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Technoeconomic analysis of single-cell food protein production

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Summary

SCP can be obtained from unicellular organisms such as: bacteria, fungi, yeast, and algae. These unicellular organisms can produce high amounts of protein in appropriate conditions, and besides its high protein content, they also contain many nutrients like, vitamins, essential amino acids, nucleic acids, and lipids. Some limitations in the production of SCPs are the high nucleic acid content (bacteria, yeast, and fungi) and the need of the cell wall removal in algae. These limitations add high costs to the production of SCPs and lead to increase the cost of the final product. Considering all the factors that contribute to the production of SPC, algae is the most favorable single cell organism to produce protein, but more specifically this report will focus on *Spirulina platensis*. The production process of protein from *Spirulina platensis* is estimated to be cheaper than the other unicellular organisms because algae have low nucleic acid content which will reduce the cost of production. This research will focus on the production process and analyze the production cost of protein by performing economic analysis, profitability analysis, and sensitivity analysis.

Motivation

As the population is exponentially increasing over time, the demand for nutritious, sustainable, and affordable food is also increasing rapidly. Therefore, a lot of research on food has been done to find and produce food that meets the population's demand on the future. One of the food research projects that has been done is about single cell protein (SCP). The production of single cell protein is an innovative and alternative protein source for humans. The single cell protein can be a perfect alternative for meat protein, yet single cell protein has higher protein content than meat or plant protein.

Research Questions

1. Why is important to find food protein alternatives?
2. Which single cell organism will be favorable to produce protein at an industrial scale?
3. What will be an estimate production cost of single cell food protein?
4. How can sensitivities affect in the production process?

Hypothesis

Bacteria has higher percentage of protein content, yet the high content of nucleic acid increase the difficulty and cost of production of its food protein for the human consumption. Yeast and fungi have low protein content which make these unicellular organisms less likely to be considered for producing food protein. Lastly, algae can be the most favorable organism to produce single cell protein at an industrial scale in an affordable cost and be consumed by the humans, which will provide many nutritious and healthy benefits.

Methods & Materials

The production process of protein from S*pirulina platensis* starts with growing the cell in a photobioreactor and adding *Spirulina platensis* inoculum and growth media. After the growth process in the PBR, the *S. platensis* biomass pass Filtration 1 (F1) and then wash the filtrated biomass to filtrate it again in Filtration 2 (F2). The filtration system that can be used is the Tangential Flow Filtration (TFF). Next, a cell lysis method is performed to separate inter-cellular and cell debris and release the inter-cellular materials . The lysis method that can be used is homogenization by High Pressure Homogenizer (HPH). After the lysis process, the product of the lysis passes through Filtration 3 (F3) to filtrate the inter-cellular material and just be left with crude protein content. The crude protein content is pass through ultrafiltration (UF) to obtain purified proteins.
Once the production process was planned, economic analysis, profitability analysis, and sensitivity analysis were performed to estimate capital cost, revenue, investment, financial inputs and outputs, cash flow, and depreciation of the production process of protein from Spirulina platensis.

Results and Discussion

The yearly production scale is 24,000 gallons of protein, which was calculated by considering the capacity of the photobioreactor and growth time of *Spirulina platensis.* Once the production scale was set, an economical analysis was performed to calculate the capital cost, operating cost, and cost of production supplies, resulting in an estimated total of $1,723,670 of investment.

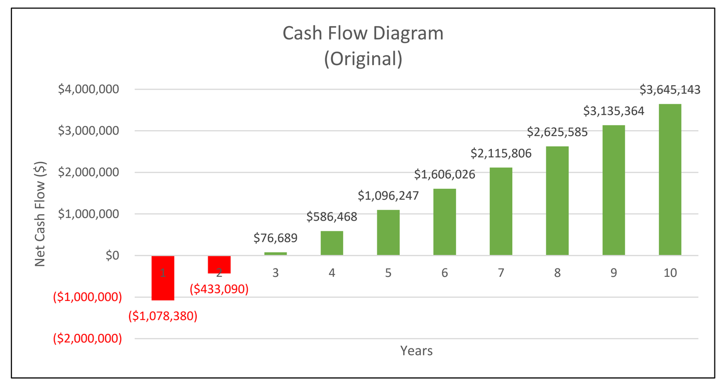
1 PBR (2500L/660 gal)
660 gal/ 10 days
1980 gal/month
24,000 gal/year

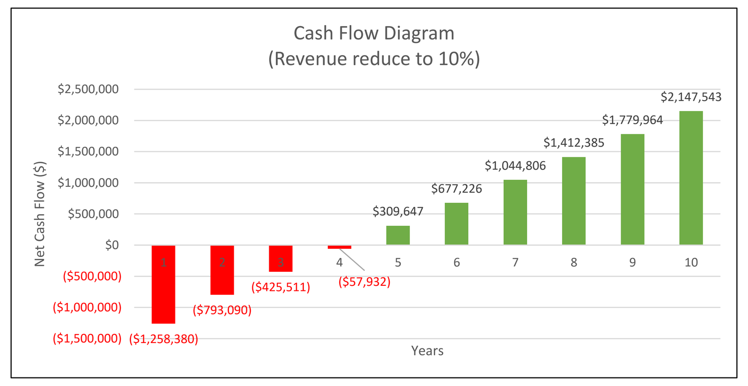
Investment	Value ($)	Value ($ per year)
Upstream		
Photobioreactor (PBR 2500L)	$118,960	$118,960
Cost of the cell (500 mL)	$50	$50
Nutrients (15.3 kg)	$260	$260
Total	$119,270	$119,270
Downstream		
Filtrations (Tangetial Flow Filtration (TFF))	$200,000	$200,000
Cell Lysis (Homogenation)	$150,000	$150,000
Ultrafiltration (UF)	$100,000	$100,000
Total	$450,000	$450,000
Unit cost of supplies		
Workers (per hr)	$20	$614,400
Electricity (kWh)	$0.14	$440,000
Water (m^3)	$0.70	$100,000
Total	$20.84	$1,154,400
		$1,723,670

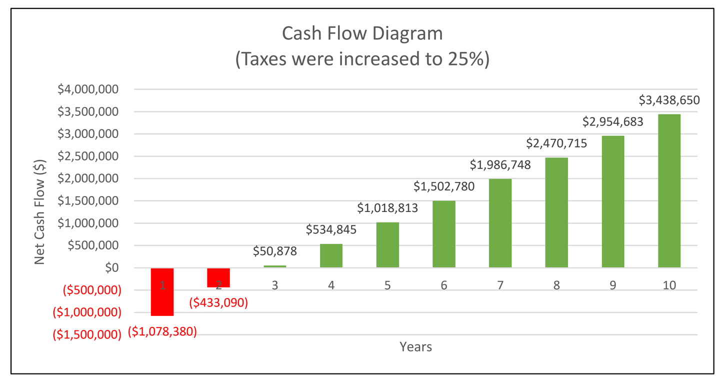
A profitability analysis was performed to calculate and analyze the breakeven point, return of investment, and cash flow during a period of 10 years of production. The yearly estimated revenue was $1,800,000, which was calculated from the yearly sell of the product. The payback period is between 2-3 years of production. Near to the third year, the production started recover the investment.

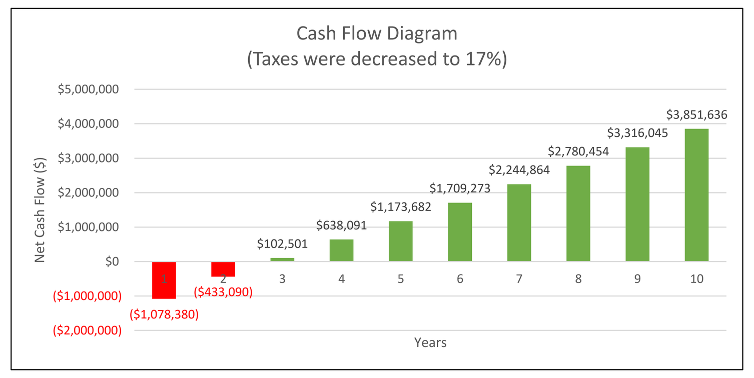
Year	Start up	1	2	3	4	5	6	7	8	9	10
Revenue		$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000	$1,800,000
Expenses		$1,154,710	$1,154,710	$1,154,710	$1,154,710	$1,154,710	$1,154,710	$1,154,710	$1,154,710	$1,154,710	$1,154,710
Investment	$1,723,670	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Depreciation		$861,835	$861,835	$0	$0	$0	$0	$0	$0	$0	$0
Taxes		$0	$0	$135,510.90	$135,510.90	$135,510.90	$135,510.90	$135,510.90	$135,510.90	$135,510.90	$135,510.90
Cash Flow		$645,290	$645,290	$509,779	$509,779	$509,779	$509,779	$509,779	$509,779	$509,779	$509,779
Net Cash Flow	($1,723,670)	($1,078,380)	($433,090)	$76,689	$586,468	$1,096,247	$1,606,026	$2,115,806	$2,625,585	$3,135,364	$3,645,143

Originally, the paid taxes of the production is 21%. Considering some changes in the revenue and taxes, these changes affect the net cash flow of the production. The first sensitivity scenario was to reduce the revenue to 10%, which caused to decrease the cash flow from $3,645,143 to $2,147,543 and increase the years of the breakeven point to 4 years. The second sensitivity scenario was to increase taxes to 25% (4% increased than original taxes). This scenario resulted in decreasing the cash flow, but not more than reducing the revenue, from $3,645,143 to $3,438,650. The last sensitivity scenario performed was to decrease taxes to 17% (4% decreased than original taxes). This scenario resulted in increasing the cash flow from $3,645,143 to $3,851,636. In summary, the main effects of changing revenue or taxes are the cash flow and breakeven point.









Conclusion

In conclusion, algae is the most favorable single cell organism to produce food protein compared to the other organisms because the production will be affordable and controllable. The yearly production will produce 24,000 gallons of protein will have an estimated cost of $1,723,670 including equipment, workers, and supplies. Furthermore, investing $1,723,670 will reach a breakeven point between 2-3 years of production, which indicates that near to the 3rd year of production earnings will start generating. In a period of 10 years of production the earning will be $3,645,143. If changes are made to the revenue or taxes, the cash flow and breakeven point can be affected. Overall, considering an appropriate and accurate data for future working will Improve the economical analysis and continue with this research.

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