Production of a Novel Automotive Wax Utilizing Zero-Discharge Technology

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Overview:

The current automotive wax market is comprised entirely of products that utilize petroleum based formulations. In an effort to lessen dependence on petroleum products, a novel automotive wax was formulated that does not contain any petroleum products. The new formulation is comprised of all natural ingredients. Heartland Wax utilizes completely renewable resources for every component including: partially hydrogenated soybean oil, soybean lecithin, soybean hulls, and xanthan gum (a fermented product). Preliminary testing of the wax indicates that it outperforms top brands currently on the market based on contact angle measurements. To further create a product that is truly environmentally friendly, a plant design that has zero discharge and minimizes energy usage was developed. The operation utilizes products and by-products produced from soybean oil refining. The only component that must be outsourced is xanthan gum and Soyblend solvent. The plant has no discharge of waste water or hydrogen gas (from hydrogenation) and utilizes regenerative heating to minimize energy usage. Overall, this allows Heartland Wax to be produced cheaper and enhances the marketability of the all natural, environmentally friendly product.

Background Information and Formulation of the Product

Automotive waxes are utilized to protect paint against oxidation from the outside world. Salt in the winter, excessive rain in the spring, damaging heat in the summer, and decay in the fall can all lead to oxidation of the paint. A thin coat of wax prevents this damage by repelling water and creating a physical barrier against the elements. Current automotive waxes are almost uniformly made of petroleum products, such as kerosene and petroleum based hydrocarbon waxes. Due to the limited amount of resources available, these products will soon become extremely expensive to manufacture.

Our product completely replaces all petroleum products and other nonrenewable resources with components that are renewable. The table below details these changes.

Prior Art Component	Prior Art Percentage	Heartland Wax Component	Heartland Wax Percentage
Water	18.26%	Water	18%
Morpholine (Emulsifier)	1.01%	Soybean Lecithin	1%
Abrasive	12.75%	Soybean Hulls	3%
5000-15000 cst Silicone Oil	0.97%	10,000 cst Xanthan Solution	2%
50-200 cst Silicone Oil	5.76%	300 cst Xanthan Solution	6%
Tall Oil Fatty Acid	1.88%	30% Hydrogenated Oil	60%
Montan Wax	4.38%	Citrus Soyblends Solvent	10%
Kerosene	5.69%		
Aliphatic Hydrocarbon	8.37%		
Aromatic Compound	40.89%		

Heartland Wax is processed utilizing the procedure described by Van Der et al(Van Der 1983). Briefly, Phase 1 consists of adding water, 30% hydrogenated SBO, 10,000 cst xanthan solution, soybean lecithin, soybean hulls, and 10% initial citrus soybean solvent to a beaker and stirring to create a suspension. This suspension is then placed into a water bath at 85˚C and stirred on medium power with a stir bar. The mixture is stirred for ten minutes in the water bath once it has reached 70˚C to ensure the melting of the hydrogenated oil. Phase 2 begins with the addition of 300 cst xanthan solution. Once the 300 cst xanthan solution is added, the mixture is stirred at 85˚C for five minutes. Phase 3 begins with the addition of 90% citrus soybean solvent, removal from the water bath, and hand stirring to homogenize the Heartland Wax. It should be of note that with larger volumes, human mixing becomes tedious and the help of a powered mixer is utilized to create a homogeneous product. Once the Heartland Wax reaches 50˚C, it is poured into the packaging containers, allowed to cool for one hour, and then it is ready to be used.

Plackett-Burman Design and Feasibility Testing

	Factor	High	Low
A	Cooling Rate	10 C/min	2.75 C/min
B	Shear	Frother	Stir Bar
C	Solvent	15%	10%
D	Dummy	-	-
E	Hydrogenated Oil	25%	20%
F	Oil	45%	40%
G	Xanthan Gum - high viscosity	3%	2%
H	Xanthan Gum - low viscosity	8%	6%
I	Dummy	-	-
J	Temperature	90 C	85 C
K	Time -Phase I	20 min	10 min
L	Time - Phase II	10 min	5 min
M	Dummy	-	-

Experiment #	A	B	C	D	E	F	G	H	I	J	K	L	M
1	+	+	-	-	+	-	+	-	-	-	+	+	+
2	+	+	+	-	-	+	-	+	-	-	-	+	+
3	+	+	+	+	-	-	+	-	+	-	-	-	+
4	+	+	+	+	+	-	-	+	-	+	-	-	-
5	-	+	+	+	+	+	-	-	+	-	+	-	-
6	-	-	+	+	+	+	+	-	-	+	-	+	-
7	-	-	-	+	+	+	+	+	-	-	+	-	+
8	+	-	-	-	+	+	+	+	+	-	-	+	-
9	-	+	-	-	-	+	+	+	+	+	-	-	+
10	+	-	+	-	-	-	+	+	+	+	+	-	-
11	-	+	-	+	-	-	-	+	+	+	+	+	-
12	-	-	+	-	+	-	-	-	+	+	+	+	+
13	+	-	-	+	-	+	-	-	-	+	+	+	+
14	-	-	-	-	-	-	-	-	-	-	-	-	-

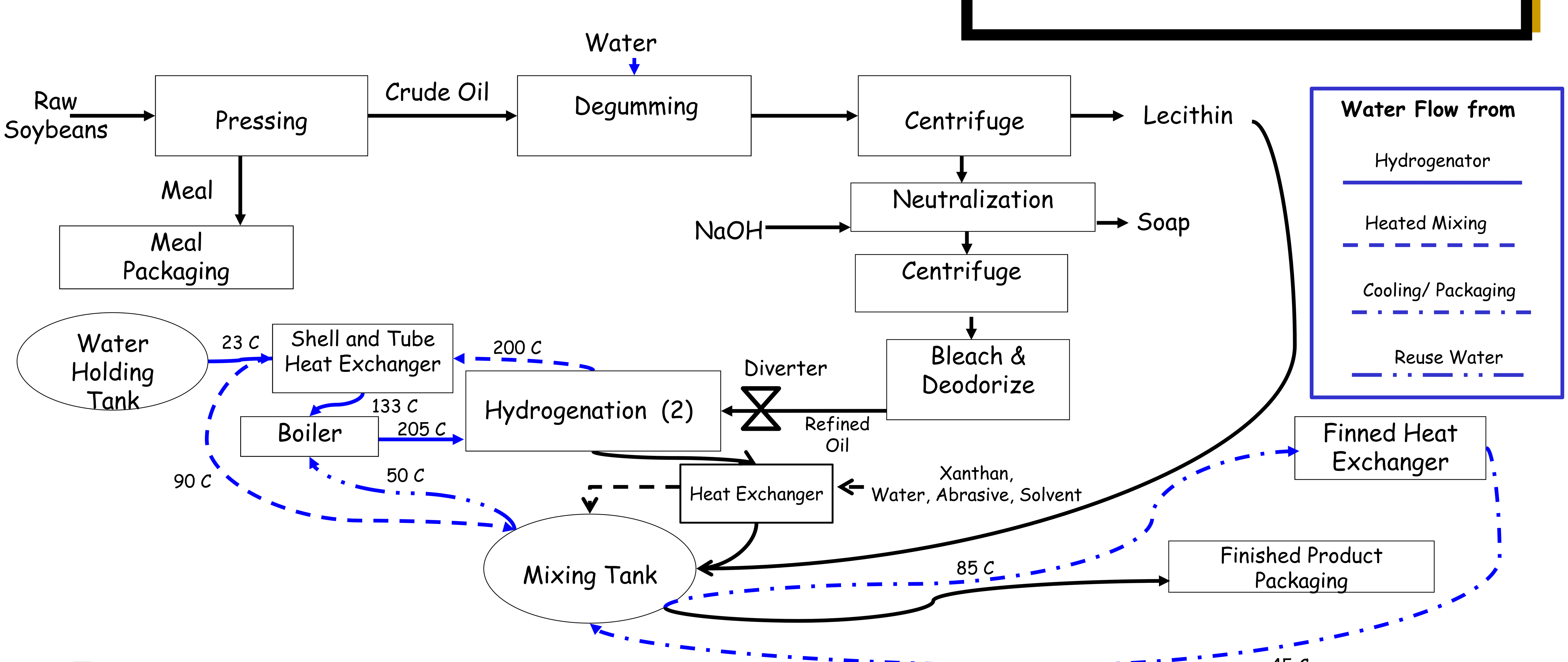
Factor	Effect	t-value	P-value	Result	
C Solvent	-10.07	-1.98	0.80	Low amount	10%
G Xanthan Gum - High Viscosity	-8.21	-1.62	0.80	Low amount	2%
F Oil	-7.07	-1.39	0.70	Low amount	40%
B Shear - Phase 1 & 3	4.93	0.97	0.50	High amount	Milk frother
E Hydrogenated Oil	-4.79	-0.94	0.50	Low amount	20%
L Time - Phase 2	1.93	0.38	0.40	High amount	10 minutes
K Time - Phase 1	-1.79	-0.35	0.40	Low amount	10 minutes
H Xanthan Gum - Low Viscosity	-1.21	-0.24	0.40	Low amount	6%
A Cooling Rate - Phase 3	-1.07	-0.21	0.40	Low amount	Slow
J Temperature - Phase 1 & 2	-0.93	-0.18	0.40	Low amount	85 C

Experiment	Contact Angle	Experiment	Contact Angle
1	63.5	8	69.0
2	55.0	9	70.5
3	64.0	10	44.0
4	63.0	11	72.0
5	56.0	12	71.5
6	38.0	13	64.5
7	49.0	14	73.5

Formulation 14 was chosen due to its large contact angle and its material costs (detailed later) were lowest. We have assumed a market share of 2%, which corresponds to two million pounds of finished product per year. Total material balances per year are shown below.

Component	w/w %	Amount needed (lbs)
Water	18.00%	360,000
30 % Hydrogenated Soybean Oil	60%	1,200,000
10000 cst Xanthan	2.00%	40,000
350 cst Xanthan	6.00%	120,000
Soyblends Solvent	10.00%	200,000
Soybean Lecithin	1.00%	20,000
Soybean Hulls	3.00%	60,000

Since all ingredients of the formulation are derived from soybeans (Soyblends Solvent and xanthan gum excluded), they can be bought direct from market. The limiting factor will be the amount of oil which will be partially hydrogenated to 30%. The annual requirement of soybean oil is approximately 1.2 million pounds. Assuming that 19% of a soybean is oil, approximately 6.3 million pounds of raw soybeans will be required per year. The soy hulls will come from the pressed meal, with the remainder of the 5.1 millions pounds of meal being sold for feed or fertilizer. Soap from the refining process will also be sold. The process flow diagram below details this process.

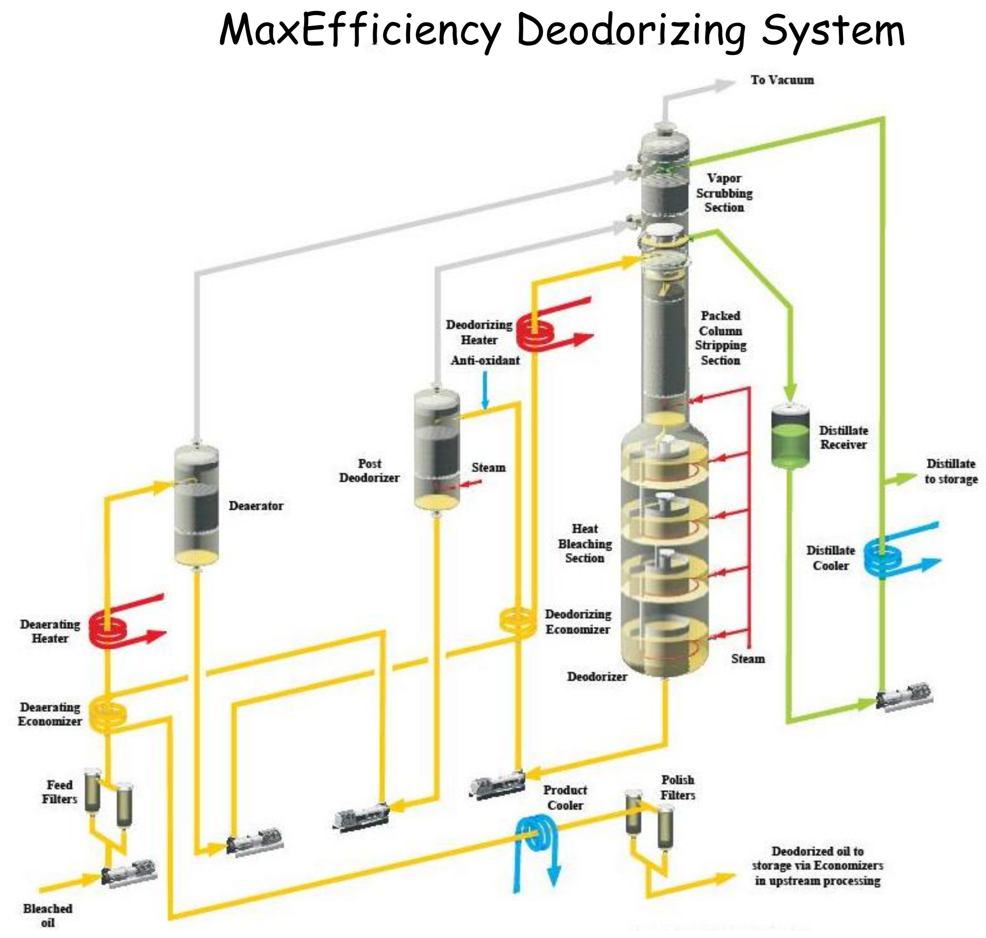


Energy Balance and Usage

In an effort to minimize the energy required to operate our plant, we incorporated many heat transfer operations to "recapture" heat. By doing so, we have saved approximately 4000 kW of energy (based on non-recycle versus recycling of water). All of the equipment in the plant, other than the boiler, is powered by electricity. Unfortunately, the process does not produce enough biodiesel (a simple conversion in the processing can make biodiesel from soap) to provide energy savings. Overall electricity requirements per day are 2,938,831 BTU/day. Overall water heating requirements are, assuming a gas-fired boiler, 16,757,505 BTU per day. A detailed summary of electricity and hot water usage is to the right.

Step	Process Type	Equipment Needed	Processing Conditions	Water	Unit	Heated Water	Unit	Electrical	Unit	Other
Pressing	Continuous	Twin Screw French Expeller Press						979,603	Btu	
Degumming	Continuous	Heated tank	70C for 15 minutes	30.08	lbs/hr					
		Pump						15,264	Btu	
		Centrifuge						939,582	Btu	
Neutralization	Continuous	Stir tank				11,768	Btu			Base (NaOH)
		Centrifuge						939,582	Btu	
Bleaching	Continuous	Stir tank				50,400	Btu			High Activity Clay
Deodorizing		Falling film heat exchanger	1-3% steam at high temp and vacuum							
		Vacuum								
Hydrogenation	Batch	Hydrogenator – filling/running	200C for 2 hours			120,803	Btu			
		Hydrogenator – running/emptying				120,960	Btu			
Mixing	Batch	Stir tank				8,054	Btu			
		Water pump	4 hP for 1 hour	192.31	lbs/hr			64,800	Btu	
Boiler	Continuous	Boiler	14,256 lbs/hr			4,874,400	Btu			ramp up requirement
						11,571,120				running requirement
		Holding tank (10,000 kg)								
						16,757,505	Btu	2,938,831	Btu	Per Day

MaxEfficiency Deodorizing System



200 Gallon Jacketed High Pressure Hydrogenator

Plant Estimates (FCI)	Costs
Total Equipment Costs	$1,289,844.06
Purchased Equipment Installation	$552,790.31
Instrumentation (Installed)	$479,084.94
Piping (Installed)	$94,027.13
Electrical (Installed)	$184,263.44
Buildings (Services Included)	$142,557.26
Service Facilities (Installed)	$184,263.44
Engineering and Supervision	$589,643.00
Construction	$626,495.69
Legal	$73,705.38
Contractor	$350,100.53
Contingency	$681,774.72
Working Capital	$1,381,975.78
Total	$6,630,525.68

Equipment and Installations		Labor, Electricity, Steam			
Total Costs	Fixed Capital Investment	Variable Costs		Material Costs	
$ 8,905,902.71	$6,632,039.00	$2,273,863.72			
				$1,878,311.02	Soy
$ 1,749,515.18	$/yr				
Total Product Costs (Assume Fixed Costs are annualized over 5 years at 10% with no depreciation (minimal costs))					
Cost Per Year	**$5,901,689.92**	**Income from meal**	**$212,500**	**Total Cost**	**$ 5,689,189.92**
Total Cost	**per Pound**				
$ 5.69					
Selling Price					
$9.00	**per pound**				

Fixed Capital Investment and Plant Costs

The total fixed capital investment was calculated from equipment costs from various manufacturers (watertanks.com, Anderson International (screw-press), Pressure Chemical Company (hydrogenators), and Peters, MS. The table to the left shows the equipment costs, electricity costs, water costs, gas costs (for the boiler), and FCI.

Future Work in the Development of Heartland Wax

- Refining formulations to optimize the functionality of Heartland Wax.
- Develop pilot plant to elucidate the effects of scale-up on production processes, with emphasis on hydrogenation.
- Shelf life testing, microbial growth challenge studies, and functional life span in use.

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Anderson Duo Expeller Press