Vitamin B12 Bioprocess Design: Part III. Analysis and Future Improvements
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Introduction & Objectives

Growing concern about preventive care in large urban areas has a great impact in the demand of vitamin B12 and makes its biotechnological process attractive for an investment. The main objective of this work is to analyze the process in order to determine whether it is sustainable or not. This further analysis is performed under economic, environmental, and social point of view, obtaining all the necessary parameters for the final decision.

A plant layout is proposed giving a complete view about the final project implementation as an industry, locating its different operational areas and determining the dimensions. Finally, as a global industry, it has to be competitive with other worldwide companies, looking for plausible improvements for the overall design.

Sustainability Assessment

Economic Analysis

Total economic data
Plant location in Brazil provides affordable prices for raw materials and allows the opening of a new market in America, taking advantage of a growing market in a growing country.

Table 1. Comparison between using 1 or 5 fermenters in plant costs and revenues

<table>
<thead>
<tr>
<th></th>
<th>1 fermenter</th>
<th>5 fermenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Cost ($)</td>
<td>9,080,000</td>
<td>17,000,000</td>
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<tr>
<td>Initial investment ($)</td>
<td>58,042,000</td>
<td>312,772,000</td>
</tr>
<tr>
<td>Annual Operational Costs ($)</td>
<td>12,784,000</td>
<td>10,980,000</td>
</tr>
<tr>
<td>Annual Production (kg/year)</td>
<td>2,065</td>
<td>9,867</td>
</tr>
<tr>
<td>Utility Production Cost ($/kg)</td>
<td>6,100</td>
<td>3,140</td>
</tr>
<tr>
<td>Utility Selling Price ($/kg)</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Gross Margin (%)</td>
<td>33.80</td>
<td>35.19</td>
</tr>
<tr>
<td>Payback Time (years)</td>
<td>20.94</td>
<td>5.15</td>
</tr>
<tr>
<td>Return of Investment (ROI) (%)</td>
<td>4.77</td>
<td>16.7</td>
</tr>
<tr>
<td>Net Present Value at 7% ($)</td>
<td>-31,211,644</td>
<td>37,596,000</td>
</tr>
</tbody>
</table>

Cash flow analysis

Sensibility Analysis

Figure 1. Cash flow of the process for 15 years. The plant starts to operate on the fourth year and there is a positive cash flow since then until the end of the project.

Figure 2. Sensibility analysis of the project, considering different scenarios regarding initial investment variations, selling forecast and taxes changes. The probability of success is 94.3% and the mean of net present value equals approximately $188M.

• The overall process has a positive NPV.
• The use of five fermenters is necessary for a positive gross margin.
• The process has a relevant low payback time and high final revenues.
• Sensibility analysis shows a 95.6% of probabilities of a favorable process, making it robust.

To sum up

The proposed design considers the necessities of the plant and is divided in six different areas: Upstream&Bioreaction (with its storage and available plant expansion land), Downstream&Packaging (and storage), Waste Treatment, Laboratories (Quality, Control and Utilities), Workshop and Offices.

Bioprocess improvement

Three different approaches are taken into consideration:

- Genetic improvement ➔ Genetically modified strains
- Metabolic optimization ➔ Component addition to the medium
- Downstream reduction ➔ Use of activated carbon

To sum up

- Genetic improvement ➔ Higher production but the plant security should be enhanced
- Metabolic optimization ➔ Increased B12 production. No industrial data.
- Downstream reduction ➔ Reduction of the separation time. No industrial data.

Figure 6. Metabolic optimization by the addition of rotenone in P. denitrificans3

Figure 5. Genes implied in vitamin B12 biosynthesis carried by P. denitrificans3. Enhanced genes in green.

Conclusions

Taking into account the information mentioned above, the vitamin bioprocess design is a suitable project. The economic data shows good future perspectives with proper assessment metrics. The environmental assays done to the process also demonstrate that all the hazardous substances are controlled and treated in an optimal way. On the other hand, the process can be improved following the proposals above, but further experimentation will need to be carried in order to implement them in an industrial scale.