Maximizing Fuel Ethanol Opportunities in Compliance to ZSD
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Praj Industries Ltd., Pune

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Who We Are

- A Knowledge Based Company
- A Global Indian Company
- A Customer Centric Company
- A Socially Responsible Corporate Citizen
- End-to-end Solution Provider
- Expertise and Experience in Process and Integration Engineering
- Technology Backed Solutions
- References Across Five Continents
- Customized Solutions
- Strong Focus on Sustainable Development

End-to-end Solution Provider

Expertise and Experience in Process and Integration Engineering

Technology Backed Solutions

References Across Five Continents

A Knowledge Based Company

A Global Indian Company

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Strong Focus on Sustainable Development

Customized Solutions
What We Do

- Alcohol/Ethanol plants
- Brewery plants
- Water and Wastewater Treatment Systems
- Critical Process Equipment & Systems
- HI Purity Systems
  - Pharma
  - Biotech
  - F&B
  - Cosmetics
- Bio-Products
  - Distillery bioconsumables
  - Livestock, health & nutrition products
  - Human health & nutrition
  - Biochemicals
Why PRAJ

Praj Matrix

- 80,000 sq ft of Labs, Pilot Plants, and Offices
- 115 technologists - 30 PhDs, 80 Masters.
- 9 Technology Centers of Excellence - Biology, Chemistry, Engineering
- 1 TPD Cellulosic Ethanol pilot plant

Engineering

- Over 1000 employees of which 85% are engineers.
- Capability to design to international standards
- Follow global engineering standards
- Skid engineering
- Adequate knowledge of latest design & simulation software such as P4D, PDMS, Chemcad, Aspen & HTRI

Customer Care

- Technical Audit
- Trouble shooting
- Spares Supply
- Supply of Equipment
- Plant/ Equipment Life Extension Services
- Preventive Maintenance
- Recommissioning

Manufacturing

- 3 manufacturing units connected highways & ports having total manufacturing capacity of 13500 T/yr
- ASME “U” & “H” certified
- Can supply equipment with “CE” certification
- ISO 9001:2008 Quality management system
Sustainability Drivers

- Volatility in Feedstock & Ethanol Prices
- Rising Energy & Water Cost
- Stringent Pollution control Norms
- Policy Uncertainty
Ethanol Maximization
Distillery-Key Unit Operations

- Fermentation
- Distillation & Dehydration
- Effluent Treatment
Fermentation

Yeast

Fermentation

Mode of Operation

Feedstock Composition
Sugar Factory Streams-Feedstock Options

Cane → 1st mill → Bagasse

- Primary Juice
- RVF Juice
- Press Mud

Bagasse → Clarification → Mixed Juice → Evaporation → Crystallization → 1st/2nd / 3rd /4th Centrifuge

- B- Molasses
- C- Molasses

2nd / 3rd /4th /5th mill → Bagasse

- Secondary Juice

Condensate → Sugar

2G Sugars
## Typical Sugar Juice Stream Composition

<table>
<thead>
<tr>
<th>Stream</th>
<th>Primary Juice</th>
<th>Secondary Juice</th>
<th>Mixed Juice</th>
<th>Filtrate Juice</th>
</tr>
</thead>
<tbody>
<tr>
<td>% w/w on Cane</td>
<td>55</td>
<td>45</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>% Pol</td>
<td>14 - 16</td>
<td>6 - 9</td>
<td>10 - 12</td>
<td>8 - 10</td>
</tr>
<tr>
<td>°Brix</td>
<td>18 - 20</td>
<td>8 - 11</td>
<td>14 - 16</td>
<td>15 - 16</td>
</tr>
<tr>
<td>FS</td>
<td>15.5 - 17.5</td>
<td>7 - 10</td>
<td>11 - 13</td>
<td>9 - 11</td>
</tr>
</tbody>
</table>

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## Typical Properties of Concentrated Streams

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Syrup (TDS (%w/w))</th>
<th>Molasses- B (FS (%w/w))</th>
<th>Molasses- C (TSS (%w/w))</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS (%w/w)</td>
<td>45-50</td>
<td>73.42</td>
<td>73-76</td>
</tr>
<tr>
<td>FS (%w/w)</td>
<td>40-45</td>
<td>50-60</td>
<td>45-50</td>
</tr>
<tr>
<td>TSS (%w/w)</td>
<td>0.2-0.5</td>
<td>1.0-1.5</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.19</td>
<td>1.39</td>
<td>1.39</td>
</tr>
<tr>
<td>Volatile Acidity (ppm)</td>
<td>1000-1500</td>
<td>1500-2000</td>
<td>3000-8000</td>
</tr>
</tbody>
</table>
Fate of Sugar

Sugar

Ethanol formation
88 – 91 %

Yeast growth
5 – 6 %

Byproducts formation
4 – 6 %
Yeast - Stress Factors

Sugar Content
Yeast can tolerate up to 38% w/v

Ethanol
23% is possible

Lactic acid
> 0.8% w/v kills

Sulfite
> 100 mg/L kills (varies with strain)

Sodium ion
> 500 mg/L kills

pH
3 - 4

Temperature
35°C max.

Acetic acid
> 2400 ppm inhibit

Dissolved Solids
> 20% w/w
Budding Yeast produces alcohol 33 times faster than non-budding!
Yeast Growth Kinetics

**Yeast Specific Productivity (liter of alcohol/kg of yeast/hour)**

**Volatile Acidity**

**PCV**

**Ethanol Concentration in Fermented Mash (%V/V)**

- Yeast production (kg yeast/kg alcohol)
- Yeast Specific Productivity (liter of alcohol/kg of yeast/hour)
- Volatile Acidity
- PCV

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Imperative-Identifying the Right Yeast!

- Collection of Yeast from different Flora and Fauna
- Microbiological and biochemical assay for different stress parameter
- Shortlisting of yeast and study of growth Kinetics
- Bench and Pilot scale process optimization and integration

XP⁺ Yeast
- High VA tolerant-2000-2800 ppm in mash
- High Ethanol Titer-10-13%v/v
- Low glyceol production
- High ethanol Generation rate
Mode of Operation

- **Batch:**
  - Simultaneous Addition of Activated cell mass and the feed
  - Reaction completion
  - Emptying
  - Cleaning

- **Synchronous (Fed Batch):**
  - Synchronized addition of activated cell mass
  - Reaction Completion (partial addition of feed and fermentation)
  - Emptying
  - Cleaning

- **Continuous:**
  - Simultaneous addition of feed, activated cell mass and reaction
  - Emptying-NO
  - Cleaning-NO
## Advantages of Synchronous & Continuous Fermentation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Synchronous</th>
<th>Continuous</th>
</tr>
</thead>
</table>
| Advantages | • Flexibility: Multiple feedstock and their combination. Can be terminated anytime depending on feedstock composition  
• Risk of Infection: Less as after termination of batch, fermenters are CIPed.  
• Yield: Higher | • First fermenter acts as fresh yeast supply to rest of the fermenter  
• High active cellmass concentration ensures fast reaction  
• Minimal Yeast Usage  
• Consistent mash quality  
• Less CIP  
• Less laborious  
• Lower CAPEX  
• Easily Automated |

Is there fermentation technology giving advantage of synchronous and continuous Fermentation with high ethanol concentration?

CombiFerm™
CombiFerm™

- **CombiFerm**: Combination of Fed batch and Continuous fermentation process
- **Biostat**:
  - Hygienic equipment design
  - Controlled feeding of feedstock & nutrient
  - Homogenous mixing
  - Temperature control
  - CIP facility for Hygienic condition for optimum cell mass concentration
- **Chemostat**:
  - Hygienic equipment design
  - Homogenous mixing
  - Temperature control
- Separation of yeast growth phase (biostat) and ethanol generation phase (Chemostat) in fermenter

- Ensuring hygienic operations in biostat by operating fermenter in fed batch mode.

- Ethanol generation in continuous mode of operation (Chemostat) for consistent mash feed to distillation.
Recycle Streams used in fermentation for feedstock dilution

- PRC Lees- **VA 1500-2000 ppm**

- Raw Spent wash Process Condensate- **1000-1600 ppm** (RSW Evaporation as ETP)

- BMSW Condensate- **500-600 ppm** (BMSW evaporation as ETP)
CombiFerm™- Best of Both

Feature:
- Scientifically Designed Fermentation Technology
- Extra-productive, New Yeast strain XP
- Advantage of Continuous and Synchronous fermentation
- Suitable for Sugarcane, Sweet Sorghum, Sugar beet based feedstock and their combination
- Compact footprint and reduced Steelwork

Advantage:
- Suitable for feedstock with high VA and lower F:N ratio
- Feedstock specific, higher ethanol concentration in fermented mash upto 15% v/v
- Compliance to reduce, recycle and reuse of effluent streams
- Reduced risk of contamination
- Reduction in CIP usage by 30-35%
- Fermentation efficiency upto 91%

Benefits:
- Increase in profitability due to higher yield
- Excellent congener profile for beverage alcohol
- Modernization opportunity to expand batch fermentation plant capacity by 15-20%
CombiFerm™ - Modernization Opportunity
Case Study - Fed Batch

100 KLPD Distillery-
- Existing Fed Batch Fermentation:
  Alcohol concentration in mash - 8.5% v/v
  Fermented mash produced - 1148 m3/day
  No. of Fermenter - 480 m3 (4 No.)
  Beerwell - 480 m3 (1 No.)

- CombiFerm:
  - Alcohol concentration in mash - 8.5% v/v
  - Fermented mash produced - 1645 m3/day
  - Plant capacity achieved - 130 KLPD
  - Increase in plant capacity - 30%
  - Payback < 1 year
## CombiFerm™- Reference List

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Client Name</th>
<th>Capacity In KLPD</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jakraya Sugar</td>
<td>45</td>
<td>Under Engg</td>
</tr>
<tr>
<td>2</td>
<td>Vishwas SSK</td>
<td>30 to 60 expansion</td>
<td>Under Engg</td>
</tr>
<tr>
<td>3</td>
<td>Jaywant Sugar</td>
<td>50</td>
<td>Under Engg</td>
</tr>
<tr>
<td>4</td>
<td>Kooll Inc., Philippines</td>
<td>50</td>
<td>Under Engg</td>
</tr>
</tbody>
</table>
EcoSmart™-Evaporative Distillation
Conventional Distillation Technologies
RS / AA Production

Ecofine – TVS

Ecofine – PV
**EcoSmart™-Evaporative Distillation-Schematic**

**Normal Distillation**

Fermented Wash → Analyser → Rectifier → RS

**EcoSmart™-Evaporative Distillation**

Evaporative Distillation → Rectifier → RS
## Energy Comparison
Various Technologies

<table>
<thead>
<tr>
<th>Alcohol Concentration Fermented wash % v/v</th>
<th>Single Mash Column Kg/lit of TS</th>
<th>Evaporative Distillation Kg/lit of TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1.8</td>
<td>1.25</td>
</tr>
<tr>
<td>10</td>
<td>1.6</td>
<td>1.05</td>
</tr>
<tr>
<td>12</td>
<td>1.35</td>
<td>0.9</td>
</tr>
<tr>
<td>15</td>
<td>1.25</td>
<td>0.8</td>
</tr>
</tbody>
</table>
EcoSmart™ Evaporative Distillation

**Feature:**
- Thermal Energy similar to Split Distillation
- Suitable for molasses & Grain based distillery to produce RS, ENA, AA
- Ethanol titer in mash 8-15% v/v
- Integrated with evaporation

**Advantage:**
- Lower steam consumption as against evaporation integrated distillation
- Reduction in water foot print
- Suitable for retrofitting
- Increase in plant capacity by 30-40%
- Lower CAPEX against split mash column

**Benefits:**
- Increase in profitability due to reduced water and energy consumption
- Modernization opportunity to expand plant capacity by 25-30%
Case Study -

EcoSmart™ Evaporative Distillation Technology
Value Addition in Modernization

Parameter

Plant Capacity

Steam Consumption

60KLPD MPR

60000 LPD of AA

2.3 kg/lit

100 KLPD Evaporative Distillation

100000 LPD of AA

1.7 kg/lit
Value Addition in Modernization

Current Operation: Steam required for 100 KLPD AA = 230 TPD (@2.3 Kg/Lit)
Modernization - Steam required for 100 KLPD AA (Plant expanded from 60 to 100 KLPD) = 170 TPD (@1.7 Kg/Lit)

Saving on steam at 100 KLPD TS = (230-170) = 60 TPD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Quantity</th>
<th>Assumed Profit Margin</th>
<th>Savings per day</th>
<th>Savings for 250 days operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>60 TPD</td>
<td>10 Rs./ lit</td>
<td>Rs. 400000</td>
<td>1000 lakhs/year</td>
</tr>
<tr>
<td>Steam</td>
<td>60 TPD</td>
<td>1200 Rs./ MT</td>
<td>Rs. 72000</td>
<td>180 lakhs/year</td>
</tr>
<tr>
<td>Total Savings</td>
<td>-</td>
<td>-</td>
<td>Rs. 472000</td>
<td>1180 lakhs/year</td>
</tr>
</tbody>
</table>

Simple Payback < 9 – 11 months
### EcoSmart™ Evaporative Distillation - Reference List

<table>
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<tr>
<th>Sr No</th>
<th>Client Name</th>
<th>Capacity In KLPD</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dalmia Bharat Sugars Ltd</td>
<td>65</td>
<td>Under Execution</td>
</tr>
<tr>
<td>2</td>
<td>Madhucon</td>
<td>45</td>
<td>Under Execution</td>
</tr>
<tr>
<td>3</td>
<td>Balrampur Sugars Ltd</td>
<td>60 - 100</td>
<td>Under Engg</td>
</tr>
</tbody>
</table>
ECOMOL™ Dehydration Technology

**ECOMOL Dehydration Plants can produce Fuel ethanol with just 500 ppm moisture!!**

- Vapour phase pressure swing adsorption using molecular sieves.
- Most advanced, twin bedded design with top entry for feed.
- Unique Vapor distribution and Insert arrangement – sieves are not subjected to shocks; enhancing their life.
- High level of automation – assures consistent product quality.
- Designs available for use of low or medium pressure steam. (1.5/3.5 bar-g)
- Steam consumption of just 0.55 kg/l for stand-alone plant (RS as feed)
- Thermally integrated combination of EcoSmart®-ED & ECOMOL, needs only 1.7 kg/l to produce Fuel Ethanol from fermented mash.

For fuel, pharma & perfumery grade Ethanol!

Over 150 Plants in operation globally
Energy Efficient Ecovap Evaporators are designed as rugged, Heavy Duty Industrial Plants

- Multiple Effect Evaporators
- Multiple Effect Evaporators with Thermo-compressor
- Multiple Effect Evaporator with Mechanical Vapour Recompression
- Distillation Integrated Multiple Effect Evaporator
- Dryer Integrated Multiple Effect Evaporator

Reference base of 116 Plants globally
Ecovap™ Evaporation Technology -
Advantages

- Ecovap Evaporators have low energy consumption; reducing OPEX.
  - Multiple effect evaporators
  - Utilization of waste heat from distillation plants (integrated systems)
  - Use of TVR / MVR
- Pre-Treatments system & condensate Polishing Units for Biomethanated Vinassee
- Ecovap Evaporators have high MTBC Values
  - Lowers CIP frequency, lowering CIP costs
  - Longer stabilized operations
  - Results in higher capacity utilization
  - ETP load minimized
- Complete process solutions – with process condensate treatment ensuring water RECYCLE.
- Flexibility – choose a system configuration to suit your budget and local environment
Thank you
Contact: maheshkulkarni@praj.net

Over 3 Decades in Sustainable Technology and Engineering Solutions!