeast Stress Tolerance

Yeast cells possess various natural protective mechanisms that help them survive and remain active under stressful fermentation conditions. To manage these stresses, yeast cells adjust the composition of their cell membranes and produce protective compounds such as glycerol and trehalose that help maintain cellular stability. They also activate stress-response systems, including the production of heat shock proteins that safeguard important enzymes and cellular proteins from damage. Additionally, yeast cells utilize antioxidant defenses to reduce the harmful effects of reactive oxygen species formed during stress. Through these adaptive responses, yeast is able to sustain its metabolic functions and continue producing ethanol even in harsh industrial fermentation environments.

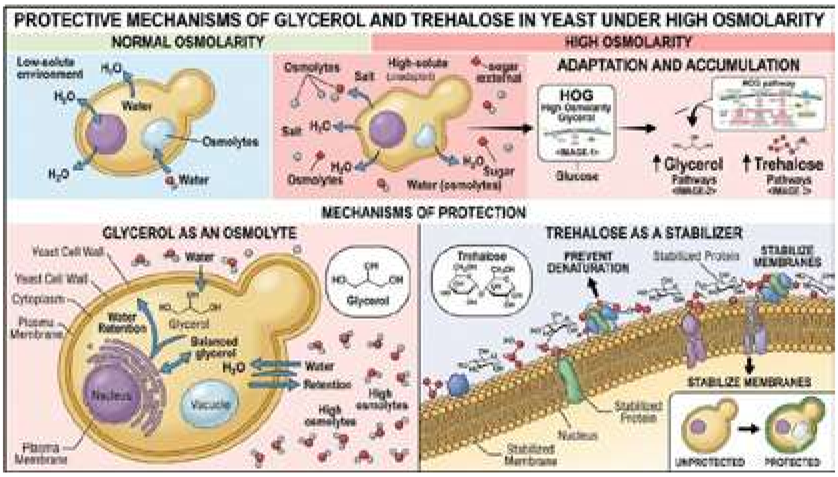


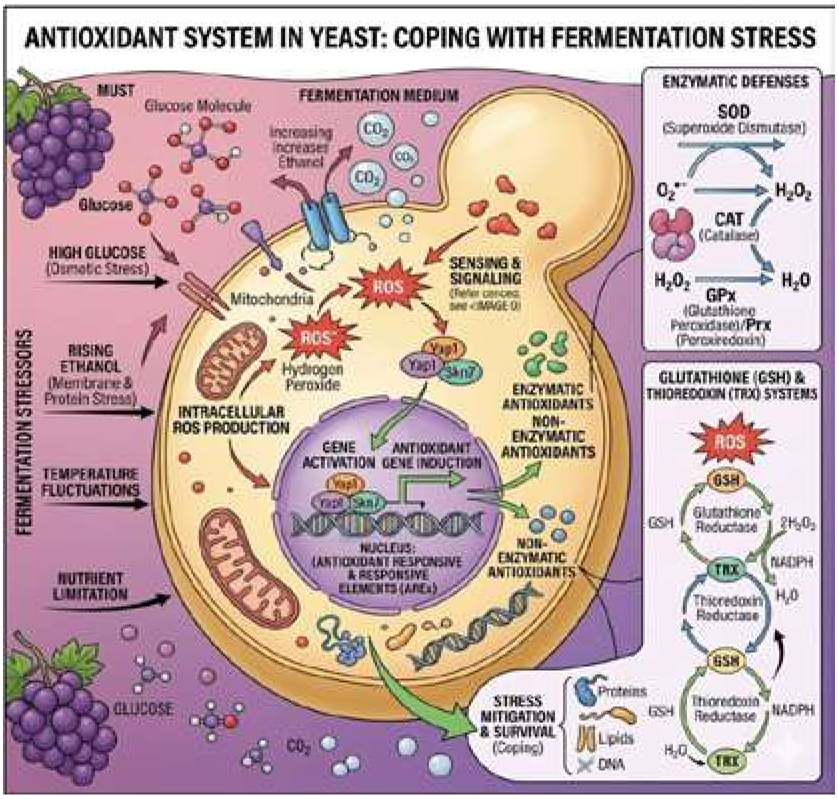
Membrane Adaptation: Yeast cells can modify the composition of their cell membranes by increasing unsaturated fatty acids and sterols. This helps maintain membrane fluidity even in the presence of high ethanol concentrations.



Heat Shock Proteins: Heat shock proteins act as molecular chaperones that protect other proteins from damage during stressful conditions such as heat or ethanol exposure.

Osmo Protectant Production: Yeast accumulates compounds like glycerol and trehalose, which help balance osmotic pressure and protect cellular structures.





Antioxidant Systems: Fermentation stress can generate reactive oxygen species. Yeast cells produce antioxidant enzymes to neutralize these harmful molecules.

Maintaining Yeast Viability in Industrial Fermentation

Ensuring that yeast remains active and viable throughout fermentation is essential for maintaining high ethanol yield and overall productivity. Yeast cells are responsible for converting sugars into ethanol, so their health directly affects the efficiency of the fermentation process. During industrial fermentation, yeast faces stressful conditions such as high sugar levels, rising ethanol concentrations, and temperature changes, which can weaken the cells and slow fermentation. If yeast loses its viability, the conversion of sugars becomes inefficient and ethanol production decreases. Therefore, maintaining suitable conditions such as proper nutrient supply, controlled temperature, and balanced fermentation conditions helps keep yeast healthy and active. By protecting yeast viability, industries can achieve stable fermentation performance and consistent ethanol production.

Nutrient Supplementation: Providing adequate nitrogen sources, vitamins, and trace elements can improve yeast metabolism and stress resistance.

Temperature Control: Maintaining optimal fermentation temperatures helps prevent thermal stress and preserves yeast activity.

Yeast Recycling and Propagation: Industrial ethanol plants often reuse yeast across multiple fermentation cycles. Proper propagation techniques help maintain a healthy yeast population.

Oxygen Management: Although fermentation is anaerobic, small amounts of oxygen at the beginning of fermentation can help yeast synthesize sterols and fatty acids necessary for membrane stability.

Contamination Control: Bacterial contamination can compete with yeast for nutrients and produce inhibitory compounds. Strict hygiene and monitoring are essential to maintain fermentation efficiency.

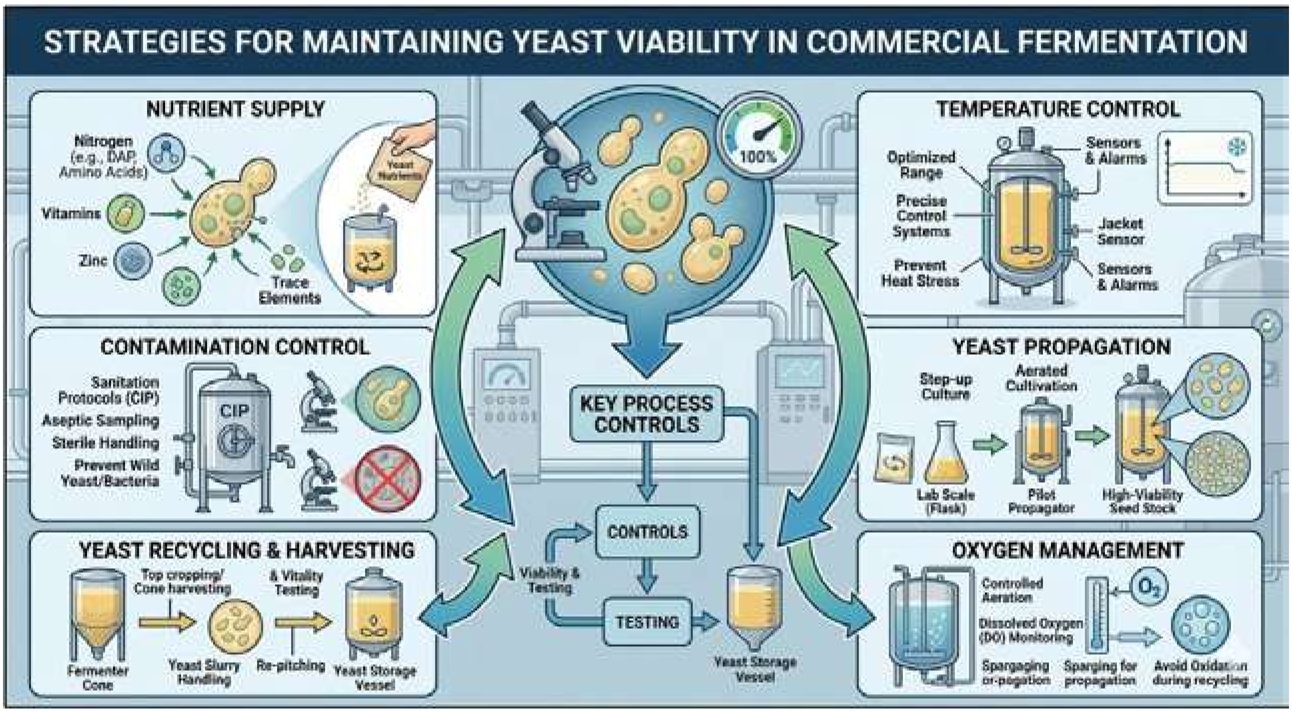


Figure. Strategies to maintain yeast viability in fermentation

Future Perspectives

Recent developments in biotechnology are creating new opportunities to improve yeast performance in ethanol production. Modern techniques such as genetic engineering and systems biology are being used to develop advanced yeast strains with enhanced ethanol tolerance, faster sugar consumption, and the ability to utilize a wider range of substrates. These improvements can help increase fermentation efficiency and ethanol yield, especially when using diverse feedstocks like lignocellulosic biomass. In addition, synthetic biology is providing innovative tools to design and construct customized yeast strains specifically suited for demanding industrial fermentation conditions. As the global need for sustainable and renewable energy sources continues to rise, enhancing yeast efficiency and resilience will remain an important focus in future bioethanol research and industrial development.

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Understanding Viscosity and Foaming in Rice and Maize-Based Fermentation

Impact on Fermentation Performance

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Introduction

Rice and maize are widely used cereal substrates in fermentation systems for the production of fermented foods, beverages, and industrial bioproducts. During fermentation, physicochemical properties such as viscosity and foaming behaviour significantly influence microbial activity, mass transfer, and overall fermentation performance. These properties depend largely on starch composition, enzymatic degradation, microbial metabolism, and process conditions. Understanding the interaction between viscosity, foaming, and fermentation dynamics is therefore essential for optimizing cereal-based fermentation processes.

Role of Starch in Viscosity Development

Rice and maize contain large amounts of starch, mainly composed of amylose and amylopectin. When cereal substrates are heated during processing, starch granules swell and gelatinize, forming a viscous paste. The temperature at which this swelling begins is known as the pasting temperature, and it marks the formation of a viscous starch network in aqueous systems.

During fermentation, microorganisms such as yeasts, Molds, and lactic acid bacteria produce hydrolytic enzymes, particularly α-amylase and glucoamylase, which break down starch polymers into smaller sugars. This enzymatic degradation gradually reduces the viscosity of the fermentation medium by converting large starch molecules into smaller dextrin's and fermentable sugars. The reduction in viscosity is particularly important in cereal fermentations because high viscosity can restrict mixing and limit the diffusion of nutrients and metabolites.

Changes in Viscosity During Rice and maize Fermentation

Fermentation significantly modifies the physicochemical properties of rice flour and starch. Studies have shown that fermentation may reduce parameters such as peak viscosity, final viscosity, and gelatinization temperature due to the partial hydrolysis of starch and structural modifications of amylopectin. Natural fermentation can also alter protein composition on the surface of starch granules. These changes affect the interactions between starch and proteins, which in turn influence gelatinization and viscosity behaviour of rice-based systems. Additionally, fermented rice extracts often exhibit non-Newtonian flow behaviour, meaning their viscosity decreases as shear rate increases. This rheological property allows fermented rice products to flow more easily during processing and consumption.

Maize fermentation shows similar trends, although the magnitude of viscosity changes can vary depending on the processing conditions and enzymatic activity. Studies have demonstrated that adding malted cereals to fermented maize significantly reduces peak viscosity due to the action of amylases produced during malting. Lower viscosity in fermented maize systems improves cooking properties and facilitates the preparation of cereal-based foods such as porridges and fermented beverages. The reduction in viscosity is particularly beneficial in high-solid fermentations, where thick slurry conditions may otherwise limit microbial growth and fermentation efficiency.

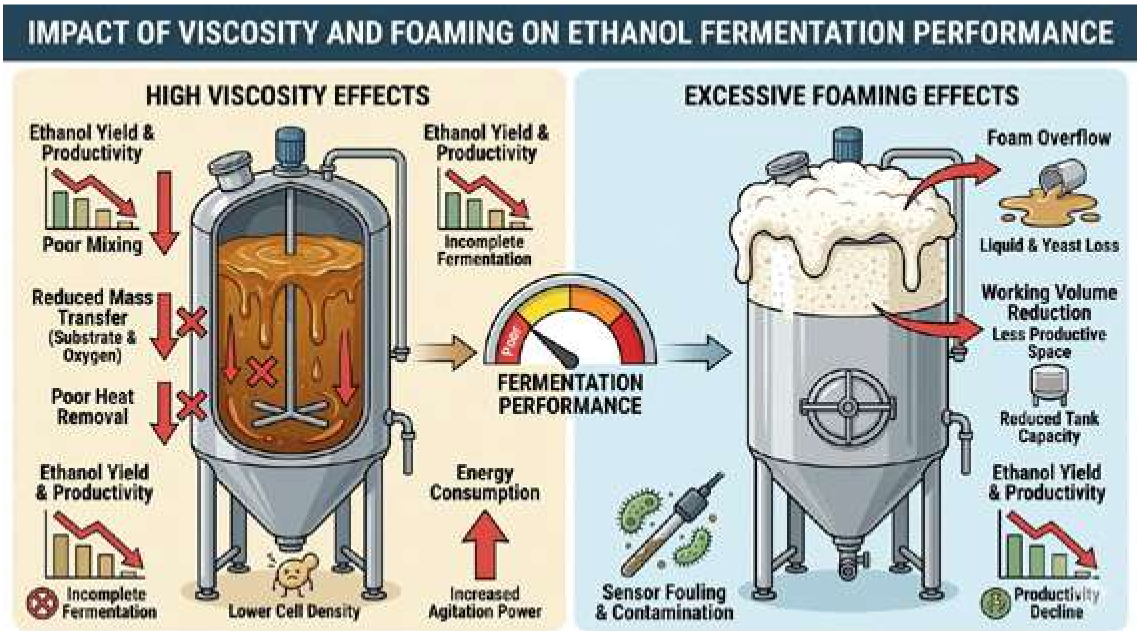

Figure. Impact of Viscosity and foaming in ethanol fermentation

Role of Foaming in Fermentation

Mechanism of Foam Formation

Foaming is a common phenomenon in fermentation processes, arising from the accumulation of gas bubbles stabilized by surface-active compounds. In cereal fermentations, it primarily occurs due to the production of carbon dioxide during microbial metabolism, along with the presence of proteins and peptides that help stabilize the bubbles. Additionally, microorganisms may produce extracellular polysaccharides that further contribute to foam formation. These compounds reduce surface tension and promote the formation of stable gas–liquid interfaces, allowing foam to persist throughout the fermentation process.

Foaming Behaviour in Cereal-Based Fermentation

In rice and maize fermentation systems, the hydrolysis of proteins and carbohydrates during fermentation releases molecules that can act as natural foaming agents. Proteins derived from cereal grains are particularly effective in stabilizing foam structures because they form elastic films around gas bubbles.

Moderate foam formation can be beneficial in fermentation as it facilitates gas exchange and indicates active microbial activity. However, excessive foaming can lead to several operational challenges, such as overflow of fermentation vessels, loss of fermentation medium, increased risk of contamination, and difficulty in controlling key process parameters. Therefore, foaming is considered an important process variable that must be carefully managed in both food fermentation and industrial bioprocessing.

Relationship Between Viscosity and Foaming

Viscosity and foaming are closely interconnected properties in fermentation systems. The viscosity of the fermentation medium influences the stability and lifetime of foam bubbles.

High Viscosity

- Slows liquid drainage from foam films
- Stabilizes bubbles
- Leads to persistent foam formation

Low Viscosity

- Allows faster bubble collapse
- Reduces foam stability
- Improves mixing and gas release

In cereal-based fermentation systems, starch degradation gradually lowers viscosity. As fermentation progresses, the reduced viscosity often results in less stable foam and improved mixing conditions.

Effect of Viscosity and Foaming

Viscosity and foaming play a crucial role in determining fermentation performance by influencing mass transfer, mixing, microbial growth, and overall process stability. High viscosity restricts the movement of nutrients, oxygen, and metabolites within the fermentation broth, which can limit microbial growth and reduce fermentation efficiency. It also increases the energy required for mixing and may lead to uneven temperature distribution, creating gradients within the fermenter. In contrast, lower viscosity enhances heat transfer, ensures uniform conditions, and supports efficient microbial metabolism by improving nutrient uptake and waste removal, ultimately increasing fermentation rates.

Foaming, while sometimes beneficial, can negatively impact process stability when excessive. It may lead to overflow of fermentation vessels, loss of broth, and increased risk of contamination, making it difficult to maintain controlled fermentation conditions. Therefore, managing both viscosity and foam is essential for stable and efficient fermentation processes.

To control these factors in rice and maize fermentation, several strategies are employed. Enzymatic treatment using enzymes such as amylases helps break down starch molecules, thereby reducing viscosity. Additionally, malting or germination of cereals activates endogenous enzymes that hydrolyse starch, further improving fermentation performance by lowering viscosity and enhancing substrate availability.

Process Optimization

Adjusting key process parameters such as **temperature, pH, solid concentration,** and **fermentation time** can significantly influence both viscosity and foam formation during fermentation. Proper optimization of these factors helps maintain ideal fermentation conditions and improves overall process efficiency. Additionally, industrial fermentation systems commonly employ **antifoaming agents or mechanical foam** breakers to control excessive foam accumulation and ensure stable operation.

Conclusion

Viscosity and foaming are critical physicochemical properties influencing the efficiency of rice and maize fermentation systems. These parameters are largely governed by starch gelatinization, enzymatic hydrolysis, microbial metabolism, and substrate composition. Fermentation generally leads to a reduction in viscosity due to enzymatic breakdown of starch, which improves mixing, mass transfer, and microbial activity. Meanwhile, foaming arises from gas production and the presence of surface-active compounds derived from cereals and microbial metabolites. Proper control of viscosity and foam formation is therefore essential for optimizing fermentation performance and ensuring the quality and stability of cereal-based fermented products.

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Sustainable Aviation Fuels (SAF) from Carbon dioxide captured in Grain & Molasses distilleries

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The aviation sector is responsible for a significant share (2-3%) of global greenhouse gas emissions. To reduce its environmental impact, the industry is increasingly focusing on Sustainable Aviation Fuels (SAF). Sustainable Aviation Fuels (SAF) is high quality alternative to traditional fossil fuels-based jet fuel produce from the renewable and waste derived source. SAF currently represents a small fraction of total global aviation fuels consumption as worldwide blending accounted approximately 0.6-0.7% till 2025, which is almost negligible in India. At present, SAF is primarily generated from cooking oil, animal fats, and vegetable oils through the HEFA (Hydro processed ester and fatty acids) pathway which accounts for approximately 80% of total SAF production. In this process oxygen is removed from the fats and oils using hydrogen and high-temperature catalytic reactions, creating hydrocarbons that are then cracked and isomerized into drop-in jet fuel, reducing lifecycle emissions by up to 80%.

Recently, Indian Oil Corporation Ltd. (IOCL) has started the production of SAF at its Panipat refinery using this process. The plant will produce 35,000 tons SAF annually from used cooking oil and fats. India has set a 5% Sustainable Aviation Fuel (SAF) blending target for international flights by 2030, with phased mandates of 1% by 2027 and 2% by 2028.

SAF production using CO2 from distilleries

One promising pathway involves capturing carbon dioxide (CO_2) generated during fermentation in grain and molasses distilleries and converting it into aviation fuel through advanced technologies contributing to a Circular Carbon Economy. This Power to Liquid hybrid approach turns a waste byproduct of ethanol production into high energy value and this approach integrates carbon capture, utilization, and renewable fuel production.

Advantages of using CO2 from the distilleries

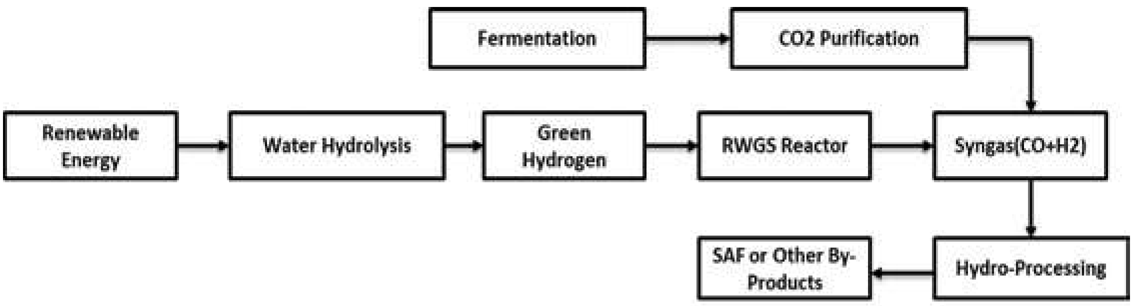
- **High purity** – Unlike the dirt smoke from a coal-based plant, CO_2 generated from the fermentation is nearly 99% pure.
- **Low capture cost** – CO_2 gas is already present in higher concentration, so the energy required to capture and purify the gas is lower than other sources like flue gas and environment.
- **Additional revenue** – Distilleries can generate the significant revenue from the waste byproduct of fermentation.
- **Environment friendly** – SAF produced this way can reduce the carbon emissions by up to 80% as compared to the currently using the fossil fuels.
- **Circular carbon cycle** – The SAF is burned by the jets to convert back it into carbon dioxide; which is just returned to the environment. This creates a carbon economy cycle rather than adding carbon from a new fossil fuel to the atmosphere.

Conversion process from CO2 to Aviation Fuels

We must require following reverse combustion process to convert carbon dioxide to aviation fuels. Since CO_2 is stable, energy must be added in form of "green hydrogen" to turn CO_2 into high energy liquid fuels. The conversion process is carried by chemical synthesis process called Power to Liquid pathway. It is also commonly referred to e-Fuels pathway or Synthetic kerosene production.

Chemically, this transformation relies on the Fischer-Tropsch (FT) synthesis process.

- **Carbon dioxide capture and purification** – During fermentation, yeast converts sugars into almost equal amount of ethanol and carbon dioxide, and the gas is directly captured from the fermenters. It undergoes basic purification to remove moisture and trace organic compounds (sulfur, higher alcohols and aldehydes) that could be harmful to the catalyst which is used in conversion process.
- **Green Hydrogen Production (Electrolysis)** – The green hydrogen gas for SAF production can be produced by electrolysis, which involves using renewable electricity to split water molecules into hydrogen and oxygen. Since SAF production requires massive amounts of hydrogen to re-energize the CO_2 from distillery, purified water and electricity (wind, solar or Hydro). The reaction is –
  $2H_2O + \text{Electricity} \rightarrow 2H_2 + O_2$
- **Reverse water gas shift** – Carbon dioxide is stable, so to turn it directly into fuels it must be first converted to carbon monoxide (CO). The reaction is –
  $CO_2 + H_2 \rightarrow CO + H_2O$



Flow Diagram of CO2 to SAF (Sustainable Aviation Fuel)

In the overall reaction, carbon dioxide (captured from distillery) reacts with green hydrogen over a catalyst to produce CO and water vapors.

- **Syngas production** – The resulting carbon monoxide mixed with more green hydrogen. This mixture is called Syngas (Synthesis gas)

- **Fischer-Tropsch synthesis** – The syngas is passed through a reactor containing a catalyst (Iron or Cobalt) at high pressure and temperature.
    - Carbon and hydrogen are relinked into the long chain called Hydrocarbon.
    - This creates a synthetic crude oil which contains mix of waxes, diesel and kerosene.
- **Hydrocracking and Refining** – The synthetic oil is then cracked and refined like crude oil in refinery. The long wax chain is broken down into simple molecules required for the jet fuels. The high-performance liquid fuels produced this way are chemically identical to the fossil-based kerosene-type jet fuel, but has zero net new carbon.

Challenge and limitations

- **High cost of Green Hydrogen** – To convert carbon dioxide into SAF, the process requires massive amount of green hydrogen and production of green hydrogen is an expensive process.
- **High sulfur challenge for molasses distilleries** – Molasses fermentation often produces gas with high levels of hydrogen sulfide and organic compounds, adding to purification costs
- **High Purity of CO_2** – Fischer-Tropsch catalyst are very sensitive to traces of sulfur, nitrogen, or higher alcohols so distillery should be required to purified near to 99.9- 100% pure carbon dioxide for the SAF.
- **Water consumption** – Requires large volumes of water for the electrolysis process to produce green hydrogen.

Conclusion

Producing Sustainable Aviation Fuels (SAF) by utilizing CO_2 is from Grain and Molasses distilleries are technically viable, decarbonizing and high energy pathway offering up to 80% lower greenhouse gas emissions, compared to fossil fuels. It is transformation of waste into wealth. The distillery CO_2 is biogenic and highly pure, and it could be the most efficient feedstock for the Power to Liquid pathway. It also avoids the land use conflict of traditional biofuels and the high cleaning cost of industrial flue gas.

"By closing the carbon loop, distilleries are no longer just a part of agriculture economy, they are the new oil field for the Sustainable era"

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Contamination Control in Fermentation

Prevention is Better Than Cure

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The bioethanol visibility in the global matrix of fuels, linked to ecological appeal and the possibility of using new raw materials justifies the increasing investments for the development of new processes. This fuel results from fermentation of sugars by yeasts, that are very useful microorganisms that are used in many industrial fermentation processes such as food and alcohol production.

The lactic acid bacteria and wild yeasts are the main contaminants, affecting yeasts performance and leading to negative impacts such as the formation of organic acids, polysaccharides and gummy biofilms. Contamination control in industrial fermentation is a critical, often daily battle, where prevention is better than cure. In industries such as wine, brewing, bioethanol and food production, a single contamination event can destroy weeks of work, cause massive financial losses, and result in contaminated products.

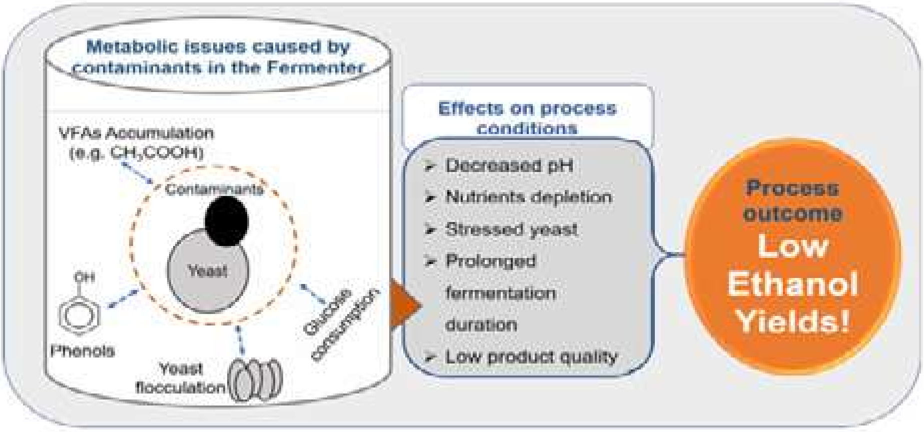
Microorganisms Commonly Associated with Contamination

- *Lactobacillus, Pediococcus, Leuconostoc and acetobacter* are the most common bacterial contaminants, particularly in fuel ethanol and beer, adapted to thrive in low pH, high alcohol conditions.
- *Dekkera bruxellensis* yeast is a notorious spoilage organism in wine and ethanol, reducing yield, creating phenolic off-flavors, and producing excessive acetic acid.
- *Schizosaccharomyces* and Candida, along with LAB, compete with yeast for nutrients and produce by-products like lactic and acetic acids, reducing ethanol yield.

Barriers to Effective Contamination Control

Multiple factors make contamination control in fermentation particularly difficult from operational complexity and risks to the sensitivity of fermentation organisms.

- **Complexity of fermentation environments:** High-nutrient fermentation creates ideal conditions for microbial growth. Extended process provides multiple opportunities for contaminants to enter fermentation processes.
- **Sensitivity of fermentation organisms:** Production strains, particularly genetically modified variants, are often less robust than unmodified, wild-type organisms. The increased sensitivity means naturally occurring contaminating organisms frequently outcompete production strains, leading to rapid process deterioration.
- **Operational and equipment risks:** Human error is a persistent risk factor in fermentation, particularly during manual interventions such as sampling, nutrient additions, or equipment adjustments.



Consequences of Contamination during fermentation (Ceccato-Antonini, 2018)

Technologies employed for the control of contaminants in ethanol fermentation processes

Microbial contaminants remain a major problem in ethanol processing plants, leading to huge financial losses. This calls for the development of robust biotechnological techniques that can be used to circumvent this problem.

Bio preservation technology

Bio preservation technology leverages the metabolites from various animals, plants, and microorganisms to inhibit or eradicate harmful microbes. Owing to their natural origin, these metabolites are generally considered safe, serving as natural preservatives.

Natural compounds

Natural products are derived from sources such as plants, animals and microorganisms. They are well known for their bactericidal properties, non-toxic nature, biodegradability, biocompatibility, and cost-effectiveness. Some of the Natural compounds with antimicrobial activities are Hop compounds, Chitosan, Chitosan nanoparticles and Chitosan nanofibers.

Antimicrobial agents

Currently, bio preservatives like nisin, natamycin, and antimicrobial enzymes have been successfully implemented (Grabowski et al., 2021). Their antimicrobial action involves impeding microbial metabolism and disrupting the cellular membrane components. Bacterial contaminants in ethanol fermentations can be controlled using different formulations of enzymatic antimicrobial mixtures typically regarded as safe for use. Apart from these, various antibiotics have also been explored, however, continuous or improper use of commercial antibiotics, penicillin and virginiamycin can lead to antibiotic resistant microorganisms, reducing long-term effectiveness.

Chemical treatments

A wide range of chemical disinfectants for Clean-in-Place (CIP) systems in fermenters has been evaluated under laboratory-scale conditions. These include sulfuric acid, phosphoric acid ammonia, hydrogen peroxide, chlorine dioxide, sulphur dioxide, amongst others. Acids are the most common disinfectants used to combat contamination in ethanol fermentations.

Thermal Sterilization

Thermal sterilization is the most widely used and reliable method for eliminating microbial contamination in fermentation processes. It involves the application of heat to destroy microorganisms, including bacteria, fungi, viruses, and even heat-resistant spores. However, its application in large scale fermenters in distilleries is limited due to the lack of techno-economic feasibility.

Special gas sterilization technology

Specific gases like ozone, chlorine dioxide and carbon dioxide are recognized for their sterilizing capabilities in food preservation. Ozone's sterilization is thorough, rapid, and leaves no residue, making it a favoured choice in the food industry (Pandiselvam et al., 2019). Carbon dioxide, on the other hand, naturally impedes the growth of aerobic microorganisms. Its effectiveness, reduction of microorganisms more than 90%, is enhanced when combined with environments of high or low pH, making it effective at controlling microbial presence in food (Li et al., 2023).

Irradiation sterilization technology

Radiation sterilization, utilizing radio waves, visible light, ultraviolet light, X-rays, gamma rays, cosmic rays, or accelerated electron rays, is known for its deleterious effects on microorganisms. Due to its strong penetrative ability, radiation can effectively exterminate 100% microorganisms within food (Stefanova et al., 2010). However, its application in the distilleries is limited due to the techno-economic feasibility.

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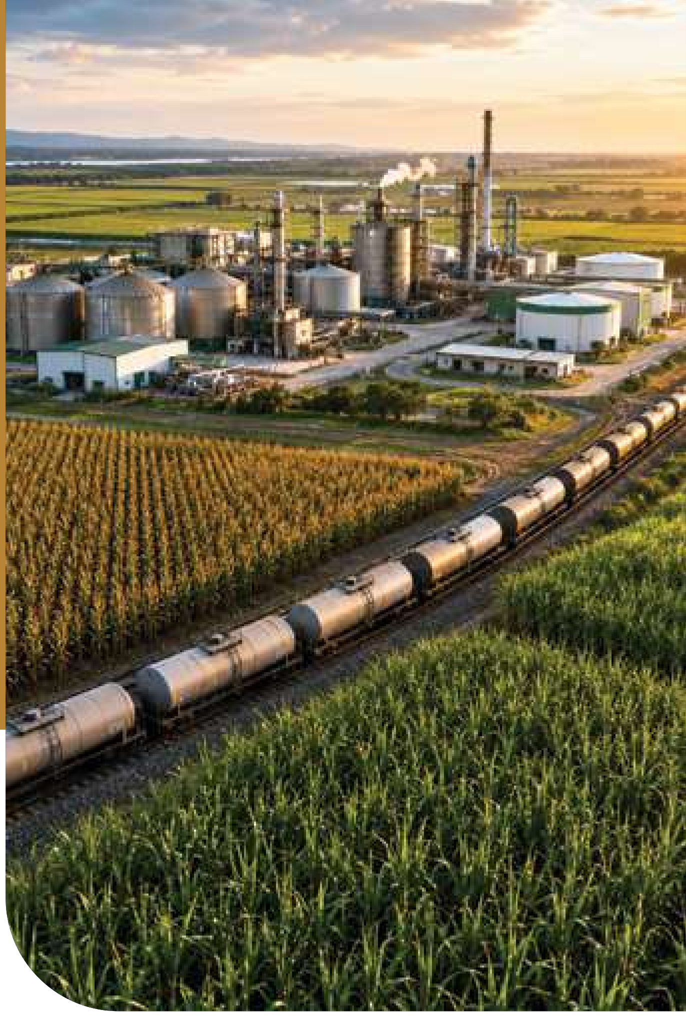
Exploring US and Brazil's Landscape for Bioethanol Production



Opportunities, Incentives, and Challenges

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Technical Sales Manager Latam – Leaf

United States and Brazil are leading the charge as the world's largest producers and consumers of ethanol. Each nation offers unique insights, varying dynamics, and different incentives for the future of bioethanol production.

Capturing Different Dynamics in Leading Markets

The U.S. ethanol market is driven by a **robust regulatory framework** and a strong focus on technological advancements. The EPA's Renewable Fuel Standard (RFS) mandates the blending of renewable fuels – including ethanol – into transportation fuel. This policy was a major catalyst and led to an increase in ethanol production and consumption over the years. In 2023, the U.S. produced **over 56 billion liters** of ethanol [1], and the recent introduction of **year-round E15** [2] would likely further bolster the domestic market and provide new avenues for growth. Indeed, widespread adoption of E15 would offer consumers a more **cost-effective** and **environmentally friendly** option at the pump and further foster energy security by reducing the impact of gasoline shortfalls.

With production reaching over **37 billion liters** of ethanol in 2025 [3] and a historically extensive sugarcane-based production, Brazil's ethanol market is second in size to the U.S. market. The market partly owes its stability to the government's **RenovaBio program** which recognizes the strategic role of ethanol in the Brazilian energy matrix for its contribution to **energy security** and **mitigation of GHG emissions** in the fuel sector. As a reflection of the current legislation and robustness of the ethanol industry in Brazil, blending rates in Brazil vary from 18% to 27.5% ethanol to gasoline [4], whereas pure gasoline and E5, E10, and E15 are not available at the pump, contrary to the U.S. More recently, the government enacted the **Fuel of the Future law** – instituting programs to foster research, production, trade, and use of biofuels to promote sustainable transportation and mobility – which increases **ethanol blending to 35%** and now includes **sustainable aviation fuels** as part of the Brazilian energy matrix.

However stable, Brazil's ethanol landscape has significantly evolved in the last decade with the emergence of **corn-based production** and **second-generation ethanol** production. Corn ethanol now accounts for 20% of the total ethanol production and is expected to rise even further in the coming years. This feedstock diversification has been driven by several factors, including the **seasonality of sugarcane** harvests and opportunities for **diversification**. On the other end, the emergence of 2G ethanol produced from sugarcane bagasse, also gained significant traction in Brazil, with plans to build new plants in the future.

Tackling America's Opportunities for Bioethanol Production With the Right Yeast Products

Despite the challenges associated with each feedstock, such as contamination and seasonality for sugarcane in Brazil, price volatility for corn in both nations, and high production costs for second-generation ethanol, **the US and Brazilian ethanol industries remain resilient**. To stay competitive and increase their profitability, ethanol producers are looking at maximizing their production **yields** and **efficiency** while minimizing costs and environmental footprint. To do so, they can turn to **appropriate yeast solutions**.

Advanced yeasts, in that sense, display higher **yields**, a higher **tolerance to osmotic stress**, and allow for smarter **management of inputs** – *when compared to traditional yeasts*. Overall, engineered yeasts have been paving the way for **increased efficiency, cost savings, and sustainable practices**.

When it comes to **corn-based ethanol production**, Evolve™ Evergreen already proved its value, both at lab- and industrial scales. Its **reliability**, even under a wide range of temperatures, enables **consistent fermentation** and sustaining plant performances. Through its enhanced metabolic capabilities, Evolve™ Evergreen's glucoamylase (GA) expression enables a **reduction of exogenous GA**, allowing smart management of inputs, which plays a role in the overall reduction of ethanol plants' operating costs.

CelluX™ 4 contributes to the industrial development of cellulosic ethanol production by derisking the fermentation of cellulosic hydrolysates. CelluX™ 4 demonstrates the ability to **resist stresses** and **maintains higher cell viability** during fermentations of hydrolyzed cellulosic material.

The Importance of Technical Support and Fermentation Nutrients

Along with the use of an appropriate yeast product to produce ethanol from the available feedstock, other parameters are crucial, such as micro and **macronutrition** to support fermentation and adequate **technical support** to make the most of current inputs.

Yeast nutrition is a key factor in the **productivity** and **viability** of ethanol production, in which reaching the highest yields and improving **fermentation consistency** are essential conditions. While the addition of nutrient supplementation does not provide guaranteed ethanol yield increases, it reduces the **variability** experienced within fermentation as a result of conditions such as varying feedstock quality, process upsets, and stressful conditions – *e.g., high heat, high osmotic stress, inhibitors*.

On the other hand, suitable **technical support** is equally important when it comes to ensuring the best performance of ethanol production. Working **in continuous collaboration** with industrial experts and product application specialists supports successful operations. At Leaf, we support ethanol producers with **a technical approach based on scientific method**. Starting from the process, we diagnose deviations and establish a baseline for your process. By defining a **performance improvement project** together, we work on the refinement of KPIs – *ethanol yield, plant productivity, or energy savings*. Thanks to established goals and data, our technical experts formulate custom recommendations to reach maximum efficiency.

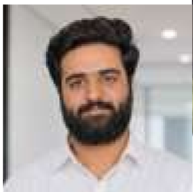
As the global demand for renewable fuels continues to grow, the experiences and best practices from the U.S. and Brazilian ethanol industries can serve as valuable lessons for other nations seeking to develop their bioethanol production capabilities. By embracing ***technological advancements****, fostering supportive policies, and optimizing processes, the ethanol industry plays a pivotal role in the transition toward a more* ***sustainable future****.*

The Fermentis Line-Up

Four Yeasts.
Endless Brewing Possibilities.

Tom Ashton
Technical Sales Support Manager Asia Pacific

Abhijeet Chindhe
Desigation - Senior Executive (Business Development)



Viren Malhotra
Business Development - Speciality Beverages

In today's brewing landscape, versatility is no longer a luxury — it's a necessity. As consumer preferences continue to evolve, Indian brewers are under constant pressure to deliver everything from hop-forward IPAs and crisp lagers to traditional wheat beers and sessionable pub ales, often while managing limited ingredient inventories and maximizing brewery efficiency.

That is where Fermentis' flagship yeast portfolio stands out. With just four proven strains — SafAle™ US-05, SafAle™ S-04, SafLager™ W-34/70 and SafAle™ WB-06 — brewers can cover an impressive spectrum of beer styles while maintaining consistency, reliability and fermentation performance batch after batch.

SafAle™ US-05

Often regarded as the benchmark American ale strain, SafAle™ US-05 is the ultimate all-rounder for modern craft brewing. Known for producing neutral, well-balanced ales with low ester production and a clean finish, it allows both malt and hop character to shine without interference. Its excellent ability to remain in suspension during fermentation supports high attenuation and reliable performance across a broad range of beer styles.

For brewers producing hop-forward beers, US-05 remains a trusted choice for American Pale Ales, West Coast IPAs, Hazy IPAs, Blonde Ales and even robust stouts where a clean fermentation profile is desired.

Recipe Inspiration: Tropical West Coast IPA

- OG: 1.062
- ABV: ~6.5%
- Hops: Mosaic, Citra and Simcoe
- Malt Bill: Pale Ale Malt, Light Munich, Wheat Malt
- Fermentation: 18–22°C with SafAle™ US-05

The clean profile of US-05 allows tropical fruit and citrus hop character to dominate while maintaining a crisp, highly drinkable finish.

SafAle™ S-04

For brewers seeking fuller body, faster fermentation and excellent clarity, SafAle™ S-04 remains one of the industry's most dependable English ale strains. Selected for its rapid fermentation profile, S-04 produces balanced fruity and floral notes while its high flocculation characteristics help create bright beers with compact sedimentation.

While traditionally associated with English styles, modern brewers are increasingly using S-04 in hazy pale ales, porters, stouts and specialty ales where enhanced mouthfeel and subtle fruit expression are desirable.

Recipe Inspiration: Coffee Oatmeal Stout

- OG: 1.058
- ABV: ~5.8%
- Malt Bill: Maris Otter, Flaked Oats, Chocolate Malt, Roasted Barley
- Addition: Cold brew coffee during conditioning
- Fermentation: 18–22°C with SafAle™ S-04

The yeast's natural ester profile complements roasted coffee and chocolate notes while creating a smooth, rounded mouthfeel.

SafLager™ W-34/70

Few yeast strains have earned a reputation comparable to SafLager™ W-34/70. Originating from the famous Weihenstephan brewing tradition, this strain is widely recognized as one of the world's most reliable lager yeasts.

Its ability to produce clean, crisp lagers with excellent drinkability has made it a cornerstone of professional brewing worldwide. Equally important for modern breweries, W-34/70 demonstrates exceptional fermentation flexibility and can perform across a wider temperature range than many traditional lager strains, making it particularly attractive for breweries looking to optimize tank utilization.

The result is a balanced fermentation profile with subtle fruity complexity and exceptional drinkability, suitable for everything from contemporary pilsners to stronger malt-driven lagers.

Recipe Inspiration: Modern Indian Pilsner

- OG: 1.048
- ABV: ~5.0%
- Malt Bill: Premium Pilsner Malt
- Hops: Hallertau Mittelfrüh and Saphir
- Fermentation: 12–15°C with SafLager™ W-34/70

A clean, refreshing lager showcasing noble hop aroma while retaining the crisp finish consumers increasingly seek in premium lager offerings.

SafAle™ WB-06

When wheat beer is on the menu, SafAle™ WB-06 delivers the classic character brewers expect. Designed for traditional wheat beer production, this strain produces the signature phenolic and fruity notes associated with the style, including distinctive clove and banana aromatics.

Its versatility extends beyond traditional German-style hefeweizens. Increasingly, brewers are using WB-06 in contemporary wheat IPAs, fruit-infused wheat beers and seasonal specialties where its expressive fermentation profile adds complexity and depth.

Recipe Inspiration: Mango Wheat Ale

- OG: 1.050
- ABV: ~5.2%
- Malt Bill: 50% Wheat Malt, 50% Pilsner Malt
- Addition: Alphonso mango puree during maturation
- Fermentation: 18–24°C with SafAle™ WB-06

The strain's natural banana and spice character integrates beautifully with tropical mango notes, creating a highly approachable beer for the Indian market.

One Yeast Portfolio. Unlimited Creativity.

The challenge facing brewers today is not simply producing great beer — it is producing a wide variety of great beer efficiently, consistently and profitably.

With SafAle™ US-05, SafAle™ S-04, SafLager™ W-34/70 and SafAle™ WB-06 in the brewhouse, breweries gain access to an exceptionally versatile fermentation toolkit capable of covering everything from crisp lagers and hop-forward IPAs to rich stouts and expressive wheat beers.

Whether you're developing your next flagship beer or experimenting with seasonal releases, Fermentis provides the reliability, performance and flexibility needed to stay ahead of changing consumer trends and continue delivering exceptional beer.

To explore the complete Fermentis brewing yeast portfolio and discover new fermentation opportunities for your brewery, connect with The Catalysts Group's team of brewing specialists.

Time to Rethink Liquefaction & Fermentation

Beyond Residual Sugar and Starch

Mr. Balu Mahendran,
Technical Sales Manager,
Novonesis

Liquefaction and fermentation are not just process steps - they are the heart and revenue drivers of the Distilling & biofuel industry. To stay competitive and innovative, we must rethink how we evaluate their efficiency. it's time to move beyond traditional metrics like residual sugar and starch. While these methods have served us well, they only tell part of the story.

Historically, we've measured fermentation and liquefaction success by calculating yields through conventional techniques. But the real question is shifting **from "How much am I getting?" to "Where am I losing?"**

With the integration of your lab with **HPLC (High Performance Liquid Chromatography)** and **Novonesis Mobile Kit**, we now have the tools to uncover deeper insights, faster than ever before.

HPLC setup allows us to detect:

- Byproducts like glycerol, lactic acid, and acetic acid
- Trace sugars such as DP1, DP2, and DP3
- Unconverted starches that may be missed in routine testing

These aren't just numbers - they're signals. Real-time analysis helps us catch inefficiencies early, make smarter adjustments, and improve overall performance on the spot.

By focusing on loss detection rather than just output, we unlock meaningful benefits:

- Continuous improvement
- Cost savings
- Process consistency
- Sustainability gains

This isn't just a technical upgrade - it's a mindset shift. We're moving from reactive to proactive, from measuring results to understanding the process behind them.

Prospects of Iso-butanol Blending in Diesel in India

Narendra Mohan
Managing Director
M/s Greentech Consultants &,
Ex-Director, National Sugar Institute

Aman Kumar
Technical Executive (Distillery)
M/s Greentech Consultants

Abstract

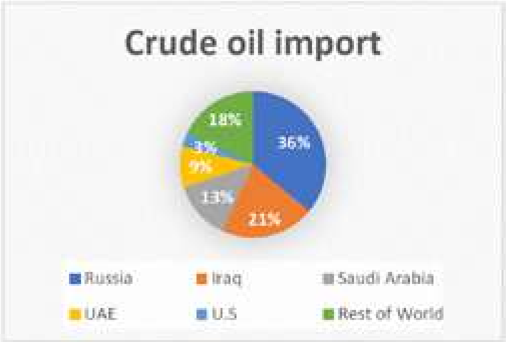
As the country has surplus ethanol capacity, to utilize the same either the ethanol blending % in petrol needs to be enhanced or ethanol is required to be used for other purposes including converting the same into SAF or Isobutanol. Recently, due to west Asia disturbance, surges have been recorded in the price of crude oil in international market. India is trying to reduce the crude oil import by increasing blending of surge of ethanol in petrol & also to blend isobutanol in diesel. Trials on blending of isobutanol in diesel have been carried out on pilot plant scale where several observations were made. Various opportunity & challenges of isobutanol blending in diesel are discussed in the article.

Key Words

Climate change, fossil fuel, greenhouse gases, energy security

Introduction

The Climate change is a major issue faced by almost all the countries. There are many factors which are responsible for climate change viz. greenhouse gas emission, utilization of fossil fuels & deforestation, etc. The gases which produced by burning of fossil fuels e.g.CO2, NOx, SOx & Fluorinated gases are accelerating the global warming. India during the Glassgow summit of COP 26, announced that we the country can achieve the net zero carbon emission by 2070. India has taken various steps including ethanol blending program, to reduce use of fossil fuels, enhance energy security, reduce carbon emissions & save foreign exchange. Presently India imports more than 80 % of crude oil to meet its requirement. The ratio of oil import from various countries (based on 2024) of India is shown in fig no.01:



The oil import is major burden on economy which can be reduced with the help of blending of cleaner fuels in petrol & diesel. As the country has already achieved 20 % ethanol blending in petrol, the way forward would be to increase blending levels, may be E85 & E100, for which important would be a role out plan for compatible flex fuel vehicles. Another option can be to blend diesel with certain percentage of isobutanol.

Figure.1 – Crude oil import by India from other countries (2024)[1]

Blending & Environment

With the increasing population, energy demand and requirement of fuels for vehicles is also increasing (Ref fig 02), which is highly impacting our environment due to emission of CO2, NOx, & SOx. The gases are harming human health directly because of increase air pollution. Unfortunately, out of the 25 most polluted cities of the world ,12 cities are in India as reflected from their poor air quality index. Although, 20 % ethanol blending in the petrol has helped to reduce the carbon dioxide emission form vehicles which are petrol driven, yet, emissions from diesel driven vehicles are of major concern.

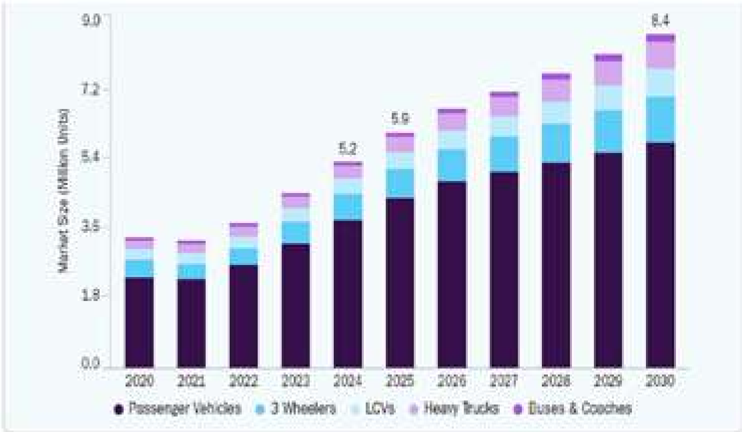
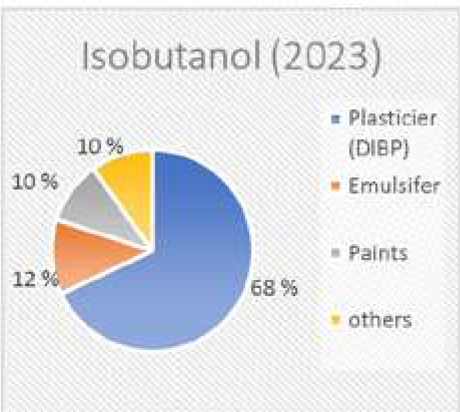


Figure.2- Automobile domestic sales trends[2]

As per details issued by PPAC (Petroleum Planning & Analysis Cell), the diesel consumption from April 2025 to March 2026 was approx.94 million MT. For further reducing the fossil fuels, blending of iso butanol in diesel has also been tried. It can be help in reducing crude oil imports, strengthening our energy security and further reducing the carbon emissions. Globally China, USA & Germany are leading producer of isobutanol. Figure 03 depicts usage of isobutanol for various purposes & also consumption patterns for diesel in the country. It can be seen that out of the total, approx. 20 % diesel is consumed for the road transport.



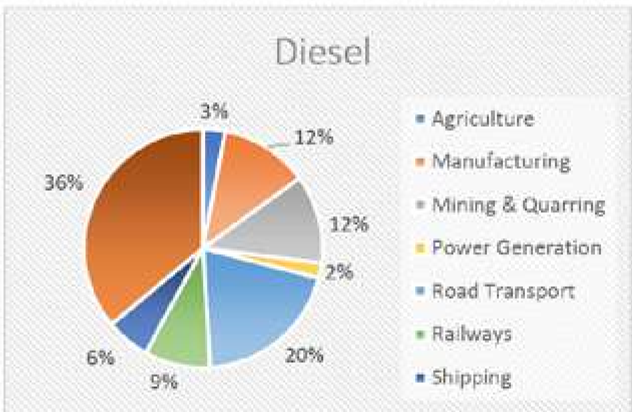


Figure.3 Consumption isobutanol and diesel in India [3]

Isobutanol & Other bio-fuels

There are serval factors which make isobutanol better for blending in diesel as compared to ethanol & methanol. Isobutanol (C4H10O) is an organic compound, having boiling point of 108 o C & density as 0.802 g/cm3. It is a flammable, colorless liquid, with sweet odor smell. It found naturally in fruits and in commercial made by different process like Hydroformylation, Reede carbonylation and Fermentation of sugars. The key quality parameters of isobutanol & other fuels are as follows:

Table No. 01 - Compassion of isobutanol with other fuels[4]

Sr. No.	Parameter	Context	Isobutanol	Ethanol	Methanol
01	Miscibility	Higher Miscibility ensure a homogeneous blend where the liquids do not from separate layers.	High	Low	Low
02	Hygroscopicity	Lower level indicates lower affinity to absorb water and ensure no phase separation occurs hence creating a stable blend.	Low	High	High
03	Energy Density (MJ/L)	A higher value indicates more energy released per unit volume.	29	19.6	16
04	Cetane Number	Higher value indicates how easily the fuel will ignite under compression thus providing smooth engine performance.	15	8	5
05	Flash Point 0C	A higher value indicates better fire safety as the liquid vapour will need a higher temperature to ignite.	27.8	16	1

Process of Production of Isobutanol

As mentioned earlier isobutanol is manufactured by different process viz. Reppe carbonylation, Hydroformylation, Fermentation of sugars. The process Reppe carbonylation, hydroformylation commonly used for production in which the compound like propylene is required as feedstock, whereas for Fermentation of sugars, engineered microbes are required which can ferment the sugars.

Carbonylation of propylene

Isobutanol is produced by the carbonylation of propylene. Two methods are practiced industrially, hydroformylation is more common and generates a mixture of isobutyraldehyde and butyraldehyde. The reaction is catalyzed by cobalt or rhodium complexes. The resulting aldehydes are hydrogenated to the alcohols, which are then separated.[5]

Reaction: $CH_3CH{=}CH_2 + CO + H_2 \rightarrow CH_3CH_2CH_2CHO$

Reppe carbonylation: In Reppe carbonylation, the same products are obtained, but the hydrogenation is effected by the water-gas shift reaction.[5]

Fermentation of sugars

The isobutanol production process begins with biomass containing any fermentable sugars. At an existing dry mill corn ethanol plant, the corn mash stream coming out of the front end of the process that feeds the ethanol fermentation is the same stream used for isobutanol fermentation. This stream is prepared for isobutanol fermentation, added to large non-sterile fermentation tanks and Gevo`s proprietary yeast is added to convert the sugars to isobutanol.[6]

Challenges: Isobutanol blend in diesel

India is first country trying to blend the isobutanol in diesel. (In India some bodies like ARAI (Automative research authority of India) in collaboration with other technology providers have taken up pilot project of 10% blending of isobutanol in diesel, over 18 months to evaluate performance, compatibility, and emissions in India conditions)[7].

There are various challenges related to process of production of isobutanol & then properties of isobutanol vis a vis diesel to facilitate blending viz. cetane no., brake thermal efficiency & isobutanol production.

Table No. 02 - Comparative table: Butanol-diesel and other alcohol-diesel blends in CI engines (2019-2024).[8]

Alcohol type & blend	BTE change	NOx change	Smoke change	HC change	Peak pressure	Notes/Novelty
1-Butanol + Biodiesel (B20-B30)	Slight decrease	Decrease (15 -20%)	Decrease (20-40%)	Increase (5-10%)	Slight Increase	Suitability in dual-fuel system; no parametric variation
Long-chain alcohols	Neutral (Comparable to baseline diesel)	Comparable to baseline diesel)	Decrease (20-60%)	Neutral	Neutral	High cetane no. maintained; soot reduction emphasized
Isobutanol + Biodiesel	Increase (3.2%)	Decrease (13-59%) (CO)	-	Increase	Increase	Binary/ternary blends; higher CO reduction than NOx
Pentanol/Octanol/ Ethanol-Diesel (Ternary)	Increase (5-10%)	Increase	Decrease	Increase	Increase HRR	Focused on oxygen effect in blends(O10E10D80)
Butanol - Diesel	Decrease (5-15%)	Decrease (5 -10%)	Decrease (40-60%)	Increase	-	Systematic review; supports butanol as transition fuel

BTE- Break thermal efficiency, CI- Compression ignition, CO -Carbon monoxide, HCHydrocarbon, HRR-Heat release rate, NO- Oxide of nitrogen

Conclusion

The blending of iso-butanol in diesel offers a promising pathway for India to enhance energy security, reduce dependence on imported fossil fuels, and lower emissions. However, the available processes, Petro-chemical Synthesis and Bio-based Fermentation yield iso-butanol at higher costs ranging from Rs. 90-130 per kg. With development of techno-economic process, suitable policy support, engine compatibility studies, and commercial-scale production, isobutanol can emerge as a sustainable biofuel component contributing to India's clean energy goals. The ethanol route for production of iso-butanol can pave way for consuming ethanol which is surplus now.

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India's Ethanol Blending Program Beyond E20

Unlocking the Next Phase of Green Growth

Ajay Kumar
Senior Analyst - Business Strategy

India has effectively achieved the E20 milestone, with nationwide E20 fuel rollout underway and ethanol blending reaching the targeted 20% level during 2025-26, a target that once seemed aspirational and now appears firmly within reach. But as the nation celebrates this landmark, a more consequential question is emerging in boardrooms, policy circles and research labs: What comes next? The answer will define India's energy security, agricultural economy and industrial competitiveness for the next decade.

India's Ethanol Blending Programme (EBP) has been one of the most successful demand-creation initiatives in the country's clean energy history. Blending volumes have grown from a negligible 1.5% in Ethanol Supply Year (ESY) 2013-14 to 14.6% in ESY 2023-24, with more than 707 crore litres of ethanol blended into petrol. The trajectory reflects a rare convergence of policy will, industry investment and feedstock abundance - primarily sugarcane-based and increasingly grain-based. Yet the road ahead of E20 demands a fresh strategic framework.

The E20 Achievement: A Platform, not a Destination

Reaching E20 has required monumental system-level changes - upgrades to distillery capacity, revision of pricing mechanisms under the Administered Price Mechanism (APM) and investment by Oil Marketing Companies (OMCs) in blending infrastructure. Between 2018 and 2024, India's ethanol production capacity expanded from approximately 550–600 crore litres in the late 2010s to nearly 2000 crore litres in 2026.

Critically, the feedstock mix has diversified. While sugarcane juice and B/C molasses remain dominant, grains - broken rice, maize and surplus FCI stock - now constitute a growing share, reducing the programme's vulnerability to monsoon variability and sugar cycle fluctuations. The government's willingness to allow multiple feedstocks and set differentiated procurement prices for each has been a structural enabler.

Beyond E20: What Does the Next Phase Look Like ?

The post-E20 landscape is not a single highway but a multi-lane expressway, with each lane representing a distinct use case for ethanol and fermentation-derived fuels.

1. E27/ E30 for Flex-Fuel Vehicles (FFVs)

The Ministry of Petroleum and Natural Gas has already signalled its intent to move beyond E20. Proposed mandates for FFV-compatible engines, supported by a draft regulatory framework issued in 2026, are expected to enable higher ethanol blends ranging from E27 to E85. Automakers such as Toyota, Suzuki and TVS have already introduced pilot FFV models in India. As OEM adoption accelerates, ethanol production capacity could increase nearly 2,700 crore litres annually by ESY 2029-30, assuming approximately 25% of petrol consumers transition to E85 fuel.

2. Sustainable Aviation Fuel (SAF) via Ethanol-to-Jet Pathway

The International Civil Aviation Organisation's CORSIA framework and India's own National SAF Policy (under formulation) are creating demand for bio-based jet fuel. The Alcohol-to-Jet (ATJ) pathway - converting ethanol to SAF through dehydration and oligomerisation - is commercially proven and ASTM-approved. India, with its growing aviation market (projected 300 million passengers by 2030), represents a significant SAF demand centre. IOCL and Praj Industries have already announced collaborative work on ATJ technology, making this a near-term commercial opportunity for the domestic fermentation industry.

3. Industrial Ethanol: Chemicals, Pharma and Green Hydrogen Synergies

Ethanol is not merely a fuel - it is a versatile industrial feedstock. Downstream derivatives including ethyl acetate, acetic acid, acetaldehyde and ethylene (via dehydration) are globally traded speciality chemicals. As India pursues import substitution in fine chemicals and pharma APIs, domestic bio-based ethanol can serve as a cost-competitive precursor. Moreover, ethanol reforming for green hydrogen production offers a distributed, low-capex pathway complementary to green hydrogen from electrolysis.

Critical Enablers for the Next Phase

The transition from E20 to a broader ethanol economy will not happen automatically. It will require deliberate action across five interconnected dimensions:

1. Feedstock Security at Scale

India's sugarcane cycle introduces supply volatility. Maize and agricultural residues (including paddy straw and bagasse) must be institutionalised as primary feedstocks through multi-year procurement contracts between distilleries and farmer producer organisations (FPOs). The 2G ethanol mission - currently led by IOCL's Panipat refinery - must be scaled beyond pilot stages with favourable capital subsidy frameworks.

2. Enzyme and Fermentation Inputs - India's Strategic Gap

India currently imports a significant share of commercial enzymes (cellulases, amylases, glucoamylases) and speciality yeast used in fuel ethanol production. As demand doubles toward 2030, this dependence represents both a cost risk and a supply chain vulnerability. Enzyme manufacturers and fermentation input companies are positioned to serve a rapidly expanding addressable market - estimated to grow at ~8-10% CAGR through 2030 - provided they invest in capacity and application development aligned to Indian feedstock profiles.

3. Infrastructure and Logistics

Storage, transportation and blending infrastructure must keep pace with production. OMCs have committed to expanding dedicated ethanol storage at depots, but last-mile connectivity - especially to distilleries in UP, Maharashtra and Karnataka - remains a bottleneck. Pipeline-based ethanol transport, as piloted in some corridors, offers long-term cost benefits over road tankers.

4. Carbon Crediting and Sustainability Certification

As India's export ambitions in green fuels grow - particularly SAF for international aviation - lifecycle carbon accounting and internationally recognised sustainability certifications (ISCC, RSB) will become commercial necessities, not optional add-ons.

5. Policy Continuity and Price Rationalisation

Investor confidence in large-scale distillery expansion depends on predictable pricing policy. The APM for ethanol procurement must evolve toward a cost-plus-return model that incentivises 2G feedstocks and advanced fermentation technologies, while maintaining supply discipline across the fuel ethanol value chain.

Opportunity Landscape for Fermentation Input Suppliers

For companies operating in the fermentation inputs space - enzymes, yeast, nutrients and process chemicals - the post-E20 era represents a structural demand inflection. Three specific opportunity windows stand out:

• Grain-Based Ethanol Expansion

Maize-based distilleries require alpha-amylase and glucoamylase enzyme cocktails specific to starch hydrolysis. As maize ethanol capacity expands - driven by government procurement prices and agricultural diversification incentives in eastern UP, Bihar and Karnataka. Suppliers with optimised enzyme blends for high-DS (dry solids) fermentation at Indian ambient temperatures will command premium positioning.

• 2G / Lignocellulosic Ethanol

The shift to agricultural residues - paddy straw, sugarcane bagasse, corn cob - for 2G ethanol production is enzyme-intensive. Cellulase and hemicellulose cocktails are the rate-limiting cost component in 2G processes. Partnerships with technology developers (Praj Matrix, IOCL R&D, DBT-ICT Centre) for enzyme optimisation at Indian biomass compositions represent high-value technical differentiation opportunities for domestic suppliers.

• Yeast Innovation for High-Stress Fermentation

Achieving higher ethanol titres (12-15% v/v) with improved Osmo tolerance and thermotolerance is a key efficiency frontier for Indian distilleries seeking to reduce energy costs. Speciality yeast strains - including immobilised yeast technology and continuous fermentation formats - represent a product innovation frontier that can significantly alter distillery economics. This is a space where Indian companies can develop proprietary solutions rather than simply distributing imported MNC products.

Conclusion: Building the Next Ethanol Economy

India's ethanol journey has been, at its core, a story of policy ambition meeting industrial capability. The E20 achievement validates this model. But the next phase demands more - broader feedstock deployment, deeper technology indigenisation and integration of ethanol into emerging value chains like SAF and industrial chemicals. For companies across the ethanol value chain - from distillers and technology providers to enzyme and yeast suppliers - the decade ahead is arguably the most consequential market formation window in India's bioenergy history. Those who invest now in application development, customer partnerships and process innovation will define the competitive landscape of 2030 and beyond.

New Joinees

Arabinda Mahato
R&D (HPLC)
1-Apr-26

Disha Chovatiya
Marketing
20-Apr-26

Shivangi Malviya
CRM
1-May-26

Akshay Sanjay Pujari
Technical Solutions
18-May-26

Rakesh Kumar Fullwari
R&D (HPLC)
3-Jun-26

Abhishek Paul
R&D (HPLC)
15-Jun-26

Anniversaries

Sushil Kumar Srivastava
Technical Solutions
10 Years

Pardha Saradhi
Business Development
10 Years

Navin Kumar Tomar
Accounts
10 Years

Joole Chauhan
R&D
10 Years

Anniversaries

B Chandra Shekhar
R&D
10 Years

Neeraj Saini
Supply Chain
10 Years

Dipti Verma
R&D
5 Years

Pankaj Kumar
Business Development
5 Years

Saurabh
Administration
5 Years

J. Kishore Kumar
Technical Solutions
5 Years

Anil Kumar Rai
R&D
5 Years

Lav Sharma
Human Resource
5 Years

Mahendra Verma
Business Development
5 Years

Vikram Yadav
Technical Solutions
5 Years

Hari Arun Mate
Business Development
5 Years

Manish Kumar
Business Development
5 Years

Deepak Chandra Gaur
Logistics
5 Years

Yavan Kumar
Production
5 Years

Significant Achievers

April 2026 - Team Admin

May 2026 - BMS Team Speciality Yeast Segment

Events

AAGHAZ 2026

BBB EXPO & SUMMIT, NEW DELHI

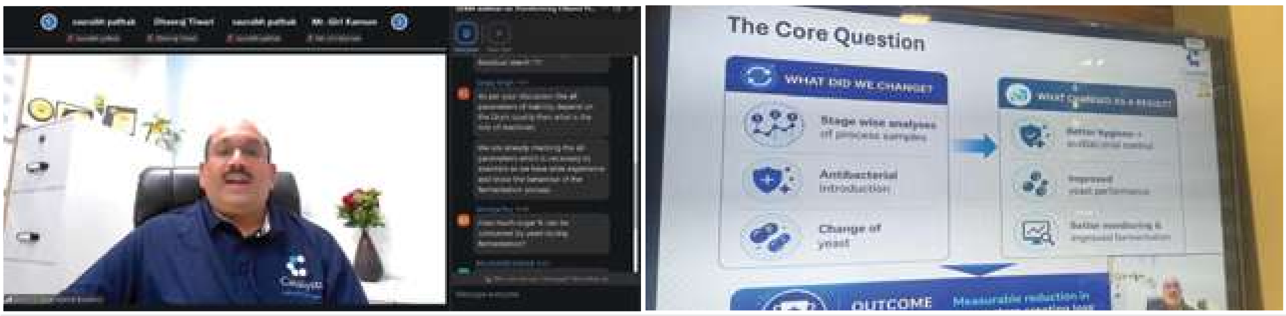
NOVONESIS CANE SHAKTI EVENT

Events

DURGAPUR OFFICE INAUGURATION

UDAAN LEAF EVENT, DELHI/HYDERABAD

UPSMA, LUCKNOW



GEMA WEBINAR (Q2)

Events

IBEC, NEW DELHI


SEIC, MUMBAI


WISMA, PUNE

Events


POSH TRAINING


MANAGER TRAINING

WORLD'S ENVIRONMENT DAY

Appreciations

GRAINFUEL
DISTILLERIES PVT. LTD.

To whomever it may concern

This is to confirm that the NIR calibration plant trial has been successfully completed. Catalysts Biotechnologies Pvt Ltd Calibrations for corn and rice (starch, protein, and moisture) have been uploaded, with starch and moisture values closely matching the laboratory manual method. It should be noted that whole grain and flour can be analysed in the rice and corn vertical.

Fermented broth calibrations for acetic acid, lactic acid, glycerol, DP4, DP3, DP2, glucose, and ethanol have also been uploaded. The results for acetic acid, ethanol, glycerol, and glucose show alignment with laboratory values, with minimal deviation. These improved NIR calibrations can significantly reduced analysis time, enhanced process monitoring efficiency, and facilitated faster troubleshooting during routine operations.

Overall, the plant trial results are satisfactory, and all calibrations are performing within the expected accuracy range. We wish you all the very best for your future operations and continued process improvements.

19/11/25

Rajeev Sharma
Lab Head
GrainFuel

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Appreciations

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SKL

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E-mail : dvpdharashivsk@gmail.com

Ref No DSKL/Admin/Disti/346/2025-26 Date 29 / 12 /2025

LETTER OF APPRECIATION

This is to certify that **M/S CATALYSTS BIO TECHNOLOGIES PVT LTD**, has been providing their solutions & technical support to our distillery.

Catalysts products have met our expectations. Their products took care of the quality of the syrup. We would like to express our sincere appreciation to dedicated technical person **Mr. Yogesh Krushnarao Mane** and his regular guidance and support to our distillery team which is very useful to continue process smoothly and so we can achieve higher alcohol percentage.

With the use catalysts products, we have observed remarkable results in our syrup-juice fermentation process.

1. Consistent alcohol percentage **12.50 % +** in fermenter wash.
2. No losses in Residual Sugar.
3. No contamination in syrup with their SOP and solutions.
4. Better fermentation efficiency and yield.
5. Controlled lactic acid contamination in fermentation processes.

We truly satisfied with their quality product and appreciate on-site technical support. We believe the Catalysts Group will keep contributing to our productivity and efficiencies.

We wish them many more success stories.

Authorised Signatory

General Manager
Dharashiv Sakhar Karkhana Ltd.
Chorakhali Tq.Kallam Dist.Dharashiv

India's
Most Trusted BIOTECH

Solutions Partner for the Sugar, Distilling & Brewing industries

Catalysts
making things happen...

23+ YEARS
★ OF EXCELLENCE ★

In 23+ years we have

- Provided customized enzyme -based solutions worth **₹3,520+ crores**
- Delivered **₹14,200+ crores** in measurable benefits
- Served **1,135+ clients**
- Across **25+ countries**

Our Industry Verticals

- Sugarcane Processing
- Distilling – Cane Syrup / Molasses
- Distilling – Grain
- Brewing, Malt & Speciality Yeast
  - ➢ Malt Extraction
  - ➢ Industrial Brewing
  - ➢ Craft Brewing
  - ➢ Malt Spirits
- Compressed Biogas

Maximizing clients' profitability through innovative Products & Solutions since 23+ yrs

State-of-the-art DSIR accredited lab

Proficient Tech Support Team

Quality certified (ISO 9001-2015, FSSC 22000, FSSAI) Formulation Facility

Channel partnership with world's top companies

FSSC 22000 · fssai · KLBD

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Channel Partners: novonesis · Leaf by Lesaffre · Fermentis by Lesaffre · DSM · Solenis

Delhi • Ghaziabad • Pune • Hyderabad • Belagavi • Durgapur

CATALYSTS GLOBAL PRESENCE

Catalysts
making things happen...
ISO 9001:2015 Certified

THE CATALYSTS GROUP

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Certifications:

FSSC 22000 · DSIR · KLBD · fssai · ISO 9001:2015 · HALAL · KOSHER

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