Biosystems Design Projects

Blake's By-Product Bash
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Client: Blake’s Hard Cider Co.
Faculty Advisor: Dr. Bradley Marks, PhD

Background
The client for this project was Blake’s Hard Cider Co.

- Apple orchard and cider mill founded in 1946 in Amada, MI specializing in agritourism
- Produces cider and pastries
- Blake’s Hard Cider Co. founded in 2013
- Produces hard cider and beer

- By-product of the cider-making process is apple pomace (Figure 1)
  - Produces 1,000,000 lb of apple pomace per year
  - Produces 36,000 lb of spent grains per year
  - Land applied to their fields which is causing soil toxicity and pH concerns

Objectives & Constraints

- **Problem Statement:**
  - Design a beneficial solution for reducing the apple pomace and spent grain by-product waste produced at Blake Farms.

- **Objectives:**
  - Minimize Blake’s by-product waste
  - Maximize profit of value-added product
  - Minimize storage time to less than 1 week

- **Constraints:**
  - Achieves payback period < 2 years
  - Footprint fits within facility
  - Implementation by September 1, 2020
  - If materials are dried, moisture content < 8% water basis
  - Flavor and quality of cider must not change
  - Compliance with 21 CFR § 120 from the FDA (U.S. Food & Drug Administration, 2001)

Design Alternatives

Four design alternatives were generated and evaluated based on several criteria: material used, profitability, capital cost, sustainability, and space required.

Feedstock for Anaerobic Digestion: Transport the materials off-site to a nearby, previously existing anaerobic digester. Anaerobic digestion uses microbes without oxygen to digest organic matter to produce biogas.

Animal Feed: Dry the apple pomace and spent grains to sell as an ingredient in animal feed.

Food Product: Dry and mill the apple pomace to create apple flour, which can be sold or substituted into baked products.

Enzymatic Addition: An addition of hemicellulase and pectinase enzyme cocktail to the apple mash before pressing. The pretreated apple mash is pressed, and results in an increase of juice yield and a decrease of apple pomace.

Selected Design

Enzymatic addition was selected as the best solution to help achieve Blake’s goals of reducing waste while increasing profits. Experiments were conducted to determine the optimal enzyme cocktail and conditions.

Bench Top Experimentation

- Bench top showed highest yield with Scott Laboratories® HC and PECSL cocktail at room temperature (Figure 2).

Pilot Scale Experimentation

- Supported bench scale findings by doubling juice yield after 2-hour maceration period (Figure 3).

Selected Design

- One step addition before pressing optimally formulated to fit within current production hours and decrease apple pomace yield (Figure 4).

Process Integration

- Timeline achieved with the implementation of 3 maceration tanks within juice extraction room.
- Juice extraction room layout designed for linear flow and complete isolation of juice extraction from beer production and canning (Figure 5).
- Enzymatic extraction can be achieved within the current production hours of 7am and 10pm (Table 1).

Table 1. Proposed workflow protocol with enzymatic extraction.

<table>
<thead>
<tr>
<th>Step</th>
<th>Enzymatic Pretreatment</th>
<th>Juice Extraction</th>
<th>Canning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4%</td>
<td>5%</td>
<td>70%</td>
<td>100%</td>
</tr>
<tr>
<td>2.2%</td>
<td>2.2%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>3.1%</td>
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<td>100%</td>
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<td>4.3%</td>
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<td>100%</td>
</tr>
<tr>
<td>9.2%</td>
<td>9.2%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>10%</td>
<td>10%</td>
<td>90%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Economics & Conclusion

The enzymatic pretreatment design was evaluated based on a payback period including capital costs, reoccurring cost, and revenue. The capital costs accounts for the equipment required to implement the design and installation costs (Table 2). Table 3 details the reoccurring costs: purchasing enzymes, energy costs, and process inefficiencies. The revenue for this solution was calculated based on the wholesale price of apples.

Table 2. Capital Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount ($)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump</td>
<td>9,000</td>
<td>10-12 tons/hr, 3” TRC fitting, Model 2718*</td>
</tr>
<tr>
<td>Tanks</td>
<td>27,354</td>
<td>3 x 2,000 gal tank, custom dimensions, Mixer</td>
</tr>
<tr>
<td>Clamps, Gaskets, etc.</td>
<td>1,200</td>
<td>$440 per piece</td>
</tr>
<tr>
<td>Hoses</td>
<td>180,000</td>
<td>3” ID, 100 psi, $109.95/ ln</td>
</tr>
<tr>
<td>Hose fittings</td>
<td>1,000</td>
<td>2” 3” hose bars, 2” 3” hose clamps</td>
</tr>
<tr>
<td>Installation</td>
<td>10,000</td>
<td>10% of equipment cost</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>81,944</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Taken from an external source (EnviroTech, 2019).

Table 3. Reoccurring Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount ($)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enzymes</td>
<td>4,423</td>
<td></td>
</tr>
<tr>
<td>Energy costs</td>
<td>2,067</td>
<td>$0.15/ kWh</td>
</tr>
<tr>
<td>Process inefficiencies</td>
<td>2,310</td>
<td>Downtime, (40 min/day)</td>
</tr>
<tr>
<td>Labor</td>
<td>100</td>
<td>Would not require additional labor</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>12,800</strong></td>
<td></td>
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</tbody>
</table>

Figure 6 represents the payback period at various juice yields to account for any decrease in functionality from the enzymes. The graphical representation allows the client to quickly assess the return on investment depending on the juice yield achieved with enzymes. The juice yield achieved with enzymes in the pilot scale experiment was 86%.

Payback period @ 86% juice yield = 2.04 mo

Figure 6. Accordion press Juice Yield (%) vs. Payback Period (months)

Conclusion

The inclusion of an enzymatic extraction step in Blake’s Hard Cider Co. current process can increase the juice yield obtained per apple while decreasing the amount of apple pomace by-product waste. This design at a juice yield of 86% (20% increase from their current process) has a payback period of 2 months. This design can be implemented in other hard cider facilities as well to decrease their amount of by-product waste.

References
