VALUE ADDITION IN DRY MILLING ETHANOL PLANTS THROUGH CORN OIL RECOVERY

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NEW TECHNOLOGIES AND FEEDSTOCKS IN ETHANOL AND DDGS PRODUCTION

Introduction

- Globally Maize/Corn is a major feedstock for Ethanol (63%) (USA, Brazil, China, India)
- Corn can replace FCI rice in long run in India, as it is cost efficient & consumes less water (Niti Aayog).
- Present yield of corn in the country varies from 3-7 tons /ha, which is 10-11 tons/ ha in USA (GM corn)
- Corn is also 3rd most important cereal crop after rice & wheat in India
- Varieties with higher yield and more starch can make more corn available for ethanol production in future
- For 660 Cr Litres of ethanol production, we will require almost 165 LMT of grains and 35 LMT of DDGS can be produced. Present DDGS production is about 5 LMT
- To generate valuable by-product is one of the key factor to improve viability of ethanol plants.

Challenges and Opportunities

- Shortage of corn availability for poultry as well as for distillery industry
- Corn prices are all time high
- DDGS price is also on decline
- GoI wants to promote corn over rice on long term basis
- GoI is considering allowing import of corn
- Therefore, there is an opportunity to recover value-added by-products from corn which can improve the financial viability of corn-based distilleries
- Shortage of edible oil in the country
- Shortage of bio-diesel in the country and GoI wants to achieve 5 % bio-diesel blending in diesel by 2030. At present it is below 0.5 %.
- Corn based distilleries has good opportunity to separate Corn germs & produce good quality edible Corn Oil & De-oiled Cake (DOC) or produce Distiller's Corn Oil (DCO).

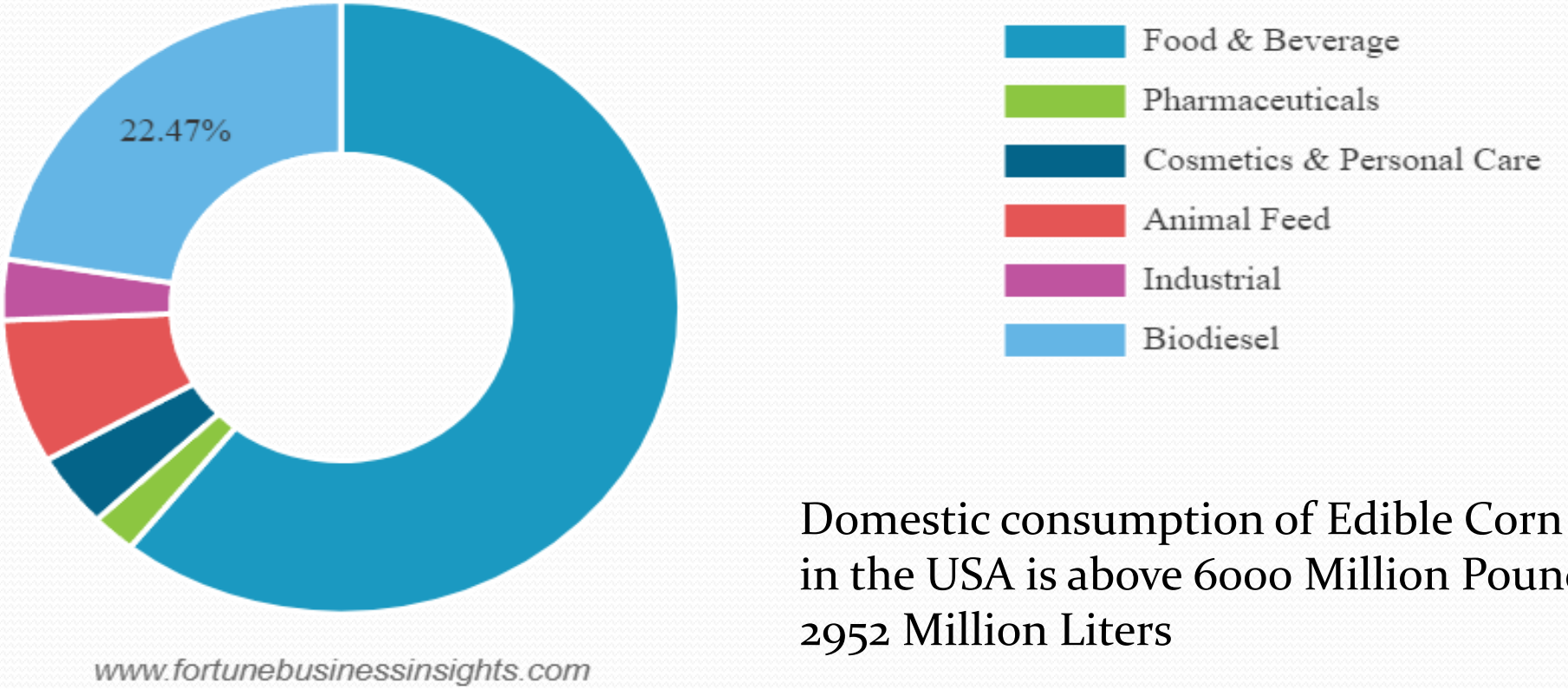
Refined Corn Oil

- Premium edible Vegetable oil with pleasant nutty flavour & good stability
- Corn Oil ranks 10th in terms of its annual production amongst all of the vegetable oils
- About 2% of the vegetable oils produced worldwide
- High levels of Polyunsaturated fatty acids (60-75%) linoleic acid
- High level of unsaponifiables (>2%)
- High level of phytosterols(>1%)
- High level of tocopherol (0.10%)
- Produced mostly by wet milling of corn but also possible to be produced in dry milling

Distiller's Corn Oil (DCO)

- Recovered after distillation and good feedstock for biodiesel production
- Not suitable for edible purpose
- It has higher levels of Lutin, Zeaxanthins and free fatty acids
- Supplement in livestock food (because of high linoleic acid, essential fatty acid for poultry and swine)
- Also used in small quantities as feedstock for rubber substitutes, rust inhibitors, inks, textiles, soaps and insecticides
- Production in USA in 2021 was 1.979 MMT
- Theoretical DCO yield potential is 33.96 kg/MT and max. obtainable is 23.23 kg/MT (with loss in wet cake)
- Average yield in USA is about 16.0 kg/MT (with 70% facilities achieving up to 15.01 kg/MT and few are achieving around 17.87 kg/MT)

Global Corn Oil Market Share, By Application, 2023

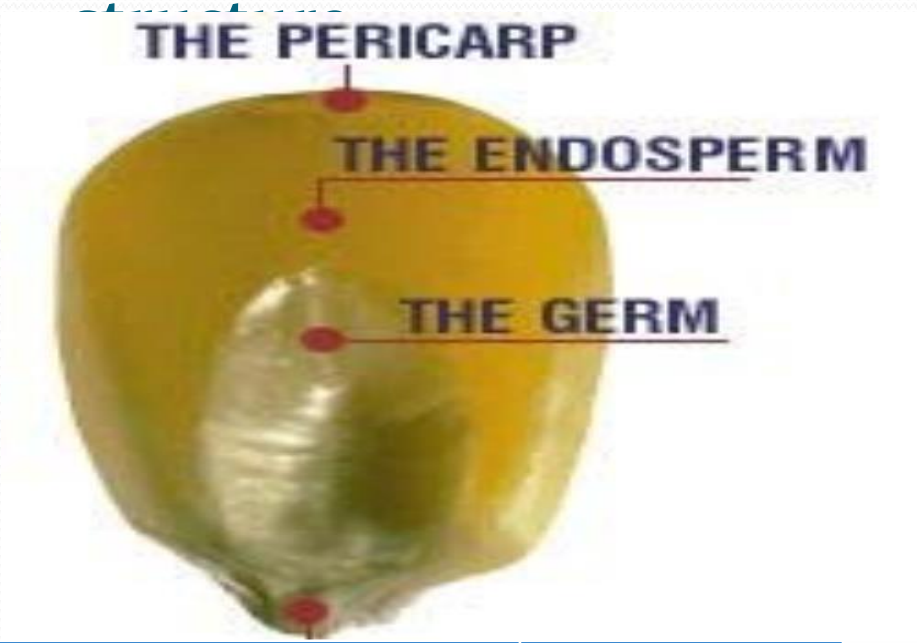


Domestic consumption of Edible Corn Oil in the USA is above 6000 Million Pounds = 2952 Million Liters

The global corn oil market size was valued at USD 6.17 billion in 2023 and is projected to grow from USD 6.52 billion in 2024 to USD 11.80 billion by 2032, exhibiting a CAGR of 7.69% during the forecast period. Source: https://www.fortunebusinessinsights.com/corn-oil-market-103810

Indian Corn

Corn kernel



Starch	61.0%
Corn Oil	3.8%
Protein	8.0%
Fiber	11.2%
Moisture	16.0%

Proximate Analysis of US Corn

Characteristic	Range	Average
Moisture (% wet basis)	7-23	16.0
Starch (% dry basis)	61 -78	71.1
Protein (% dry basis)	6 - 12	9.5
Fat (% dry basis)	3.1 – 5.7	4.3
Ash (Oxide) (% dry basis)	1.1 – 3.9	1.4
Pentosans (as xylose) (% dry basis)	5.8 – 6.6	6.2
Fiber (Neutral detergent residue) (% dry basis)	8.3 – 11.9	9.5
Cellulose + Lignin (Acid detergent residue) (% dry basis)	3.3 – 4.3	3.3
Sugars, Total (As glucose) (% dry basis)	1.0 – 3.0	2.6
Total Carotenoids (mg/kg)	12- 36	26.0

3rd Advance Estimates of corn production in India

Year	Area (Lakh Ha)	Production (Million Tonnes)	Yield (Kg/Ha)	MSP Rs/Qtl
1950-51	31.60	1.73	547	-
2014-15	91.85	24.17	3612	1310
2015-16	88.06	22.56	2563	1325
2016-17	96.33	25.90	2689	1365
2017-18	93.80	28.75	3065	1425
2018-19	91.32	27.71	3035	1700
2019-20	95.69	28.77	3006	1760
2020-21	98.92	31.65	3190	1850
2021-22	99.58	33.73	3387	1870
2022-23	100.75	34.61	3435	1962
2023-24	------	37.67*	------	2225

5th largest producer and 14th largest exporter of corn in the world

*Estimated

APY of major corn growing states (2022-23)

State	Area (Lakh Ha)	Production (Lakh Tonnes)	Yield (Kg/ha)
Karnataka	16.27	52.02	3197
Madhya Pradesh	16.14	52.55	3256
Maharashtra	12.47	37.33	2994
Rajasthan	9.61	18.85	1961
Uttar Pradesh	7.93	17.24	2174
Bihar	4.93	20.36	4130
Telangana	4.74	27.62	5827
Gujarat	3.91	7.74	1979
Tamil Nadu	4.18	30.76	7345
Andhra Pradesh	3.26	20.55	6305
All- India	**100.75**	**346.12**	**3435**

Varieties with yield of 9 MT/ha will be introduced by ICAR

Estimates of Corn requirement by ESY-2025-26

Estimated Corn requirement (MMT) for 2023-24 (175 Cr. Lit.)	4.49
Estimated Corn requirement (MMT) for 2025-26	14.10
Estimated Rice Requirement (MMT) for 2023-24 (90 Cr. Lit.)	2.00
Estimated Rice Requirement (MMT) for 2025-26	2.22
Estimated Corn Ethanol Requirement in Cr Lit. by 2025-26	550
Estimated Rice Ethanol Requirement Cr. Lit. by 2025-26	100
Corn ethanol % of total grain ethanol	84.0
Additional Corn Requirement (MMT) by 2025-26	10.0

This year (ESY 24-25) offers received by OMCs for ethanol supply is for 970.60 Cr. Lit.
Damaged Grains=105.70 Cr. Lit., Corn=473.70 Cr. Lit.,
Total Grain route=579.4 Cr. Lit.(59.68%), Total Sugar route=391.40 Cr. Lit.(40.32 %)
which exceeds first time the required quantity of 916 Cr. Lit.

Wet Vs Dry Milling of Corn

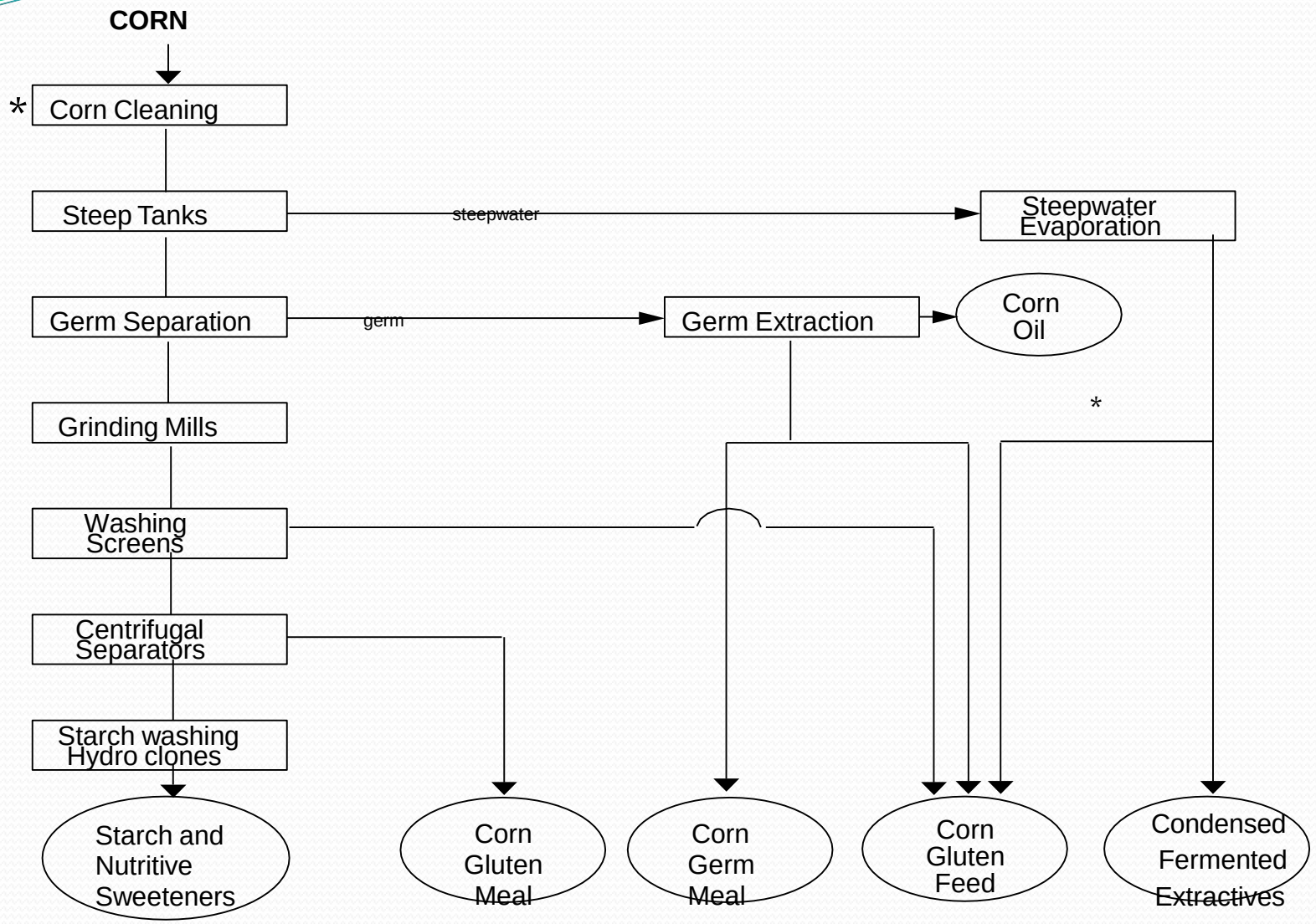
- Wet Milling

1. Designed to extract highest use and volume from each component of corn kernel.
2. Versatile process
3. Capital intensive
4. Higher operating cost
5. Ability to produce variety of products.
6. Lower ethanol yield (starch lost with other co-products)

- Dry Milling

1. Designed to produce ethanol.
2. Less versatile/simple process.
3. Less capital intensive
4. Main product is ethanol (but also DDGS & CO_2- valuable by-products)
5. Edible Corn oil or DCO
6. Higher ethanol yields

Corn Wet-Milling Process Overview

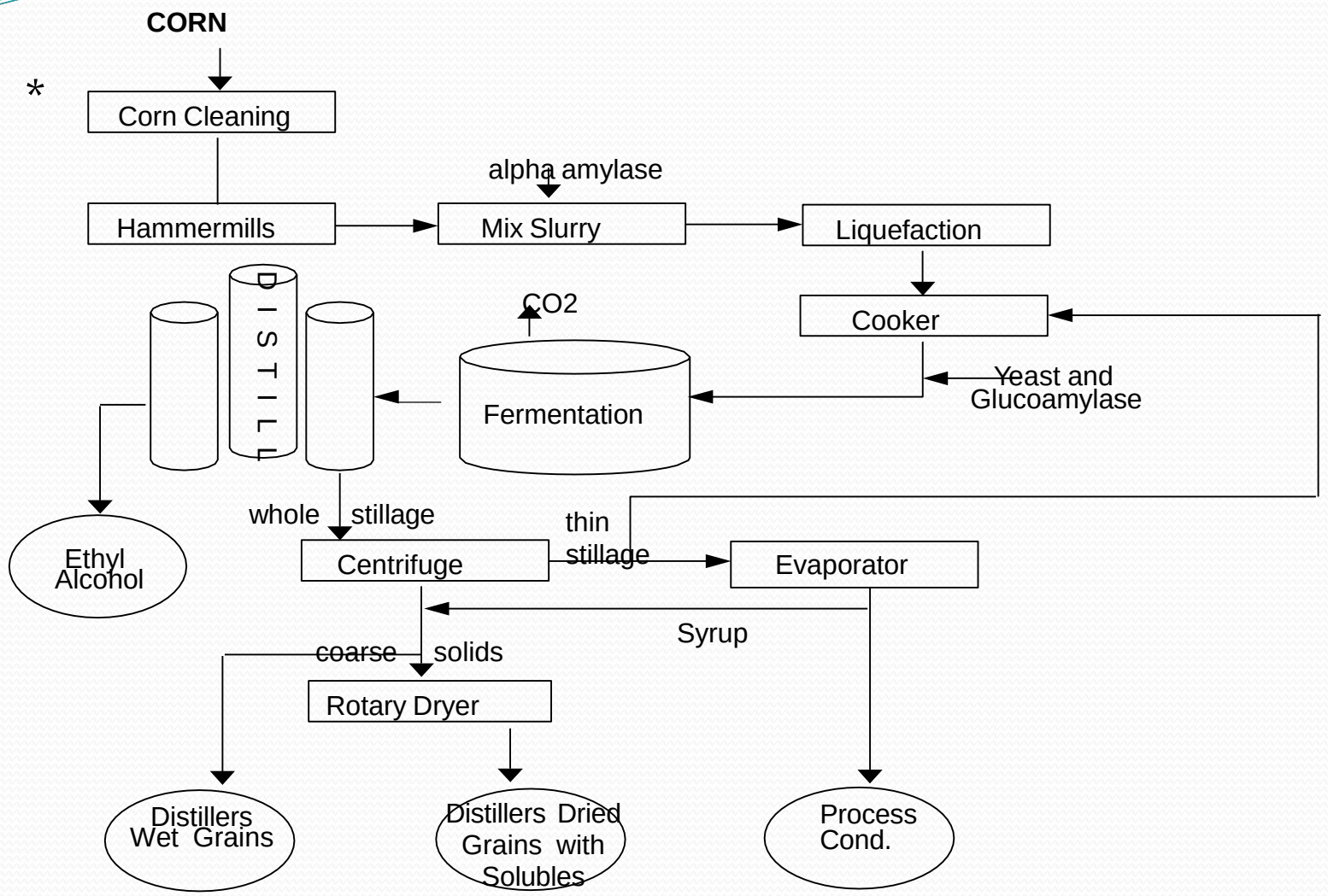


Feed Industry Co-products

Products Per MT of Corn

Starch	kg	562.20
Gluten Feed	kg	223.62
Gluten Meal	kg	44.88
Corn Oil	kg	28.74

Corn Dry Milling Process Overview



Products Per MT of Corn

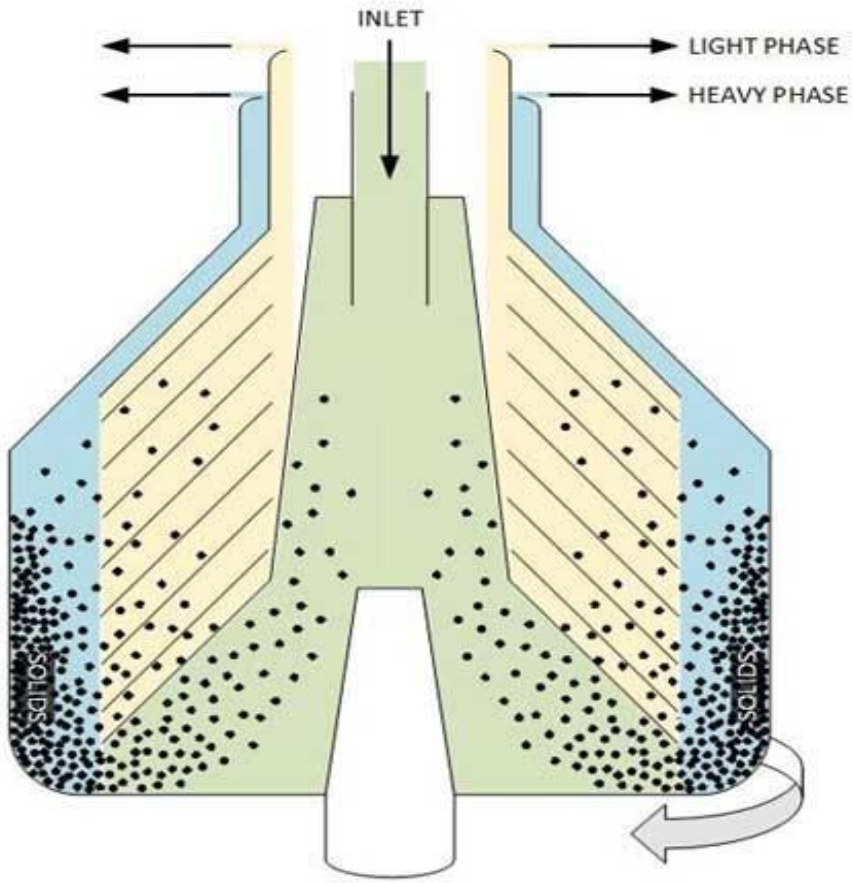
Ethanol	Lit	402
DDGS	Kg	280-290
Recoverable CO_2	Kg	240-250

Back End recovery of corn oil
(after distillation)

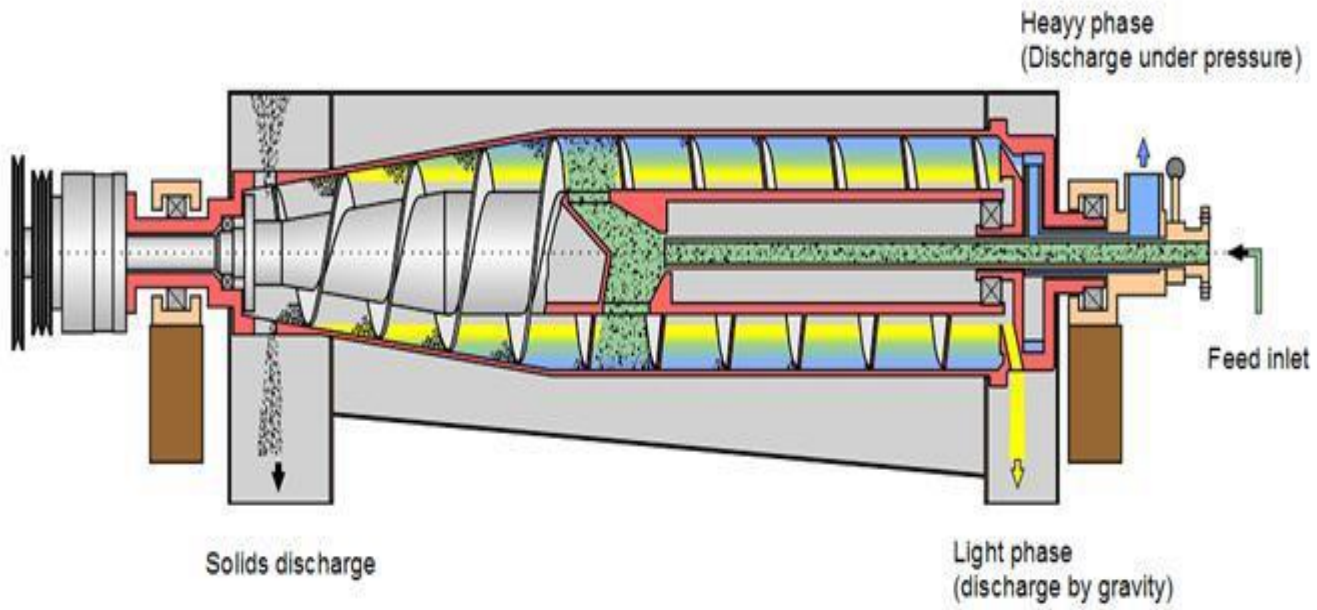
Back End Recovery

- Corn Oil in the form of "**Distiller's Corn Oil**" (DCO) can be recovered from whole stillage or thin stillage or syrup
- From stillage or syrup, DCO is recovered by mechanical/ physical processes by using the principle of centrifugal force
- Decanters, Tricanters or Disc Stack Separators are used commonly in US ethanol plants
- Decanters separate wet cake (solid) and thin stillage (liquid) from the whole stillage coming out of analyser column. The usual distribution of oil is 67% in thin stillage and 33% in wet cake.
- Tricanters simultaneously separate 2 immiscible liquids with different densities & one solid phase.
- All phases are discharged separately from a tricanter, the heavy liquid (water) and solid phases are discharged by an impeller, whereas the light liquid (Oil) phase is discharged by gravity.

Disc Stack Centrifuge Vs Tri-Canter



Disc Stack Centrifuge Bowl

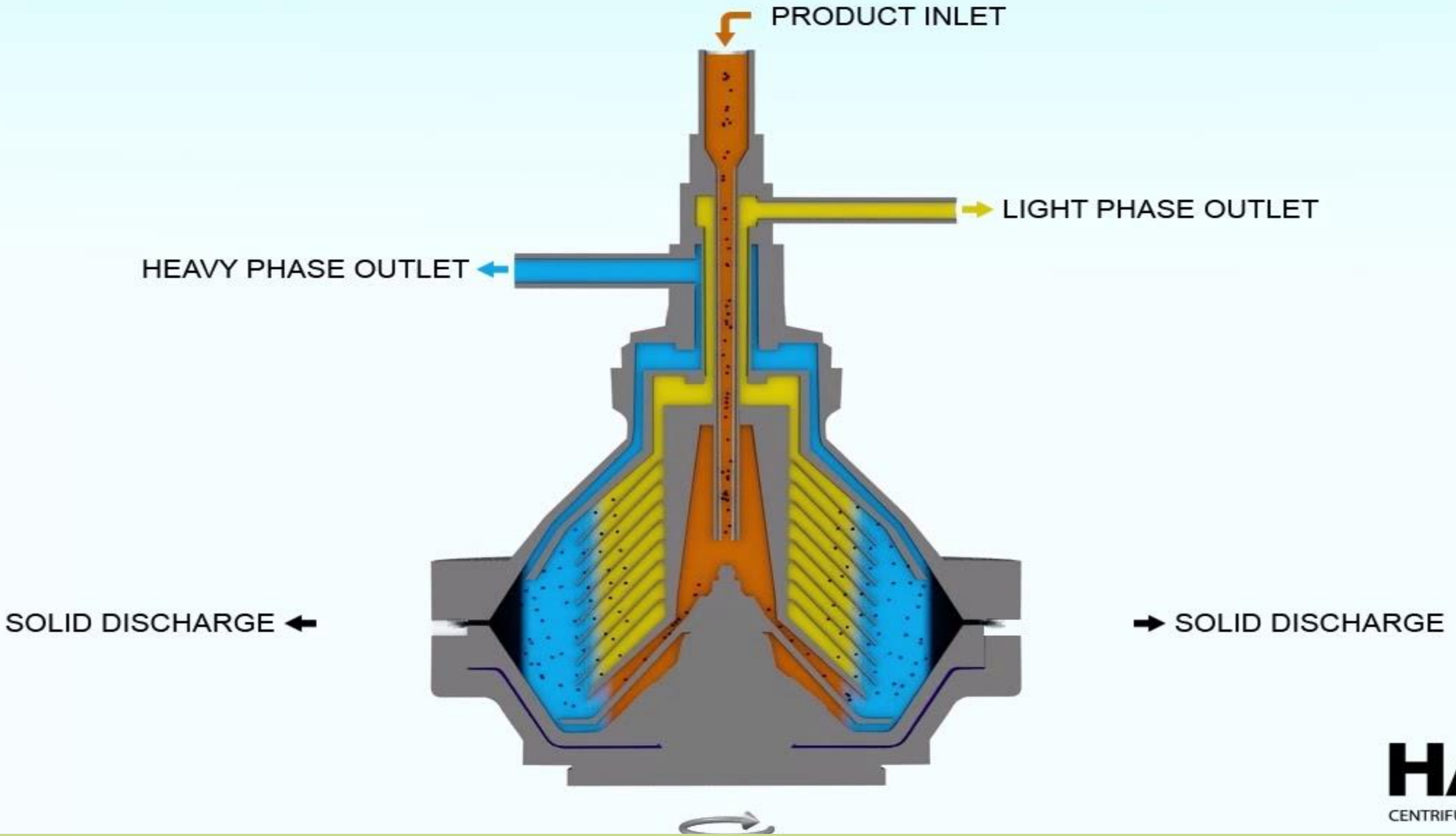


Tri-Canter

Disk Stack Separators

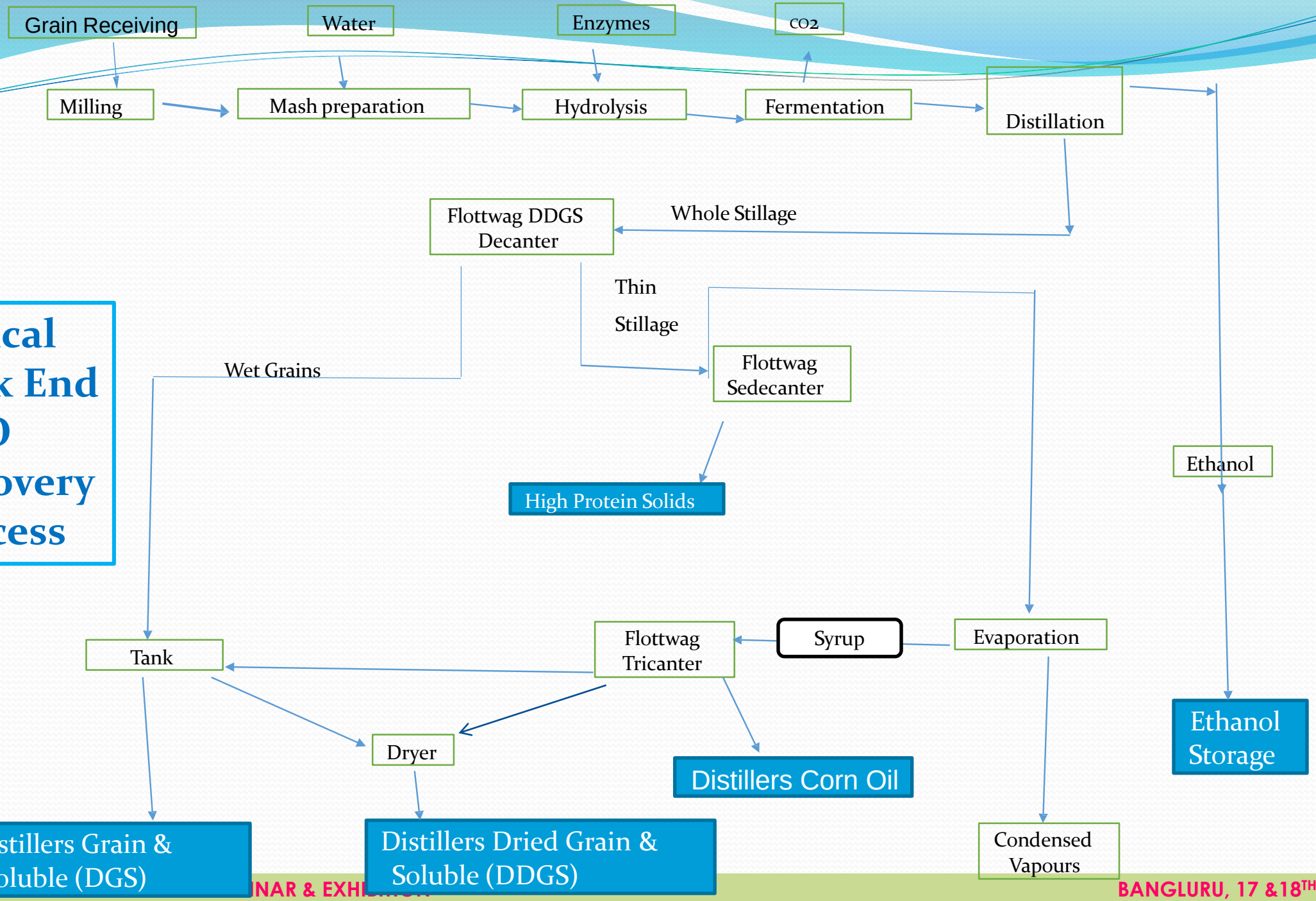
- Also known as conical plate centrifuge or disc bowl centrifuge- Separates solids from liquids or two liquid phases from each other on the basis of difference in densities.
- The denser phase (solid or liquid) moves towards the wall of rotating bowl while the less dense phase moves towards the centre
- It has facilities so that both the phases can be discharged continuously, manually or intermittently.
- As compared to tricanters, disk stack separators are in more use in USA-DCO recovery plants

Disc Stack Centrifuge



HAUS
CENTRIFUGE TECHNOLOGIES

Typical Back End DCO Recovery Process



Enzymes and Demulsifiers

- For effective liberations of oil from germ by milling, enzymes (Liquefaction protease-Novozymes) are available which can hydrolyse oleosomes and liberate protein-bound oil in the germ (at least 10% increase in oil recovery)

- Demulsifiers are added to syrup to disrupt oil in water emulsion stability thereby allowing oil to coalesce into larger droplets that can be more easily separated by mechanical means

Preliminary Cost-economics of DCO recovery

- Indian corn contains about 4 % oil on wet basis
- Out of 4 %, about 2 % can be recovered by back-end recovery methods
- Therefore, for 200 MT/day consumption of corn the recovery of DCO will be about 4000 Kg/day
- Lowest Capex is expected to be Rs. 3.00 Cr. (Capex can increase in case of Disc-stack centrifuges and related technologies)
- DCO bulk selling price is expected to be Rs. 70 per Kg
- Therefore, per day revenue will be Rs. 2.80 Lakh and per annum revenue will be Rs. 840 Lakhs
- Further value addition is possible if suitable capacity bio-diesel plant can be established in the distillery premises

Front End Recovery of Corn Oil

(before fermentation)

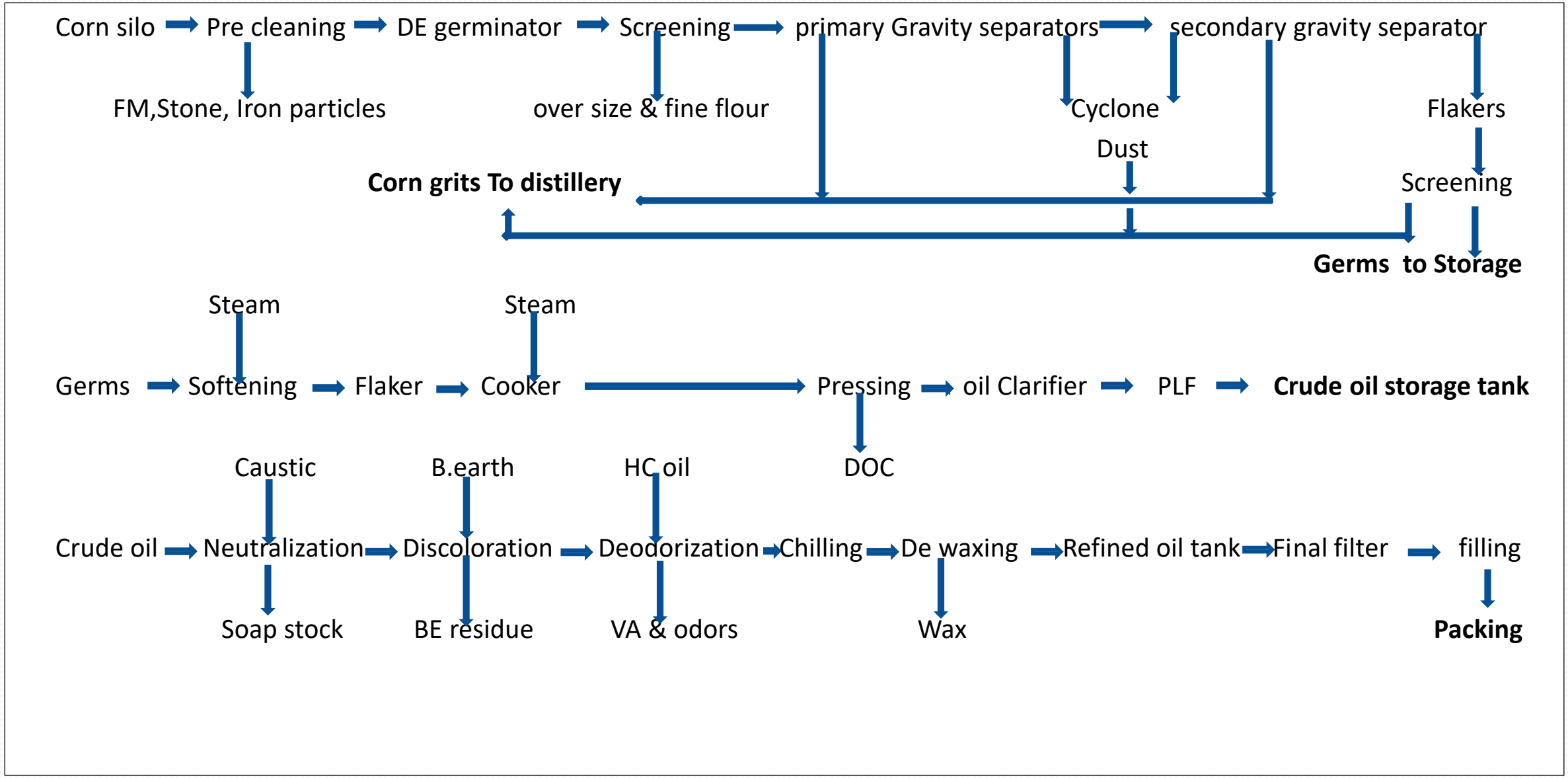
(Established first time in India at Grainotch Ind. Ltd., Maharashtra)

2016

Front end recovery working principle

- Corn germ fraction represents 10% of the mass of kernel & it contains 15-50% oil.
- Corn germ separation is well established technology
- Corn germ can be removed before fermentation by dry de-germination and is pressed or extracted with hexane to produce corn oil.
- There are different technologies available & in operation around the world.
- The wet germ separation technique has been adapted for efficient germ separation so for.
- In distillery operations, the dry milling technique is quite suitable.
- The germ separation in dry milling process and further refining is good option for distillers/ethanol producers.
- Dry milling germ separation is based on physical separation principles consisting of pre cleaning, breaking, screening, gravity separation, flacking, cooking & pressing.

Process flow chart at Grainotch (2016)



Germ Separation plant & machinery

Degerminator

Gravity separators

Flacker

Shifter

Oil press & refining machinery

Softening & cooking

Press machine

Oil Filling machine

Zhengzhou Qie Grain and Oil Machinery Co. Ltd., China

Design capacity & mass balance-70KLPD Distillery

200 MT/day corn

Parameters	Design capacity	Design qt., Kg/d	Achieved results	Actual qt.kg/day
Germ % in corn	8	16000	6	12000
Oil % in germ	40	5120	32	2688
Press eff.%	80		70	
Refining Loss, %	1.5	76.8	2	53.7
Actual Refined oil, kg/day		5043		2634

DOC Production is 12000-2634=9366-10 % loss=8429 kg/day
OR approximately 3.2 times of Oil

Utilities & chemicals

Particular	Unit of major	Consumption /day
Electricity	Kwh	6000
Steam	MT/day	7.50
Coal	Kg/day	250
Water	M3/day	50
Caustic soda	Kg/day	40
Bleaching earth	Kg/day	70
Phosphoric acid	Kg/day	4.0
TBHQ	Kg/day	0.40

Cost of production and profitability

Particular	Cons. per day	Unit rate	Total value (Rs)	Cost, Rs/Kg
Raw material, kg	12000*	18	216000	82.00
Electricity, kwh	6000	10*	60000	22.78
Steam, kg	7500	2.65	19875	7.54
Coal, kg	250	8.5	2125	0.80
Water, m3	50	11	550	0.21
Chemical				0.75
Manpower				1.00
Maintenance				0.50
Packing cost,Rs/kg				15.00
Interest & dip.				12.66
Total cost, Rs/kg				143.04
Oil price, Rs/kg (bulk)				120.0
DOC, Rs/kg (Rs. 18 x 3.2)				57.60
Soap stock, Rs/kg				0.25
Total				177.85
Margin, Rs/kg				34.81

Total Capital investment for 5 TPD refined corn oil plant =Rs. 10.00 Cr.

Profit of Rs. 1.31 /Litre of ethanol

Retail price Rs. 180-190 /Litre

Conclusions

- Government of India is planning to promote corn cultivation over rice for ethanol production.
- In dry milling ethanol production, it is possible to produce corn oil apart from DDGS and CO_2 as by-products
- In future, better verities of corn with higher starch/oil content will be made available for use in distilleries
- Edible Corn Oil recovery can help the corn-based grain distilleries to improve its economics if proper care is taken during designing of distillery & oil recovery plant (steam power balance, germ separation and oil plant technology selection).
- Edible Corn oil production will promote make in India policy and will reduce import of edible oils in the country
- By recovering DCO, it is possible to go for bio-diesel production in future for corn-based distilleries or they can sale DCO to the bio-diesel production units
- Deterioration of corn/germ quality during storage needs to be considered

Thanks...!!!

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