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Objectives
- Create a novel prebiotic supplement from fermented turmeric, chicyo root extract (inulin), and black pepper extract (pipérine)
- Optimize the process design for product quality, equipment/plant size, and minimal production costs

Rationale, Market Size, and Ethical considerations
- Global dietary supplement market value: $133.1 billion
- Prebiotic market worth $4.07 billion, expected 10.4% growth by 2023
- Inulin accounts for 40% of prebiotic market value - powerful prebiotic that supports healthy bacteria in the microbiome
- Turmeric worth $44.2 million, contains powerful antioxidant curcumin - considered one of the most effective anti-inflammatory herbs
- Piperine significantly increases bioavailability of curcumin
- Fermenting turmeric further increases bioavailability of curcumin
- Herbal supplements may support healthy lifestyles and help prevent chronic diseases that could affect millions of people worldwide
- Considered nontoxic to humans and environment
- Currently no supplements on the market combine these ingredients

Summary of Laboratory Experiments
- Plackett-Burman Design of Experiments (DOE)
  - Developed in 1960s to help optimize designs with many factors
  - Helps determine which factors have significant impact on an outcome
- DOE aimed to optimize tablet tensile strength
  - Tensile strength is critical for product quality
- Design does not use excipients which normally would increase tablet strength
- JMP software used for statistical analysis

Table: DOE results suggested that compaction pressure (CP) of the tablet press was the only significant factor on tensile strength

Economic Optimization of Unit Operations

<table>
<thead>
<tr>
<th>Process</th>
<th>Cost Components</th>
<th>Description</th>
<th>Formula</th>
<th>Unit</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction</td>
<td>Main cost is ethanol - other costs include steam and power to heat vessel</td>
<td>Heat method to minimize annual costs is adjusting ethanol concentration vs. inulin precipitation</td>
<td>Ethanol concentration is held constant for industrial scale</td>
<td>$1,434,631</td>
<td></td>
</tr>
<tr>
<td>Fermentation</td>
<td>Minimize annual cost for fermentation vessel and cost of electricity for agitation</td>
<td>Constraints include preservation of the product, which was not able to be assessed on lab-scale experiments</td>
<td>The lowest annual cost was found to be $2,983 per liter with a vessel volume of 693 L</td>
<td>$1,411,557</td>
<td></td>
</tr>
<tr>
<td>Sterilization</td>
<td>Minimization of the cost by balancing heat exchanger cost through size, steam, and water loads</td>
<td>Constraints include the rate of temperature dependent degradation of curcumin</td>
<td>Flash heating and cooling considered too expensive</td>
<td>$980,155</td>
<td></td>
</tr>
<tr>
<td>Tablet Pressing</td>
<td>Low annual cost - optimized for possible plant growth and machine capabilities rather than costs</td>
<td>Operating costs (electricity) were considered negligible (&lt;3.05% of investment)</td>
<td>Initial purchase cost was considered to be the only significant annual cost</td>
<td>$494,045</td>
<td></td>
</tr>
</tbody>
</table>

Conclusions & Areas of Exploration
- This design is promising in terms of having a high market demand, being feasible with current industrial processes, and yielding a high profit.
- Future work should consider specific factors not able to be quantified in this work such as the amount of curcumin that is converted to tetrahydrocurcumin glucuronide, the purity of extracted inulin, and the degradation of the tablet both physically and chemically over time. These factors could then be optimized to increase health benefits.
- In vivo consortial and evolutionary studies of the human microbiota while taking this supplement would be another future step to further support our claims of this prebiotic supplement having health benefits. Bifidobacterium and Lactobacillus are the two main bacterial groups which we hypothesize our supplement supports and these should be among the first investigated for growth.