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UNLOCKING THE DIAMOND IN CORN

HAPPY NEW YEAR 2026

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CORN OIL EXTRACTION
MICROBIOLOGICAL ASPECTS

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2026

HAPPY
NEW
YEAR

As we step into the New Year, we extend our heartfelt gratitude for your partnership. Together, we achieved meaningful milestones this year. We look forward to building bigger, bolder, and more impactful successes in 2026. Wishing you a year filled with progress and prosperity.

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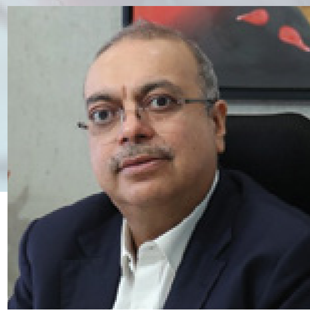
From the Managing Director's Desk



Munish Madan
MANAGING DIRECTOR

For too long, distilleries and biorefineries in India have focused primarily on their headline product — ethanol — while the residual streams, such as the oil-rich germ fractions of grain and maize, have lingered on the margins of strategy. Today, that by-product, Distillers Corn Oil (DCO), is emerging as a significant value-stream — positioned to deliver both commercial returns and sustainability gains.

India's ethanol story is accelerating. According to Petroleum Planning & Analysis Cell (PPAC), India achieved 20% ethanol blending in October 2025, with the average blending level at 19.2% from November 2024 to October 2025. With the government's target of E20 (20% blending) by 2025-26 now achieved ahead of schedule, grain-based feedstocks such as maize and damaged food grains are increasingly entering the equation.

That momentum creates opportunity. On average in Indian dry-milling contexts, approximately 8–12 kg of corn oil can be recovered per ton of processed grain, and when refined this oil becomes a valuable feedstock for biodiesel, oleochemicals and even emerging segments like sustainable aviation fuel (SAF). In one technical presentation, recovery benchmarks of ~28.74 kg per ton were cited in dry-milling process flow (approx. ~2.8% of mass). India's policy support further strengthens the case: the National Policy on Biofuels (Amended 2023) and the Global Biofuels Alliance (launched at G20 in 2023) reflect New Delhi's ambition to lead a renewed bioeconomy. For plant operators, this means DCO extraction isn't optional—it's a strategic component of future-proof operations. The economics support this shift: the corn oil market (into which DCO is increasingly integrated) was valued globally at approx. USD 6.5 billion in 2024 and is expected to grow to USD 11.5 billion by 2034. Meanwhile, the dedicated global DCO market was valued at USD 6.12 billion in 2024 and projected to grow at a CAGR of 4.85% through 2030.

Building on this momentum, technological innovation is not simply about installing equipment — it's about unlocking biological performance. Advanced enzyme systems and high-efficiency oil-recovery workflows are transforming germ oil extraction from theory into practice. At Catalysts, our team collaborates with enzyme and yeast solution providers to maximize oil-extraction performance and downstream conversion efficiency. In other words: biology + data = value.

“The future belongs to those who find value where others saw no use.”

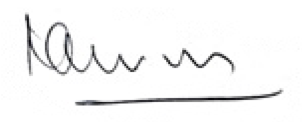
That leadership statement captures the essential mindset for the industry ahead. India is not merely catching up — it is poised to leapfrog competing geographies by leveraging scale, feed-stock diversity and technological partnerships. For instance, if half of India’s grain-based distilleries adopt DCO recovery systems, national output of corn oil could exceed 250 million litres annually, supporting large-scale biodiesel production and reducing edible-oil import dependency. Moreover, India’s corn-ethanol production is expanding rapidly, strengthening the feed-stock base.

Beyond the numbers, the operational implications are real: improved oil recovery means better feed-stock economics, more resilient business models and stronger alignment with ESG (environmental, social, governance) priorities. It means that a sugar–ethanol plant, a maize-based distillery or a biogas facility can transition from resource-intensive operations to smart, circular bio-systems.

In conclusion, the message is straightforward: as global energy systems evolve, the boundary between “by-product” and “value-stream” is being redrawn by innovation. The DCO revolution is not a distant concept—it is here. At our company, our vision is to enable this transformation through scientific partnerships, enzyme innovations and process excellence.

The journey ahead is not simply about producing more — it is about producing smarter. Because the future of energy, like the future of biotechnology, belongs to those who adapt early and act decisively.

Warm regards,



Munish Madan

Unlocking the Diamond in Corn:

Distillers Corn Oil and India's Biofuel Breakthrough

Prashant Kumar Jha
Technical Sales Manager
Novonesis India

In the heart of India's agricultural landscape, corn has long stood as a symbol of abundance - feeding families, fuelling industries, and now, offering a new kind of treasure: **Distillers Corn Oil (DCO)**. Once overlooked, DCO is emerging as a transformative co-product in ethanol production, poised to redefine profitability and sustainability for biofuel producers across the country.

Lessons from the U.S.: Turning Crisis into Opportunity

The U.S. ethanol industry faced a reckoning in 2012 - drought, rising corn prices, and plummeting crude oil margins threatened its survival. The turning point came with the realization that the residual oil in grain distillers could be extracted and monetized. By 2018, over 90% of U.S. ethanol plants were recovering DCO, creating a multi-billion-dollar safety net against market volatility.

India's Moment: Ready to Leap Ahead

India, now the world's fifth-largest corn producer, has seen its maize yield rise from 2.6 MT/Ha to 3.5 MT/Ha in recent years. With government mandates pushing ethanol blending and corn-based ethanol production expanding, the conditions are ripe for India to replicate - and potentially surpass - the U.S. success story. [Corn Proje..._PHB India]

DCO offers a threefold advantage:

- Economic Value: A new revenue stream beyond ethanol and DDGS.
- Energy Efficiency: Enhanced process optimization and reduced energy losses.
- Sustainability: A low-carbon feedstock for biodiesel and green fuels.

The Formula for Successful DCO Production

From our experience at Novonesis, DCO success depends on three interconnected pillars:

1. **Biological** – Yeasts and enzymes at the front end ensure starch breakdown, reduce glycerol formation, and free up oil for downstream recovery. Our specialized enzymes, for instance, can boost DCO recovery by 10%, while simultaneously increasing DDGS protein

quality.

2. **Operational** – Well-trained operators who understand not only "how" but also "why" each piece of equipment functions are critical. Decanters, in particular, play a decisive role: poor separation can let oil escape with wet cake, reducing recovery.
3. **Mechanical** – Equipment such as decanters, evaporators, and tri-canters must be optimized and maintained. Small adjustments - like fine-tuning differential speed, managing solids loading, or optimizing evaporation draws - can have outsized impacts on oil recovery.

From Whole Stillage to DCO: The Process Pathway

- **Front-End Enzymes:** Alpha-amylases and proteases reduce viscosity, hydrolyze proteins, and unlock trapped oil.
- **Decanters:** The balance point where free oil can either be captured or lost. Optimization is essential.
- **Evaporators:** Thin stillage concentration affects separation efficiency; viscosity control is vital.
- **Tricanters/Disc Stacks:** The final separation step, delivering three phases - solids, defatted syrup, and the precious DCO stream.
- **Demulsifiers:** Used carefully, these additives improve separation, though overdosing can be as harmful as underdosing.

Quality Assurance: Measuring What Matters

Reliable measurement is the foundation of improvement. Common methods include:

- PET Ether Extraction
- Acid Extraction
- Hexane Extraction
- Emerging Alternatives such as the Babcock method for validation.

Each offers different insights, but consistency is key to monitoring plant performance.

India's Strategic Edge in DCO Adoption

The Indian ethanol industry has a unique chance to leapfrog. With global learnings at hand, plants here can adopt **best-in-class enzyme technology, optimized operational training, and reliability-centered maintenance from the start.**

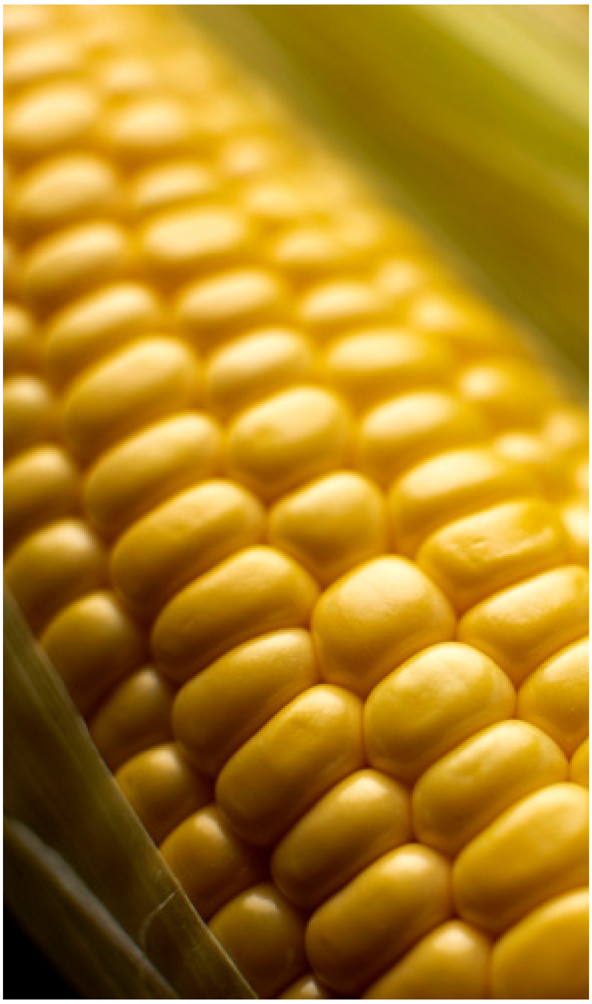
Novonesis, with its innovative enzyme solutions, is already helping producers extract **10% more DCO** and increase ethanol yield by an additional **1%**. This dual benefit - higher revenue from DCO and improved DDGS quality - creates a win-win for producers and downstream markets alike.

Conclusion: A Diamond Ready to Shine

Corn has always been golden for the ethanol industry. But within that gold lies a diamond: **DCO** - waiting to be unlocked. For India, embracing DCO isn't just about boosting margins; it's about building resilience, future-proofing the ethanol sector, and contributing to a greener economy.

The fields are ready. The technology is here. And the diamond - Distillers Corn Oil - is ready to shine.

For more information, check out our webinar: DCO Webinar Link!



Rapid Corn oil estimation with Near infrared spectroscopy:

An effective analytical technique with new perspectives

Dr. Anup Kumar Singh
(Application R&D)

Mrityunjay Verma
(Application R&D)

The search for renewable energy and sustainable resources around the world has changed the way we grow crops and manufacture products. The bioethanol industry is a key part of the renewable energy sector. Ethanol production, particularly from corn in the United States and from sugarcane in Brazil and Asia, has grown from a niche energy initiative into a mainstream renewable fuel solution over the past three decades. This transition has been driven by government mandates, environmental regulations, and consumer demand for cleaner energy sources. Henceforth, as ethanol plants multiplied and production capacity surged, questions about profitability, feedstock efficiency, and environmental performance grew louder. Profit margins in ethanol production are frequently narrow, significantly affected by feedstock expenses, energy costs, and fuel regulations. This has led the industry to seek ways to optimize every aspect of the process, ensuring that nothing goes to waste. The result is the transformation of conventional ethanol plants into biorefineries, where multiple value streams are derived from a single raw material. One of the most significant advancements in this evolution has been the commercial extraction of Distiller's Corn Oil (DCO). DCO used to be a small part of distiller's grains, but now it is considered as a valuable product that may be used in many ways, including biodiesel feedstock, and industrial chemicals.

The rise of DCO exemplifies how bioethanol production can align with the principles of the circular bio economy, i.e, maximizing resource utilization, reducing waste, and creating new revenue opportunities.(Mohammadi Shad et al., 2021)Corn oil is a valuable co-product obtained from maize, particularly in dry-grind ethanol plants where distillers' corn oil (DCO) is separated from thin stillage. The oil content in maize kernels directly influences the efficiency of extraction, energy yield, and economic value of the process. Traditional chemical methods of oil analysis, such as Soxhlet extraction, are time-consuming, labour-intensive, and destructive to the sample.(Barrera-Arellano et al., 2019). Henceforth, to address the inherent limitations associated with conventional manual analytical methods, Near-Infrared (NIR) Spectroscopy has emerged as a sophisticated and reliable technique for the precise, rapid, and non-destructive characterization of the physicochemical constituents of raw materials, products, and by-products.

It is one of the most valuable technologies which increases the accuracy and efficiency of ethanol plants and related industries. The NIR electromagnetic radiation was the first part of the electromagnetic spectrum discovered which is invisible to the naked eye. William Herschel reported, in the year 1800, on what he called "radiant heat", detected by a rising of the temperature observed by means of a conventional blackened bulb thermometer placed beyond the red end of the projected visible spectra of the sunlight, dispersed by a glass prism. It is most advanced technology used for the analysis of samples in the food industry in only 6 seconds, and can determine moisture, protein, fat, ash, starch and many other parameters with excellent accuracy. NIR technology is also used in the famous James Webb Space Telescope (JWST) by NASA. JWST has multiple near-infrared (NIR) instruments, including the Near-Infrared Spectrograph (NIRSpec) and the Near-Infrared Camera (NIRCam). NIRSpec captures light with wavelengths ranging from 0.6 to 5.3 microns, which includes visible red and mid-infrared. NIRCam is the primary near-infrared imager for the telescope. It has cameras that capture two-dimensional images and spectrographs that spread light out into a spectrum. Meanwhile, in ethanol industry, NIR spectroscopy is primarily used to monitor and control raw materials, fermentation processes, and the final ethanol product quality. It measures the absorption of near-infrared light by materials in the 780–2500 nm wavelength range. Different chemical compounds absorb NIR light at specific frequencies, which allows NIR spectroscopy to identify and quantify various components in a sample. Since the pioneering works, the multivariate characteristic of the analytical methods based on NIRS became evident. There are many such applications NIR in ethanol industries described in the following section.

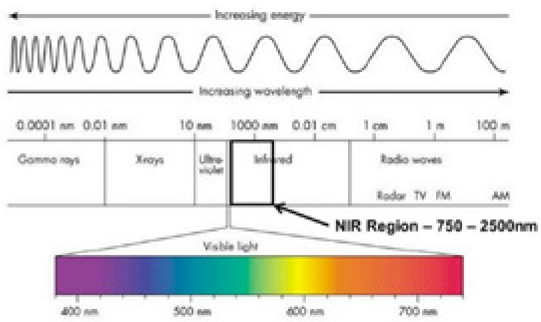


Fig.1. Electromagnetic spectrum with NIR band highlighted (Source- KPM analytics)

NIR spectroscopy offers a rapid, non-destructive, and accurate alternative for determining oil content in maize kernels, flour, and even during in-line processing. This allows ethanol producers and grain processors to screen large numbers of maize samples in seconds, ensuring consistent quality and maximizing recovery of corn oil as a high-value by-product.(Fassio et al., 2015)

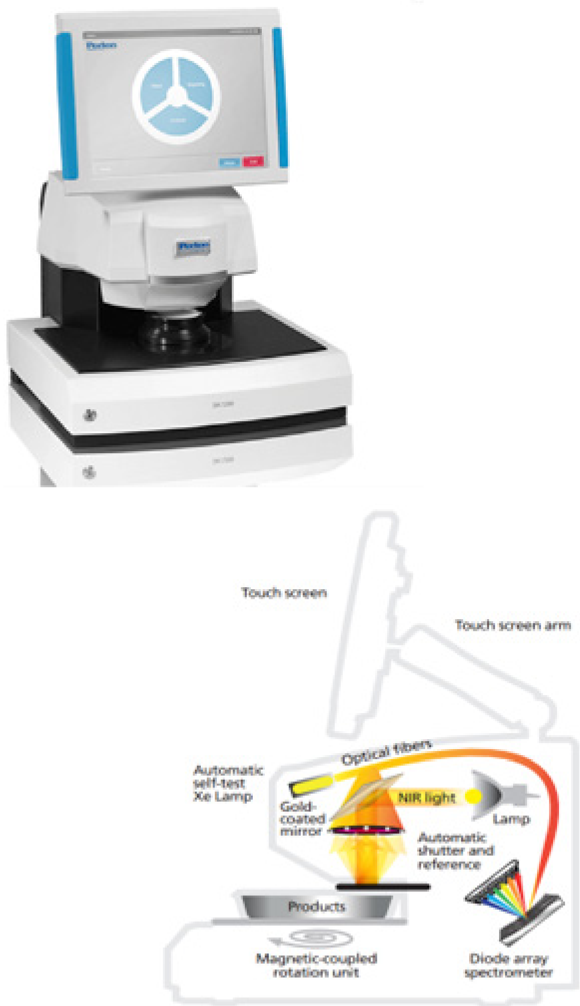


Fig.2. The DA 7250 NIR analyser by Perkin Elmer and its working mechanism (Source- Perkin Elmer)

Role of NIR in the Ethanol Industry

Raw Material Analysis

The quality and composition of raw materials such as corn, rice, sugarcane, wheat, molasses syrup and other biomass directly affect the efficiency of ethanol production. NIR spectroscopy is used to analyse the moisture, protein, starch, sugar content (Sucrose, maltose, glucose, fructose etc), acetic acid, lactic acid and fibre content in these feedstocks. By understanding the precise composition of the raw materials, manufacturers can optimize the efficient and fast fermentation process, adjust input levels, and reduce waste. (Peiris et al., 2020)

Advantages:

- Easy to use
- Minimal or no sample preparation
- Quick and non-destructive analysis of samples.
- Precise measurements of feedstock components.
- Real-time adjustments to optimize the input mix.

Fermentation Process Monitoring

Fermentation is the critical stage in ethanol production where sugars in the raw material are converted into ethanol by yeast. NIR spectroscopy enables real-time monitoring of the fermentation process by measuring the concentration of key compounds, including sugars (Sucrose, maltose, glucose, fructose etc), ethanol, and byproducts like glycerol and organic acids (acetic acid and lactic acid). This continuous data allows for precise control of fermentation conditions, other microbial contamination ensuring higher yields and reduced energy consumption.

Advantages:

- Real-time data collection.
- Ability to detect deviations early, preventing loss of efficiency.
- Improved control over fermentation parameters such as temperature and pH levels.

Ethanol Concentration and Purity

After the fermentation process, the ethanol produced needs to be purified and distilled. NIR can determine ethanol concentration in mixtures at various stages of the distillation process. This ensures that the final product meets the desired specifications for either biofuel or beverage-grade ethanol. Furthermore, it can detect impurities or unwanted byproducts, facilitating corrective measures to improve quality.

Advantages:

- Accurate determination of ethanol content.
- Identification of impurities for quality control.
- Non-invasive and rapid testing without the need for chemical reagents.

Moreover, NIR is also used in the various industries: -

- Agriculture and Food Industry: - In agriculture, NIR spectroscopy is revolutionizing how we assess crop quality and composition. Farmers and agronomists use NIR to evaluate the moisture, protein, fat, and fibre content of grains, cereals, and other crops.(Chapanya et al., 2019; Peiris et al., 2019)
- Pharmaceuticals: - The pharmaceutical industry benefits greatly from NIR spectroscopy, particularly in the areas of drug formulation and quality control. NIR allows for the real-time monitoring of manufacturing processes, helping to ensure that tablets and capsules contain the correct dosage of active ingredients.
- Textiles and Paper Industry: - In the textile industry, NIR spectroscopy is used to analyse the composition of fibres and dyes, ensuring that products meet quality standards and specifications. It helps in the rapid identification of materials, which is particularly useful in recycling processes where different types of fibres need to be sorted and processed. Similarly, in the paper industry, NIR spectroscopy aids in monitoring the quality of raw materials and finished paper products.
- Chemicals and Petrochemicals: - NIR spectroscopy plays a vital role in the chemical and petrochemical industries, where it is used to monitor the quality and consistency of raw materials and final products.(Hao et al., 2012; Jiang, 2020)

Advantages of NIR Spectroscopy

- Non-Destructive Testing: NIR spectroscopy does not require sample destruction, making it ideal for continuous monitoring and quality control.
- Speed and Efficiency: The technique provides rapid results, often within seconds, allowing for real-time analysis and decision-making.
- Minimal Sample Preparation: NIR typically requires little to no sample preparation, which reduces labour and time costs.
- Cost-Effective: Given its ability to analyse multiple parameters simultaneously, NIR spectroscopy can reduce the need for multiple analytical tests, saving on both equipment and operational costs

Conclusion

NIR spectroscopy is an indispensable tool in modern ethanol production, offering a rapid, accurate, and cost-effective means of analysing raw materials, monitoring fermentation, and ensuring the quality of the final product. As the ethanol industry continues to grow, particularly in the biofuel sector, NIR spectroscopy will play an increasingly important role in optimizing production efficiency and sustainability. By providing real-time insights into every stage of production in the industries, NIR spectroscopy enables manufacturers to produce higher-quality ethanol more efficiently and with less environmental impact.

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Refining Distillers Corn Oil for diesel blending or high-value feedstock applications

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Application R&D

Anil Kumar Rai
Application R&D

Introduction

Plants capture sunlight through photosynthesis, converting carbon dioxide (CO_2) and water (H_2O) into biomass, which can be broadly classified into three main categories: carbohydrates, lignocellulose, and lipids. Energy derived from this biomass forms a renewable source of fuel. In the current scenario, India has effectively adapted to producing biofuels from starch- and sugar-rich feedstocks, as well as from used vegetable oils. Presently, ethanol production in India relies on syrup, molasses, or grains such as rice and maize. Distillers Dried Grains with Solubles (DDGS), a by-product of rice and maize ethanol production, is a high-energy material that is currently underutilized in the feed industry despite its potential value.

National Biofuel policy 2018

India has successfully achieved its target of 20% ethanol blending in petrol (E20) by 2025. To support this, the country's grain-based distilleries are projected to have a production capacity of 740 crore liters for the year 2025–26, with an estimated ethanol requirement of approximately 500 crore liters. Meeting the E20 mandate would require around 165 million tons of grain, while achieving E30 blending would necessitate about 24 million tons of grain per year.

	2020	2025	2030	2035	2047	
Crude oil Required		6.2	7.4	8.4		Million barrol/day
Ethanol	28.4	45.7	63.2	79.8		Cr liter
Maize required			45	65	100	Million tonn

Bioethanol from maize in India

In this article would like to focus on the possible contribution of Corn based grain industry to participate in Biodiesel via production of Distillery corn oil. Maize is a focus crop for government of India. New MSP has been declared at Rs 22.25/Kg in the coming crop season. The Aim is to reach 65Million Ton by 26/27 where there will be enough maize for everyone.

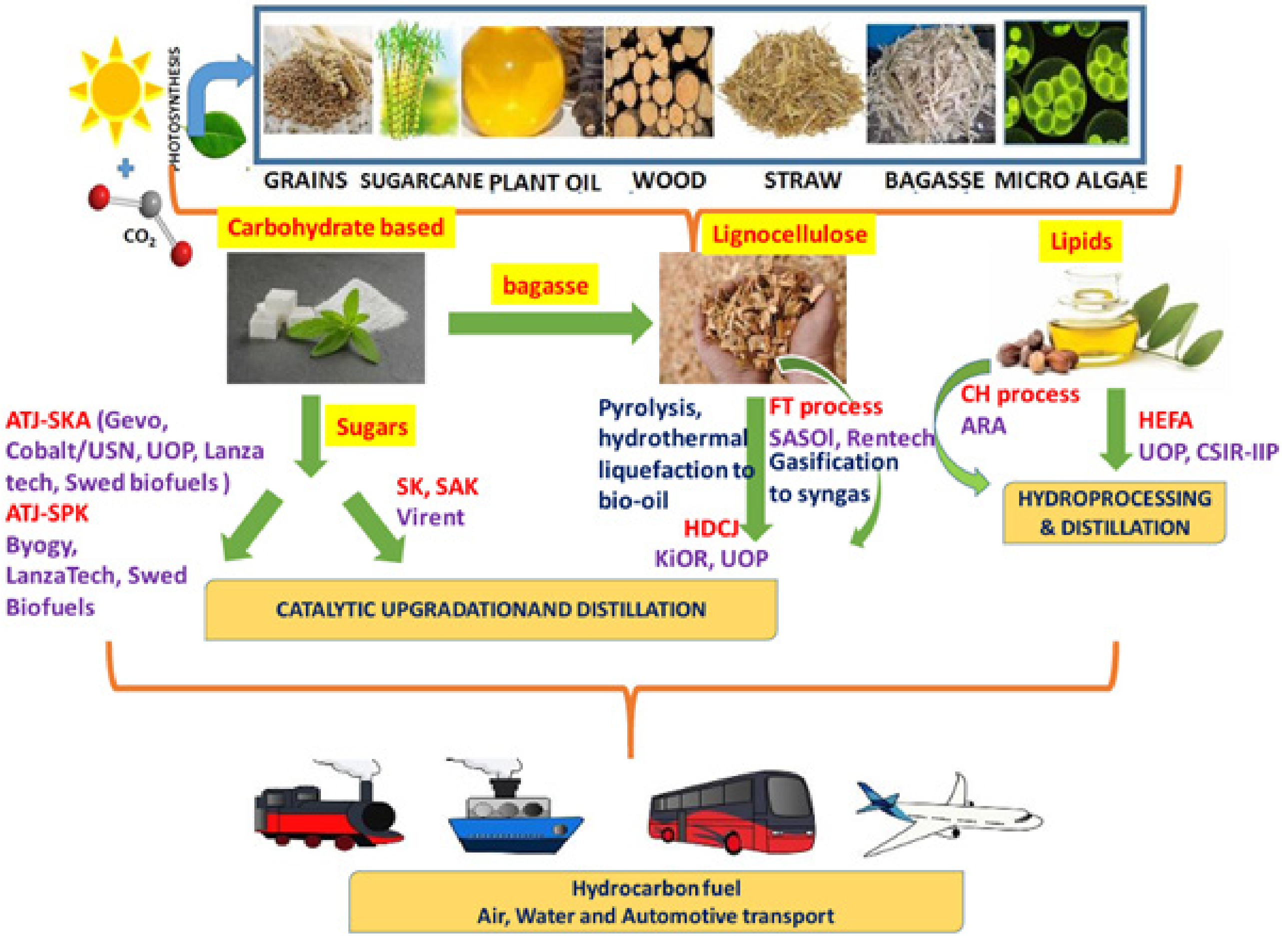


Figure 1: Pathways for renewable bio-jet production

Why maize to be preferred for bioethanol?

- Due to limited Damaged food grains (DFG) not available in sufficient quantity, major focus for grain industry will be obvious primarily Maize only.
- High productivity potential (3.9 ton/hectare yield)
- Multiple cropping/year (round the year industry functioning (No longer depend on dual feedstock)
- Local production / consumption could reduce transport cost
- Lesser water and environmental footprint (half of sugarcane and rice)
- By product DDGS for feed industry.
- Sustainable production and farmer profitability.

ESY	2023-24	2024-25	2025-26	(Nov-Oct)
Ethanol	150	250	350	Cr Liter
Maize Required	4.0	6.6	9.2	Million ton

Challenges with maize crop:

To ensure the quality and safety of harvested grains, it is essential to minimize mechanical damage during harvesting and while heaping cobs or grains. Grains should be dried to less than 14% moisture to allow safe storage, preferably on a clean threshing floor or using a dryer. Proper aeration must be maintained during storage to prevent insect infestation and spoilage. Pre-harvest application of atoxigenic isolates of Aspergillus flavus can help reduce aflatoxin contamination. Additionally, employing a world-class drying system before storing grains in silos ensures optimal packing, preservation, and long-term quality.

Classification of DDGS and their chemical composition as per NASEM 2021

Attributes	DDGS (High fat) Feed code: NRC16F59	DDGS (High protein) Feed code: NRC16F60	DDGS (low fat) Feed code: NRC16F61	Corn DDGS	Mixed DDGS	Rice DDGS
DM	89.1	91.1	89.9	87.6-93.5	87.3-92.6	89.6-91.4
Ash	5.4	4.0	5.3	5.4-9.0	8.0-10.2	4.01-5.03
Crude Protein	30.2	39	31.0	27.1-36.4	33.8-38.3	44.7-48.4
RUP % CP	47	47	47			
NDF	32.1	37.6	30.8	30.2-39.7	28.9-31.2	40.5-45.6
ADF	14.6	17.7	14.8	8.9-11.9	11.5-12.3	12.9-16.82
ADICP	2.85	3.97	3.15			
Starch	4.5	6.2	6.1	2.9-13.9	<1-3.7	-
Crude Fat	12.54	7.56	8.90	6.4-9.5	5.6-7.6	9.12
DE (Mcal/Kg)	3.49	3.34	3.44			
Ca	0.12	0.08	0.11	0.05	0.15	0.13-0.7
P	0.88	0.64	0.89	0.77	0.92	0.35-1.34
S	0.67	0.64	0.71	0.72	0.37	0.55

BIS standard for DDGS

The BIS (Bureau of Indian Standards) standard for DDGS provides regulatory guidelines to ensure the quality, safety, and consistency of Distillers Dried Grains with Solubles (DDGS) used in animal feed. DDGS, being a high-protein and energy-rich by-product of ethanol production from grains such as maize and rice, must meet specific criteria for moisture content, crude protein, crude fiber, fat, ash, and microbial limits to ensure nutritional value and safe consumption by livestock. The standards also set limits for mycotoxins, including aflatoxins, to prevent health hazards in animals. Adherence to BIS standards helps feed manufacturers maintain product uniformity, enhance feed efficiency, and comply with regulatory requirements, supporting both animal health and the sustainability of the biofuel industry.

Table.1. Amino Acid Profile DDGS v/s Soyabean meal

Parameter	Corn DDGS	Rice DDGS	Soyabean Meal
Arginine	1.05	1.47	3.48
Valine	1.63	1.12	2.25
Histidine	0.70	1.01	1.26
Isoleucine	1.52	0.93	2.15
Leucine	2.43	2.94	3.61
Lysine*	0.77	0.64	2.95
Metheonine	0.54	0.61	0.64
Phenylalanine	1.64	1.28	2.40
Threonine	1.01	0.92	1.83
Tryptophan	0.19	0.24	0.64

**Lysine adjustment for monogastric feed formulation required*

Challenges to use DDGS in animal feed

Distillers Dried Grains with Solubles (DDGS) present several challenges in terms of quality and safety. There is no standardized nutrient profile for DDGS, and its chemical composition is highly variable. Being rich in unsaturated fatty acids, DDGS is particularly prone to oxidation, while high moisture, humidity, temperature, and improper drying or storage can increase the risk of aflatoxin contamination, which is three times higher than in grains. According to BIS regulations, aflatoxin B1 levels in both dairy and poultry feed should not exceed 20 ppb, as even small amounts can transfer to animal products—1–6% of aflatoxin B1 in dairy feed can appear in milk as aflatoxin M1, and 0.1–0.2% in poultry feed can transfer to eggs and meat. In parallel, the development of oil-based additives and hydro-processed vegetable oils for synthetic fuels supports decarbonization in the transportation sector. Biodiesel, including fatty acid methyl esters (FAME) derived via transesterification of oils with methanol, serves as a blendstock with fossil diesel. However, challenges such as low-temperature flow properties and oxidation stability necessitate the use of renewable and synthetic fuel additives to ensure storage stability, engine performance, and cleaner combustion. Key additives include dehazers/demulsifiers—typically non-ionic detergents like polyethers or sugar-fatty acid esters—to prevent haziness and water accumulation in blends; water-fuel compatible biocides, such as thiazoles, thiocyanates, isothiazolins, cyanobutanes, and dithiocarbamates, to control microbial growth; and bio-based green corrosion inhibitors, derived from natural polymers, amino acids, oleochemicals, and plant extracts, with oleic, linoleic, and palmitic acid chemistries being particularly effective in mitigating acidic corrosion.

Oil-based additives have been developed as green additives for cetane, lubricity and oxidation stability enhancements for meeting diesel specifications.

- Oxygenate-based cetane improver Bio-mass derived oxygenated compounds such as methanol or dimethyl ether (DME) are promising alternative cetane improver additives for meeting SOx, NOx, methane, and BC (black carbon) emissions.
    a. Diethyl Ether (DEE)
    b. Nitrate derivative of methyl oleate (MODN)
- Lubricity Improver: Synthetic esters based on vegetable oil fatty acids and alcohols are reported as excellent lubricity enhancers for diesel fuel.
    a. Methyl oleate is produced using methanol and oleic acid.
    b. glycerol is reported to be utilised for the production of Solketal, which is an excellent oxidation stability enhancer, acts as an octane booster.
- Pour point depressant The use of ozonized vegetable oils as a pour point depressant for neat biodiesel has been reported in the literature.
    a. Ozonized vegetable oils (1–1.5% by weight) prepared from sunflower oil, soybean oil and rapeseed oil to -24, -12 and -30 °C, respectively.
    b. methacrylate polymers and copolymers have been used as Cold Flow Properties improvers and Pour Point Depressants.
    c. Oxymethylene dimethyl ethers (OMEn) are produced using methanol from waste biomass added to mitigate emissions.
- Antioxidants (gum inhibitors) like 2,6 di-tertiary-butyl phenol, 2,6 di-tertiary-butyl-4-methyl phenol additives to prevent the formation of gum and other antioxidation products.
- Fuel system icing inhibitors added Diethylene Glycol Monomethyl Ether.
- Antistatic additive (Stadis 450) to mitigate risks of electrostatic ignition by increasing the electrical conductivity of fuels, reducing the risk of electrostatic hazards.

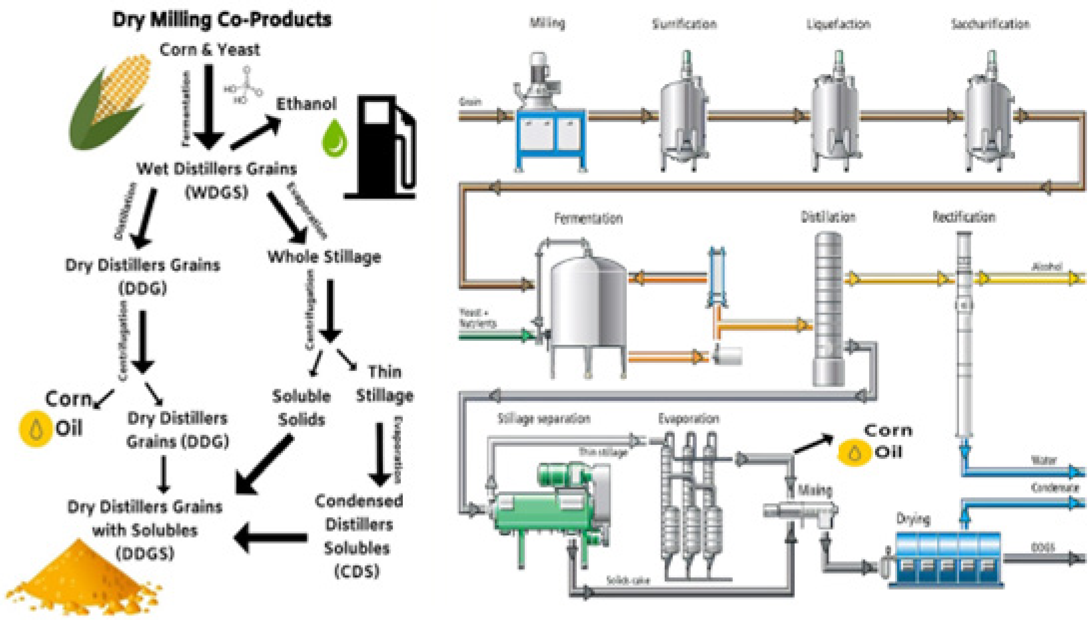
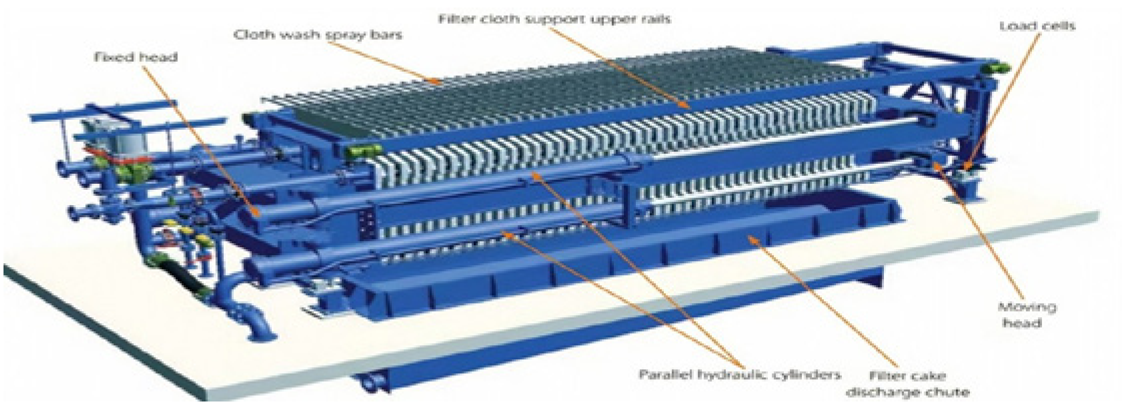


Fig 2: Corn based distillery with option to recover Distillery Corn Oil (Biodiesel) from SYRUP concentrate via decanter or through DDGS solvent recovery mode.

Note: Edible corn oil can be recovered from corn grain directly using solvent / mechanical method before fermentation.

DCO is typically rich in aromatic hydrocarbons and contaminants (metals, sulphur, nitrogen, Conradson carbon, etc.), and it requires purification before being blended into diesel or used as a feedstock for hydrocracking or hydrotreating.

1. **Pretreatment (Feedstock Preparation)**
    - Centrifugal Separation / Filtering – Preheated oil (~50-70°C), mild agitation, addition of phosphoric/ citric acid optional to hydrate phospholipid gums, residence 15-30min. It removes suspended solids, gums, and impurities.
    - Drying – heat gently to remove water (moisture causes soap formation).



Acid Esterification (if FFA > 2%, recommended) High free fatty acids (common in DCO) are reduced by reacting with **methanol + sulfuric acid (H_2SO_4)**. Reaction converts FFAs → methyl esters, lowering acidity.

- Residence time 30-60min. monitoring of FFA drop <1%
- **Catalyst: sulfuric acid (H_2SO_4)**, ~0.5–1% of oil weight (~5-10Kg/1000Kg oil)
- **MeOH Alcohol:** ~5-15wt% (~5-15Kg MeOH/1000kg oil)

2. **Base-Catalyzed Transesterification**

- React the DCO with **methanol (CH_3OH)** in presence of a catalyst (**NaOH** or **KOH**).

$$Triglyceride\ (oil) + 3CH_3OH\ \ (methanol) \xrightarrow{NaOH\ /\ KOH} 3Fatty\ Acid\ Methyl\ Esters\ (FAME,\ biodiesel) + Glycerol$$

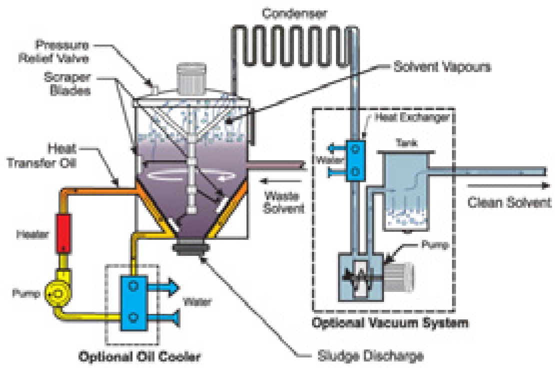
- The FAME is biodiesel; glycerol is a byproduct.
- **Catalyst:** NaOH or KOH, ~0.5–1% of oil weight (~5-10Kg/1000Kg oil)
- **Alcohol-to-oil molar ratio:** ~6:1 methanol: oil (~217Kg MeOH/1000kg oil)
- **Conditions:** Temp: 55–60 °C, time: 1–2 hours, Agitation required

3. **Separation**

- After reaction, let mixture settle in a decanter, allow glycerol (heavier layer) to settle to form Two layers-

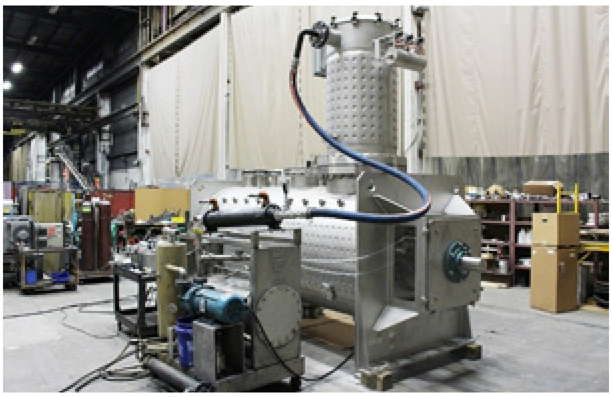
Top: Biodiesel (FAME),

Bottom: Glycerol + catalyst + impurities



4. **Purification:**

- Washing: Wash biodiesel with warm water (mist spray or gentle mixing, countercurrent) to remove residual methanol, soap, and catalyst.
- Drying: Heat to 100–110 °C or use vacuum drying to remove residual moisture.
- Policing/adsorption



5. **Glycerol Recovery (Byproduct)**

- Crude glycerol contains methanol, catalyst, soaps, and water.
- Refined glycerol (distillation/neutralization) for use in pharma, cosmetics.

6. Quality Testing

Specifications for Biodiesel (FAME) standards EN 14214 (EU/India)

Property	Unit	EN 14214 Requirement
Ester Content	% (m/m)	≥ 96.5
Density (15 °C)	kg/m^3	860–900
Viscosity (40 °C)	mm^2/s	3.5 – 5.0
Flash Point	°C	≥ 120
Sulfur Content	mg/kg	≤ 10
Cetane Number	–	≥ 51
Carbon Residue (10% distillation residue)	% (m/m)	≤ 0.3
Sulphated Ash	% (m/m)	≤ 0.02
Water Content	mg/kg	≤ 500
Total Contamination	mg/kg	≤ 24
Copper Strip Corrosion (3 h, 50 °C)	Rating	Class 1
Oxidation Stability (110 °C)	h	≥ 8
Acid Value	mg KOH/g	≤ 0.5
Iodine Value	g I_2/100g	≤ 120
Phosphorus Content	mg/kg	≤ 4
Methanol Content	% (m/m)	≤ 0.2
Free Glycerol	% (m/m)	≤ 0.02
Total Glycerol	% (m/m)	≤ 0.25
Monoglycerides	% (m/m)	≤ 0.8
Diglycerides	% (m/m)	≤ 0.2
Triglycerides	% (m/m)	≤ 0.2
Alkali Metals (Na+K)	mg/kg	≤ 5
Alkaline Earth Metals (Ca+Mg)	mg/kg	≤ 5

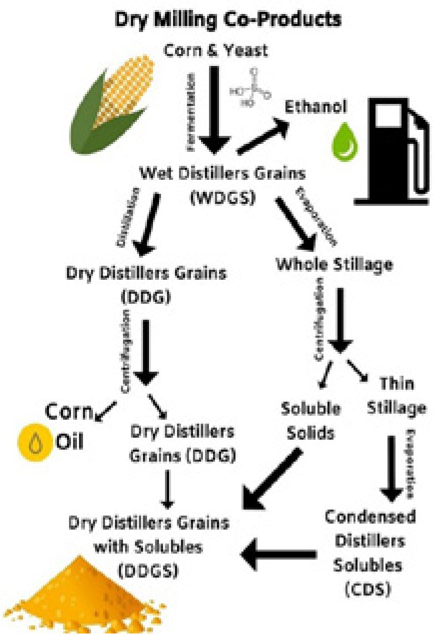
Yields

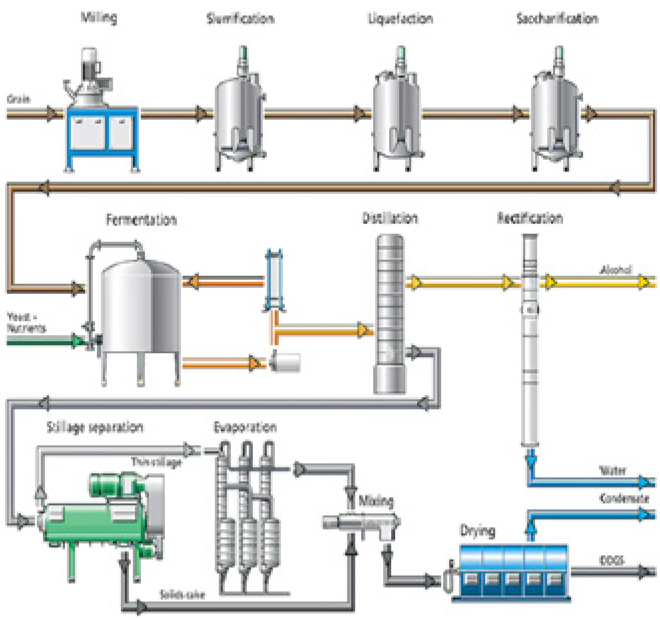
- From 100 kg of DCO, typically 95–98 liters of biodiesel can be produced (depending on FFA and processing efficiency). Biodiesel produced can be used as B100 (100% biodiesel) or blended with petroleum diesel (B20, B5, etc.).

Mass Balance	Input		Output			
Particulars	DCO (oil)	Methanol feed	Biodiesel (FAME)	Glycerol (pure)	Methanol recovered	Methanol consumed
(oil)	Kg	Kg	Kg	Kg	Kg	Kg
Case A: Theoretical (100% conv., stoich MeOH)	100	10.86	100.51	10.41		
Case B: Practical (98% FAME, 6:1 MeOH, 85% recovery)	100	21.72	98.5	10.41	18.46	3.26

Key control points & instrumentation (recommended)

- T-101 level transmitters (LT) — storage control.
- FT on feed and methanol lines (flow control).
- pH & temperature control in esterification/neutralization reactors.
- Temperature control (TC) in reactors and distillation reboiler.
- Vacuum gauge & control for vacuum dryer and methanol distillation.
- Conductivity / water test after washing; GC for methanol residual in final biodiesel.
- Safety: flashpoint monitoring & inerting (N_2) where required; explosion relief on methanol handling.





Corn Oil Extraction: Microbiological Aspects

Joole Chauhan
(R&D)

Corn oil is a valuable edible and industrial oil obtained from the germ of maize. While mechanical and chemical extraction methods dominate the industry, microbiology plays a crucial role in both **process optimization** and **product safety**.

1. Overview of Corn Oil Extraction Process

Corn oil is typically obtained in two major ways:

- **Dry milling** – Primarily used for cornmeal and flour, with oil recovered as a by-product.
- **Wet milling** – Corn is steeped in water (often with SO_2) to soften kernels, enabling separation of germ, starch, and fibre. Germs are then pressed or solvent-extracted to yield oil.

In both processes, microbial control is critical to prevent spoilage, ensure oil stability, and meet food safety standards.

2. Microbiological Relevance in Corn Oil Production

A. Fermentation By-products in Wet Milling

During steeping, controlled microbial growth (especially lactic acid bacteria) can improve kernel softening, but uncontrolled microbial contamination (e.g., Bacillus, Enterobacter, or moulds) can cause:

- Off-odours and flavours in oil
- Loss of germ quality

- Reduced extraction efficiency

B. Microbial Enzymes

Enzymes such as cellulases or proteases from selected microorganisms may be used in research or industrial settings to break down cell walls and improve oil release. However, their purity and residual activity must be monitored to avoid contamination.

C. Quality Control Testing

Microbiology labs ensure:

- **Total Plate Count (TPC)** is within safe limits
- **Yeast and Mold Counts** are minimal to prevent rancidity
- Absence of pathogens such as Salmonella and E. coli
- Proper sterilization of water used in steeping and cleaning

D. Role of Antimicrobials

Antimicrobial agents may be added to steeping tanks or processing water to control unwanted microbial growth. The choice of antimicrobial must comply with food safety regulations.

3. Storage and Shelf Life

Even after extraction, residual moisture in oil or improper storage can allow mold spores to grow or oxidative rancidity to accelerate. Microbiologists help monitor:

- Moisture content
- Peroxide values
- Microbial contamination during packaging

4. Industrial Applications

Beyond edible oil, corn oil is used in biodiesel production. In such cases, microbial fermentation may be intentionally applied in pretreatment steps to enhance lipid yield from residual germ meal.

5. Conclusion

Corn oil extraction is not only a mechanical or chemical process - it has a strong microbiological dimension. From controlling microbial contamination during steeping to testing final product quality, microbiologists ensure that corn oil is safe, stable, and compliant with food safety standards. Continuous research into microbial enzymes and bioprocessing may further improve extraction efficiency in the future.

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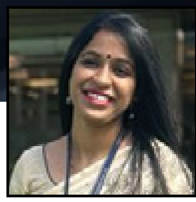
GC-FID: A tool for analysis of FAMEs in corn oil



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GC-FID (Gas Chromatography with Flame Ionisation Detector) has been widely used to determine the fatty acid composition of corn oil. Fatty acids are the major component of lipids, and the physical, chemical, and physiological properties of a lipid class depend primarily on its fatty acid composition (Table-1). The fatty acid composition is determined as Fatty Acids Methyl Esters of (FAMEs) by gas-liquid chromatography (GC)1,2

The triglyceride (TG) in the oil is esterified by using an alkylation derivatization reagent (sodium methoxide) because fatty acids present in oils may be difficult to analyse in their free state due to their high polarity and formation of hydrogen bonds that consequently result in adsorption problems. Before the fatty acid composition of a lipid can be analysed by gas chromatography, the lipid must be converted to low molecular weight, volatile, nonpolar derivatives i.e. methyl esters. This conversion usually is through transesterification – the glycerol (sugar alcohol) portion of the triglyceride (ester) is displaced by another alcohol, in the presence of an acid. The reaction is represented by the general equation (Figure-1). Hence, methylation reduces fatty acids polarity and methyl esters offer better stability and quick quantitative samples for gas chromatography analyses.

S.No.	Fatty Acid	Type	Approximate content
1	Palmitic	Saturated	10–13%
2	Stearic	Saturated	1–2%
3	Oleic	monounsaturated	25–30%
4	Linoleic	polyunsaturated	55–60%
5	Linolenic	polyunsaturated	<1%

Table -1 Major Fatty acid present in corn oil

Extraction Method - Prior to GC-analysis the corn oil is converted into FAMEs which includes several steps-

Step-1 Lipid Extraction

Extraction of oil using Soxhlet extraction, hexane, or another nonpolar solvent.

Step-2 Transesterification to FAMEs- (Base Catalysed) (Figure-1)

1. Add a known volume of corn oil (~50 mg) to a small round bottom flask.
2. Add methanolic KOH (0.5 M) which is act as catalyst.
3. Heat the extract at 60–70°C for 10–20 minutes.
4. So, the Reaction will convert triglycerides into Fatty Acid Methyl Esters.

Step-3 Extraction of FAMEs-

1. After transesterification, add hexane or heptane to extract the FAMEs.
2. Add water to separate phases.
3. Collect the organic layer, which contains the FAMEs.
4. Dry over anhydrous sodium sulphate to remove moisture.
5. Filter and transfer to a GC vial.

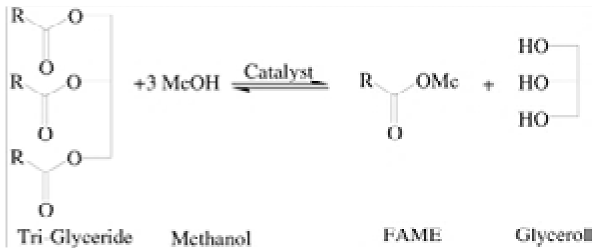

Figure-1 Mechanism transesterification reaction TG to FAMEs

Parameters	Value
Injection	1 µl
Inlet (Spilt/Spitless)	275 °C (50:1 split)
Oven Program	70 °C (hold for 0.5 min),
	60 °C/min to 165 °C (hold for 0.5 min),
	10 °C/min to 200 °C (hold
Column Flow	3.0 mL/min (hydrogen)
Makeup Flow	3.3 mL/min (hydrogen)
Restrictions 1 and 2	0.55 m × 100 µm
LUMA Temperature Setpoint	275 °C
FID Temperature Setpoint	300 °C
Column	Agilent DB-Fast FAME (30 m × 250 µm, 0.25 µm)

Table -2 Parameter used for FAMEs Analysis by GC-FID1

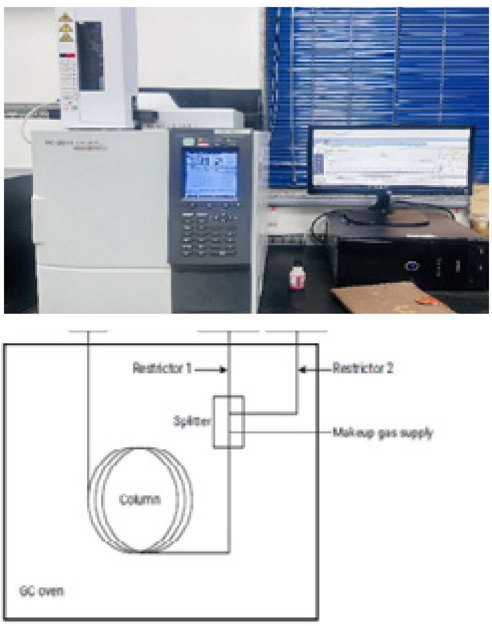

Figure-2 GC-FID and its configuration used for FAMEs analysis

Conclusion

GC-FID analysis of Fatty Acid Methyl Esters (FAMEs) is essential for accurately determining the fatty acid composition of corn oil. This analysis is important for ensuring nutritional quality, maintaining product consistency, detecting adulteration, and meeting with other regulatory standards. Instead of that, biodiesel production, GC-FAME analysis is vital for evaluating fuel quality and transesterification efficiency. By converting fatty acids to their methyl ester forms, GC-FID allows precise, reliable, and reproducible profiling of corn oil's fatty acid content, making it an important tool in both food and industrial applications

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Distillers Corn Oil: Enhancing Yield and Sustainability in Modern Ethanol Biorefineries

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Introduction

The global quest for renewable energy and sustainable resources has reshaped the modern agricultural and industrial landscape. Among renewable energy sectors, the bioethanol industry occupies a significant role. Ethanol production, particularly from corn in the United States and from sugarcane in Brazil and Asia, has grown from a niche energy initiative into a mainstream renewable fuel solution over the past three decades. This shift has been driven by government mandates, environmental laws, and consumer demand for cleaner energy sources. However, as ethanol facilities expanded and production capacity increased, concerns about profitability, feedstock efficiency, and environmental performance got louder. Feedstock costs, energy prices, and fuel policies all have a significant impact on ethanol production margins. This has led the industry to seek ways to optimize every aspect of the process, ensuring that nothing goes to waste. The result is the transformation of conventional ethanol plants into biorefineries, where multiple value streams are derived from a single raw material.

One of the most significant advancements in this evolution has been the commercial extraction of Distillers Corn Oil (DCO). Once overlooked as a minor component in distiller's grains, DCO is now recognized as a high-value product with applications ranging from biodiesel feedstock to animal nutrition and industrial chemicals. The rise of DCO exemplifies how bioethanol production can align with the principles of the circular bioeconomy: maximizing resource utilization, reducing waste, and creating new revenue opportunities.

Distillers Corn Oil: Meeting Current Industrial Demands

The demand for Distillers corn oil in India has risen due to the Ethanol Blending Policy and the promotion of biofuels. India aims for approximately 20% ethanol blending in petrol. To achieve that objective, the government is promoting ethanol production from corn, rice, surplus food grains, and other starch-rich resources, in addition to conventional molasses and sugarcane. This amplifies the quantity of distiller's grains and oils generated as by-products.

The government has raised the price of corn-based ethanol in its recent initiatives. This reallocates additional feedstocks to ethanol, hence augmenting byproduct (including oils) production. Aside from biofuel and bioenergy, the feed business, encompassing poultry, dairy, and animal producers, persistently seeks additional cost-effective sources of energy and protein in feed. Distillers dried grains (DDGS), by-products of ethanol and corn production, function as cost-effective substitutes for oilseed meals like soybean meal. This increases the demand for these co-products.

As ethanol production from grains escalates, the availability of DDGS increases, leading feed manufacturers to employ them more extensively. Due to increased returns and government policy, a greater number of farmers are cultivating corn and cereals instead of traditional oilseed crops. This simultaneously enhances the supply of raw materials for ethanol/DCO, hence elevating feed-meal prices and rendering DDGS/DCO more competitive. Moreover, maize (corn) is being significantly diverted to ethanol production, increasing competition and demand. India is under import pressures for corn and raw materials due to rising domestic demand for feed and fuel, leading to increased domestic prices. This increases the worth of DCO and its by-products as local alternatives.

Corn Kernel to Corn Oil: Pathway to Distillers Corn Oil (DCO)

The distribution of oil within the corn kernel is highly uneven, with the germ fraction serving as the predominant reservoir, contributing approximately 80–84% of the total oil content. The aleurone layer, although limited in its overall mass, accounts for nearly 12% of the kernel oil, while the starchy endosperm contains only about 5%. This compositional profile underscores the germ as the principal target for industrial oil recovery, given its high lipid concentration and extractive potential. In contrast, the relatively low oil content of the endosperm and aleurone layer suggests that their role in commercial oil extraction is minimal, though they may contribute to minor lipid recovery during whole-kernel processing. The localization of oil in specific anatomical fractions is therefore a critical factor in designing efficient corn fractionation and valorisation strategies. The primary raw material for DCO production is whole corn grain, which contains oil naturally distributed throughout the kernel. Unlike food-grade corn oil (extracted from germ via hexane in wet milling), DCO is recovered post-fermentation during ethanol production in dry-mill plants. The process begins with cleaning and grinding corn kernels into fine flour. This flour is mixed with water and enzymes to convert the starch into fermentable sugars, which are then fermented using yeast to produce ethanol. Once the ethanol is distilled and removed, the remaining by-product whole stillage contains proteins, fiber, and oil.Through centrifugation, this stillage is separated into two streams; Wet Distillers Grains (WDG): the solid component, rich in nutrients and thin Stillage; a liquid rich in solubles and oil. The thin stillage is then evaporated to form a concentrated liquid called syrup (or Condensed Distillers Solubles – CDS). DCO is primarily recovered from thin stillage or syrup using high-speed centrifuges, sometimes aided by enzymes and demulsifiers to improve separation efficiency.

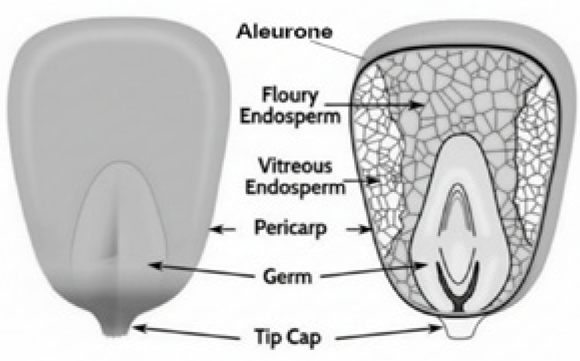

Figure 1. Diagrammatic representation of a corn kernel showing the major anatomical fractions—pericarp, endosperm, and germ (oil-rich fraction).

Methods for DCO extraction

Extracting corn oil from ethanol production byproducts involves several methods aimed at maximizing yield and quality while keeping costs and environmental impact low. The best technique often depends on the feedstock types like whole stillage, thin stillage, CDS, DDGS, wet cake, or syrup. There are mainly 3 methods available for corn oil extraction: chemical, enzymatic and mechanical extraction.

Chemical demulsification uses surfactants and additives such as Tween® 80-Span® 80 and silica nanoparticles to break emulsions and boost oil release before centrifugation, improving recovery from syrup and CDS. Supercritical CO_2 extraction, which uses carbon dioxide at high pressure and moderate temperature, offers pure, solvent-free oil but requires costly equipment, limiting its use.

Enzymatic treatments with lipases, cellulases, and proteases break down cell walls and emulsions, freeing more oil. This method, especially enzymatic-assisted aqueous extraction (EAAE), produces clearer, phospholipid-free oil with lower energy use and environmental impact. Traditional solvent extraction with hexane remains effective for dried coproducts, recovering even bound oils.

Mechanical centrifugation separates stillage into solids, liquids, and sometimes an oil-rich cream, allowing further oil recovery. Concentrating thin stillage into CDS and centrifuging helps isolate free oil from other components. Thermal and pH pretreatments, often combined with chemical or enzymatic agents, further break emulsions and improve oil separation. Together, these methods offer a range of options, each with trade-offs in efficiency, cost, and sustainability. Ongoing improvements and combining these approaches hold promise for better corn oil recovery from ethanol coproducts.

Chemical Demulsification- Stream used: CDS/ syrup

Chemical demulsification is a widely studied approach for enhancing corn oil recovery from ethanol production byproducts, particularly condensed distillers solubles (CDS) and syrup, where oil is tightly bound in stable emulsions. This method employs chemical additives such as surfactants and solid agents like silica nanoparticles to disrupt the interfacial films that stabilize oil-in-water emulsions. By reducing interfacial tension and breaking down emulsion stability, these demulsifiers liberate entrapped oil, which can then be more efficiently separated by centrifugation or other mechanical processes. Chemical demulsification is valued for its ability to improve oil yield without requiring extensive thermal or enzymatic pretreatments. However, its industrial application must balance cost, chemical dosage, and potential downstream impacts on coproduct quality and environmental sustainability (Luangthongkam et al. 2015). Decanting the whole stillage into thin stillage and wet cake usually results in 40-60% of the total oil in the maize kernel remaining in the wet cake and the remainder going to thin stillage. Condensed corn distillers with soluble (CCDS) with a water content of 60-85 % are created by further evaporating the thin stillage, and a disk stack centrifuge is used to separate the DCO from the CCDS (Wang et al., 2009).

Supercritical CO_2 Extraction- Stream used: DDGS or whole stillage (dried)

A wide range of compounds can serve as supercritical fluids, but carbon dioxide is the most commonly used in the food industry due to its non-toxic and non-flammable nature, high purity, low cost, recyclability, and ease of removal from final products. In the extraction of corn oil, compressed carbon dioxide is introduced into a supercritical fluid extraction (SFE) reactor containing flaked corn germ (Carlson et al., 2001). The process operates at around 50°C and pressures between 351 and 562 kg/cm². Once the system is depressurized, the oil is collected in a reservoir, resulting in a product free from solvent residues (Bozan and Temelli, 2002). One key advantage of using supercritical fluids is their ability to achieve high mass transfer rates for solutes. This is due to their higher diffusivity, lower viscosity, and reduced surface tension compared to traditional liquid solvents. These properties make supercritical fluids an effective and attractive option for extraction and separation processes. This method offers the advantage of producing high-quality, solvent-free oil, but its drawbacks include high initial investment and limited industrial adoption.

Enzymatic Treatment- Stream used-whole stillage or syrup

Enzymatic-assisted aqueous extraction (EAAE) utilizes specific enzymes to break down plant cell walls, allowing oil to be released into an aqueous solution. The effectiveness of this process heavily depends on the type and activity of enzymes used, as well as the pretreatment conditions. Common enzymes employed in this method include cellulase, α-amylase, and pectinase. According to Luangthongkam et al. (2015), combining cellulolytic enzymes with protease and phytase during fermentation can enhance oil separation in thin stillage.

This enzymatic approach offers several benefits for industrial oil extraction, such as reduced environmental impact, lower energy requirements, and improved product quality. A key advantage of this method is that the extracted oil is free from phospholipids, resulting in clearer, less turbid oil. Enzymes like lipases, cellulases, or proteases are used to break emulsions and cell walls, enhancing oil release. This step is often combined with centrifugation or thermal treatment for improved extraction.

Solvent Extraction- stream used- DDGS, wet cake, or syrup

Solvent extraction is a widely used method for recovering corn oil from ethanol production byproducts, including whole stillage. Whole stillage is a slurry that remains after ethanol distillation and contains solids (mainly fibre, protein, residual starch) and liquids rich in dissolved solids and emulsified oil (Moreau et al., 1999). In this method, organic solvents are used to dissolve the oil present in the stillage matrix, separating it from solids, proteins, and carbohydrates. Solvent extraction is particularly effective at recovering both free and bound oil, including oil trapped in cell structures or emulsions, which might not be fully recoverable through centrifugation alone. Common solvents used for Distillers Corn Oil (DCO) extraction include hexane, ethanol, isopropanol, acetone, mixed solvent systems, and emerging green solvents. Hexane is the most widely used due to its high oil solubility, low boiling point (~69°C), ease of recovery, and cost-effectiveness, though it is flammable and poses health and environmental risks. Ethanol is a safer, renewable alternative capable of extracting both polar and non-polar compounds, but it is less selective for oil, costlier, and more challenging to recover. Isopropanol, with moderate polarity, helps break emulsions and extract lipids, offering better selectivity than ethanol but still less efficient than hexane, while also being flammable and volatile. Acetone is a strong solvent useful for lipid and pigment extraction, often in combination with other solvents, but is unsuitable for food-grade oil due to toxicity concerns. Mixed solvent systems, such as hexane-isopropanol or ethanol-acetone blends, improve extraction efficiency in emulsified systems like stillage. Emerging green solvents, including deep eutectic solvents (DES) and ionic liquids, are being explored as cleaner, safer alternatives with comparable performance.

Type of corn oil	Feedstock (% oil)	Process	Oil Recovered wt%
Corn oil from pressing and/or solvent extraction of dry milled corn germ	Germ from corn dry mill (15–25%)	Pressing or hexane extraction	90–99%
Corn oil from aqueous enzymatic extraction of germ from corn dry mills	Germ from corn dry mill (15–25%)	Water, enzymes, and centrifugation	40–60%

Table 1: A Comparison of the Feedstock, Process Details, and Yields of Various Corn Oils.

Thermal / pH Pretreatment- Stream used: syrup

A significant portion of the oil in CCDS remains trapped in emulsions or bound to proteins and carbohydrates, making recovery inefficient through conventional methods such as centrifugation alone (Wang, T., & Johnson, L. A. 2011). Recent studies have demonstrated that combining physical and chemical treatments can significantly enhance oil recovery from CCDS. Heating, for example, has been shown to make a major difference: raising the temperature from approximately 25 °C to 59 °C improved oil yield by a factor of 2.5. Heat helps to break down the physical interactions that hold oil within the matrix, allowing it to separate more easily.

pH also plays a critical role. Acidic conditions (low pH) resulted in much better oil recovery compared to alkaline environments. Interestingly, when working under alkaline conditions, the use of a reducing agent such as sodium metabisulfite, in combination with heat, improved oil release—suggesting a path forward for recovering oil even in less favourable pH environments.

Chemical extraction methods also proved highly effective. The use of polar solvents like isopropanol or butanol led to oil recovery rates exceeding 80%. Even more effective was a co-solvent system combining hexane and ethanol, especially when paired with the co-extraction of zein, a corn-derived protein. This approach yielded the highest recovery, reaching approximately 89%.

In addition, a more mechanical approach—churning CCDS at a mildly acidic pH (~3.5) and moderate temperature (~50 °C) for several hours—also achieved up to 80% oil recovery, highlighting the value of combining physical agitation with chemical conditioning.

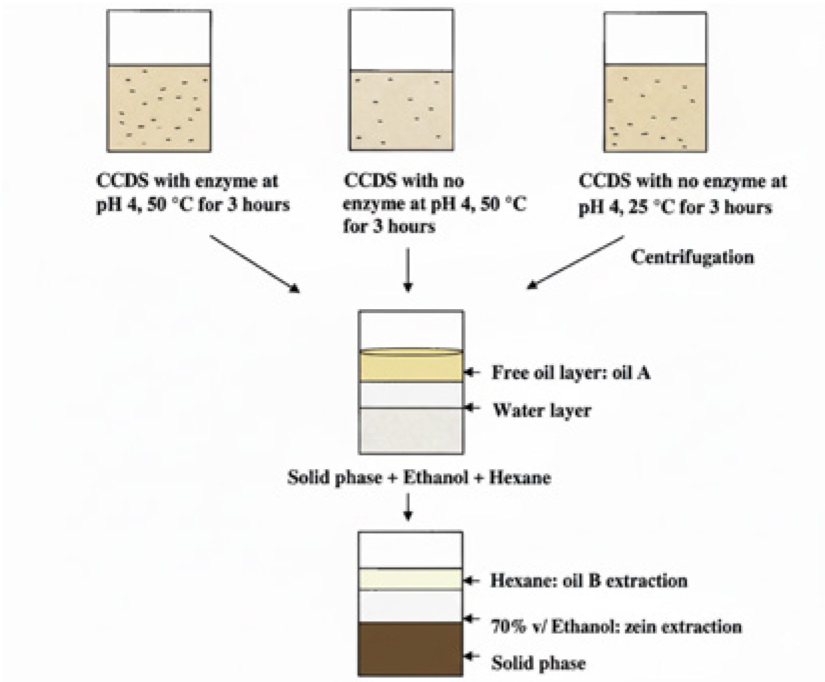

Fig 2: Schematic representation of the oil and zein co-extraction. (AOAC Official Methods 2000)

Mechanical separation / centrifugation- stream used- whole stillage.

Whole stillage, a major byproduct of the ethanol production process, is initially subjected to centrifugation using decanter or tri-canter centrifuges to achieve phase separation. This process yields three primary fractions: wet cake, predominantly composed of solids and serving as the precursor for Distillers Dried Grains with Solubles (DDGS); thin stillage, a liquid fraction containing dissolved and suspended constituents; and, occasionally, an intermediate oil-rich cream layer. The thin stillage, which retains residual oil, can undergo further centrifugation or treatment to enhance oil recovery, thereby improving the overall yield.

For oil recovery from the concentrated stream, thin stillage is routed to evaporators where water removal concentrates the soluble components, forming Condensed Distillers Solubles (CDS). CDS is a syrup-like matrix containing residual oil, soluble nutrients, and fine suspended particles. Corn oil is subsequently recovered from CDS using disk-stack or tri-canter centrifugation, in which the oil forms a distinct floating fraction that can be skimmed off. This multi-stage recovery strategy not only maximizes oil extraction from stillage but also enables the efficient production of value-added co-products such as DDGS and CDS for feed and industrial applications.

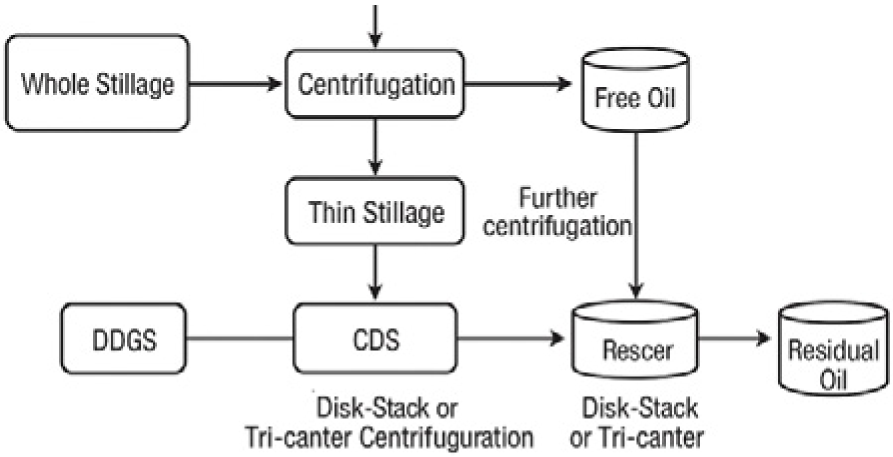

Figure 2: Schematic representation of corn oil recovery from ethanol production byproducts. Whole stillage is first centrifuged into wet cake, thin stillage, and an occasional oil-rich cream layer. Thin stillage is either directly centrifuged to recover free oil or sent to evaporators to produce Condensed Distillers Solubles (CDS), from which residual oil is extracted using disk-stack or tri-canter centrifugation. The process maximizes oil recovery while generating value-added co-products such as DDGS and CDS.

Role of Enzymes Corn oil enhancement

The plant cell wall is a complex, dynamic structure that provides mechanical support, protection, and regulates cell growth. Its primary components include cellulose, a linear polymer of β-1,4-linked glucose units forming microfibrils; hemicellulose, a heterogeneous group of branched polysaccharides that crosslink with cellulose; pectin, a gel-like matrix rich in galacturonic acid that contributes to wall porosity and flexibility; and structural proteins such as extensins that reinforce the wall. In addition, secondary cell walls, which develop after cell growth, contain lignin, a phenolic polymer that adds rigidity and water resistance. In maize (Zea mays), a C4 cereal crop, the cell wall composition varies with tissue type but typically consists of approximately 35–40% cellulose, 20–25% hemicellulose, 15–20% lignin in mature tissues, and minor amounts of pectin and proteins, contributing to both structural integrity and resistance against pathogens. This composition not only influences plant growth and development but also affects digestibility and processing in food and biofuel applications. Enzymes play a vital role in enhancing corn oil extraction by breaking down the complex structures within corn mash and stillage that typically trap oil. Acting as biological catalysts, enzymes such as cellulases, hemicellulases, pectinases, and proteases target plant cell walls and protein matrices, disrupting the physical and chemical barriers that hinder oil release. This breakdown reduces the emulsion stability and structural integrity of the mash, allowing oil to separate more easily. Additionally, amylases help by converting starches into sugars, reducing viscosity, and further improving oil recovery (Majoni et al., 2011). Through these combined actions, enzymes significantly increase the efficiency of mechanical separation processes like centrifugation.

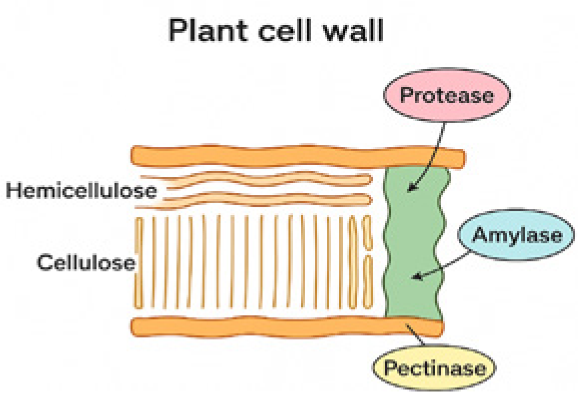

Figure 3. Schematic representation of plant cell wall composition

Main enzymes used in corn oil Extraction and their specific roles:

Proteases degrade proteins surrounding oil droplets, releasing the trapped oil and facilitating its separation during centrifugation. Cellulases target cellulose in plant cell walls, loosening the fibrous structure to free oil contained within the tissue, while hemicellulases break down hemicellulose, further dismantling complex carbohydrates and aiding oil release. Pectinases act on pectin in the cell walls, loosening the matrix to improve oil liberation, and amylases convert starch into simple sugars, reducing mash viscosity and thereby enhancing both oil separation and overall extraction efficiency. Collectively, these enzymes synergistically improve the yield and efficiency of oil recovery processes.

Mechanism for Enzyme action in corn oil extraction:

Cell wall disruption	Corn kernels, especially in the fiber and germ parts, have oil enclosed within cell walls made of complex polysaccharides like cellulose and hemicellulose Cellulase enzymes break down complex polysaccharides in corn fiber and germ cell walls, releasing trapped oil and reducing slurry viscosity to improve oil separation.
Breakdown of protein oil complexes	Proteases break down protein-lipid complexes in corn, releasing bound oil, promoting droplet merging, and improving mechanical separation efficiency.
Hydrolysis of starch	Starch directly does not attach to oil, any remaining starch can hinder oil extraction. During fermentation, amylase enzymes break down this starch into sugars it lowers viscosity. It indirectly easy movement and release of oil droplets.
Coalescing oil droplets	Enzymes break down emulsifiers like proteins and phospholipids, allowing small oil droplets to merge into larger ones, improving separation during centrifugation or decanting.
Enhanced separation Efficiency	It reduces emulsion stability and increases free oil, improving slurry properties and boosting distillers corn oil (DCO) recovery during centrifugation.

Importance of enzymatic Treatment in oil recovery:

A modified enzymatic extraction approach using a 4-hour incubation at 50°C and pH 4.0, optimal for cellulases and xylanases, greatly improved oil recovery from corn germ, with commercial cellulases like Multifect GC, GC 220, and Celluclast achieving yields of up to 80%. In comparison, non-enzymatic extraction resulted in significantly lower yields (~27%), while other enzymes such as proteases and pectinases produced moderate improvements (30–44%) (Moreau et al,2004). To further optimize extraction, three enzyme-based strategies were tested. The first applied cellulase (GC220) in a buffered system, achieving around 56.6% yield, with microwave pretreatment outperforming boiling. The second method combined cellulase with alkaline proteases (Alcalase or Multifect Neutral) under similar conditions, increasing yields to approximately 65.6%, though not significantly beyond protease use alone. The third approach eliminated buffers entirely, adjusting pH with sulfuric acid and potassium hydroxide, resulting in yields up to 64.1% from dry-milled germ and 80.9% from enzymatically milled germ (E-Germ), highlighting its potential for efficient, scalable industrial application (Moreau et al,2009).

To enhance oil extraction from Distillers Dried Grains with Solubles (DDGS) through a combination of physical fractionation and enzymatic treatment. Using sieving and aspiration, it was determined that particles measuring between 0.42 and 0.84 mm provided the highest oil yield, with the heavier fractions being richer in oil. Based on this, two oil-rich fractions were selected for further enzyme treatment. Protease, cellulase, and hemicellulase enzymes were applied both individually and in combinations at a 5% dosage. The greatest oil recovery, 94%, was achieved when all three enzymes were used together, with the protease and cellulase combination closely behind at 93% (Huda et al,2021). Individually, protease and cellulase moderately increased oil extraction, while hemicellulase had little effect. Overall, the integration of fractionation and targeted enzymatic treatment markedly improved oil recovery from DDGS.

Industrial Advantages for DCO:

Higher Oil Recovery and Improved Efficiency

Enzymes degrade cell walls and protein structures, freeing more oil compared to mechanical or solvent techniques, thereby enhancing oil extraction and minimizing waste.

Reduced Costs and Energy Consumption

Enzymatic extraction operates at gentler conditions, decreasing energy demand and chemical usage, which results in lower production expenses and less need for extensive refining.

Environmentally Friendly

Enzymatic methods reduce chemical solvents and emissions, offering a sustainable, eco-friendly alternative that meets stricter environmental standards.

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Microbial Contamination and Spoilage of Corn oil

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Grain and oil crops are pivotal agricultural commodities that significantly impact the national economy, people's livelihoods, and overall food security. The quality and safety of these products can directly influence food safety and international food prices.

Corn oil, a refined edible oil considered microbiologically stable compared to high-water foods, is influenced by microbial activity at several stages from corn handling through final processing. Microbial aspects range from spoilage risks and contamination to the use of microorganisms in oil processing and innovation.

Types of Microbial Contamination in Corn Oil

Bacteria: Refined corn oil is less prone to spoilage, but contamination can still occur if the refining or handling process is inadequate, leading to rare but impactful recalls due to pathogens like Salmonella (https://corn.org/policies/product-safety-quality/). Common contaminants can include Bacillus spp., Staphylococcus, Escherichia coli, Klebsiella spp., Pseudomonas spp., and Acinetobacter spp. These bacteria can spoil oil, cause off-flavours, and influence the microbiome if consumed.

Fungus: Mycotoxin contamination is a major threat to the quality of grain and oil crop products, and therefore the prevention and control of mycotoxin contamination in grain and oil crops is a top priority for all major grain- and oil-producing countries. Fungal species such as Aspergillus fumigatus and Mucor spp. have been detected in corn oil, with A. fumigatus unique to corn oil among common food oils. These fungi may produce mycotoxins, which are a concern especially if the source corn is mold-damaged before extraction (Zhang et al., 2021).

In grain storage and milling, moulds dominate due to low water activity, but improper storage or excess moisture increases risk from spoilage fungi. Bacterial contamination is rarer but still possible, especially if water content is elevated (Doyle, 2013).

Microorganisms in Corn Oil Production and Biotransformation

Certain microorganisms are harnessed for industrial biotransformation or processing of corn oil. For example, Pseudomonas aeruginosa has been used for single-step conversion of corn oil phytosterols into steroid intermediates. Oleaginous yeasts and fungi (like Ustilago maydis) are studied for microbial oil production using corn stover as substrate, providing a sustainable alternative to plant-derived oils (Gokulan et al., 2021).

Microbial activity may induce off-flavors, rancidity, and reduce shelf life. Consumption of contaminated corn oil can expose users to microbial toxins (e.g., aflatoxins), cause intestinal disturbances, increase inflammation, and disrupt gut microbiota. Processing steps such as refining, deodorization, and heating are very effective in removing or inactivating bacteria, yeasts, moulds, and their spores, making finished corn oil generally regarded as microbiologically stable.

Spoilage Mechanisms

Hydrolysis and Oxidation: Microbes produce lipases and other enzymes that break down triglycerides, creating free fatty acids and leading to rancidity. They can also cause colour changes, cloudiness, and reduce nutritional value.

Mycotoxin Production: Fungal contaminants may produce toxic compounds such as aflatoxins or ochratoxin, posing serious food safety risks.

Sensory Changes: Spoilage often presents as off-flavours, odours, and visible mould growth. Oil can also become turbid or lose its original colour.

Corn oil's microbial aspects encompass both the risks of contamination (mainly fungal, some bacterial) and innovative uses of microbes for oil production and processing. Good manufacturing, storage, and refining practices are essential to minimize microbial risks, while research continues into microbial and enzymatic strategies for improving yield and sustainability in corn oil production.

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Physical and Chemical properties of Distillery Corn oil

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Introduction

Distillers Corn Oil (DCO) is derived from the production of corn-based ethanol processes. It serves as a high-quality fat and energy source in animal feed for poultry and swine diets due to its high metabolizable energy (ME) content and essential fatty acids. DCO is also a significant and fast-growing feedstock for biodiesel production and has other industrial applications like rust inhibitors and soaps. The product is intended for non-human consumption only. It containing higher levels of bioactive compounds like tocotrienols and phytosterols, making it valuable for both livestock nutrition and biofuels.

Characteristics of Distillers Corn Oils

Total Fatty Acids:	85%
Unsaponifiable Matter:	2.5%
Insoluble Impurities:	0.5%
Maximum Free Fatty Acids:	18%
Maximum Moisture:	1%

Physical properties

Appearance and Odour: Distillery Corn oil is typically a dark, light reddish-orange liquid, distinguishing it from the golden-yellow colour of refined corn oil. The odour of distillers' corn oil (DCO) is typically pungent and can also have a burnt or smoky character due to the fermentation and drying processes involved in ethanol production.

Stability: It has good stability during storage due to its high polyunsaturated fatty acid content; it is more prone to oxidative spoilage because it is a strong oxidising agent.

Density and Viscosity: The relative density of DCO is typically around 0.912 to 0.925 g/cm3, with specific figures varying by source and temperature. The viscosity of corn oil decreases as temperature increases. In one study, DCO was reported to have a viscosity of 28.7 cp at 40°C.

Melting point and Boiling point: The melting point of distiller's corn oil is quite low, falling in the range of -18 to -10 °C (-0.4 to 14 °F), so due to low melting point Distillers Corn Oil in liquid state under normal temperature.

Like other oils, distillers corn oil doesn't have a single, fixed boiling point instead it boils over a range of temperatures. The flash point is a more practical measurement, representing the lowest temperature at which the oil's vapours can ignite with an ignition source. The flash point is typically around 254 °C (489.2 °F) for distiller's corn oil.

Insoluble impurities: Insoluble impurities in distillers corn oil (DCO) include particulate matter from the corn and processing, such as fine solids, undigested residues, non-lipids compounds and potentially some gums and waxes that remains after ethanol fermentation and oil recovery process. These impurities are physical contaminants rather than chemical compounds, and their presence and levels can vary significantly depending on the source and processing of the DCO.

Solubility: Distillers Corn Oils are soluble in organic solvent like ether, benzene, chloroform. It has limited solubility in ethanol but insoluble in water.

Chemical properties

Distillers corn oil (DCO) is high in polyunsaturated fatty acids (54-62%) (PUFAs) like linoleic acid, saturated fatty acids (15-18%) such as palmitic acid, and monounsaturated fatty acids (25-33%) including oleic acid. It also contains significant amounts of phytosterols, tocopherols, and carotenoids and exhibits higher free fatty acid (FFA) and lower oxidative stability compared to refined corn oil.

Poly unsaturated fatty acids: Distillers corn oil (DCO) is rich in polyunsaturated fatty acids with linoleic acid being the most prevalent.
The fatty acid profile of DCO includes the following key PUFAs -

- Linoleic acid (C18:2 n-6) - This is the most abundant PUFA in distillers corn oil, typically making up 54–62% of the total fatty acids and a type of polyunsaturated omega-6 fatty acid. Linoleic acid is a key component of DCO, contributing to its energy value and making it a popular ingredient in animal feed.
- α-Linolenic acid (C18:3 n-3): DCO contains only minor amounts of this omega-3 fatty acid, usually less than 1% to 2% of the total fatty acids.

Mono unsaturated fatty acids - Distillers corn oil (DCO) is rich in monounsaturated fatty acids (MUFAs), with sources indicating that MUFAs can make up around 25% to 33% of its total fatty acid composition, with oleic acid (C18:1) being the primary MUFA present.

Saturated fatty acids - Distillers corn oil (DCO) is relatively low in saturated fatty acids (SFAs), with estimates around 15% making it a more desirable option for feed and other applications compared to oils with higher saturated fat.

The typical proportion of saturated fatty acid in Distillers Corn Oils -

- Palmitic acid (C16:0): Generally, the most abundant saturated fatty acids, making up about 11% to 14% of the total fatty acid content.
- Stearic acid (C18:0): Usually present in a smaller amount, around 1% to 2% of total fatty acid content.

Other Saturated fatty acids: DCO also contains trace amounts of longer-chain SFAs, such as arachidic acid (C20:0), behenic acid (C22:0), and lignoceric acid (C24:0).

Phytosterols: DCO contains high levels of phytosterols, sometimes exceeding 19000 mg/kg or 1.9% this makes DCO a valuable and sustainable source for these bioactive lipids. The major components of phytosterols are β-sitosterol, sitostanol, camp sterol, and campestanol.

Tocopherols (Vitamin E) - The oil includes various tocopherols, such as alpha-tocopherol and gamma-tocopherol which are potent antioxidants that help to stabilize the oil and contribute it to the high oxidative stability. Range of Tocopherols in DCO 0.08% to 0.12%.

Carotenoids - DCO is a valuable source of carotenoids, including lutein and zeaxanthin, known for their roles in vision and as antioxidants. Carotenoids are powerful antioxidants that help protect cells from damage caused by free radicals. Carotenoids generally found in DCO between 0.02 to 0.05%. It contains lutein because it is a by-product of corn processing and corn is the natural source of lutein; the yellow pigment is responsible for its colour.

Unsaponifiable matter - These are substances in an oil or fat that cannot be transformed into water-soluble soaps when treated with an alkali. Generally, unsaponifiable matter in DCO varies 1 to 2.5%.

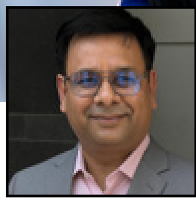
Free Fatty Acids (FFAs) - DCO generally has a higher Free fatty acids content compared to conventional corn oil. Typical DCO can have a free fatty acid content ranging from below 2% to as high as 18%. The composition of DCO is similar to refined corn oil, with dominant fatty acids being oleic acid (monounsaturated) and linoleic acid (polyunsaturated) while DCO has a fatty acid profile similar to refined corn oil, it has a key difference in its concentration of free fatty acids (FFAs). The extraction process for DCO can leave it with a significantly higher FFA content compared to refined corn oil and this makes it a popular and affordable feedstock for biodiesel and a valuable energy source in animal feed.

Flammability - Distillers Corn Oils are incompatible with strong oxidising agents such as acid and bases. If it is involved in fire the oil can produce irritating vapours and toxic gases such as carbon oxides.

Oxidative Stability - DCO is typically more stable than refined corn oil but is susceptible to oxidation over time, with peroxide and thio-barbituric reactive substances (TBARS) content increasing with extended storage, indicating spoilage. High FFA levels reduce an oil's oxidative stability. This makes it more prone to rancidity and affects its shelf-life. DCO also contains higher levels of antioxidants like lutein and zeaxanthin, making it more oxidatively stable than conventional corn oil.

Problems Faced During Syrup Fermentation

Maximizing efficiency, yield, and process stability in sugar mills



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Understanding Syrup Fermentation

Syrup fermentation is a core process in alcohol and ethanol production in sugar mills. In this process, concentrated sugar syrup—derived from molasses or sugarcane juice—is converted into ethanol and carbon dioxide by yeast. Efficient fermentation maximizes ethanol yield and ensures by-products, such as vinasse and residual sugars, remain manageable for further processing or disposal.

Importance for the sugar industry:

Sugar mills often run **integrated distilleries**, where molasses or syrup is used as a feedstock for ethanol production.

Fluctuations in syrup composition, sugar concentration, and yeast performance directly influence **alcohol yield, fermentation rate**, and **overall production economics.**

Benefits of optimized syrup fermentation:

- Consistent ethanol yield and product quality.
- Reduced fermentation cycle time and process losses.
- Improved regulatory compliance through better effluent management.

Key process parameters for optimal fermentation:

Parameter Ideal Range

Initial °Brix (sugar concentration) 60–65 °Brix

Fermentation temperature 30–32 °C

pH 4.2–4.5

Yeast viability ≥ 90%

Free Amino Nitrogen (FAN) 500–600 mg N/L

How Problems Develop During Fermentation

Problems during fermentation usually develop due to a combination of syrup quality, nutrient imbalance, temperature/pH variations, and microbial contamination:

- **Sugarcane storage and quality:** Prolonged storage of sugarcane before crushing reduces sucrose content, promotes microbial growth, and results in lower-quality juice. This can lead to syrup with inconsistent sugar concentration and poor fermentability, reducing ethanol yield.

- **Syrup quality:** Impurities, high viscosity, or inconsistent sugar content stress yeast.
- **Nutrient balance:** Yeast requires nitrogen, minerals, and vitamins to efficiently convert sugar into ethanol.
- **Temperature and pH:** Small deviations affect yeast metabolism, causing sluggish or incomplete fermentation.
- **Microbial contamination:** Bacteria in molasses or syrup compete with yeast for sugar, produce acids, and increase residual sugar.
- **High Sulphur Content:** Sulfur is often used in sugar processing, especially in cane juice clarification, to control microbial growth and prevent discoloration. However, its presence in syrup or juice can have multiple effects on fermentation, sugar quality, and downstream processes.

Major Fermentation Challenges

Low Alcohol Recovery

Low alcohol recovery is one of the most common and economically significant problems in syrup fermentation.

Causes:

- Excessive sugar concentration (>65 °Brix) causing osmotic stress.
- Nutrient deficiency: Insufficient nitrogen, phosphorus, magnesium, or zinc.
- Contamination by lactic acid bacteria or wild yeasts.
- Poor yeast management: Repeated reuse or improper rehydration.
- pH drift outside 4.0–5.0 range.

Effects:

- Lower ethanol concentration (<8–10 % v/v).
- Higher residual sugar in the fermented wash.
- Sluggish or incomplete fermentation, increasing cycle time.

Solutions:

- Maintain initial syrup concentration at 60–65 °Brix.
- Supplement nutrients to achieve FAN 500–600 mg N/L.
- Use fresh, viable yeast (≥90%) and maintain proper propagation practices.
- Monitor pH, temperature, and sugar consumption regularly.

Syrup Brisk Fluctuation

Fluctuating syrup brisk indicates unstable fermentation kinetics.

Causes:

- Cuses osmotic stress on yeast..
- Create a hypertonic environment around yeast cells.
- Low yeast adaptation to high sugar concentration.
- Rapid changes in syrup Brix (sugar concentration).

Effects:

- Irregular sugar utilization.
- High residual sugar in the fermented wash.
- Increased yeast stress leading to H_2S formation or autolysis.
- Yeast cells experience shrinkage and reduced turgor pressure (osmotic stress).

Solutions:

- Gradual and controlled syrup feeding instead of single large charges.
- Ensure proper mixing to prevent localized high Brix zones.
- Monitor Brix drop and syrup brisk daily to detect fluctuations early.
- Use high viability yeast (≥90%) and maintain adequate nutrients (FAN 200–300 mg N/L).
- Use High tolerance yeast to reduce osmotic shock.

Temperature Control Issues

Temperature fluctuations are a major cause of fermentation problems.

Causes:

- Low-capacity or undersized cooling jackets, coils, or cooling towers fail to remove metabolic and exothermic heat efficiently.
- Feeding syrup at elevated temperatures increases the thermal load in the fermenter, stressing yeast cells.

- Uneven cooling or heating within fermenters creates hotspots or cold zones, leading to inconsistent fermentation.

Effects:

- Low temperatures (<28 °C) sluggish fermentation, incomplete sugar conversion, increased residual sugar and fermentation time.
- High temperatures (>34 °C) cause yeast stress, by-product formation, foam formation, and off-flavors.
- Frequent fluctuations reduce ethanol yield by 5–8%, increase cycle time, and compromise product quality.

Solutions:

- Maintain a stable fermentation temperature between 32–34 °C.
- Upgrade or ensure sufficient cooling capacity in fermenters, coils, and cooling towers.
- Ensure uniform thermal distribution using proper agitators or circulation systems.

Challenges using Sulphited Syrup

Sulphitation (addition of SO_2) during juice or syrup processing is done to inhibit microbial contamination and preserve syrup color by preventing browning.

Causes:

- Residual SO_2/bisulfite in syrup forms sulfurous acid in the fermenter.
- Excessive sulphitation during juice/syrup processing.
- Sudden addition of high-sulphite syrup into fermenters.
- Low buffering capacity in fermentation medium.

Effects:

- Fermentation pH drops below the optimal range (4.2–4.5).
- Slowed yeast metabolism and sugar conversion.
- Higher risk of H_2S formation and stuck/ sluggish fermentation.

Solutions:

- Measure pH of sulphited syrup before fermentation.
- Adjust pH to optimal range using liquid ammonia or sodium carbonate.
- Limit SO_2 addition during juice clarification (<50 ppm)..
- Gradual feeding of sulphited syrup into the fermenter..

Microbial Contamination Issues

Causes:

- Inadequate cleaning of fermenters, pipelines, tanks, and auxiliary equipment
- Residual sugar deposits that promote bacterial growth.
- Improper handling or storage of yeast and nutrients
- Contaminated molasses, syrup, or cane juice entering the fermenter

Effects:

- Lactic acid bacteria convert sugars into lactic acid, and acetic acid bacteria oxidize ethanol into acetic acid.
- Acid production lowers the fermentation pH below the optimal range (4.2–4.5), slowing yeast metabolism.
- Contaminating bacteria compete with yeast, leaving unfermented sugar in the wash. • Organic acids and metabolites reduce ethanol quality.

Solutions:

- Regular cleaning of fermenters, tanks, pipelines, and auxiliary equipment using caustic CIP and sanitizers. Remove all sugar residues.
- Check microbial load, pH, residual sugar, and ethanol levels regularly to detect contamination early.
- Use high-viability yeast (>90%), maintain optimal nutrients (FAN 500–600 mg N/L), and ensure sterile rehydration and inoculation practices.
- Routine inspection of cooling systems, pumps, filters, and other equipment to minimize contamination risk.

Foaming and Excess CO_2 Release

Excessive foaming can result in overflow and contamination.

Causes:

- High protein or surfactant content in syrup.

- Rapid CO_2 evolution from over-pitching or high temperature.
- Excessive agitation.

Effects:

- Loss of volume and ethanol yield.
- Increased contamination risk.
- Operational hazards and cleaning challenges.

Solutions:

- Use food-grade antifoam agents (silicone or vegetable-based).
- Moderate agitation and control syrup feed rate.
- Maintain 15–20% headspace in fermenters.

Other Common Challenges

- Stuck or arrested fermentation: Extreme osmotic stress, high ethanol toxicity, or contamination.
- Poor syrup quality: High suspended solids or unfiltered syrup reduce yeast contact and efficiency.
- Volatile acidity (VA) increase: Bacterial contamination increases acetic acid, reducing alcohol quality.

Best Practices

- Maintain pH between 4.2–4.5 to support yeast activity and control bacterial growth.
- Keep fermentation temperature steady at 32–34 °C for consistent yeast performance.
- Regulate syrup concentration between 60–65 °Brix to prevent osmotic stress.
- Use yeast with ≥ 90% viability to ensure quick fermentation initiation.
- Maintain FAN (Free Amino Nitrogen) at 500-600 mg N/l for optimal yeast growth and reduced H_2S formation.

Additional practices:

- Use filtered, consistent-quality syrup.
- Strict sanitation of fermenters, pipelines, and equipment.
- Daily monitoring of Brix drop, residual sugar, and ethanol percentage.
- Avoid prolonged storage of sugarcane; crush fresh cane promptly to maintain juice quality.
- Follow SOPs for yeast pitching, aeration, and feeding schedules.

Conclusion

Syrup fermentation in sugar mills is complex but manageable with proper monitoring and control. Problems such as low alcohol recovery, syrup brix fluctuations, temperature instability, sulphur formation, foaming, and poor-quality cane due to prolonged storage can be systematically addressed through balanced nutrition, optimal yeast management, and process stability. Proactive troubleshooting ensures higher ethanol yield, better quality, and improved operational efficiency in sugar mills.

Enzyme-Based Solutions for Dextran and Starch Reduction in Sugar Manufacturing Plant: A Case Study

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Abstract

This study investigates the impact of enzymatic treatment on dextran and starch reduction in a sugar manufacturing plant. By incorporating Enzydex and Enzylase in specific dosing patterns across different processing stages, significant improvements were recorded in both process efficiency and sugar recovery. The results demonstrated an average 49% reduction in dextran and 77% reduction in starch, leading to enhanced juice clarity, reduced viscosity, improved filterability, and a net recovery gain of 0.22%. This case study highlights the effectiveness of biocatalytic interventions in improving sugar quality and yield while reducing processing losses.

1. Introduction

Sugar manufacturing faces persistent challenges due to polysacchrides such as dextran and starch, which adversely affect juice clarification, crystallization, and molasses quality. Dextran, a polysaccharide produced by microbial contamination, increases viscosity and hampers crystallization, while starch interferes with filterability and final molasses purity.

Biocatalysis, through targeted enzymatic applications, offers a sustainable solution to mitigate these challenges. The present study examines the enzymatic intervention in a sugar manufacturing plant (capacity: 5500 TCD), with the objective of quantifying reductions in dextran and starch and evaluating the subsequent impact on sugar recovery and processing efficiency.

2. Methodology

2.1 Plant Details

- **Plant Capacity:** 5500 TCD
- **Enzyme Dosing Pattern:**
  - Enzydex: 1.0 ppm each in Mix Juice, Syrup, and B-Heavy Molasses (total 3 ppm).
  - Enzylase: 1.5 ppm in Mix Juice, 1.5 ppm in Syrup, and 2.0 ppm in B-Heavy Molasses (total 5 ppm).

3. Challenges at the Plant

The sugar manufacturing process faced multiple challenges due to high dextran load, where clear juice contained 3,355 ppm/100 Brix and final molasses recorded 15,704 ppm/100 Brix, resulting in higher viscosity, sluggish boiling, and sugar losses. Similarly, excess starch content was observed, with clear juice averaging 1,038 ppm/100 Brix and final molasses reaching 2,317 ppm/100 Brix, causing turbidity, poor juice filterability, and crystallization difficulties. These impurities also led to operational inefficiencies, including poor clarifier performance, increased molasses % cane, higher boiling house losses, and reduced centrifugal purgability, all contributing to sugar loss. Consequently, recovery issues arose, with average recovery restricted to 11.05% and bagging recovery efficiency at 11.32%. In short, both dextran and starch significantly inflated process losses and reduced overall profitability.

4. Experimental Design

Data were collected before and after enzyme application across multiple process stages (Primary Juice, Mix Juice, Clear Juice, Un-sulphated Syrup, B- and C-Massecuite, B-Heavy Molasses, and Final Molasses). Dextran and starch levels were analysed in ppm/100 Brix, while operational data such as cane crushed, bagged sugar, recovery, and losses were recorded.

5. Status Before Enzyme Application

A baseline evaluation conducted for eight consecutive days highlighted the true extent of the issue. Average dextran in clear juice was recorded at 3,355 ppm/100 Brix, while starch levels were at 1,038 ppm/100 Brix. Recovery parameters confirmed the inefficiencies, with average recovery at 11.05% and bagging recovery efficiency at 11.40%. Process losses averaged 1.95%. These figures made it evident that intervention was necessary to unlock higher recoveries.

6. Observations and Issues Addressed

The key issues identified were excessive viscosity, poor crystallization, higher final molasses purity, and overall increased sugar losses. Both dextran and starch were contributing significantly to these inefficiencies, making traditional chemical approaches insufficient.

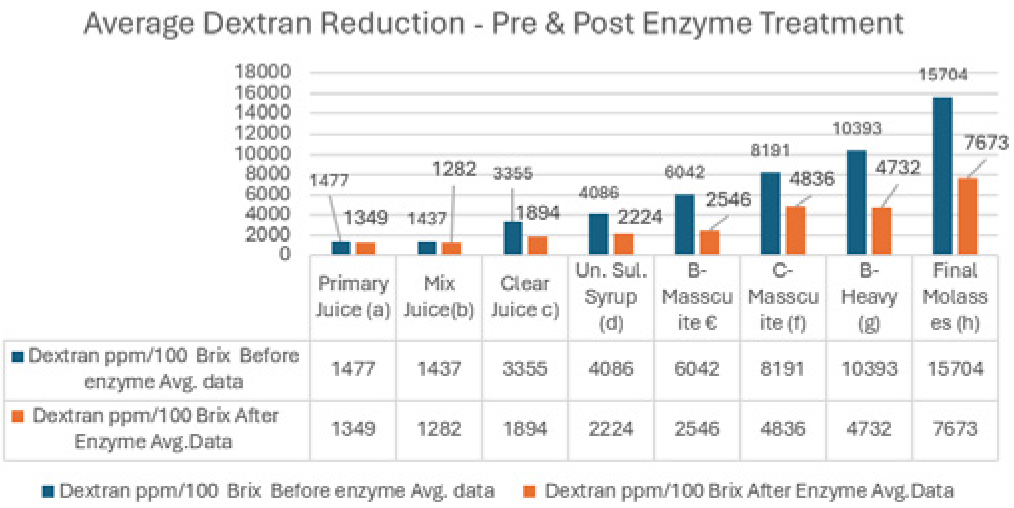
7. Protocols and Solutions Suggested

Catalysts Bio-Technologies Pvt. Ltd. introduced a dual-enzyme treatment strategy. Enzydex was applied to hydrolyze dextran into smaller oligosaccharides, while Enzylase targeted starch degradation. The dosing was distributed strategically across mix juice, syrup, and B-heavy molasses to maximize effectiveness. Monitoring was conducted throughout the trial period to ensure reliability of the results.

8. Results

8.1 Dextran Reduction

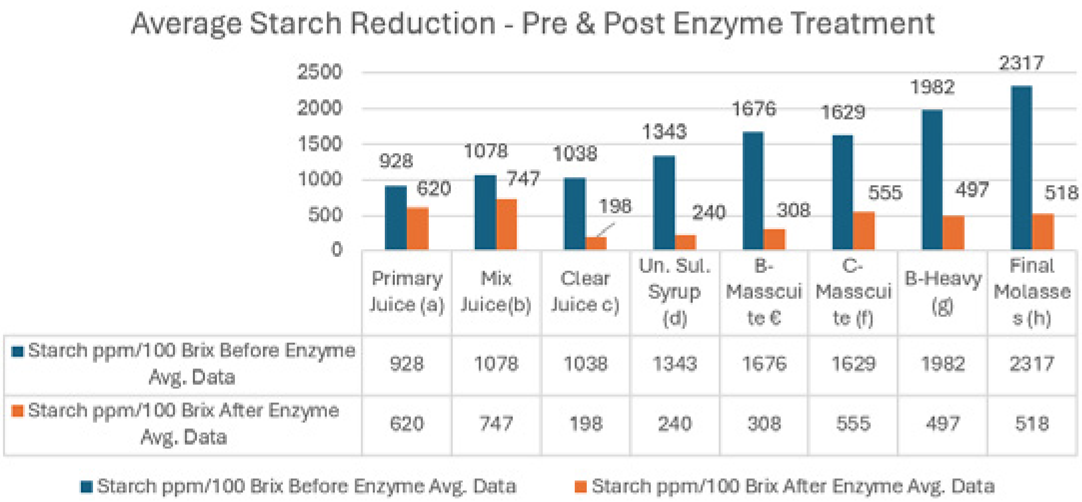
- Average dextran reduction: **49%** post-enzyme treatment.
- Clear Juice: reduced from **3355 ppm/100 Brix** to **1894 ppm/100 Brix**.
- Final Molasses: reduced from **15704 ppm/100 Brix** to **7673 ppm/100 Brix**.



	Primary Juice (a)	Mix Juice(b)	Clear Juice c)	Un. Sul. Syrup (d)	B-Masscuite €	C-Masscuite (f)	B-Heavy (g)	Final Molasses (h)
Dextran ppm/100 Brix Before enzyme Avg. data	1477	1437	3355	4086	6042	8191	10393	15704
Dextran ppm/100 Brix After Enzyme Avg.Data	1349	1282	1894	2224	2546	4836	4732	7673

8.2 Starch Reduction

- Average starch reduction: 77% post-enzyme treatment.
- Clear Juice: reduced from 1038 ppm/100 Brix to 198 ppm/100 Brix.
- Final Molasses: reduced from 2317 ppm/100 Brix to 518 ppm/100 Brix.



	Primary Juice (a)	Mix Juice(b)	Clear Juice c)	Un. Sul. Syrup (d)	B-Masscuite €	C-Masscuite (f)	B-Heavy (g)	Final Molasses (h)
Starch ppm/100 Brix Before Enzyme Avg. Data	928	1078	1038	1343	1676	1629	1982	2317
Starch ppm/100 Brix After Enzyme Avg. Data	620	747	198	240	308	555	497	518

8.3 Recovery Improvements

- Average bagging recovery improved by 1.11% (from 11.40% to 12.51%).
- Net bagging recovery gain after adjusting for pol % cane: 0.89 units.
- Sugar saving due to dextran reduction estimated at ~11 tons per day, contributing to a total recovery improvement of 0.22%.

8.4 Calculations

- Benefits on Recovery due to reduction in Dextran's analysis (Before and After analysis)
- CLEAR JUICE%CANE =99% , AVG.CRUSHING =5000TCD, 1 PART DEXT. = 4 PART OF SUGAR SAVING
- BRIX=16.80 , DEXTRAN REDUCE = 2592 PPM
- QTY. OF SUGAR SAVED = [{Crushing X (Clear juice % cane/100) x(Brix/100) X 4(Reduced Dext.ppm)}in gram

  = {(5000x0.99x0.1548x1461x4)/1000}in kg

  = 4478.02 Kg

  =44.78 Qtl.=4.48 Tons.

- GAIN IN RECOVERY % =(Qty. of Sugar Saved in tons X 100)/Crushing
  = (4.48X100)/5000 = 0.09%
- Final Molasses %CANE = 4.5 % , CRUSHING =5000TCD, 1 PART DEXT. = 4 PART OF SUGAR SAVING.
- BRIX=89.7 DEXTRAN REDUCE = 8031PPM
- QTY. OF SUGAR SAVED = [{Crushing X (FM % cane/100) x(Brix/100) X 4(Reduced Dext.ppm)}in gram
  = {(5000x0.045x0.897x8031x4)/1000}in kg
  = 6483.4Kg
  = 64.83 Qtl= 6.48Tons
- GAIN IN RECOVERY % = (Qty. of Sugar Saved in tons X 100)/Crushing
  = (6.48X100)/5000 = 0.13%
- TOTAL GAIN IN RECOVERY = 0.09 % +0.13% =0.22 %.

9. Additional Observations

- Improved juice clarity in clarifiers.
- Enhanced filterability and reduced syrup/massecuites viscosity.
- Faster boiling rate and improved centrifugal purging.
- Reduction in molasses % cane and total process losses.

10. Discussion

The enzymatic intervention demonstrated clear benefits in addressing two of the most critical bottlenecks in sugar manufacturing—excessive dextran and starch accumulation. By adopting a dual-enzyme approach, the plant was able to substantially reduce non-sugar impurities across all process stages. The consistent reduction in dextran (49%) and starch (77%) translated into lower viscosity, improved clarification, and more efficient crystallization.

Operationally, these improvements enhanced throughput in clarifiers, increased massecuite manageability, and allowed for faster boiling and improved centrifugal performance. Importantly, the enzymatic approach provided a sustainable alternative to chemical treatments, eliminating dependency on high chemical dosages while maintaining compatibility with existing process parameters.

The recovery gains (0.22%) and sugar savings (~11 tons/day) underscore the economic viability of enzyme-based interventions. Moreover, the results highlight the importance of strategic enzyme dosing across multiple points—mix juice, syrup, and B-heavy molasses—combined with continuous monitoring and process adjustments. These measures ensured reliable outcomes and maximized enzyme effectiveness under varying operating conditions.

11. Conclusion

This study validates the effectiveness of biocatalytic solutions in sugar manufacturing. The dual-enzyme strategy using Enzydex (for dextran hydrolysis) and Enzylase (for starch degradation) resulted in measurable improvements in process efficiency, product quality, and overall sugar recovery. The intervention not only reduced processing losses but also delivered sustainable economic benefits by improving recovery by 0.22%.
For plants facing similar challenges, enzyme-based strategies represent a practical, scalable, and environmentally sustainable solution. The outcomes affirm that targeted biocatalysis can transform conventional sugar processing into a more efficient, cost-effective, and future-ready operation.

Unlocking Value Through GST Reform: What Actually Changed for India's Bio-Industrial Inputs

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India's latest GST rationalisation is good news for operators and finance teams—less noise, clearer rates, and fewer arguments at the time of booking invoices. Practically, the framework now centres on two operative slabs, 5% and 18%, with a narrow de-merit category. For our world—sugar, molasses, grain and molasses distilling, brewing, and compressed biogas (CBG)—the only way to turn this policy into P&L impact is to anchor every discussion to the HSN on the invoice. If the HSN sits in the 5% schedule, you benefit. If it sits in the 18% schedule, nothing changes. That's the whole game.

Two inputs matter most to our plants. Fermentation yeast invoiced under HSN 2102 is now squarely in the 5% slab. Prepared enzymes invoiced under HSN 3507 remain at 18%. Everything else follows its declared HSN. Holding this simple line avoids misquotes, last-minute disputes, and the kind of "savings" that evaporate during reviews. It also lets procurement and AP process documents faster with fewer exceptions.

The operational win is predictability. We do not need a policy thesis to make this work; we need disciplined paperwork. We will keep stats minimal and focus on execution. Where yeast is material, the lower slab reduces GST outflow and eases working capital. Where enzymes dominate, the lever is productivity—dose optimisation, steadier conversions, and short experiments that become standards. Separating the tax story (yeast) from the productivity story (enzymes) keeps everyone honest and speeds up decisions.

Financial Impact (HSN-Verified Only)

Item Description	HSN	GST Slab (post-reform)	GST on ₹10,00,000 Base	Note
Fermentation Yeast	2102	5%	₹50,000	Applies only when the supplier prints HSN 2102 on the invoice.
Prepared Enzymes (e.g., glucoamylase, blends)	3507	18%	₹1,80,000	Unchanged; focus on ROI per kg and yield, not slab.

If your earlier yeast invoices used a higher GST, moving to 5% reduces outflow on those yeast lines. Validate against your own contract history before reporting savings.

The broader context is straightforward: the simplified slab structure reduces ambiguity; the itemised schedules give a single source of truth. What unlocks value is not arguing categories—it's using the right HSN every single time. For multi-site operators, that means less time lost to rework and fewer audit queries. For plant teams, that means cleaner pricing conversations with vendors and faster booking at AP.

Because many teams asked for a simple tool to take to management, here is a yeast-only calculator. It avoids speculation and works only where the invoice HSN is 2102. Replace the example numbers with your actuals.

Yeast-Only Savings Calculator (Example Values)

Segment	Annual Yeast Spend (₹)	Old GST Used in Your Contracts (%)	New GST (post-reform)	Annual GST Outflow (Old)	Annual GST Outflow (New)	Annual Difference (₹)
Grain Distillery (150 KLPD)	3,00,00,000	12%	5%	36,00,000	15,00,000	21,00,000
Molasses Distillery (100 KLPD)	1,80,00,000	12%	5%	21,60,000	9,00,000	12,60,000
Brewery (0.8 MHL/year)	1,00,00,000	12%	5%	12,00,000	5,00,000	7,00,000

How to use: change the spend and your **old yeast GST** to match your contracts. Use this only for SKUs invoiced under **HSN 2102**. Do **not** include enzymes or blends unless the invoice clearly shows 2102.

What This Means on the Ground

For procurement, it means cleaner, shorter negotiations. When yeast is clearly at 5%, we can separate the tax effect from service levels—cold-chain adherence, QC documents, and on-site tech support. With enzymes still at 18%, we shift the vendor conversation to measurable performance: conversion at steady dose, stability under stress, or cycle-time impact. Small, reversible pilots with 24–48-hour readouts will let us prove or disprove claims quickly and lock wins into SOPs. Finance will see the impact in fewer reworks, lower rejection rates, and steadier energy intensity—not just in tax lines.

For plant leaders, it means fewer escalations. Posting the right HSN in the PO and watching for it on the invoice eliminates most rate debates. It also speeds up booking and ITC cycles. If we keep improvements simple—one-variable pilots, one-slide proof, and one-line SOP deltas—we turn policy clarity into operating calm.

For AP, it means faster, safer bookings. A clean gate—5% booked only when the invoice shows HSN 2102—prevents silent leakage and avoids later reversals. Exceptions are logged and cleared, not buried. Less manual override means fewer errors and cleaner audits.

Internal Finance Perspective: Action Plan (No Remap Edition)

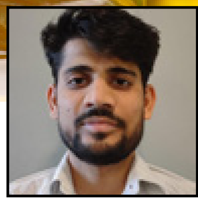
We are not changing ERP masters right now. Until system changes are possible, we'll enforce accuracy at the document level using front-door controls and a lightweight tracker. No downtime, no remapping, just tighter paperwork.

This keeps us compliant without touching masters. As and when an ERP update is convenient, the same rules can be embedded into the SKU master. For now, the gate lives in the PO, the invoice, and a small checklist that AP can run in seconds.

Closing Note

The GST reform helps, but the benefit shows up only when the HSN is correct and visible. Keep the message simple: yeast at 5% (HSN 2102), enzymes at 18% (HSN 3507), everything else by its HSN. Keep the stats minimal, keep the tables clean, and let your own numbers do the talking. If we hold that line, we will get faster bookings, fewer disputes, and a quieter, more predictable P&L—exactly what good finance and good operations should deliver together.

The Golden Grain: Corn Oil Overview



Ajay Kumar
Analyst-Business Strategy

Introduction: The Emerging Role of Corn Oil in India's Edible Oil Landscape

The Indian edible oil sector is one of the largest and most dynamic in the world, characterized by shifting consumer preferences, high import dependency, and a renewed focus on domestic oilseed production. Within this environment, corn oil, extracted from the germ of the maize kernel, is rapidly emerging as a significant contender. Known for its light texture, neutral taste, and exceptional health profile, corn oil offers a high smoke point, making it ideal for various Indian cooking methods, including deep-frying. Its rising prominence is directly linked to major shifts in consumer awareness and government policy, positioning it for substantial growth in the coming decade.

Corn oil primarily exists in two forms: edible and non-edible. While the refined edible variety is favoured for household cooking, baking, and salad dressings due to its neutral flavour and low cost, the non-edible variant is critical in a diversified range of industrial applications, including pharmaceuticals, cosmetics, and most notably, the burgeoning biofuel sector. As a key co-product of the maize-based ethanol industry, corn oil is becoming strategically valuable, moving from a niche product to a high-potential segment in India's agricultural and energy economy.

Current Market Scenario: Health, Diversification, and Untapped Potential

The Indian corn oil market is currently valued at USD 0.60 Billion in 2024 and its expansion is powered by twin engines: consumer health consciousness and diversification across multiple industries.

Health-Conscious Consumption and Culinary Appeal

A primary driver is the increasing national concern over lifestyle diseases such as cardiovascular issues, obesity, and high cholesterol. Consumers are actively seeking healthier alternatives to traditional oils, and corn oil fits this demand profile.

It is widely regarded as a heart-friendly option because it is rich in polyunsaturated fats (PUFA), particularly Omega-6 fatty acids, and possesses a low saturated fat content. Furthermore, its high concentration of Vitamin E provides antioxidant benefits, enhancing its appeal as a nutritious cooking medium. The oil's high smoke point ensures stability at high temperatures, making it a preferred choice for the food processing industry, especially in the manufacturing of snack foods.

Regional and Product Dynamics

Historically, the consumption of corn oil in India has shown regional concentration, with the Western region noted as the primary user. However, the rising tide of urbanization and increased disposable income is leading to a shift in dietary habits across the country, encouraging a greater adoption of packaged and branded cooking oils, thereby broadening corn oil's geographical market. Within this, the market is witnessing a clear trend: a growing consumer demand for Non-GMO (Genetically Modified Organism) corn oil due to escalating health and safety concerns, pushing manufacturers toward more transparent and organic sourcing.

Industrial Applications and the Maize Ecosystem

Beyond the kitchen, corn oil's versatility is strengthening its market position. The food processing sector utilizes it extensively, and in the pharmaceutical and cosmetics industries, it serves as a reliable ingredient in topical creams, ointments, and as a carrier for drug molecules.

Most critically, corn oil production is intrinsically linked to the larger maize sector, which is India's third most important cereal crop. A significant portion of corn oil is obtained as Distillers Corn Oil (DCO), a valuable co-product from ethanol production. While the Dry Milling process is often preferred by distilleries for its efficiency in producing DCO alongside ethanol, the industry is increasingly focused on developing technology to maximize the yield and value of this by-product.

Future Perspective: Growth Trajectory and Strategic Opportunities

The outlook for the Indian corn oil market is robust, driven by favourable government policies and the integration of corn oil into the nation's energy security plans.

Market Projection and Growth Drivers

Looking ahead, the India corn oil market is projected to reach a value of USD 1.10 Billion by 2033, exhibiting a healthy Compound Annual Growth Rate (CAGR) of 6.10% between 2025 and 2033. This aggressive growth is underpinned by several strategic opportunities:

- **The Biofuel Thrust:** The strongest future driver is the use of corn oil as a feedstock for biodiesel production. The Indian government's goal to accelerate the nationwide ethanol blending has significantly boosted the ethanol (and thus maize) industry. Since DCO is a by-product of this massive ethanol production push, the supply of corn oil is set to increase substantially, making it a sustainable and reliable source for both edible and non-edible markets.
- **Addressing the Edible Oil Gap:** India imports over 60% of its edible oil demand. There is a recognized need to boost domestic edible oil availability, with national consumption projected to increase to over 30 million metric tons by 2030. Promoting corn oil production is seen as a crucial strategy to enhance India's self-sufficiency, leveraging the existing large area under corn cultivation.
- **Technological Advancement:** The industry is investing in advanced extraction and refining techniques, such as enzymatic degumming and cold-press methods, which improve the oil's stability, yield, and nutritional retention. These innovations are key to meeting the rising demand for high-quality and sustainable oil options.

Challenges and Constraints in the Growth Journey

Despite the promising trajectory, the Indian corn oil market faces certain structural challenges that could impede its growth if not strategically managed.

Raw Material Volatility and Supply Chain Risks

The production of corn oil is directly vulnerable to the volatility in corn prices, which are highly sensitive to unpredictable factors like adverse weather patterns, global supply dynamics, and government procurement policies. Furthermore, a projected domestic demand-supply gap for maize (estimated between 6 to 9 million metric tons in the coming decades) threatens the consistent and cost-effective availability of the raw material. Since corn oil supply is also interlinked with the performance of the ethanol sector, any fluctuation in fuel demand or policy could indirectly affect DCO availability and pricing.

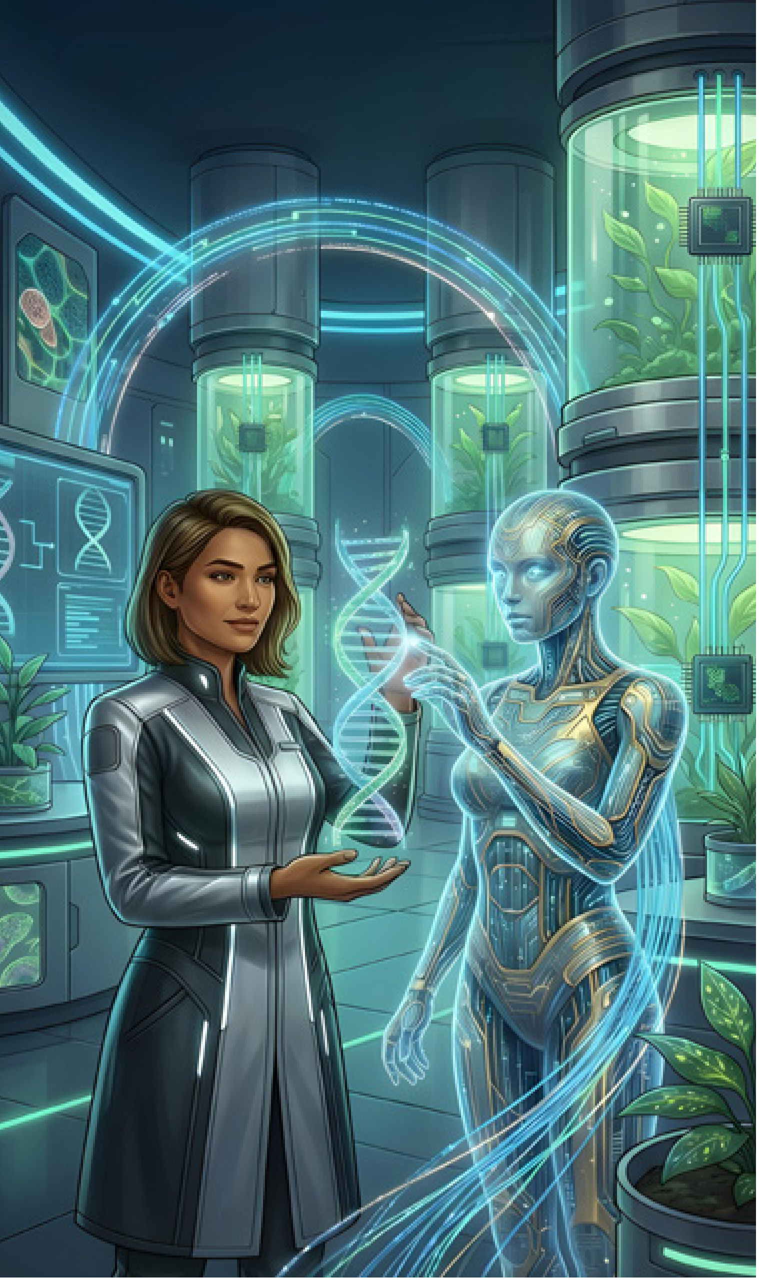
Competitive Pressure and Consumer Perception

Corn oil operates in a highly competitive market, contending with other oils that are popular in different Indian regions, such as mustard, groundnut, and palm oil, as well as oils perceived as superior health alternatives like olive, rice bran, and canola oils. The dominance of palm oil in imports, which makes up about 59% of the imported edible oil volume, also exerts significant pressure on domestic oil pricing and market share. The market must continually invest in consumer education to highlight corn oil's unique benefits, particularly its heart-health profile, to overcome competition and change ingrained regional consumption preferences.

Conclusion: A Strategic Future for Corn Oil

The corn oil market in India stands at a critical juncture, poised for a transformative phase of growth. The confluence of rising health awareness, increasing urbanization, and the nation's ambitious energy goals—particularly in the biofuel sector-is creating an environment ripe for expansion. The shift in viewing corn oil not just as an edible product, but as a strategic co-product (DCO) of the thriving ethanol industry, provides a dual market opportunity that few other edible oils possess.

To realize the projected market growth of 6.10% by 2033, stakeholders must focus on mitigating raw material volatility through increased high-yield maize production and contract farming, as well as adopting advanced, sustainable processing technologies. By strategically addressing the supply chain challenges and capitalizing on the immense demand for healthier edible oils and renewable energy, corn oil is set to secure a golden, strategic position in India's future economic and dietary landscape.



The Future of Bio-Industries: AI and the Human Advantage

AI won't replace you — but it will replace those who don't use it wisely

Sanya Mahindru
Marketing Executive

Introduction – The Age of Intelligent Collaboration

Across sugar mills, distilleries, brewery operations and biogas plants, one thing is changing rapidly: data. Sensors, control systems and process logs are generating far more information than ever before. Enter artificial intelligence (AI) — the capacity to make sense of that data in real time, to predict, optimise and steer operations.

Yet there remains a myth: "AI will replace human workers". In reality, AI will augment human capability. The real risk lies not in machines taking over, but in teams refusing to delegate to AI-tools and remaining stuck in manual, reactive workflows. The plants that succeed will be those where human experience and machine intelligence work together.

AI's Emerging Role in the Bio-Industries

In the familiar terrain of sugar-based ethanol production, brewery fermentation or biogas digestion, AI applications are beginning to move from pilot stages to real-world deployment.

- **Fermentation Dynamics & Monitoring:** A 2024 study on mixed-culture beer fermentation used recurrent neural networks (RNNs) to model and predict fermentation outcomes. The authors reported significantly improved predictive accuracy of yeast behaviour and process yield. (O'Brien, Zhang, Allwood & Rawsthorne, 2024)
- **Anhydrous Ethanol Dehydration & Control:** A July 2025 paper demonstrated that AI models

— decision tree, random forest and LightGBM — could predict ethanol composition in dehydration units with R^2 up to 0.997, outperforming traditional control models. (da Silva et al., 2025)

- **Broader Food/Biotech Context:** In food biotechnology, AI-tools are accelerating enzyme/yeast strain optimisation, enabling “precision fermentation” where microbes are tuned via AI to produce target molecules more effectively. (Teng et al., 2023; Sidorkiewicz et al., 2025)
- **Operational Efficiency & Marketing:** A report of breweries in 2023 found AI usage improved fermentation monitoring efficiency by ~22% and helped reduce energy or input waste.

These applications illustrate three practical domains: process optimisation, predictive control/ maintenance, and data-driven business/marketing intelligence. For sugar, ethanol or biogas plants, this means topics like feedstock yield prediction, yeast health monitoring, process downtime forecasting, or customised customer/market targeting.

When Data Meets Enzymes: The Power of Smart Bio-Processes

For a biotech provider of enzymes, additives and yeast (such as our company), integrating AI into the value chain opens new strategic advantages:

- **Smart Strain & Enzyme Optimisation:** AI can analyse large historical datasets (yeast performance, fermentation logs, contamination events) to recommend best-performing strain/ enzyme combinations for specific conditions — e.g., high temperature, poor water quality, recycled molasses.
- **Real-Time Process Monitoring + Intervention:** By layering sensor data (oxide levels, pH, temperature, dissolved oxygen) with machine learning models, plants can flag deviations early (fungal contamination, glycerol spikes, delayed fermentation) and trigger corrective actions (stress-tolerant yeast addition, water treatment, adjust cooling) rather than discovering losses post-factum.
- **Yield Prediction & Business Insight:** AI models make it possible to forecast yield losses (for example, hidden glycerol formation or contaminated batches) and integrate that into commercial decision-making (feedstock sourcing, production scheduling, maintenance planning).

Thus the collaboration: your biotech solutions deliver the biological tools; AI gives the predictive & decision layer; human teams execute and interpret.

The Human Factor – Why Psychology Still Wins

Even with the best AI-tools, the human element remains critical. There are key psychological and organisational aspects:

- **Resistance to Delegation:** Many plant managers or technical leads worry, “If I rely on an AI model, do I lose control?” In fact, the opposite is true: by delegating routine monitoring and data-driven alerts to AI, team members can focus on higher-value work – strategy, optimisation, troubleshooting.
- **Training & Adaptation:** Successful AI adoption requires teams who understand both the biology (yeast, enzymes, fermentation) and the analytics (data, models, interpretation). Investing in training builds the mindset shift from reactive fixes to proactive insights.
- **Leadership Mindset:** The leaders who thrive will be those who create a culture where humans use AI, not fear it. The mantra becomes: “We don’t replace staff with AI — we replace outdated ways of working.”
- **Trust & Explainability:** Especially in production plants, operators must trust AI recommendations. Research in predictive maintenance emphasises explainable AI (XAI) — systems that provide transparent reasoning rather than black-box decisions. (Pashami et al., 2023)

In short: technology changes fast. But human judgement, continual learning and collaborative culture remain irreplaceable.

The Future: Smarter Plants, Stronger People

So what does this mean for sugar, ethanol, molasses, brewery or biogas operations in the coming years?

- **Smarter yards & digital twins:** AI will generate digital models of your plant – fermentation, distillation, biogas digestion – where you can simulate scenarios (feedstock variation, yeast performance drop, water quality issues) and test interventions virtually before implementing them.
- **End-to-end optimisation:** From the cane/ sugar-molasses feedstock to enzyme/yeast performance to fermentation yield to energy recovery in biogas – AI linked with your biotech solutions enables end-to-end optimisation of the bio-economy.
- **Sustainability & cost control:** Plants using AI-driven monitoring will reduce waste, lower energy consumption, minimise downtime and improve yield — thus better aligning with global ESG (environmental, social, governance) goals.
- **Human-plus-machine workforces:** The roles of plant technicians, fermentation specialists and process engineers will shift. Instead of manually monitoring and reacting, they will interpret AI insights, design interventions and manage exceptions. Employees who adopt this shift will gain strategic value; those who cling to legacy workflows risk being left behind.
- **Strategic advantage for suppliers:** For biotech companies, offering enzyme/yeast solutions bundled with AI-enabled analytics or dashboards becomes a differentiator. By aligning biological innovation with data intelligence, you shift from commodity supplier to strategic partner.

Conclusion – Embrace the Human-AI Partnership

AI is not coming to replace you. But it will transform how you work, what you prioritise and how you add value.

In the sugar-to-ethanol, brewery and biogas sectors:

- AI models can detect fermentation anomalies early, optimise enzyme/yeast usage, predict yield losses, and support sustainability goals.
- Biotech companies can leverage AI to fine-tune strain/enzyme selections, deliver analytics to clients and co-create smarter processes.
- The human advantage remains: judgment, creativity, leadership, continuous learning. The professionals who thrive will be those who **delegate wisely**, adapt quickly and collaborate effectively with machines.

In essence, this is a call to action for the industry — to reassess data flows, identify where AI tools can strengthen operations (from fermentation and maintenance to yield prediction and marketing), and promote a culture of intelligent collaboration. The future of bio-industries will belong to those who seamlessly connect biology with analytics, and human insight with artificial intelligence.

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Customer Retention via CRM: Modern Strategies Backed by Recent Trends

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(CRM Manager)

In today's B2B environment, especially within sectors such as biotechnology, fermentation, and related industrial applications, customer retention is no longer a nice-to-have — it's essential. Recent research from service and sales organizations underscores this shift. A 2024 Salesforce report reveals that **91% of service teams** now expect to drive greater revenue through customer retention, cross-selling, and upselling. Salesforce Meanwhile, **88% of customers** say that good service increases their likelihood of purchasing from the same company again. Salesforce These expectations signal a pivot in how companies must use their CRM strategies: not just as a tracking tool, but as a proactive driver of relationship value.

One of the first steps for this shift is understanding customer expectations at a granular level. According to Salesforce's "Customer Engagement Research," **73% of customers expect companies to understand their unique needs and expectations**. Salesforce In industrial biotech and fermentation, that might mean knowing the specifics of a customer's process conditions, enzyme performance requirements, raw material sourcing constraints, or seasonal demand cycles. A CRM ought to capture this type of data so that engagement is timely, relevant, and trusted.

Technology plays a major role here. A State of Sales report from Salesforce shows that **89% of sales teams in India** have either fully implemented or are experimenting with AI, with the leading benefit being improved data quality and accuracy. Salesforce High-quality data is foundational for any retention strategy: without it, segmentation, personalized follow-ups, or proactive service become unreliable.

The SaaS industry offers strong benchmarks illustrating why retention matters so much. In its 2023 SaaS Retention Report, ChartMogul found that the **median net revenue retention (NRR)** across SaaS businesses was **102%**. ChurnZero In practical terms, this means many SaaS companies are not just keeping existing customers but growing revenue from them through renewals and upsells. For industrial or biotech firms, while product dynamics differ, the lesson remains: companies that retain well often grow faster and more sustainably.

Comparative data across industries help set realistic retention targets. The TryPropel.ai 2025 benchmarks show that **B2B SaaS industries** retain **90-95%** of customers annually, while **IT & Managed Services** retain about **81%**, and **Financial Services around 78%**. trypropel.ai These rates give a useful frame of reference for what high retention looks like, particularly for businesses operating via contracts, repeat purchase orders, or service renewals. For industrial biotech and fermentation firms, aiming for retention figures in line with these sectors (or even improving where possible) is a path toward competitive advantage.

So, how can a CRM system be designed and used to capture these benefits? First, by investing in **data accuracy**: capturing full profiles, technical history, usage logs, purchase patterns, and feedback. Without clean data, AI-driven insights, predictive alerts, or automatic follow-ups will misfire. AI experiments in sales contexts already show that when data quality improves, customer satisfaction and retention follow.

Second, leveraging CRM for **personalization at scale** is integral. When customers feel understood — their needs anticipated, challenges recognized before they occur — loyalty increases. This is backed by the high percentage (73%) of customers expecting companies to understand them. CRMs should enable custom segmentation (by usage, product line, geography), schedule proactive service check-ins, and trigger campaigns or technical updates that reflect each customer's specific context.

Third, **proactive customer service and feedback loops** are critical. If a CRM tracks feedback or service tickets diligently, and teams respond before issues escalate, this builds trust. As we saw, 88% of customers say good service influences repeat purchase decisions. So, service teams shouldn't just resolve issues, but use them as signals to deepen engagement — e.g., share improvements, send tips, or arrange consultations.

Fourth, essential CRM strategies include mapping customers by value. Not every account will generate equal revenue or strategic benefit. Using benchmarks helps indicate what "good" retention looks like in your sector. Prioritize high-potential accounts with personalized outreach and more frequent value interaction, while ensuring base level engagement for others to avoid surprise attrition.

Additionally, integrating AI and workflow automation into CRM actions produces measurable benefits. For instance, automating follow-ups, reminders for renewals, and alerts for usage drop-offs can free up human resources and improve responsiveness. Sales teams in India experimenting with AI report strong gains in data quality, which in turn supports more accurate forecasting and better customer decisions. Salesforce

Finally, measuring ROI is essential. Use metrics like **Net Revenue Retention, Churn Rate, Renewal Rates, Upsell/Cross-sell Revenue from Existing Customers**, and Customer Satisfaction Scores. Benchmark against industry data: if your retention is significantly below the 80-90% range seen in IT/Managed Services or B2B SaaS, that signals room for improvement.

In an era where customer expectations evolve faster than products themselves, the true differentiator for B2B organizations lies in how intelligently they manage relationships. Modern CRM systems, when powered by accurate data, AI insights, and proactive engagement, turn customer information into strategic intelligence.

For industrial sectors like biotechnology and fermentation, where partnerships are built on performance, consistency, and trust, CRM is not just a digital ledger — it's the foundation for sustained growth. By combining predictive analytics with human understanding, companies can anticipate client needs, minimize churn, and unlock long-term value.

As global benchmarks show, organizations that prioritize retention outperform those focused solely on acquisition — not just in revenue stability, but in customer advocacy and market resilience. The path forward is clear: treat CRM not as an operational tool, but as a growth catalyst that aligns teams, strengthens relationships, and ensures that every interaction moves the partnership forward.

Nisha Malhotra
(HR Head)

Role of Artificial Intelligence in HR Processes within the Biotechnology Industry

In the rapidly evolving biotechnology sector, Human Resources (HR) departments are increasingly leveraging Artificial Intelligence (AI) to streamline operations, enhance talent acquisition, and foster employee development. AI's integration into HR processes is not just a trend but also a strategic move to address the unique challenges faced by biotech companies.

AI in Recruitment and Talent Acquisition

Recruiting top-tier talent in biotechnology requires precision and efficiency. AI-powered tools are revolutionizing this process by automating candidate sourcing, screening, and matching. For instance, AI algorithms can analyse vast datasets to identify candidates with the right skill sets, reducing the time-to-hire and minimizing human bias.

Moreover, AI platforms assist entry-level biotech job seekers by helping them understand in-demand skills and matching them with suitable roles. This is particularly beneficial in a field where technical expertise is paramount.

Employee Training and Development

Continuous learning is vital in biotechnology, where scientific advancements are constant. AI-driven training programs offer personalized learning experiences, adapting to individual employee needs and learning paces. These programs can simulate complex scenarios, allowing employees to practice and refine their skills in a risk-free environment.

For example, AI agents designed for professionals in the biotechnology industry support roles like lab technicians and research scientists by handling repetitive tasks, data entry, and compliance checks. This enables teams to focus on complex problem solving and innovation, enhancing overall productivity.

Performance Management and Employee Engagement

AI tools are transforming performance evaluations by providing data-driven insights. Machine learning algorithms can analyze employee performance metrics, feedback, and other relevant data to offer objective assessments. This approach helps in identifying high performers, areas for improvement, and potential leaders within the organization.

Additionally, AI can monitor employee engagement levels by analyzing communication patterns, survey responses, and other indicators. Early detection of disengagement allows HR to implement timely interventions, reducing turnover and fostering a positive work culture.

Administrative Efficiency and Compliance

Biotech companies operate in a highly regulated environment, necessitating strict adherence to compliance standards. AI can automate administrative tasks such as document management, regulatory reporting, and audit preparations, ensuring accuracy and timeliness. This automation not only reduces the risk of human error but also frees up HR professionals to focus on strategic initiatives.

Conclusion

The integration of AI into HR processes within the biotechnology industry is proving to be a game-changer. From recruitment to training, performance management to compliance, AI is enhancing efficiency, accuracy, and employee satisfaction.

As the biotech sector continues to grow and evolve, embracing AI in HR will be crucial for staying competitive and fostering a workforce equipped to meet future challenges.

Appreciation

DALVKOT
BIOFUELS

Subject: Letter of Appreciation

We would like to sincerely thank **Naturegen Biotechnologies LLP** (The Catalysts Group) – South Team for their excellent support in the Liquefaction and Fermentation processes right from the commissioning period.

We truly appreciate the timely technical assistance provided by your team, as committed. It has made a significant difference in ensuring our operations run smoothly.

We are equally pleased with your consistent on-time delivery of materials while maintaining high quality standards. Your team has demonstrated remarkable commitment, coordination, and professionalism throughout the process.

It has been a pleasure working with such a dedicated and responsible team. Your efforts have greatly contributed to our success, and we deeply value the support extended to us.

We look forward to continuing this association and wish the entire Catalysts Group team the very best in your future projects and continued success.

For Dalvkot Biofules Pvt Ltd

Authorized signatory

Plant Address: Plot no:15B8 De- Notified Area, Krishnampalem Village,Rambilli Mandal, Anakapalli Dist, APSEZ Industrial Area, Andhra Pradesh. Pin: 531016, GSTIN- 37AAHCD5789P1ZM,

New Joinees


Vishal Ravindra Powar
BD
28-Jul-25


Jitendra Kumar
Credit Control
05-Aug-25


Vikas Singh
CRM
05-Aug-25


Ankit Agarwal
Supply Chain
01-Sep-25


Shubham Garg
BD
09-Jul-25


Arjun Arunrao Sable
Logistics
09-Jul-25


Atul Tyagi
Technical Solutions
14-Jul-25


Ayan Maity
Technical Solutions
14-Jul-25


Anurag Kumar
Technical Solutions
14-Jul-25

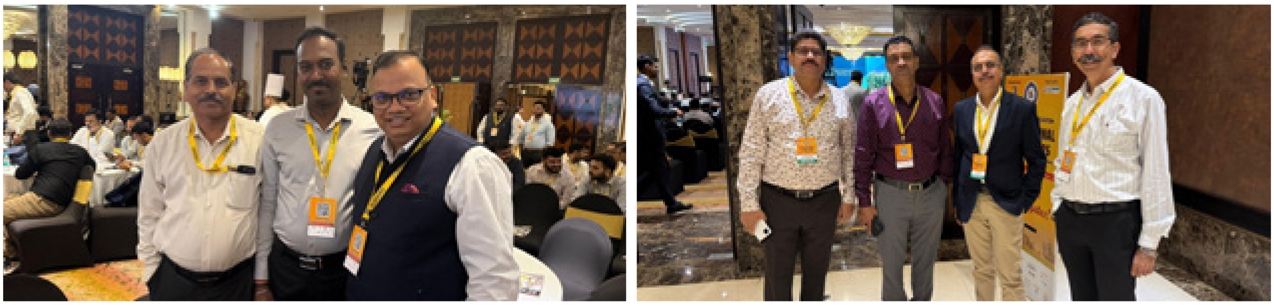

B Dileep Kumar
Technical Solutions
18-Aug-25


Shreshtha Abhijit Chanda
Microbiology
24-Sep-25


Rohit Subhash Patil
R&D
24-Sep-25

Events

CII SugarTech 2025 (26 September 2025)



UPDA International Summit 2025, Noida, Uttar Pradesh

71st Philsutech Annual National Convention, Phillipines

The Pioneer BioFuels360° Summit, New Delhi

Events


STAI 2025, Bharat Mandapam, New Delhi

GEMA, New Delhi


Sugar & Bioenergy Summit 2025, Khandala



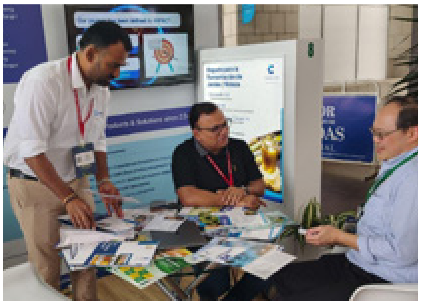


South Team, West Team & NKT Team OFF Site Whistle Woods Jungle Resort, Dandeli

Events

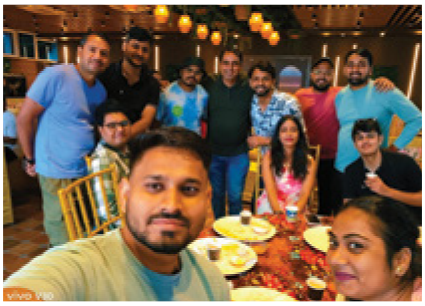


Joe White Maltings x The Catalysts Group, Bengaluru




XXXII ISSCT Congress 2025, Columbia





Offsite North Team, The Riverview Retreat, Jim Corbett


The SpiritX Summit 2025, Hyderabad

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