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Background:

- Statement of Problem:** Grape seed oil is a popular and nutritious product which contains numerous potential in many industries. Consumption of various grape seed oil related products has been increased. Therefore, in order to fulfill the rise of demand more effectively, an efficient extraction method for grape seed oil is required.
- Previous related Work:** Current extraction methods contain screw press (approx. 80% efficiency), Soxhlet extraction (approx. 90% efficiency) and supercritical fluid extraction (approx. 90% efficiency). These data are not for grape seed oil extraction.
- Goal:** A combination of mechanical press and organic solvent leaching process is to be utilized to improve the overall efficiency of grape seed oil extraction. The mechanical deconstruction of the seeds can also improve the performance in solvent extraction stage.
- Constraints:** The modern supercritical method is not available in lab which would result a higher quality of purer product. The results of the lab scale experiment are not statistically strong enough thereby need further iterations.



Morphological Analysis:

Separation	Environmental	Economic	Efficient	Final result
Skimming	✓	✓	✓	✓
Mixing	✓	✓	X	X
Drying	✓	✓	✓	✓
Oven	✓	✓	✓	✓
Other method, such as freeze dry	✓	X	✓	X

Separation	Environmental	Economic	Efficient	Final result
Expeller press	✓	✓	✓	✓
Soxhlet	✓	✓	✓	✓
Extraction	✓	✓	✓	✓

Experiments:

Mixing / Seeds Separation

Oven Drying

Extraction

Pressing

Separating:

- Separating was conducted by a Hamilton mixing tank with water.
- The agitation gave the pressure to separate grape seeds from grape pomace.
- Seeds were floating on the water and collected.

Drying:

- An oven was used to dry to seeds.
- Water content in seeds was brought to around 5% after drying by heating at 90 °C for 2 hours.

Pressing:

- The dry seeds then were sent to a Carter Press.
- 4 pressures from 2,500 psi to 10,000 psi were added on the seeds.
- 5 temperatures were maintained to figure out the oil extracting rate with different pressures.
- The seeds weight loss after pressing is the amount of oil extracted.
- Oil was absorbed by the oil absorbing paper.

Solvent Extraction:

- The extracted seeds then were feed to solvent extraction.
- The solvent was petroleum ether.
- Several trials of solvent extraction were carried out with different amount of solvent to figure out the ability of solvent extraction.
- Each trial was put on the hot plate and stirred with magnet to accelerate the extraction rate at room temperature for 20 minutes.

Distillation:

- Due to the high evaporating rate of petroleum ether, distillation was conducted by setting the extracted oil and solvent together overnight at room temperature.

Experimental Data:

Mixing / Seeds Separation

Trial #	Water (gallon)	Grape Pomace (gallon)	Wet Seeds (g)	Mixing Time (min)	Skimming
1	10	1	2214	5	No
2	5	1	2214	5	Yes
3	5	1	2214	5	Yes
Total Wet Seeds: 1663					

Oven Drying

Plate #	Plate (g)	Plate + Seeds (g)	Plate + Dry Seeds (g)	Dry Seeds (g)	% Water Loss	% Total Water Loss
1	738.1	1356.6	998.5	1173.3	183.3	69.4
2	601.8	1090.5	499.1	909.9	179.9	70.2
3	692.9	1280	587.1	1092.7	187.9	68.1
Total Seeds: 1644.7 Total Dry Seeds: 490.9						

Pressing

Plate #	Seeds before (g)	Seeds after (g)	Oil (g)	Oil (ml)	Total yield
1	187	1610	530	530	4.27
2	1410	1640	647	647	62.72
3	187	1610	530	530	4.27
4	187	1610	530	530	4.27

Extraction

Plate #	Seeds before (g)	Seeds after (g)	Oil (g)	Oil (ml)	Total yield
1	188	176	65	65	1.04
2	112	126	65	65	6.8
3	188	176	65	65	6.35

Market Analysis:

- Easy & Efficient to obtain grape seeds from wine pomace (received grape pomace from Purdue Wine Grape Team for lab experiment)
- Increase of U.S. wine sales along with U.S. wine retail value
- Grape: Out of Top 10, 3rd valued commodity, worth 5.2 billion
- Large U.S. & global grape markets based on production & consumption
- Sufficient amount of seeds left as waste from most grape industries
- Increase of wine sales leading to more grape seeds left at a low price
- Broad grape seed oil product markets in industries (e.g. Food, Cosmetic, and Health)
- Annual grape growth causing industry to produce wine at certain time
- Increase profits by improving oil yield and selling grape seed oil products



Fig 1: Wine retail value in billion dollars from Wine Institute 2015. An increasing trend is shown. Grapeseed oil production can proceed after wine production.

- Rising of grape seed oil market potential (2007-2011)
- More spending on grape seed oil related products for health, beauty, and diet
- Prediction of more increase on potential market values of grape seed

	2007	2008	2009	2010	2011
Grapes produced (t)	76092	83055	67474	71525	87217
Pomace produced (t)	19023	20763.75	16868.5	17881.25	21804.25
Pomace seeds (t)	2619.08664	2858.7531	2322.45508	2461.8905	3002.00914
Pomace seed oil (mL)	472488862.4	515725207.2	418975891.1	444130340.7	541568904.9
Market Potential (\$)	4,403,596,198	4,806,558,931	3,904,855,305	4,139,294,775	5,047,422,194

Fig 2: Pomace seed oil market potential. Values are determined using President's Choice grape seed oil.

Final Design:

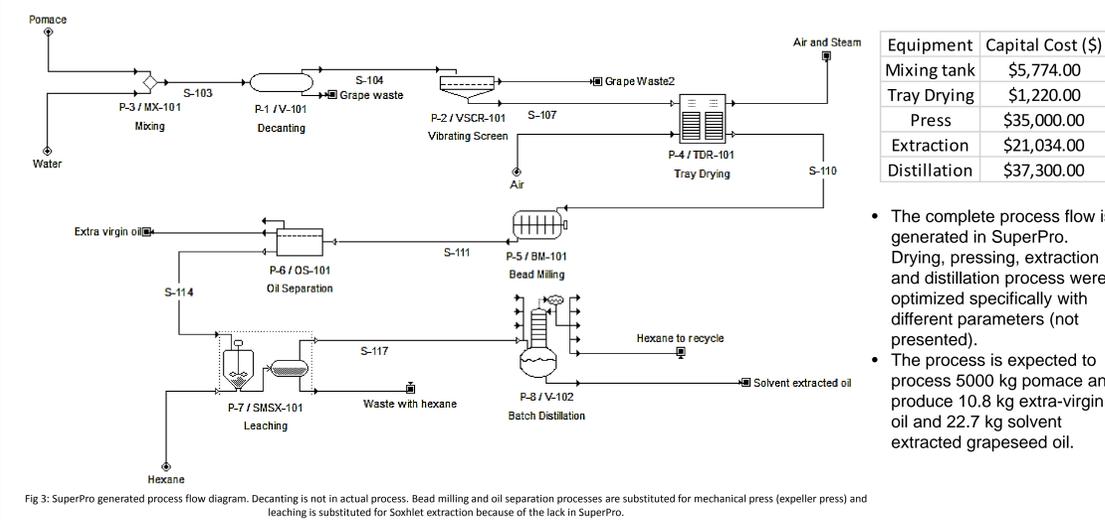


Fig 3: SuperPro generated process flow diagram. Decanting is not in actual process. Bead milling and oil separation processes are substituted for mechanical press (expeller press) and leaching is substituted for Soxhlet extraction because of the lack in SuperPro.

Economic Analysis:

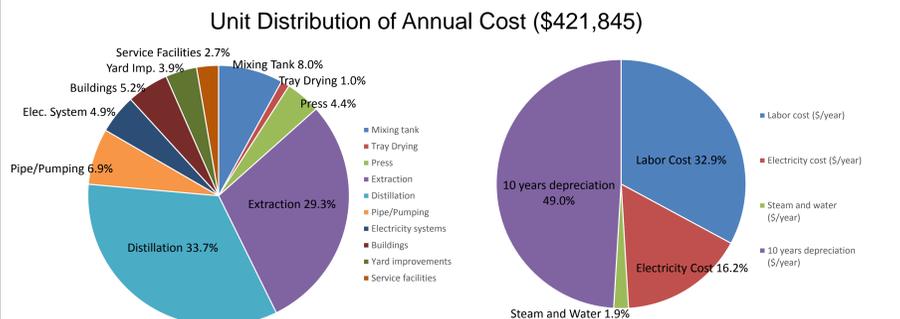


Fig 4: Pie chart for total annual cost. Left chart is separating by processing unit and right chart is separating by cost category.

Table 1: Cost break down

	Fixed capital investment (\$)	Labor cost (\$/batch)	Electricity cost (\$/batch)	Steam and water (\$/batch)	10 years depreciation (\$/year)
Mixing tank	5,774.00	100.00	0.12	0.64	577.00
Tray Drying	1,220.00	10.00	1.30	0.00	120.00
Press	35,000.00	11.07	38.47	0.00	1,875.00
Extraction	21,034.00	314.64	0.00	0.00	402.52
Distillation	37,300.00	340.00	49.20	38.59	1,377.30
Pipe/Pumping	6,510.07	38.30	65.53	4.18	488.80
Electricity systems	6,510.07	40.94	21.14	0.00	144.78
Buildings	24,048.52	0.00	61.30	1.77	425.85
Yard improvements	10,213.04	49.12	0.00	0.00	173.73
Purchased equipment installation	33,192.39	0.00	0.00	0.00	0.00
Service facilities	1,540.99	22.52	9.73	0.00	796.27
subtotal	85,104.09	1,236.50	154.09	39.23	4,372.22
Total	159,707.37	907.18	148.08	47.02	6,351.64

Total Capital Investment (TCI) \$225,608.77
Total Product Cost (TPC) \$421,844.94

Researched market price

	Production (ml/batch)	price/kg	revenue/batch
Extra-virgin	13500	\$0.07	\$984.24
Extracted	28350	\$0.01	\$264.22
total revenue/year			\$410,744.00

1.15 times price

	Production (ml/batch)	price/kg	revenue/batch
Extra-virgin	13500	\$0.08	\$1,131.88
Extracted	28350	\$0.01	\$303.86
total revenue/year			\$472,355.60

Annual Net Profit (Np) with 35% tax \$32,831.93
Return on Investment (ROI) 14.55%

Fig 5: Cumulative cash position neglecting the time value of money. It is shown that cumulative cash becomes positive after about 7 years.

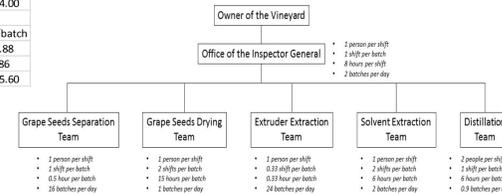


Fig 6: The organizational and operation chart of the grape seed extraction process, based on the optimizations. The production needs total of 16 hours per day.

Global/Societal Considerations:

- Efficient usage of wasted grape seeds from wine making process leads to economic benefits (e.g. Profit, More jobs, and Broad market).
- Since hexane is employed for the extraction process and is hazardous for human health, the grape seed oil might cause some health problems. Possible health & contamination issues need to be considered.
- Non environmental friendly wastes are also generated in the process (e.g. Broken equipment and wasted chemical).

Improvements and Recommendations:

- It is recommended that the super critical fluid should be used for the extraction process.
- In the solvent extraction, the solvent can be recycled and reused.
- Drying is supposed to use lower temperatures to conserve more beneficial nutrition.
- Expanding the production and batch on pressing extraction to have a more valuable product, virgin pressed grape seed oil.
- The hot air produced from the drying part can be used on distillation.
- The waste from the grape seed oil extraction is totally organic, which can be used as a fertilizer of the plants or vines in the vineyard.

Sponsor: Dr. Martin Okos

Reference:

Technical Advisor: Dr. Martin Okos
Instructors: Dr. Martin Okos

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