Soybean Oil Processing

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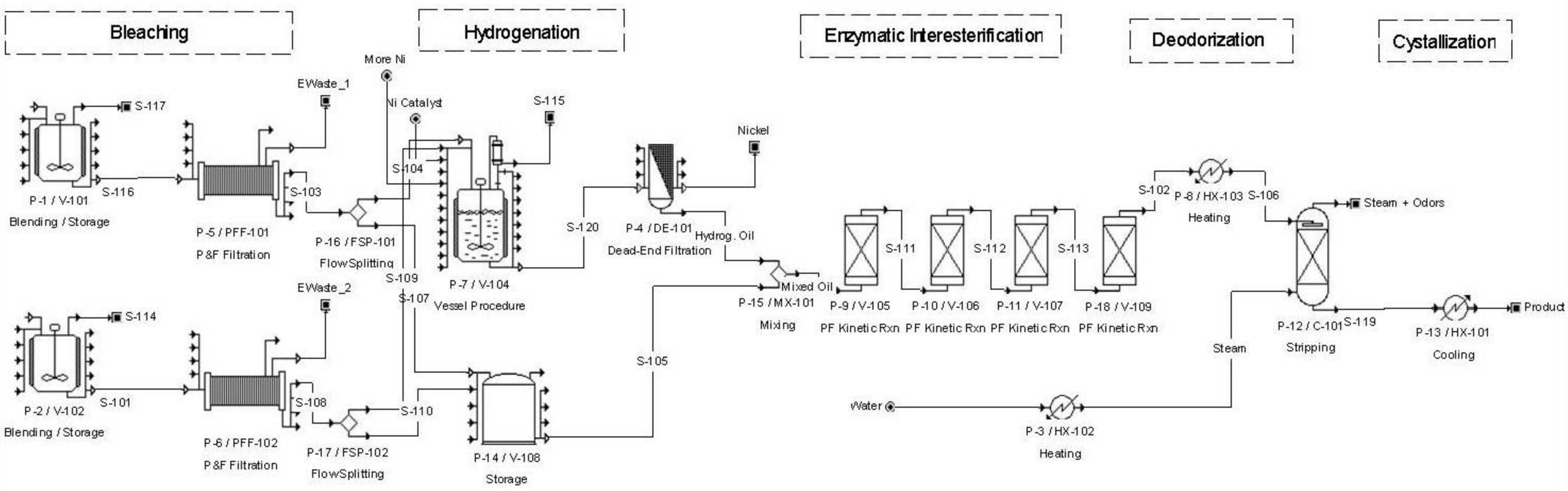
Objective: To optimize shortening production from refined oil using bleaching, hydrogenation, enzymatic interesterification, and crystallization techniques.



Unit Operations

- ***Bleaching***: Bleaching Earth, sodium bentonite, is used to absorb impurities including:
  - Color Bodies
  - Oxidation Products
  - Trace Metals
- ***Hydrogenation***: A nickel catalyst and hydrogen gas react by breaking double bonds in triglycerides. Single bonds between the carbon chain and hydrogen are formed. Resulting product is:
  - More stable
  - Has Firm Consistency
- ***Enzymatic Interesterification (EIE)***: An enzyme is used to cleave and reform bonds between liquid oil and solid fat. Resulting product has:
  - Lower melting point
  - Combined properties of oils and fats
- ***Deodorization***: Vacuum steam distillation is used to remove trace materials and volatile components in the oil. Resulting product has:
  - Bland flavor
  - Reduced color bodies
  - Reduced odors
- ***Crystallization***: A scrape surface heat exchanger is used to cool the hot processed oil. Resulting product is:
  - Firm, Semi-solid
  - Ready for Packaging

Experimental Design

***Objective*:** To optimize shortening production from refined oil using bleaching, hydrogenation, enzymatic interesterification, and crystallization techniques.

Starting Material:

650 g Refined Soybean Oil
350 g Fully Hydrogenated Soybean Oil

Procedure:

Mix starting material, heat, add bleaching earth
Filter bleaching earth
Add enzyme, heat and allow enzyme to react
Filter out enzyme
Crystallize

Analysis Tools:

Hunter Colorimeter
Texture Analyzer

Variables:

Bleaching Earth Concentration
Bleaching Time
Enzyme Concentration
Enzyme Mixing Speed
Crystallization Temperature
Crystallization Mixing

Reaction Conditions:

Unit Operation	Temperature	Time	Concentration	Mixing Speed
Bleaching	110-120°C	10 or 30 minutes	0.5% or 1.5%	6
EIE	65-70°C	6 hours	0.3% or 0.6%	4 or 8
Crystallization	Ice cooling or No cooling	Varying	NA	Hand or Mixer

Results

Sample	Bleaching Time	Bleaching Earth Conc.	EIE Mixing Speed	Enzyme Conc.	Crystal. Temperature	Crystal. Mixing	Color 'L'	Color 'b'	Firmness (g)
1	10	1.5	High	0.06	No Coolant	Hand	83.85	12.7	4.70
2	10	1.5	High	0.03	Ice	Mixer	77.51	12.94	763.51
3	10	0.5	Low	0.06	No Coolant	Mixer	72.95	29.99	2.51
4	30	0.5	High	0.03	No Coolant	Hand	80.78	17.38	107.46
5	10	0.5	Low	0.03	Ice	Hand	67.52	24.22	278.52
6	30	1.5	Low	0.03	No Coolant	Mixer	79.03	14.26	73.86
7	30	0.5	High	0.06	Ice	Mixer	74.34	20.87	532.99
8	30	1.5	Low	0.06	Ice	Hand	74.51	12.86	683.92
Control	-	-	-	-	-	-	88.57	5.41	116.37

*The bleaching earth concentration and bleaching time played the biggest role in final product color.
*Higher bleaching earth concentrations yielded product with color closer to the control sample.
*Longer bleaching times also yielded product with more ideal color.
*Texture had the potential to be influenced by the EIE or the crystallization conditions.
*EIE conditions had no significant effect on the firmness of the products.
*Crystallization temperature had the greatest impact

Final Products 1-8 with the control in front

Refined Oil, Refined Oil with Hard Fat, Refined Oil with Bleaching Earth

Experiment Conclusions

*Higher bleaching earth concentrations and longer bleaching times are beneficial.

*EIE conditions were not significant because all of the reaction conditions allowed the reaction to go to completion.

*Crystallization without cooling did not promote crystal growth significantly so the products did not harden enough. The coolant used may have been too cold prompting rapid crystal growth and a very firm product.

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Plant Design Economics

Economic Overview

*Raw material costs are approximately 85% of the total product cost
*The break-even cost is $3.71.
*The DFCR is 15%
*Waste reduction steps will significantly reduce costs
* The cost of crude soybean oil is rapidly increasing and difficult to source in the United States.

Capital Investments

Direct Costs	Cost/year ($)
Equipment	1,853,125
Installation	870,968
Instruments/ controls	667,125
Piping	1,260,125
Electrical	203,843
Buildings	333,562
Yard	185,312
Service	1,297,187
Total	6,671,250

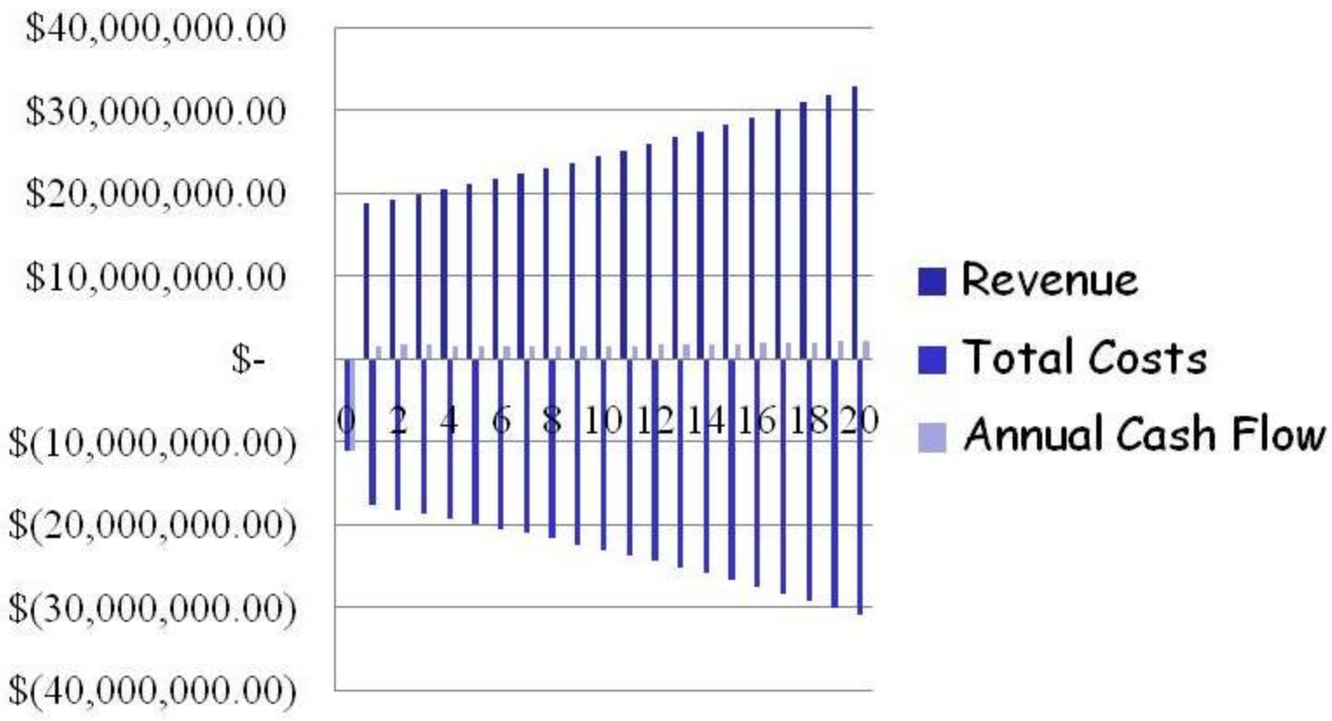
Indirect Costs	Cost ($)
Engineering	611,531
Construction	759,781
Legal	74,125
Contractor	407,687
Contingency	815,375
Total	2,668,500

Working Capital	1,649,281
Fixed-Capital Investment	9,339,750

Total Capital Investment	10,989,031

Break Even Chart

After Tax Cash Flows



Raw Material Costs

Material	Unit Price ($/lb)	Total Cost/year ($)
Alkali Refined Oil	0.59	1,926,860
Bleaching Earth	3.00	58,791
Nickel Catalyst	6.00	11,760
Enzyme	18.14	14,587
Total		2,011,998

Revenue

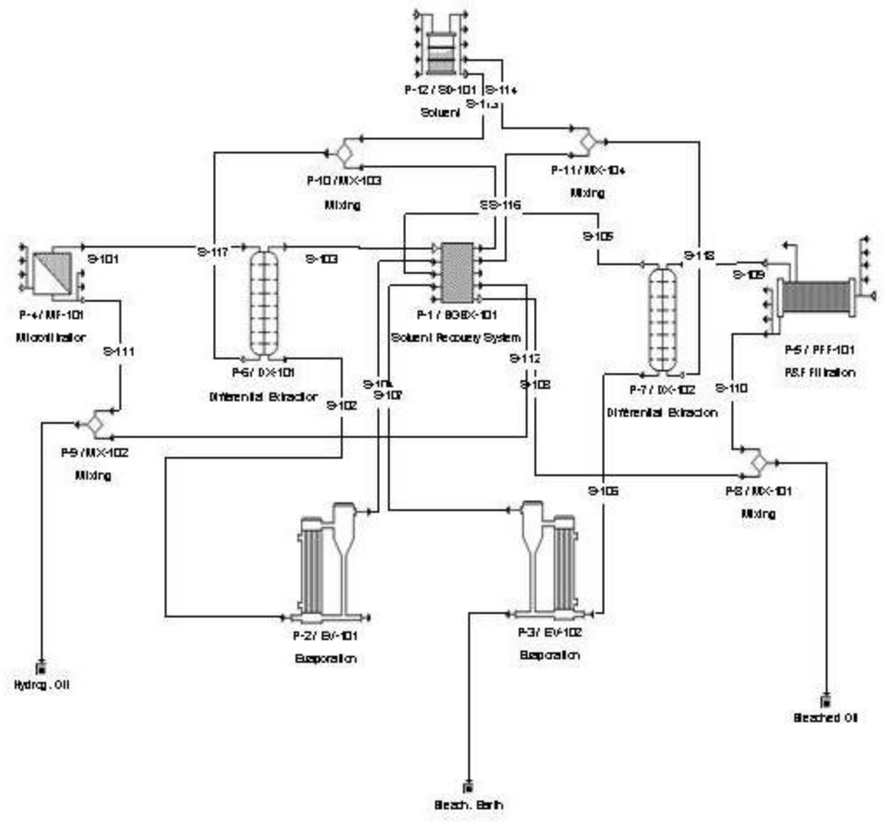
Product	Unit Price ($/lb)	Total Revenue/year ($)
Vegetable Shortening	3.91	28,150,197

Total Waste

Component	kg/lb MP	kg/h	kg/year	%
Bleaching Earth	0.003	2.268	19597	16.36
Nickel	0	0.227	1960	1.64
Soybean Oil	0	0.026	229	0.19
Water	0.014	11.34	97976	81.81
Total	0.017	13.861	119761	100

Waste Reduction System

*Recovers spent bleaching earth, nickel catalyst, and soybean oil from the two filtration systems.
*A water recovery and reuse system will significantly lower water waste.
*Condensing steam from the stripper will recover heat, water, and volatiles.
*Recovering and reusing water from CIP will reduce waste.



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