

Manu Bhargava^a, Jack Hamlin^a, Matthew Rodibaugh^a, Alex Smith^a

Objective

This senior design capstone project seeks to create a healthy beef jerky product that has a clear list of all ingredients. It will be sold at a lower price than current beef jerky products on the market. Currently, the annual beef jerky sales amount to almost \$600 billion. The production goal is 1.1 million kg beef jerky annually.

Global Factors

Dietary trends in America have pushed for protein consumption over carbohydrate consumption. This trend has increased meat snack consumption and caused companies to produce meat snacks pertinent to specific diets. The health focused changes help confront the societal issue of obesity. Load required for thawing is 1189 kJ per batch. The duration of the thawing stage is 8.5 hours. The mixing stage requires 10 minutes. During the mixing stage, 36.23 kJ is required per batch and 925 gallons of water per week are required for cleaning. This water and small particles of food are considered waste. In the forming stage, the flow rate is approximately 1,500 kg/ hr. The load required is found to be 58.72 kJ for each batch. In drying, waste includes evaporated water and melted fat. 85.3 kW were required per batch and 210 gallons of water were used to clean weekly.

Alternatives

Thawing (obtain a malleable base to create product):

- Reach-in Refrigerator
- Cold-room

Mixing (create a homogeneous mixture):

- Meat Grinder
- Baffles Mixer
- Ribbon Mixer

Forming (obtain uniform strips of meat):

- Extruder
- Sheeter

Drying (evaporate water and melt fat to dehydrate beef):

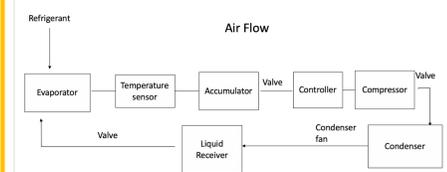
- Smokehouse
- Microwave
- Infrared Oven

Economic Analysis

Using the equipment costs seen below in conjunction with Table 6-9 in PTW, the FCI and TCI were determined to be \$847,468 and \$996,896 respectively. To determine the total product cost, several assumptions were made using Table 6-18 in PTW. The result was a total product cost of \$15.28/kg. The total annual production was 1,124,337 kg beef jerky. The annual cash flow was calculated to be \$13,593,974. The return on investment was calculated as 13.63%. Based on the return on investment, the beef jerky production process is profitable.

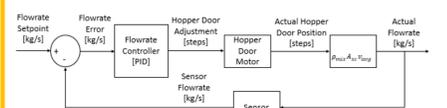
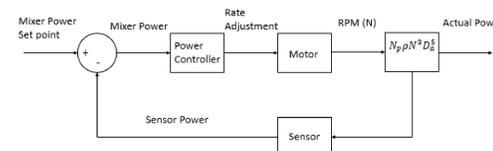
Operation	Thawing	Mixing	Forming	Drying
Equipment	Condenser \$10,369	Mixer \$50,000	Former \$46,350	Dryer \$30,000
	Evaporator \$42,763	Conveyor \$16,993	Conveyor \$16,993	

Process Controls and Optimization



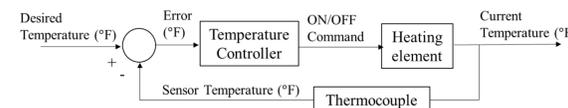
Thawing requires manipulation of air flow.

Mixing requires control over power and flowrate.



Constant feed flow rate is crucial to the forming stage.

Temperature is the significant factor in the dehydrating stage.



Optimized refrigerant flow rate was found to be $10^6 \text{ m}^3/\text{hr}$ by minimizing the total annual production cost. The optimized production from mixing was found to be 407.5 kg/s by minimizing the total annual production cost. The optimized hopper door diameter was calculated to be 4.37 cm. The variable cost of conveyor systems was used to determine this parameter. The ideal temperature was found to be 190°C by using the variable cost of heating.

Design of Experiments

Recipe:

1 lb. ground beef	1 tbsp. Soy Sauce	1/2 tsp. Onion Powder
1/4 tsp. Salt	1 tsp. Black Pepper	1 tsp. Lemon Pepper
1 tsp. Red Curry Powder	1 tsp. Ginger Powder	1/4 tsp. Coriander
1/2 tsp. Garlic Powder	1 tbsp. Worcestershire Sauce	

Initially, all ingredients were mixed together and rolled out. The meat slurry was then cut into strips of equal size and thickness. The stripes were then cooked at a low oven temperature for an extended time period.

Coded value	Salt (tsp)	Temp (°F)	Lean %	Thickness (mm)
-1	1/8	160	85	5
0	1/4	220	90	6
1	1/2	240	96	7



Toughness Response ANOVA Data

Term	Effect	Coef	SE Coef	T-Value	P-Value
Constant	-	2.600	0.279	9.31	0.000
Salt	0.250	0.125	0.312	0.4	0.705
Temperature	0.250	0.125	0.312	0.4	0.705
Lean %	1.750	0.875	0.312	2.80	0.038
Thickness	-0.250	-0.125	0.312	-0.4	0.705

- No significant factor for taste response
- Lean % significant for toughness ($p < 0.05$)

Design of Experiments

A SuperPro flow diagram was developed to model the overall production. The total time for a batch was found to be 12.77 hours but due to operations occurring concurrently, the recipe cycle time is only 8.33 hours. This gives 2.87 batches per day and 1,124,337 kg beef jerky annually.

