OIL RECOVERY FROM CORN IN

DRY MILLING ETHANOL PLANTS

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OUTLINE

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- Refined and Distiller's Corn Oil
- Structure and composition of corn
- Corn production estimates
- Wet and dry milling
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- Corn oil recovery at Grainotch
- Conclusions

Introduction

- Globally Maize/Corn is a major feedstock for Ethanol (63%)
- 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)
- Varieties with higher yield and more starch can make more corn available for ethanol production in future
- Corn is also 3rd most important cereal crop after rice & wheat in India
- 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
- With this opportunity there is challenge in front of grain distiller's to keep cost of production in control.
- To generate valuable by-product is one of key factor to reduce cost of production of ethanol.
- 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

- Corn Oil ranks 10th in terms of its annual production amongst all of the vegetable oils
- Premium edible Vegetable oil with pleasant nutty flavour & good stability
- About 2% of the vegetable oils produced world wide
- 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 but also possible to be produced in dry milling

DCO (Distiller's Corn Oil)

- Recovered after distillation and good fFeedstock for biodiesel production (Affordable)
- Not suitable for edible purpose
- 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
- Consumption in USA in 2018 was 0.94 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 13.40 kg/MT (with 75% facilities achieving up to 15.01 kg/MT and few are achieving around 17.87 kg/MT)

Indian Corn

Corn kernel structure

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

Proximate Analysis of 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

2^{nd} 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

APY of major corn growing states

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**

AIDA estimates of Corn requirement by ESY-2025-26

Corn requirement (MMT)	3.51
Rice Requirement (MMT)	7.00
Corn Ethanol in Cr Lit.	125
Rice Ethanol Cr. Lit.	325
Corn ethanol % of total grain ethanol	30%

WET Vs DRY MILLING OF CORN

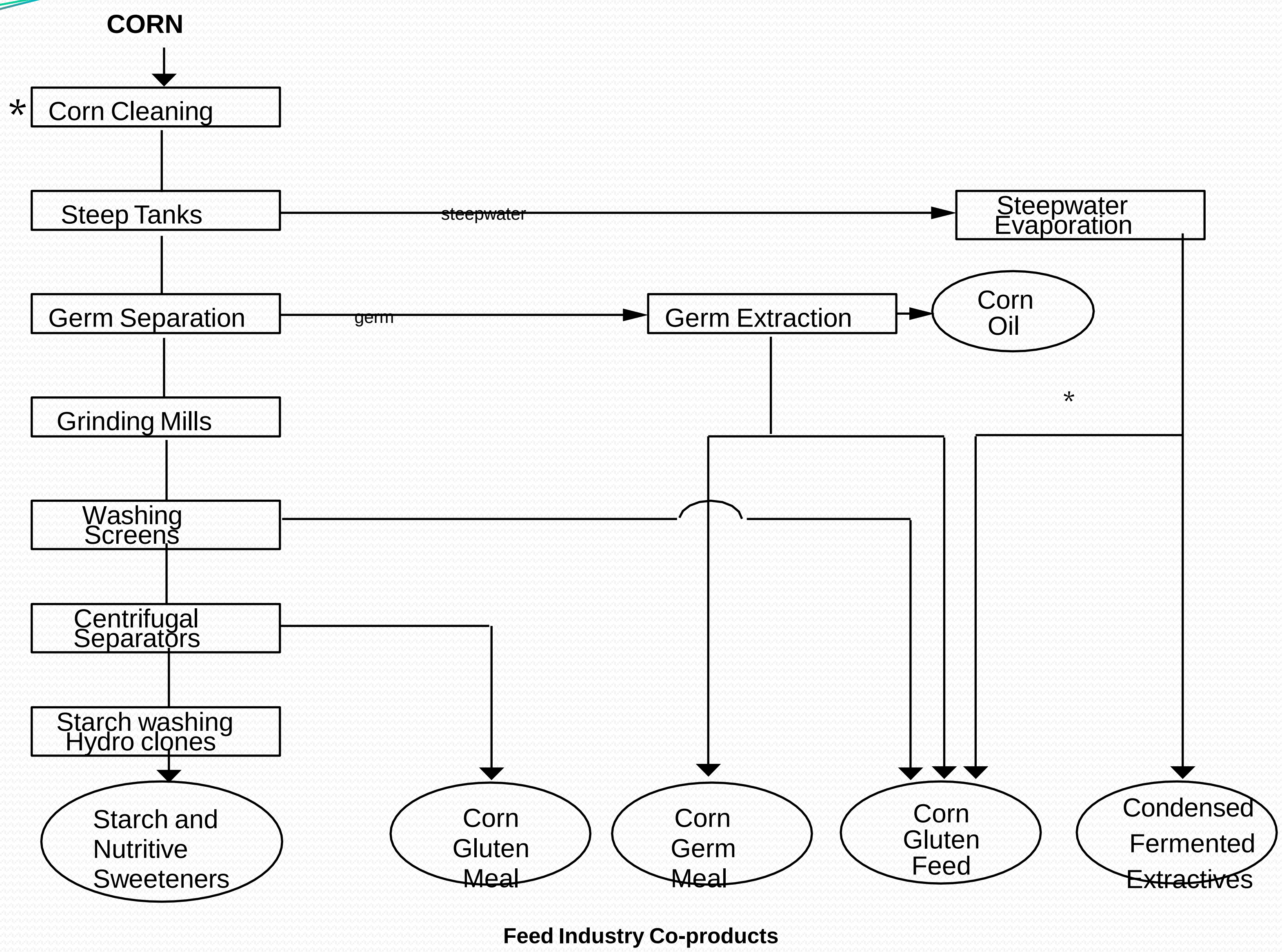
- Wet Milling

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- valuable by-product)
5. Corn oil or DCO
6. Higher ethanol yields

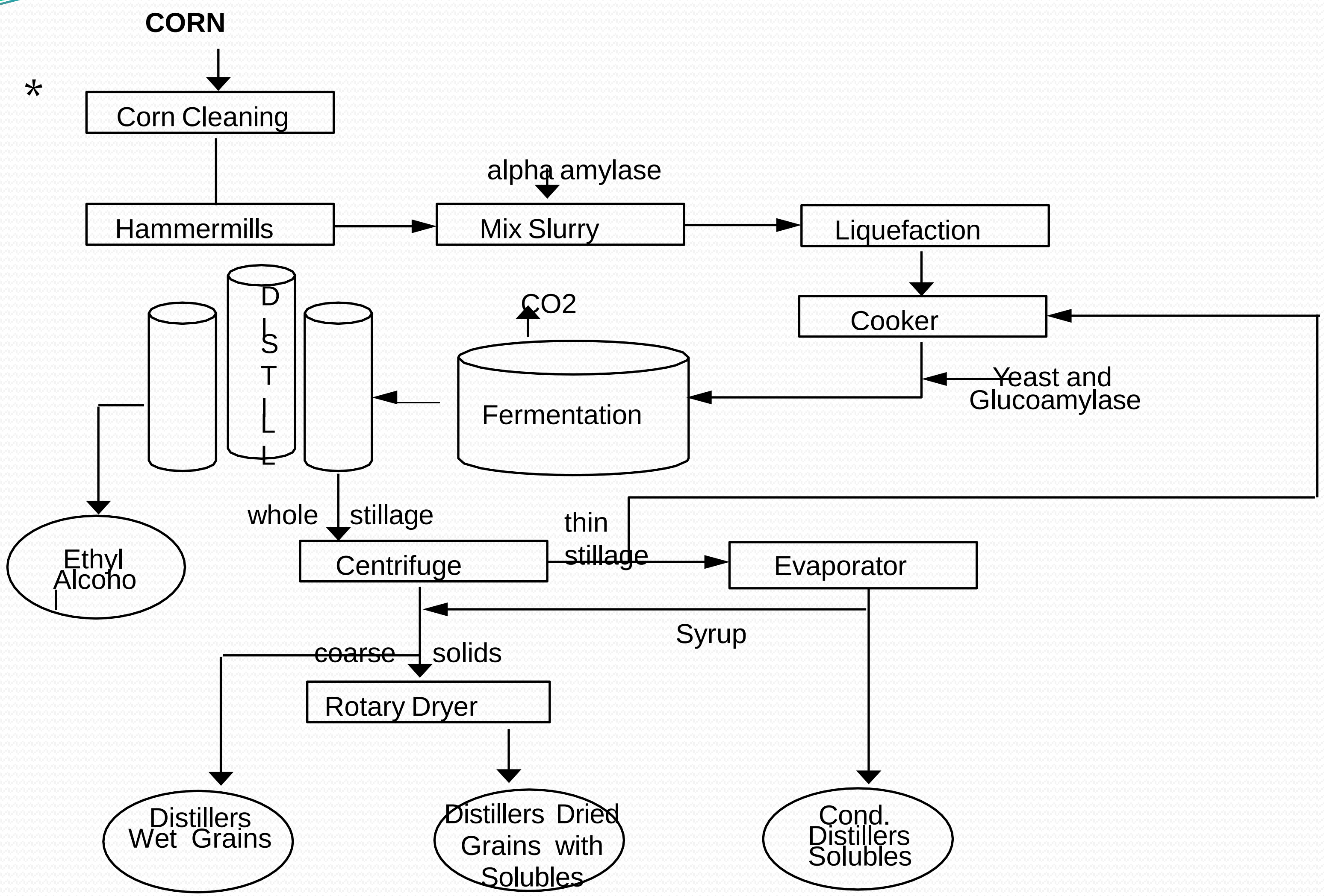
Corn Wet-Milling Process Overview



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	322
CO_2	Kg	322

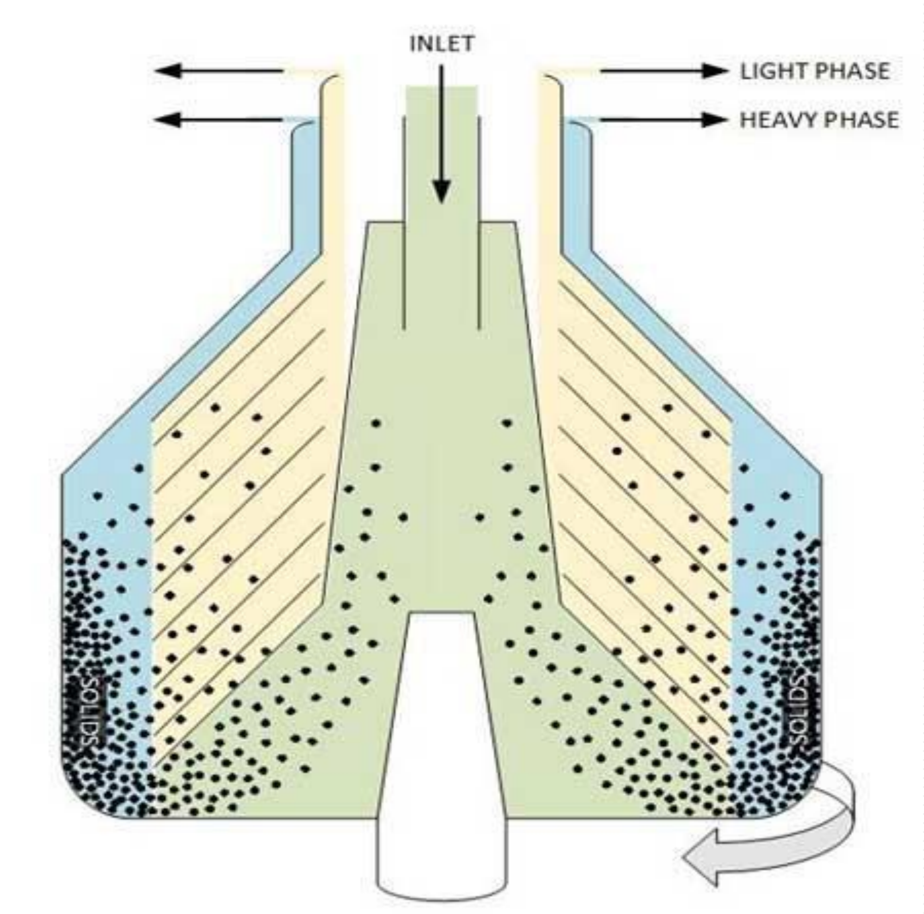
Back end recovery of corn oil

(after distillation)

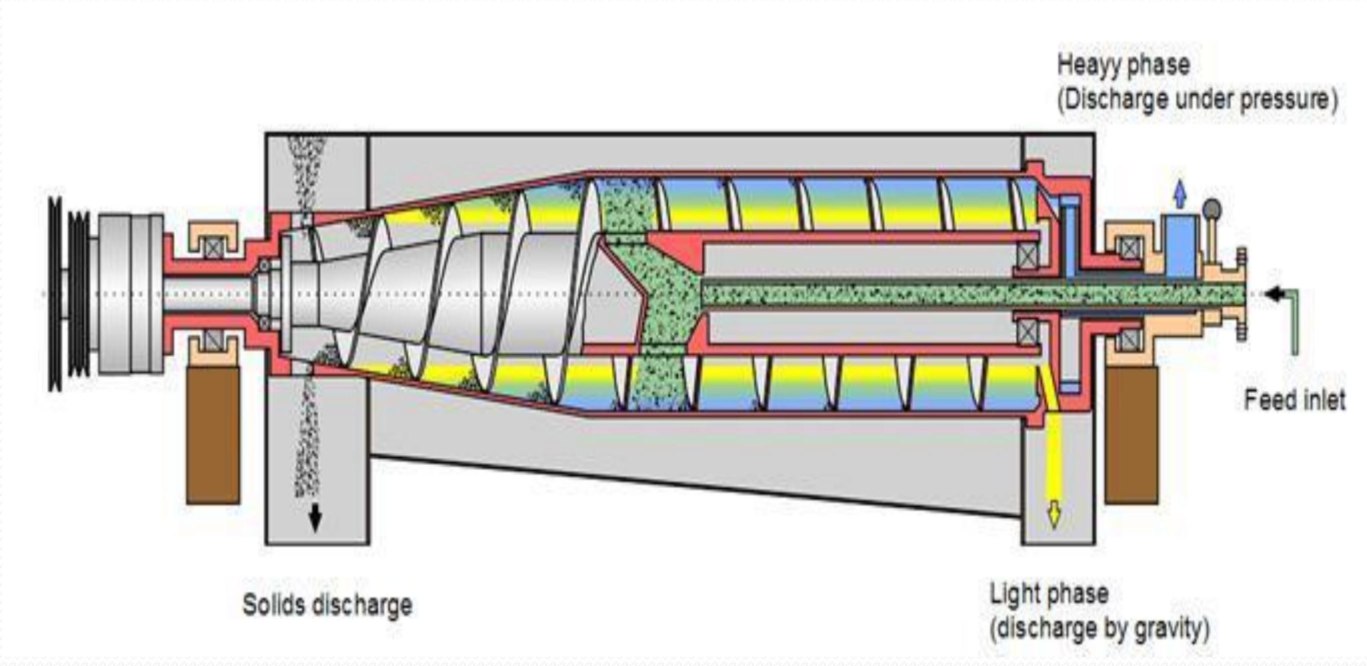
Back End Recovery

- Corn Oil in the form of "**Distillers Corn Oil**" (DCO) can be recovered from thin stillage or syrup
- From thin stillage or syrup, DCO is basically 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

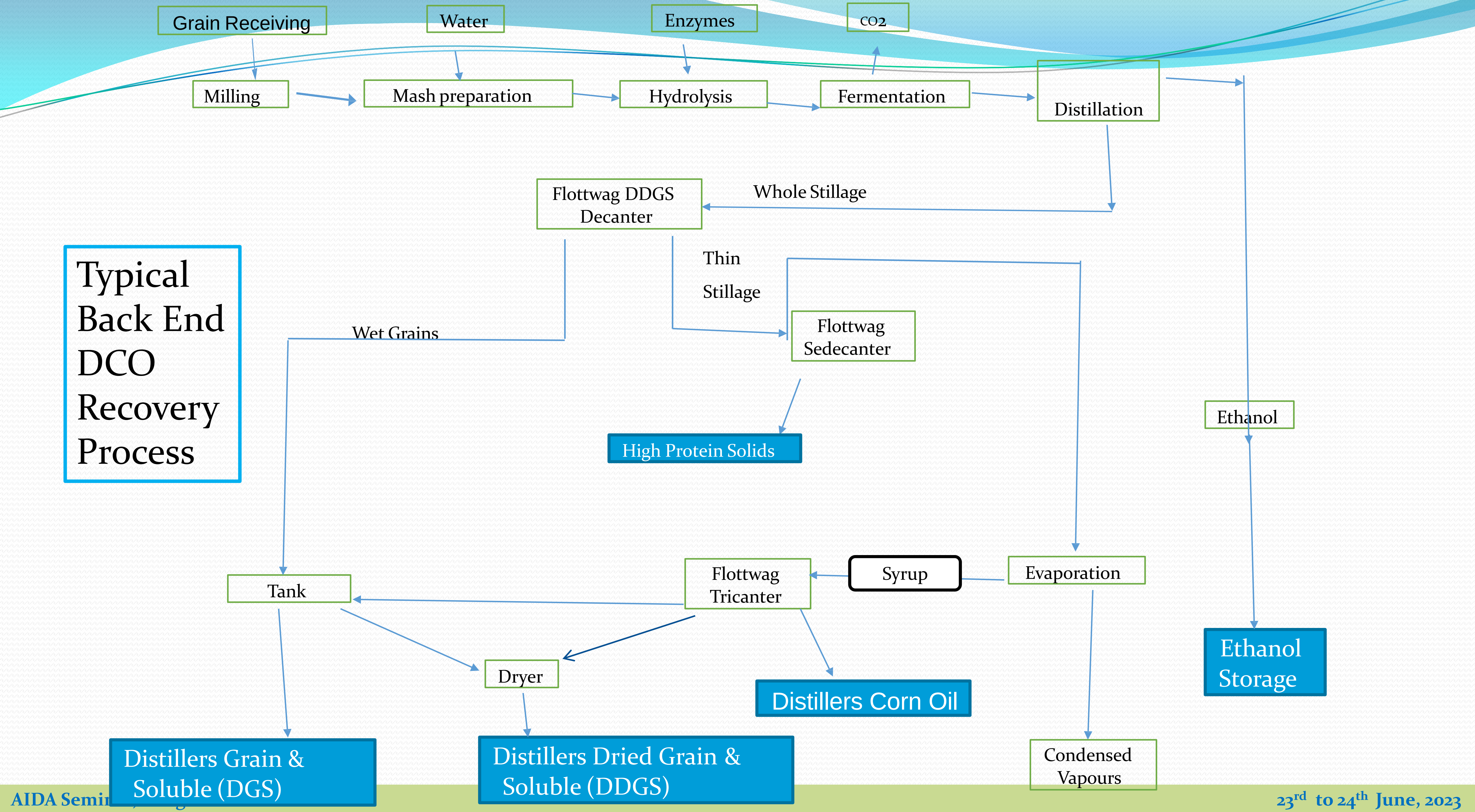


Disc Stack Centrifuge Bowl



Tri-Canter

Typical Back End DCO Recovery Process



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

Trucent’s COSS-SL

- The COSS-SL utilizes a skid-mounted disc stack centrifuge at its core and performs efficient mechanical extraction of DCO from stillage or syrup.
- Trucent’s COSS-SL offers emulsion breaking chemistry, process analytics, and centrifuge offerings designed to achieve high-efficiency removal of corn oil from stillage or syrup.
- It produces high-centrifugal acceleration for the recovery of free corn oil without any negative side effects to the ethanol or DDG production process.
- The syrup enters the centrifuge bowl and is distributed within a vertical disc stack, which increases the surface area of separation and, therefore, efficiency. The disc’s thickness, spacing, and angle; the location of the rising channels; and the number of discs in the COSS-SL disc stack are all designed specifically for DCO extraction.

COSS-SL: Skid mounted disk stack centrifuge
Over 70 installations in USA

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 (Nalco)

Front end Recovery of Corn Oil

(before fermentation)

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

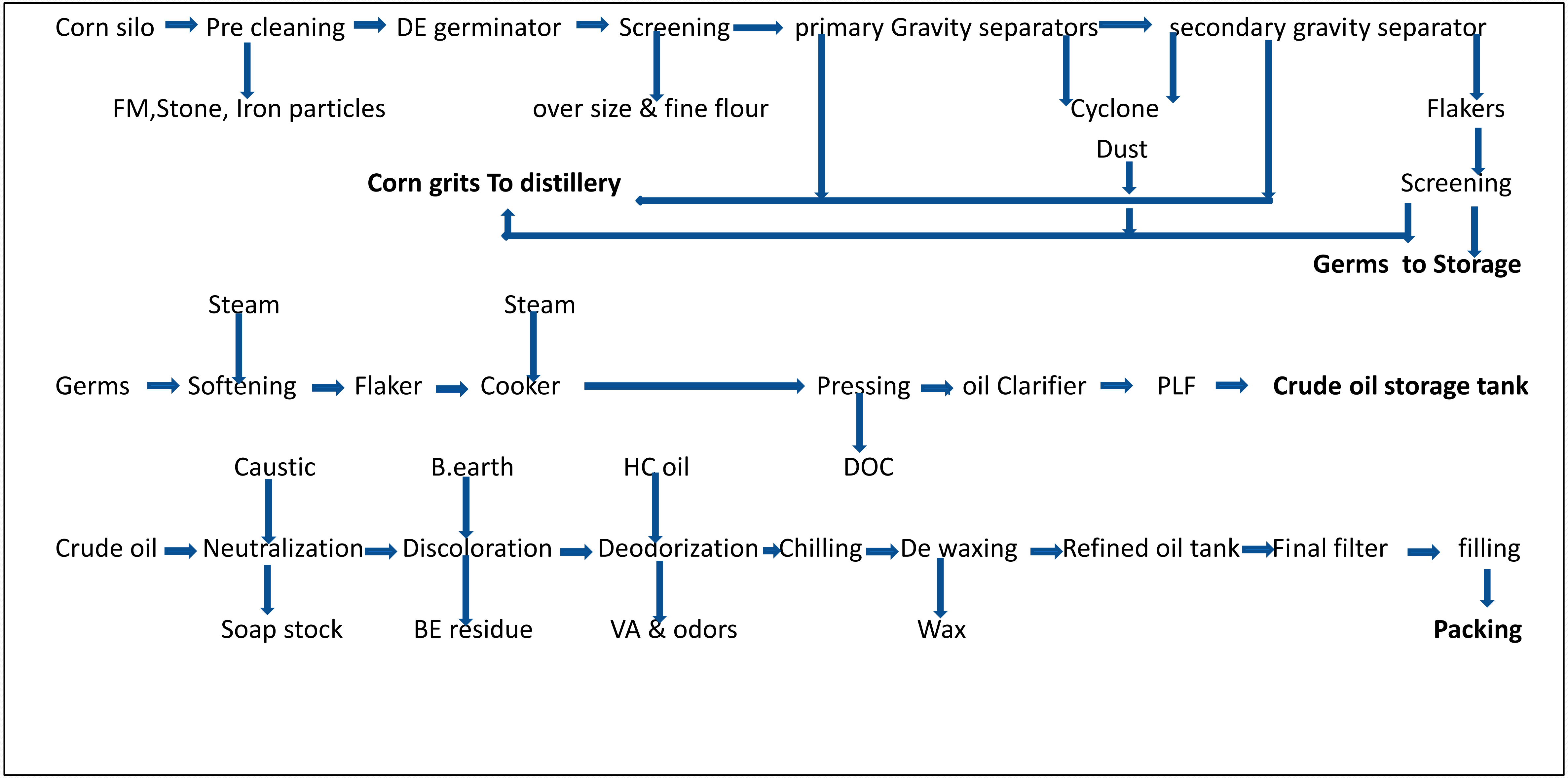
Front end Recovery of Corn Oil

- Corn germ fraction represents 10% of the mass of kernel & it contains 15-30% oil.
- Corn germ can be removed before fermentation by dry de-germination and is pressed or extracted with hexane to produce corn oil.
- It is also possible to remove corn germs in dry grind ethanol plant before fermentation using other techniques.
- Wet technique- one '**Quick germ**' process involved soaking kernels in water, gently grinding & separating the fiber & germs by floatation.
- Other wet fractionation methods have been developed using enzymes to improve separation and purify the germ, fibre and endosperm fraction.

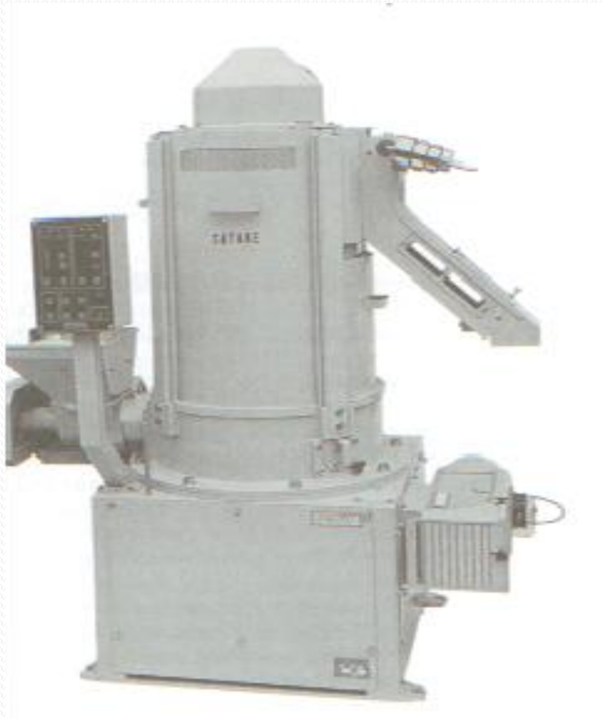
Front end recovery working principle

- Corn germ separation is well established technology.
- 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.

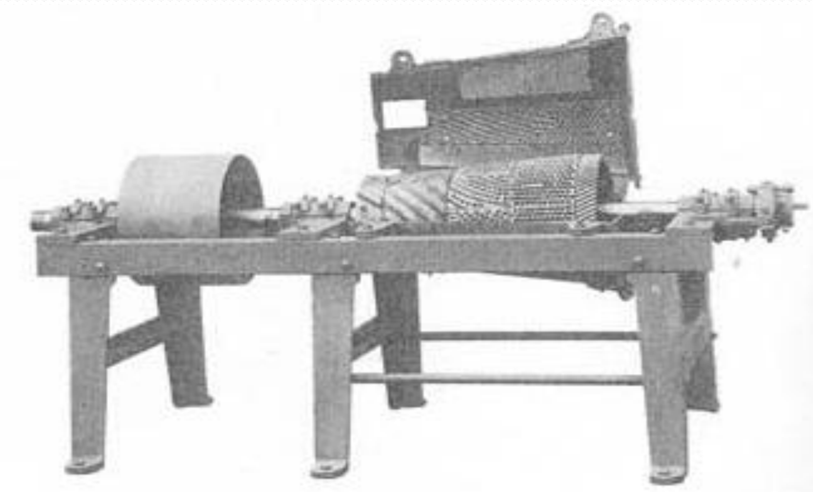
Process flow chart at Grainotch (2016)



Dry Fractionation Equipment



Satake Degerminator



Beall Degerminator

Germ Separation plant & machinery

Degerminator

Gravity separators

Flacker

Shifter

Oil press & refining machinery

Softening & cooking

Press machine

Refinery

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

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	12000*	21	252000	95.67
Electricity ,kwh	6000	10*	60000	12.00
Steam, kg	7500	2.65	19875	7.54
Coal, kg	250	8.5	2125	0.80
Water, m3	50	11	550	0.11
Chemical				0.75
Manpower				1.00
Maintenance				0.50
Packing cost,Rs/kg				15.00
Interest & dip.				12.66
Total cost, Rs/kg				146.03
Oil price, Rs/kg				140.0
DOC,Rs/kg				30.00
Soap stock,Rs/Kg				0.25
Total				170.25
Margin, Rs/kg				24.22

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

Profit of minimum Rs. 0.96 /litre of ethanol

Merits & De-merits

Merits	Demerits
Helps to reduce ethanol cost of production	Overall efficiency is low as compared to wet milling
Easy to install & operate as compared to wet milling	Power Consumption is quit high
Good quality DOC can be produced	Process losses are high due to deterioration of corn/germ quality during storage
High quality refined edible oil can be produced	Challenge in marketing due to unawareness
Capital cost would be low as compared to wet milling	Maintenance cost is quit high as most of equipment are vibratory & rotating
Space requirement is also less	The steam & power balanc with this setup is a challenge to distilleries

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TC-5509

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ULR-TC550921000008051F

TEST REPORT

Sample ID : F/05/21/0569	Report No. F/05/21/0569	Report Date	27/05/2021
Name and address of Customer	**Grainotch Industries Limited** Gat No. 238 & 239, Bhendale Village Aurangabad Nagar Highway, Tal. Gangapur, Dist. Aurangabad- 431110, Maharashtra		
Sample Drawn by	Customer	Sample Description / Type	Maize Refined Oil (Group: Food and Agricultural Products and Residues in Food Products, Subgroup: Fats, Oils and Related Products)
Sample Identification	~Batch No.: 2021-5/25CR Sample No.: 5 Sample Date: 18.05.2021	Date - Receipt of Sample	20/05/2021
Sample Quantity / Packing	1 L x 1 no. plastic bottle	Date - Start of Analysis	20/05/2021
Order Reference	As per your Work Order No. GIL/20-21/JOBWORK/115 dated 17.12.2020	Date - Completion of Analysis	26/05/2021

Sr. No.	Parameter	Result	Limits as per FSSR, 2011	Unit	Method
	CHEMICAL TESTING				
	Fatty Acid Profile				
1	Saturated Fatty Acids	**14.9**	-	g/100g	AOAC, 20th Ed.,2016, Method no.996.06, Ch-41
2	Monounsaturated Fatty Acids	**33.7**	-	g/100g	AOAC, 20th Ed.,2016, Method no.996.06, Ch-41
3	Polyunsaturated Fatty Acids	**46.6**	-	g/100g	AOAC, 20th Ed.,2016, Method no.996.06, Ch-41
4	Trans Fatty Acids	**<0.1**	-	g/100g	AOAC, 20th Ed.,2016, Method no.996.06, Ch-41
	Physical & Chemical Parameters				
5	Refractive Index at 40°C	**1.4659**	1. 4637 - 1.4675	-	IS 548 (Part 1):1964
6	Saponification Value	**189**	187 to 195	-	IS 548 (Part 1) :1964
7	Iodine Value	**115**	103 to 128	-	IS 548 (Part 1) : 1964
8	Unsaponifiable Matter	**<0.1**	Not more than 1.5	g/100g (%)	IS 548 (Part 1) : 1964
9	Acid Value	**0.14**	Not more than 0.50	-	IS 548 (Part 1):1964
10	Test for Argemone oil	**Negative**	Negative	-	FSSAI Lab Manual (30), 2016
11	Rancidity	**Absent**	Free from Rancidity	-	FSSAI Lab Manual (38), 2016
12	Suspended matter/ Foreign matter	**Absent**	Free from Suspended matter/Foreign matter	-	AEC/C/SAP/F-127
13	Separated Water	**Absent**	Free from Separated water	-	AEC/C/SAP/F-91
14	Added Colouring Matter	**Absent**	Free from Added Colouring Substances	-	FSSAI Lab Manual (4), 2016
15	Mineral Oil	**Absent**	Free from Mineral Oil	-	FSSAI Lab Manual, (28-A), 2016

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ULR-TC550921000008051F

Sample ID : F/05/21/0569	Report No. F/05/21/0569	Report Date	27/05/2021

Sr. No.	Parameter	Result	Limits as per FSSR, 2011	Unit	Method
16	Tertiary Butylhydroquinone (TBHQ)	<10	-	mg/kg (ppm)	AEC/C/SAP/F-87
	Metal Contaminants				
17	Lead (as Pb)	<0.05	Max. 0.1	mg/kg (ppm)	AEC/C/SAP/INS/3-4
18	Copper (as Cu)	<0.05	Max. 30	mg/kg (ppm)	AEC/C/SAP/INS/3-4
19	Arsenic (as As)	<0.05	Max. 0.1	mg/kg (ppm)	AEC/C/SAP/INS/3-4
20	Tin (as Sn)	0.076	Max. 250	mg/kg (ppm)	AEC/C/SAP/INS/3-4
21	Cadmium (as Cd)	<0.02	Max. 1.5	mg/kg (ppm)	AEC/C/SAP/INS/3-4
22	Mercury (as Hg)	<0.01	Max. 1	mg/kg (ppm)	AEC/C/SAP/INS/3-4
	Crop Contaminants				
23	Aflatoxin (Total)	-	Max. 10	-	-
24	Aflatoxin B_1	<10	-	µg/kg	AEC/C/SAP/INS/1-2
25	Aflatoxin B_2	<5	-	µg/kg	AEC/C/SAP/INS/1-2
26	Aflatoxin G_1	<10	-	µg/kg	AEC/C/SAP/INS/1-2
27	Aflatoxin G_2	<5	-	µg/kg	AEC/C/SAP/INS/1-2
	Pesticide Residues				
28	Phenthoate	<0.005	Max. 0.01	mg/kg (ppm)	AEC/C/SAP/INS/1-1
29	Trichlorfon	<0.005	Max. 0.05	mg/kg (ppm)	AEC/C/SAP/INS/1-1

Note: Sample ID F/05/21/0569 bears two Test Reports- F/05/21/0569 and F/05/21/0569N and below Remark is based upon both these Test Reports.

Remark: The analysed food sample results are within the limits (wherever specified) of Food Safety and Standards (Food Products and Food Additives) Regulations, 2011 (Chapter 2, 2.2.1 (15)) & Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011 (Chapter 2, 2.1, 2.2.1(1), 2.3.1) with respect to the parameters tested, without applying measurement uncertainty (Reference: Report No. F/05/21/0569 and F/05/21/0569N).

Ninad Soundankar
Technical Manager (Chemical)
Reviewed & Authorised by

Ashwamedh Engineers & Consultants

End of Report

Note:
1. The result listed refer only to the tested sample(s) and applicable parameter(s).
2. This report is not to be reproduced except in full, without written approval of the laboratory.
3. In case sampling is not done by laboratory, the results apply to the sample as received.
4. There are no additions to, deviations or exclusions from the method.

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TEST REPORT

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Sample Drawn by	Customer	Sample Description / Type	Maize Refined Oil (Group: Food and Agricultural Products and Residues in Food Products, Subgroup: Fats, Oils and Related Products)
Sample Identification	~Batch No.: 2021-5/25CR Sample No.: 5 Sample Date: 18.05.2021	Date - Receipt of Sample	20/05/2021
Sample Quantity / Packing	1 L x 1 no. plastic bottle	Date - Start of Analysis	20/05/2021
Order Reference	As per your Work Order No. GIL/20-21/JOBWORK/115 dated 17.12.2020	Date - Completion of Analysis	26/05/2021

Sr. No.	Parameter	Result	Limits as per FSSR, 2011	Unit	Method
	CHEMICAL TESTING				
	Physical & Chemical Parameters				
1	Hexane	**<0.1**	Not more than 5	ppm	By GC-MS/MS
	Metal Contaminants				
2	Methyl Mercury (Calculated as the element)	**<0.01**	Max. 0.25	mg/kg (ppm)	AEC/C/SAP/INS/3-14

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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 available for use in distilleries
- Oil recovery can help the corn based grain distilleries to improve its economics considerably if proper care is taken during designing of distillery & oil recovery plant (steam power balance, germ separation and oil plant technology selection).
- Corn oil production will promote make in India policy and will reduce import of edible oils in the country

Thanks...!!!

1L

02L

05L

15L