CHALLENGES IN SUGARCANE JUICE/SYRUP FERMENTATION AND POSSIBLE SOLUTIONS

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OVERVIEW

- Ethanol demand
- Feedstock & mill section- Sulphitation Vs Defecation
- Characteristics of different feedstock
- Fermentation process
- Characteristics of spent wash from different routes
- Distillation process
- Dehydration (ethanol) process
- ETP section
- Conclusions

HIGHLIGHTS-ETHANOL DEMAND FOR EBP

- To achieve 20% blending by 2025 about 9000 million liters of ethanol would be required. Total alcohol requirement would be 12000 million litres.
- Out of total requirement of 12000 million liters, 6600 million liters of ethanol is required to be supplied by sugar industry.
- To produce 6600 million liters of ethanol by sugar industry, minimum 6.0 MMT of surplus sugar would be diverted to ethanol production.
- The sugar production has reduced to 33.0 MMT from 35.80 MMT in the previous crushing season (after diversion).
- Total about 4.50 MMT of sugar has been diverted through sugar cane juice or B-heavy molasses for production of ethanol.
- Ethanol blending in India has increased from ~1.5% in 2013-14 to ~10% in 2021-22 and expected to go to 12 % in year 2022-23 (5500 million litres)

HIGHLIGHTS-ETHANOL DEMAND FOR EBP

- The rates of ethanol derived from different sugarcane feedstock are now revised (SJ/Syrup- Rs. 65.61/L)
- OMCs has achieved 10 % blending 5 months before the targeted date.
- GoI is expected to save foreign exchange of about Rs. 41,000 Cr. due to 10 % blending.
- This year sugar production, particularly in Maharashtra, is has gone down to 11.30 MMT and GoI has restricted export of sugar to 6.00 MMT
- GoI wants to go for 20 % blending by 2025 and it is expected that in few states, 15 % blending will start in coming days (MH, UP and KA)???

EOI FOR SUPPLY OF ETHANOL (IN CRORE LTRS) BY OMC'S FROM 2020-21 TO 2024-25

Item Details	Dec'20-Nov' 21	Dec'21-Nov' 22	Dec'22-Nov' 23	Dec'23-Nov' 24	Dec'24-Nov' 25
Ethanol manufactured from Sugar Cane juice/ Sugar/ Sugar Syrup / B-heavy molasses /C Hy molasses / Damaged food grains* / others**	465	470	500	540	580

*Damaged food grain such as broken rice, wheat, etc. which are unfit for human consumption.

**In case of any other feed stock as advised by Ministry of Petroleum and Natural Gas (MoPNG).

OMCs want to go for 20 % blending by 2025 (12 billion liters)

SUGARCANE JUICE FEEDSTOCK

- Primary juice
- Secondary juice
- Mixed mudy juice
- Mixed clarified juice
- Filtrate from Dorr Oliver
- Syrup at about 28-30^{0}Brix (before 2nd body) – vapour balance ??
- Concentrated Syrup at 60^{0}Brix (Single sulphited or defecated)

- SO_2 and sulphites are poison to yeast
- Juice and syrup has very less salts and therefore, no buffering capacity
- Results in lowering the pH in fermentation
- Higher RT in fermentation (30 Vs 50 hrs)
- Constant brix of syrup is a big problem
- High dextran, strach and LA- inhibition
- Low monosaccharides-slow attenuation

The difference between carbonation and sulphitation in the cane juice clarification process is that in the carbonation process, milk of lime and carbon dioxide is used while in sulphitation process, Sulphur dioxide is used with lime and phosphoric acid.

FEEDSTOCK AND MILL SECTION

- Sugar percentage or recovery in sugarcane depends on varieties, geographical region, harvesting time, temperature, soil, etc.
- Sugar concentration in the sugarcane juice/syrup has important role in determining final alcohol concentration during fermentation (Constant brix, No shock feeding).
- Juice/Syrup is highly perishable, it can get easily contaminated (LA levels)
- If mill operation is interrupted for more than one hour, contamination level can increase in the juice which can be carried further to fermentation (frequent CIPs)
- To avoid contamination in mill section, the mill sanitation/ hygienic conditions should be proper and kept dry during long shutdowns to avoid stagnancy of juice in mill section- Judicious application of mill sanitation chemicals/CIP

CHARACTERISTICS OF DIFFERENT FEEDSTOCK

S. N.	Parameters	C Molasses	BH Molasses	Cane syrup
1	pH	5.01	5.41	4.74
2	°Brix	88.0	86.0	57.00
3	Total Reducing Sugars, %	50.08	61.00	52.58
4	Unfermentable Sugars, %	5.01	2.60	0.67
5	Fermentable Sugars, %	45.07	58.40	51.91
6	Carbonated ash, %	10.0	9.8	1.0
7	Sulphated ash, %	13.0	11.5	2.5
8	F/N	1.05	2.2	6.4
9	Volatiles acidity (ppm)	5000	2000	800
10	Sp. Gravity	1.40	1.35	1.19
11	Total microbial count (CFU/gram)	5.6×10^3	8.8×10^1	7.5×10^1
12	Sulphites, ppm	NE	NE	300-400
13	Shelf life	1-2 years	1-2 years	Perishable

SUGARCANE MIXED JUICE COMPOSITION

S. No.	PARAMETER	COMPOSITION	UNITS
1	Water	75-80	%
2	Sucrose (Pol)	10-16	%
3	Reducing Sugars	0.4-1.0	%
4	Organic matter	0.5-1.0	%
5	Inorganic compounds	0.2-0.6	%
6	Nitrogenous compounds	0.5-1.0	%
7	Brix (Solids)	12.0-22.0	%
8	Purity (ratio of sugars to non-sugars)	80.0-87.0	%
9	Ash	0.4-0.7	%
10	CaO	600-800	ppm
11	P_2O_5	60-300	ppm
12	N_2	0.03-0.04	%

SUGAR MANUFACTURING PROCESS

- During white sugar manufacturing
  - Syrup is normally double sulphited in India but for fermentation single sulphited syrup should be used
  - Due to presence of high amount of sulphites (inhibitory), It takes additional time for completion of fermentation (48-50 hrs)
  - Nutrients and additives should be used properly in PF and fermenters
- During raw sugar manufacturing
  - Defecation process is used
  - Syrup produced is easy to ferment because of absence of sulphites with less retention time (28-30 hrs)

SUGAR MANUFACTURING PROCESS

- The brix of syrup after evaporation is normally at 55 to 60 Deg. brix which can be partially or totally diverted for fermentation after cooling
- The brix of syrup should not vary substantially.
- Syrup at 55 to 60 Deg. brix should be diluted to 28 to 30 Deg. brix either using recycled spent wash or secondary juice or clear juice or mixed juice
- Syrup at 28 to 30 Deg. brix can be also withdrawn after first body and can be used for fermentation without dilution after cooling
- The sugar syrup cooling and preparation system should be close type to avoid contamination
- Syrup transfer pump area should be kept clean and contamination free
- Syrup buffer tank retention should be minimum
- The syrup transfer line distance from sugar mill to distillery should be minimum and leak proof- sucrose crystallization can take place in transfer line
- Proper cooling arrangement should be provided so that syrup temperature is maintained at around 35 Deg C before feeding to PF & Fermenters

FERMENTATION PROCESS

- Fed-batch fermentation with four fermenters is suitable for syrup fermentation under Indian conditions and to achieve 13% (v/v) alcohol concentration in wash
- Yeast culture
  - It is recommended to use active dry yeast and/or pure culture
  - Minimum cell count of 3.5×10^8 cells per ml cell (pre-fermenter) & 2.5×10^8 cells per ml (fermenter)
  - Transfer at least 12 to 15 % of yeast culture (of total volume of fermenter) from pre-fermenter
- Feeding cycle of fermentation is very important and has to be optimized.
- Microscopic examination of syrup samples from different sample points as well as fermentation broth samples to be carried out in every shift
- After transfer of every batch (fermenter), the fermenter need to be cleaned and sterilized with formalin and steam
- Fermenter pH can be controlled in between 4.2 to 4.5 using liquid ammonia or other ammonia source

FERMENTATION PROCESS

- Add required quantity of nutrients and additives in fermenter and distribute the addition in four intervals based on fermentation reaction progress
- Maintain fermenter temperature around 33 - 35 Deg C. In North Indian states, fermenter temperature can go down below 30 Deg during winter season
- In fermentation, contamination of *lactobacillus* and wild yeast need to be examined routinely with judicious use of antibiotics/anti-microbial agents and good manufacturing practices
- For Mixed Juice fermentation
  - It can take about 12 to 14 hrs retention time and alcohol percentage is low (7.5 % to 8% v/v)
  - Due to low buffering capacity of juice, fermented wash pH falls below 4.0
  - Results in higher quantity of spent wash generation (10-12 L/L alcohol)

NUTRIENT ADDITION IN PRE-FERMENTER & FERMENTERS

S. N.	Parameters	Pre-fermenter	Fermenter
1	ADY (Kg)	10	5
2	Urea (Kg)	10	150
3	DAP (Kg)	3	20
4	MgSO4 (Kg)	0.250	5.0
5	ZnSO4 (Kg)	0.250	5.0
6	Enzyme (Kg)	0.350	1.0
	Note- Additives & nutrient consumption for typical 60 KLPD distillery plant (70 M^3-PF and 290 M^3-Main Fermenter)		

FERMENTATION PROCESS

- For syrup fermentation
  - To achieve alcohol concentration of 13% (v/v), it can take about 48 to 50 hrs to complete the reaction with sulphited syrup
  - The residual sugars should be minimum (0.8 %) but can increase if proper fermentation doesn't take place (loss of sugar)
  - The spent wash produced from syrup can be recycled back to fermentation process to minimize the fresh water requirement and to reduce the quantity of spent wash
- For juice as well syrup fermentation, maximum quantity of fermented wash need to be transferred to wash settling tank before CIP and cleaning of fermenters

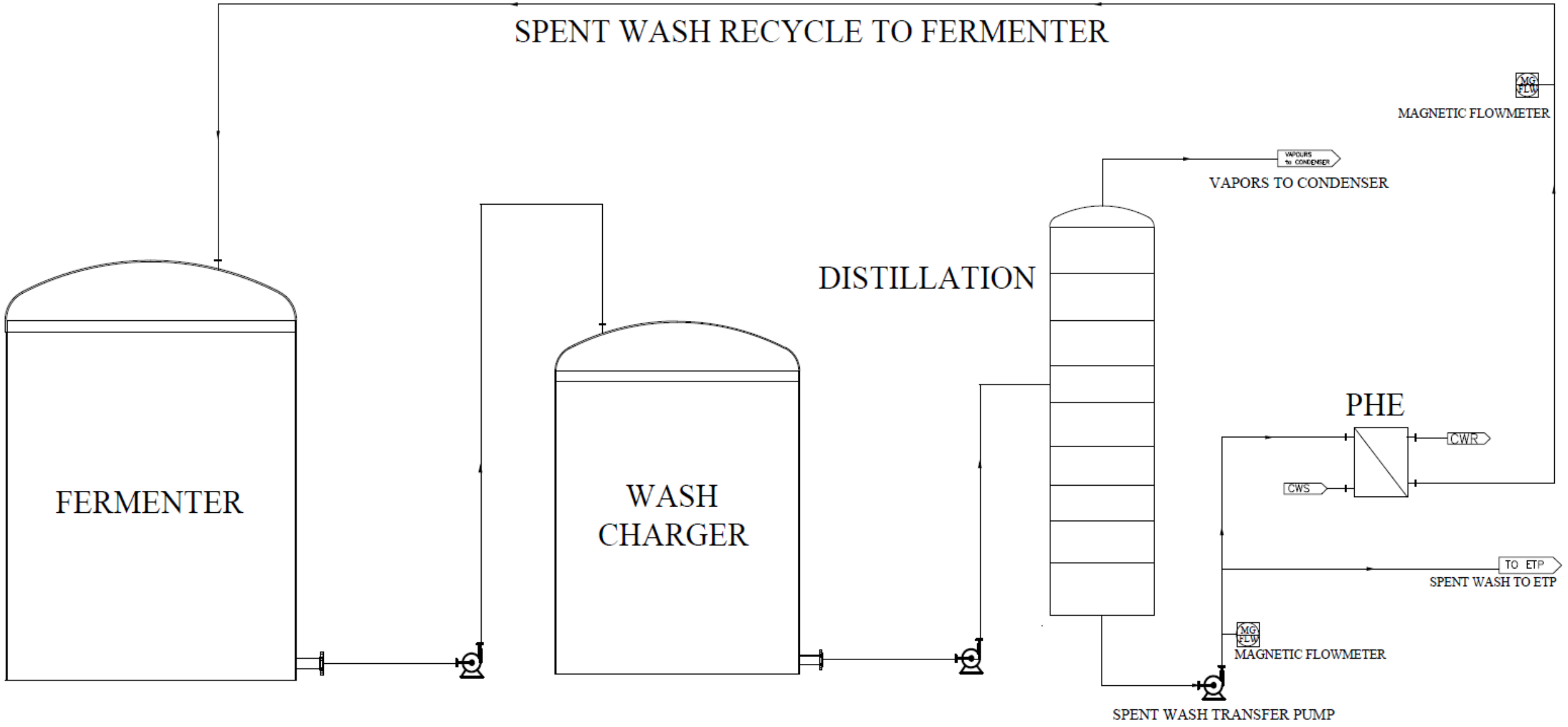
SULPHITE INHIBITION

- The syrup at 60^0brix is once sulphited and contains sulphites and sulphates that inhibit yeast and retards the rate of fermentation and requires additional retention time.
- How to reduce the sulphite inhibition?
  - Follow defecation method
  - Use mixed juice or secondary juice for dilution of syrup
- In few cases, we have set-up parallel defecation-evaporation system to avoid sulphit inhibition problem (Capex ??)

CHARACTERISTICS OF SPENT WASH FROM DIFFERENT ROUTES

S. N.	Parameters	C Molasses	BH Molasses	Cane syrup After recycle
1	pH	4.0	4.2	3.5
2	Color	Dark Brown	Yellowish brown	Pale Yellow
3	Quantity (L/L alcohol)	9	7	3
4	°Brix	12.0-14.0	7.5-8.5	5.5-6.0
5	COD (mg/L)	120000	80000	50000
6	BOD (mg/L)	60000	40000	25000
7	Dissolved solids (mg/L)	60000	50000	24000
8	Suspended solids (mg/L)	30000	20000	6000
9	Total solids (mg/L)	90000	70000	30000
10	Nitrogen (mg/L)	1000	700	600
11	Phosphorus (mg/L)	300	200	150
12	Potassium (mg/L)	10000	4000	1500

SPENT WASH RECYCLE SYSTEM - PFD



DISTILLATION PROCESS

- The acidic nature of fermented wash (pH 3.2-3.5) results in corrosion and damage to
  - Analyzer column plates and bottom segment
  - Analyser column re-boiler tubes
  - Rectifier column re-boiler tubes
  - Wash feed line to distillation and Spent wash transfer lines

    (Change MOC to SS316)
- Rectified spirit produced in distillation is also acidic. It can affect the equipment with higher contact time

DEHYDRATION - ETHANOL PROCESS

- The acidic nature of rectified spirit (pH 3.9-4.0) results in corrosion or damage to
  - Day storage tank (leakages)
  - Evaporator column bottom segment leakage
  - Evaporator column re-boiler tubes/PHE plates damage
  - Life of molecular sieves
- In few cases, we are neutralizing RS with caustic in rectifier reflux tank or feed tank/regeneration tank of MSDH section
- If ethanol stored for long time, there is possibility of ethanol storage tank corrosion or damage
- S content in ethanol – less than 10 ppm; Lower pH of ethanol ??

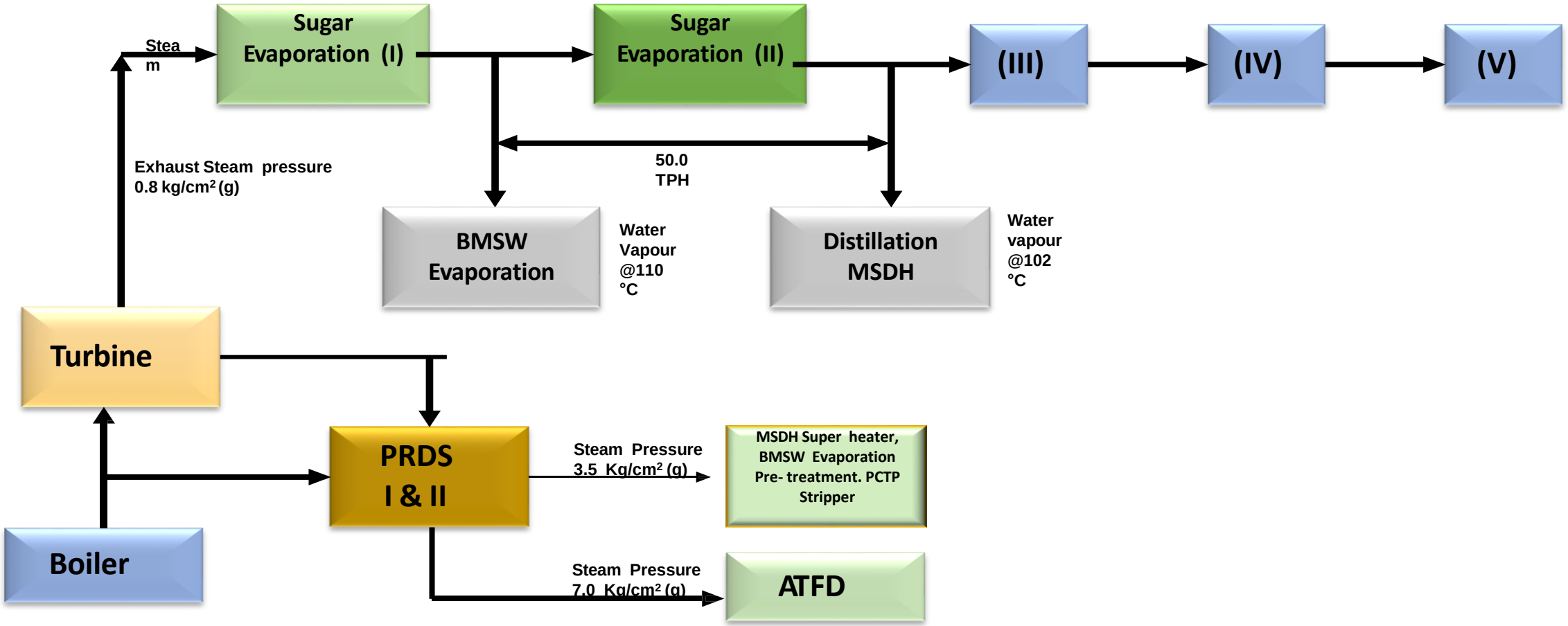
ETP SECTIONS

- Lesser biogas production, lower methane in biogas from spent wash of syrup fermentation
- Substantial scaling problem in case of evaporation of spent wash from syrup fermentation
- Lower volume/quantity of spent wash from syrup fermentation
- The profitability will vary depending on the downstream effluent treatment system
- Incineration route is not really suitable when syrup is used as a raw material (as the calorific value and quantity of spent wash is substantially less)
- Spent wash generation will be 3 L/L of alcohol as against 8-10 L/L alcohol for C-molasses
- Highest profit can be earned if direct bio-composting of raw spent wash is allowed

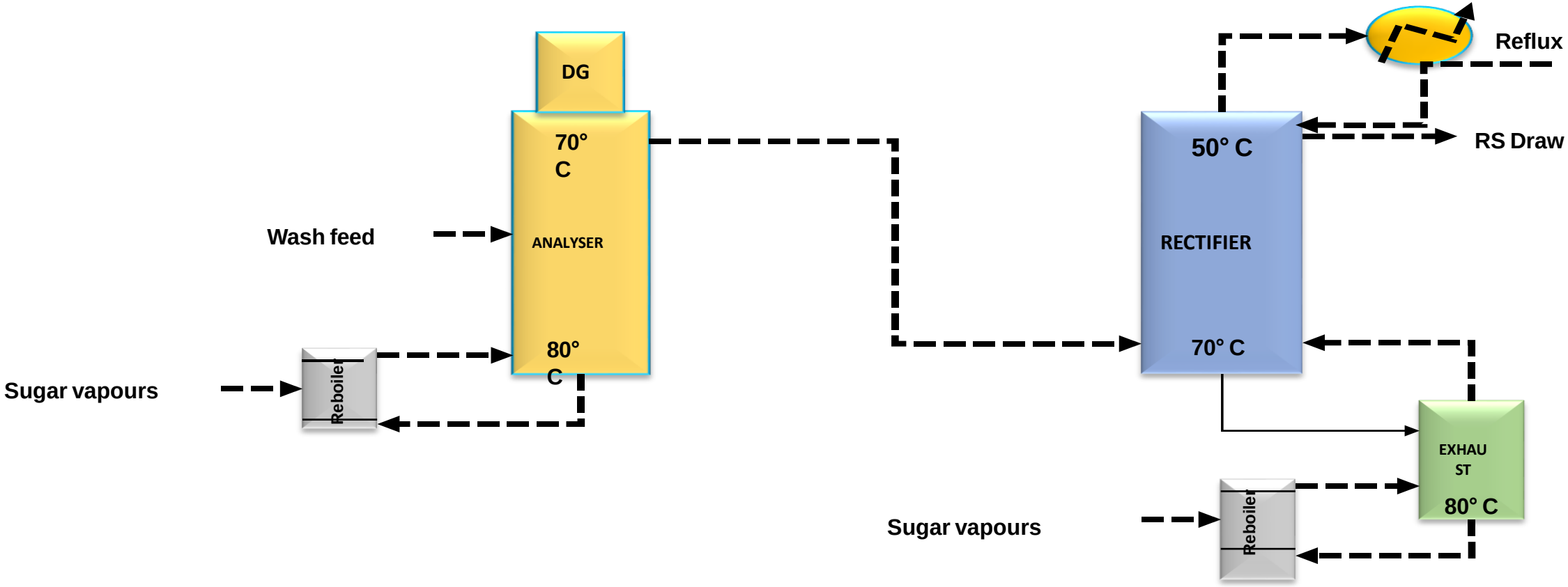
DEDICATED SUGARCANE JUICE/SYRUP TO ETHANOL PLANT

- There will be additional capital investment for sugar unit (up to juice evaporation plant) + distillery & downstream ETP
- It is possible to go for defecation process which will result in higher fermentation efficiency
- Steam consumption in distillery can be substantially reduced if juice evaporation vapours are used for ethanol production as done in Brazil
- It is possible to go for syrup in season and bio-syrup in off-season (lowest profit)
- Dedicated plants below 100 KLPD capacity are not financially viable

BRAZILIAN MODEL: STANDALONE SYRUP TO ETHANOL



BRAZILIAN MODEL: STANDALONE SYRUP TO ETHANOL



Both columns will be operated under vacuum

CONCLUSIONS

- It is possible to go for syrup in season and BH molasses or bio-syrup in off-season
- Possible to increase the capacity by 1.5 times above the installed capacity while using sugarcane juice/syrup (NIPL)
- The profitability will vary depending on the downstream effluent treatment system
- Incineration route is not really suitable when syrup is used as a raw material (as the calorific value and quantity of spentwash is substantially less)
- Highest profit can be earned if direct bio-composting of raw spentwash is allowed
- Reduced pollution load on downstream effluent system. SW will be 3 L/L of alcohol as against 8-10 L/L alcohol for C-molasses
- It is possible to divert substantial quantity of sugar through ethanol production from syrup. Thus, we can reduce the increasing sugar stocks in the country.

CONCLUSIONS

- Highest price for ethanol from sugarcane juice/syrup (Rs. 65.60/L)
- High alcohol concentration in wash & recycle of spentwash and thus reduction in spentwash quantity
- Ethanol payment is made by OMCs within 21 days (??)
- Priority lifting by OMCs for ethanol from sugarcane juice/syrup
- Indirect benefits in sugar mill such as
  - Increasing in crushing capacity
  - Reduction in steam consumption (bagasse saving) in sugar mill
  - Higher export of power
  - Saving in handling & bagging charges of sugar
  - Reduction in interest burden on sugar stocks


Thank You!