



# Design of a soy-based meat analogue and its production plant

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## Objective

- Optimize a formula for a soy-based meat analogue whose texture most closely resembles that of bulk sausage and whose recipe includes only raw soybeans, oil, water, and spices.
- Design a zero discharge production plant for manufacturing the meat analogue.

## Background

Extruders have been used for a wide variety of products with a high productivity and low cost. The quality and nutritional value of these products is higher and undergoes less degradation due to the quick heating process. Extrusion inactivates enzymes that affect flavor and nutritional properties of the food<sup>1</sup>. When subject to high shear, soy bean protein will change to a fibrous structure similar to that of meat.

NASA has proposed using extrusion during space missions to produce a variety of foods using limited ingredients and small processing equipment. Transportation of materials is the leading restriction as it costs \$1 million/kg to reach the space station. Using an extruder to produce a meat analog from raw soybeans will create a product offering high quality taste and essential nutrients.

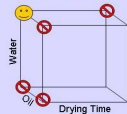
## Experimental Procedure

- Our objective was to determine the optimum moisture and oil formulation and drying time that that would give the sensory and textural properties of cooked sausage.
- Ingredients were mixed for 3 minutes
  - Dough was extruded through a Kitchen-Aid mixer
  - Analogue was dried in an oven for set time (15 or 30) minutes at 100 °C
  - The texture of the meat analogue was analyzed and compared to the texture of cooked, bulk sausage

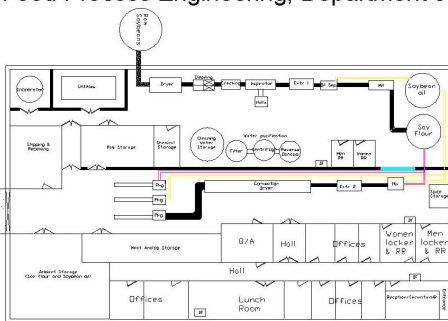


- Pre-trials were done using a spaghetti die and forming "clumps"
- Extruding without a die and forming "logs" produced a better texture
- The first drying trial conducted for 30 minutes was too dry, so all remaining trials were conducted dried for 15 minutes.

Figure 1: Experiments were conducted using three factors. Time constraints prevented a full factorial from being completed. Completed experiments are denoted by a slash if results were sub-optimal and a smiley if results were optimal.



Final Recipe (48% Moisture)  
 50 g soy flour  
 46.8 g water  
 5 g Italian sausage spice  
 8 g oil



## Zero Discharge Plant Layout:

- Area: 17000 ft<sup>2</sup>
- Generating 25 new jobs on the floor and 9 engineering and managerial positions.
- Operating 24 hrs/day; 300 days/year
- Soybean hulls will be burnt in incinerator to create energy.
- CIP Cleaning will be used on the equipment and water will be treated through water purification system.
- Particulates will be incinerated and water re-used.
- Extruders have no effluent streams.

## Economic Analysis

Revenue Stream	Year 1	Year 2	Year 3	Year 4	Year 5
Meat Analogue	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Energy Production	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Water Purification	500,000	500,000	500,000	500,000	500,000
Incineration	500,000	500,000	500,000	500,000	500,000
Total	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000

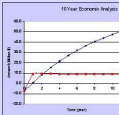


Figure 4: A 10 year economic analysis shows that the plant has the potential to successfully earn a profit.

Meat Analogue  
 Sold in 17.6 oz packages  
 (0.5 kg) for \$150/package

## Conclusions

A meat analogue, whose texture closely resembled that of sausage, was successfully produced using soy flour, soybean oil, and water. The product is made using high shear technology in the form of an extruder. Our simple recipe combined with low-energy extrusion technology is appropriate for use in space stations and third-world countries. We took this process one step further and designed a large scale production plant. After a preliminary economic analysis we can conclude that the proposed plant design has the potential to earn a \$50 million profit after 10 years of production.

## Future Work

- Additional sensory analysis and product color optimization
- Increasing extruder flow rate to increase yield and incorporation of air bubbles.
- Further economic analysis
- Marketing proposal to attract national audience

## Literature Cited

- Wenger, Wairot B. *Soybean Processing for Oil and Meal & Non-Soybean Technology*. Soy Innovations International.
- Soybean Association of North America. 2007. *Sales and Trends*. Retrieved 3/4/2017 from [www.soyinfo.org/industry/sales-and-trends](http://www.soyinfo.org/industry/sales-and-trends)
- Amazon. 2007. *Boca Burger*. Retrieved 4/11/2007 from [www.amazon.com](http://www.amazon.com)

## Processing Plant

- Raw material inputs to the plant include raw soybeans, water and spices.
- Soybeans will be dried and de-hulled in-house
- Soybean oil and soy flour will be co-products along with texturized soy protein
- Plant design allows for zero discharge

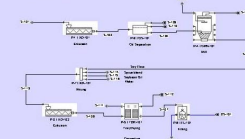


Figure 3: Process flow diagram for producing texturized soy protein.

## Experimental Results

Samples were subjected to force using Stable Micro Systems – Texture Exponent 32, which generated force versus time curves (Figure 2). The curves were compared to a curve generated using cooked, bulk sausage. The low water/low oil sample dried for a short time yielded the curve that most closely matched the sausage curve. It also had the best sensory ratings; other samples were too dry or had less desirable flavor.

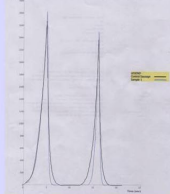


Figure 2: Texture Analyzer curves demonstrate that the texture of the high water/low oil sample dried for a short time most closely resembled the texture of cooked sausage.

## Market Analysis

- \$547 billion in meat analogue sales were made in 2004<sup>2</sup>
- Boca™ Burgers sell for \$4.69/10 oz<sup>3</sup>
- Estimated market demand of 70 million pounds/year meat analogue
- Attempt to capture 5% market share in first year
- Will produce 69,000 pounds/week

## Key Processing Steps

- First Extrusion: Re-constitutes raw soybeans into soy meal.
- Oil Separation: Solvent-free technique using a screw press. Soybean Oil is also recovered for later use and resale.
- Mill: Soy flour is produced for next processing step and resale.
- Second Extrusion: High shear is used to convert globular proteins into a fibrous structure for meat analogue texture.
- Tray Drying: Product is dried to a moisture content (12%) below water activity of 0.6 so the product is shelf stable.

## Acknowledgments

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