

Continuous Marshmallow Processing

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Objective:

Design a continuous process to produce marshmallows

- Minimize process inefficiencies
- Reuse resources/energy throughout process
- Production rate of 500 lbs/hour
- Process intended for vegan marshmallow manufacturing

Background Review:

- Initial plant layout and equipment types based on layout proposed by Doumak (1962)

Parameter	Value	Unit
Viscosity, μ	5.37	10^{-4} Pa-s
Density, ρ	786.4 – 262.1	kg/m^3
Consistency Index, K	563.1	$\text{Pa}\cdot\text{s}^n$
Flow Behavior Index, n	0.379	

Marketing:

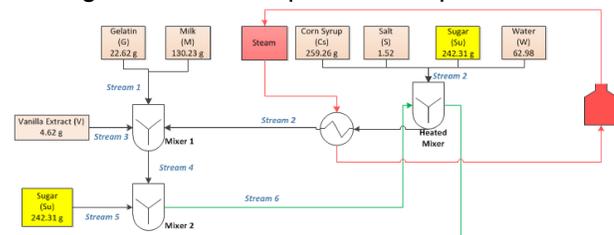
- Americans spend over \$150 million on marshmallows each year with trends increasing.
- In the last three years, the number of vegans in America has risen from 3.05 to 7.82 million and is projected to increase.

Ethical Impact:

- Vegan marshmallows provide vegans with an alternative solution to marshmallows that fits their ethical views.

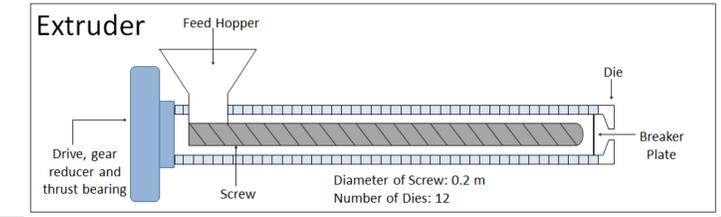
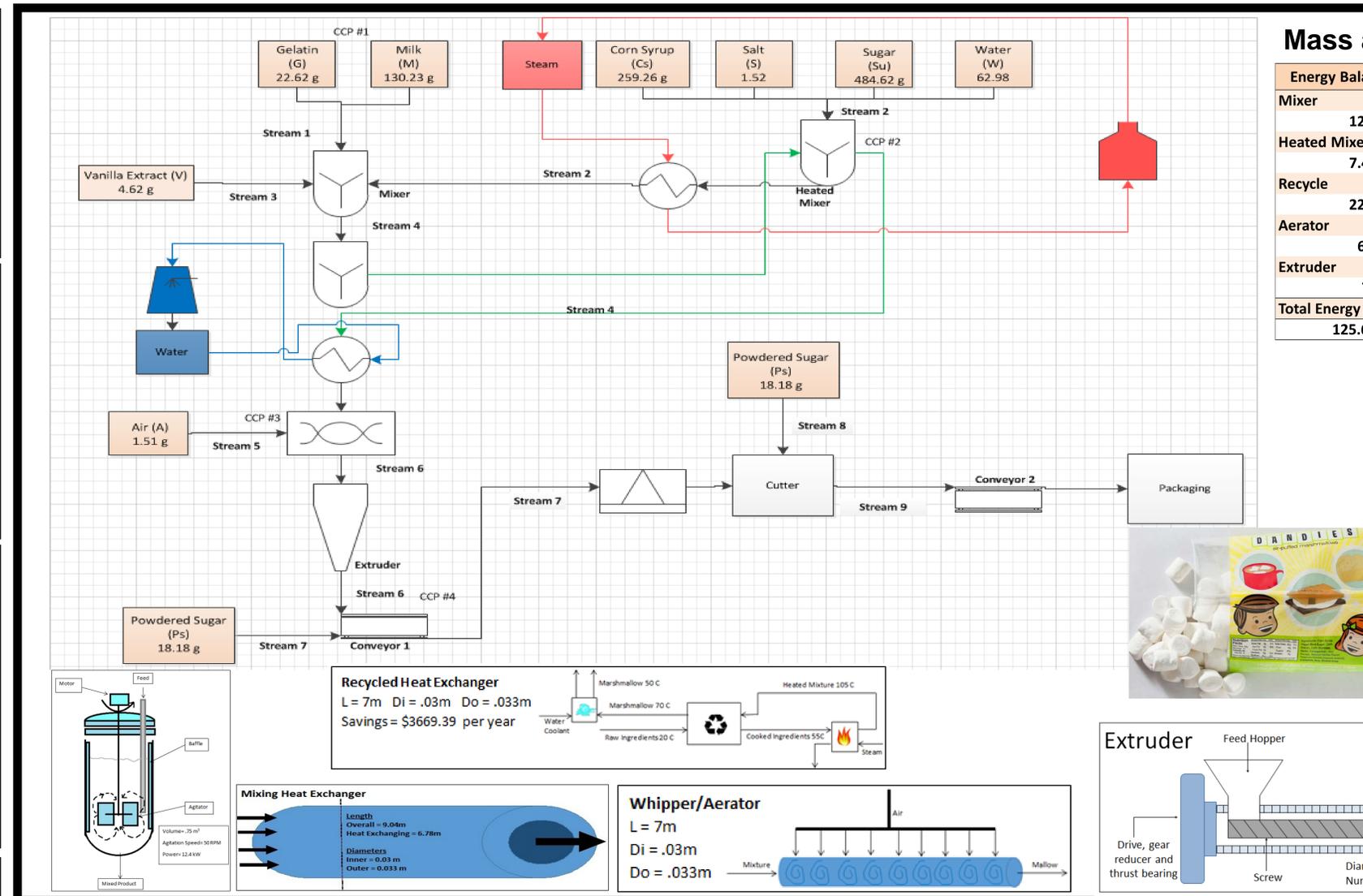
Alternative Solutions:

- Substitute vanillin and milk powder to reduce raw materials cost
- Use of holding tank with no agitation to hydrate gelatin
- Use of depositing extruder to produce correct marshmallow size and shape while eliminating need for guillotine cutter
- Use sugar to decrease product temperature



Mass and Energy Balance

Energy Balance	Mass Balance	Flow rates (kg/hr)
Mixer	Stream 1 (Mixer)	
12.4 kW	Gelatin	5.47
	Milk	31.48
Heated Mixer		36.95
7.45 kW	Stream 2 (Heated Mixer)	
Recycle	Corn Syrup	62.67
22.7 kW	Salt	0.37
Aerator	Sugar	117.14
6.1 kW	Water	15.22
Extruder		195.41
77 kW	Stream 3 (Vanilla Extract)	
Total Energy		4.62
125.65 kW	Stream 4	
		233.47
	Stream 5 (Air)	
		0.000695
	Stream 6 (Extruder)	
		233.83
	Stream 7 (Powdered Sugar)	
		4.13
	Stream 8	
		237.96
	Stream 9	
		242.09
	Desired is 226.796 kg/hr (500lb/hr)	



Economics:

Location: Gary, Indiana

Total Product Cost	\$ 5,044,331.25
Raw Materials	\$ 4,035,465.00
Annual Revenue	\$ 5,720,779.22
Income Tax Rate	0.085
Depreciation	\$ 141,928.76
Annual Cash Flows	\$ 631,013.84
Breakeven Point	3.5 years
ROI	35.20%

Purchased Equipment	\$
Mixer	\$ 77,000.00
Heating Heat Exchanger	\$ 31,786.96
Recycle Heat Exchanger	\$ 15,891.10
Cooling Heat Exchanger	\$ 31,786.96
Extruder	\$ 39,250.00
Packaging	\$ 100,000.00
Other	\$ 272,000.00
Fixed Capital Investment	\$ 1,419,287.56
Working Capital	\$ 283,857.51
Total Capital Investment	\$ 1,703,145.07

Sustainability:

Water Recovery and Reuse

- Condensate recovery to reduce energy and cost
- Cascading to reduce water consumption
- Cartridge filter to remove debris from water going into equipment
- Membrane bioreactor and reverse osmosis filter to clean water

Renewable Resources

- Collection of rainwater
- Geothermal energy for steam and electricity generation

Social/Global Impact:

- As veganism increases in the United States and around the world, having plant-based options allows for vegans to sustain their lifestyles.

Acknowledgements:

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