Production of a Novel Co-Extruded Hot Dog Product

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Problem Statement

This project is in conjunction with the 2010 Sara Lee Innovation Award. In recent years, Sara Lee's Ball Park® line has not launched any innovative products. In hopes of expanding Ball Park Franks into a frozen convenience product, we have designed and optimized a new product platform consisting of a co-extruded concentric cylinder frankfurter surrounded by a fresh bread coating. The inner cylinder serves as a complimentary sauce to the outer section of turkey hot dog, and the breading acts as a vehicle for on-the-go convenience.

We also constructed a lab-scale device to perform the co-extrusion. Additionally, an industrial process was designed for this novel product. The manufacturing process utilizes 3 separate product streams: sauce cooking, meat emulsion, and dough forming. Moreover, the process was designed with sustainable and zero emission constraints in mind. We utilized engineering techniques such as heat and mass transfer methods, scale up, mass and energy balances, and economic analysis.

Meat Formula		Chili Formula		Dough Formula	
Ingredients	% Percentage	Ingredients	% Percentage	Ingredients	% Percentage
Turkey (15% Fat)	79.60%	Crushed Tomatoes	38.32%	Wheat Flour	58.48%
Corn Syrup	4.77%	Tomato Juice	25.77%	Water	33.34%
Instant Dry Milk	4.67%	Red Kidney Beans	24.14%	Butter	5.32%
Salt	1.59%	Red Onion	3.54%	Sugar	1.11%
Nitrates	0.23%	Concentrated Beef Base	2.80%	Salt	1.09%
Ice	8.79%	Vegetable Oil	2.68%	Yeast	0.66%
Liquid Smoke	0.33%	Chili Powder	1.92%		
		Garlic	0.48%		
		Onion Powder	0.29%		
		Cumin	0.07%		
		Oregano	0.05%		
		Black Pepper	0.05%		

Benchtop Procedure

Chili Sauce Component:

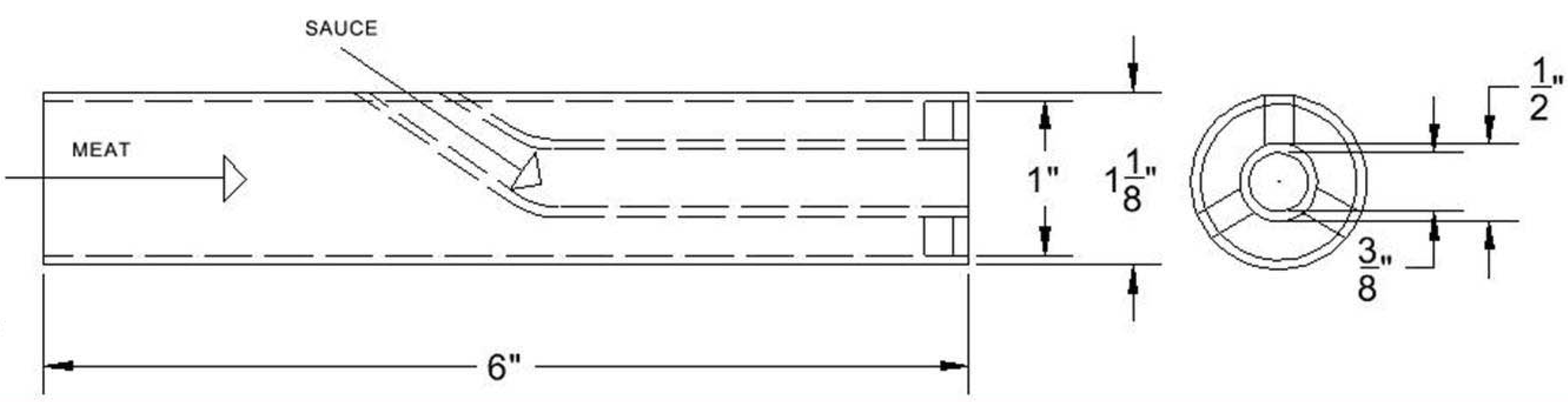
- Sauté diced onions and minced garlic in vegetable oil
- Add remaining ingredients, simmer 20 minutes
- Blend sauce in food processor
- Place sauce in extruder
- Connect tubing to co-extrusion device

Hot Dog Component:

- Mix dry ingredients
- Emulsify meat, ice, and spices in food processor until reaches 55°F
- Place emulsion into extruder
- Co-extrude sauce and hot dog streams into collagen casing
- Cook in oven at 180°F until center temperature is 170°F

Dough Component:

- Heat water to 115°F
- Mix yeast, sugar and salt into water, rest 5 min.
- Pour melted butter and yeast mixture into flour
- Mix ingredients until ball is formed
- Knead for 8 min., let rest 1 hr. in humid bowl
- Sheet dough to 3/16"
- Wrap dough around hot dog
- Boil in caustic bath (pH 8.7) 30 sec.
- Bake at 425°F for 5 min., 40 sec.
- Freeze entire product



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Plackett-Burman Optimization Testing of Hot Dog Texture

Based on the results of our large-scale sensory test, the texture of our product needed improvement. To this end, we designed a Plackett-Burman experiment to test the effect of 5 variables on hot dog texture. Result measures average sensory response on a hedonic scale from 1 to 9.

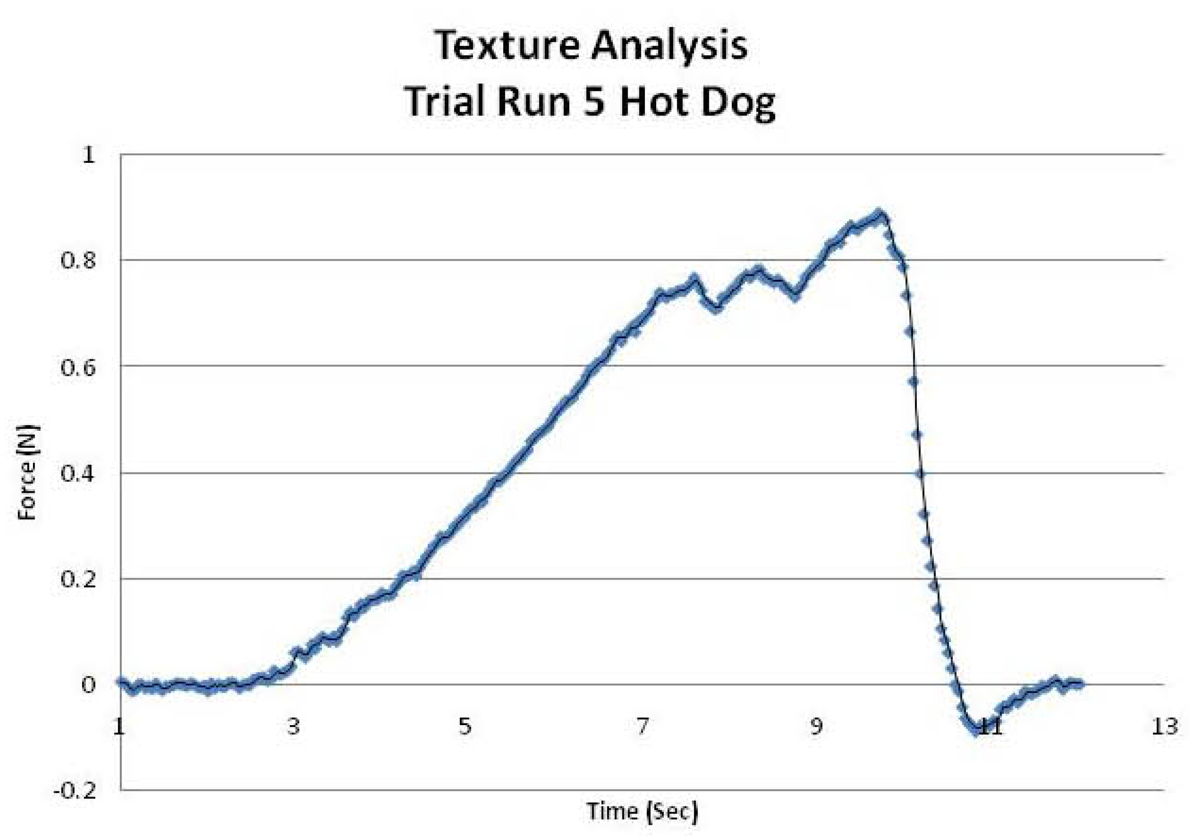
	Factor	High	Low
A	Percent Water	12%	9%
B	Mix Time	1 min	2 min
C	Protein Level	6%	4%
D	Salt Level	2%	1%
E	Starch Level	2%	0%
F	Dummy Variable	-	-
G	Dummy Variable	-	-

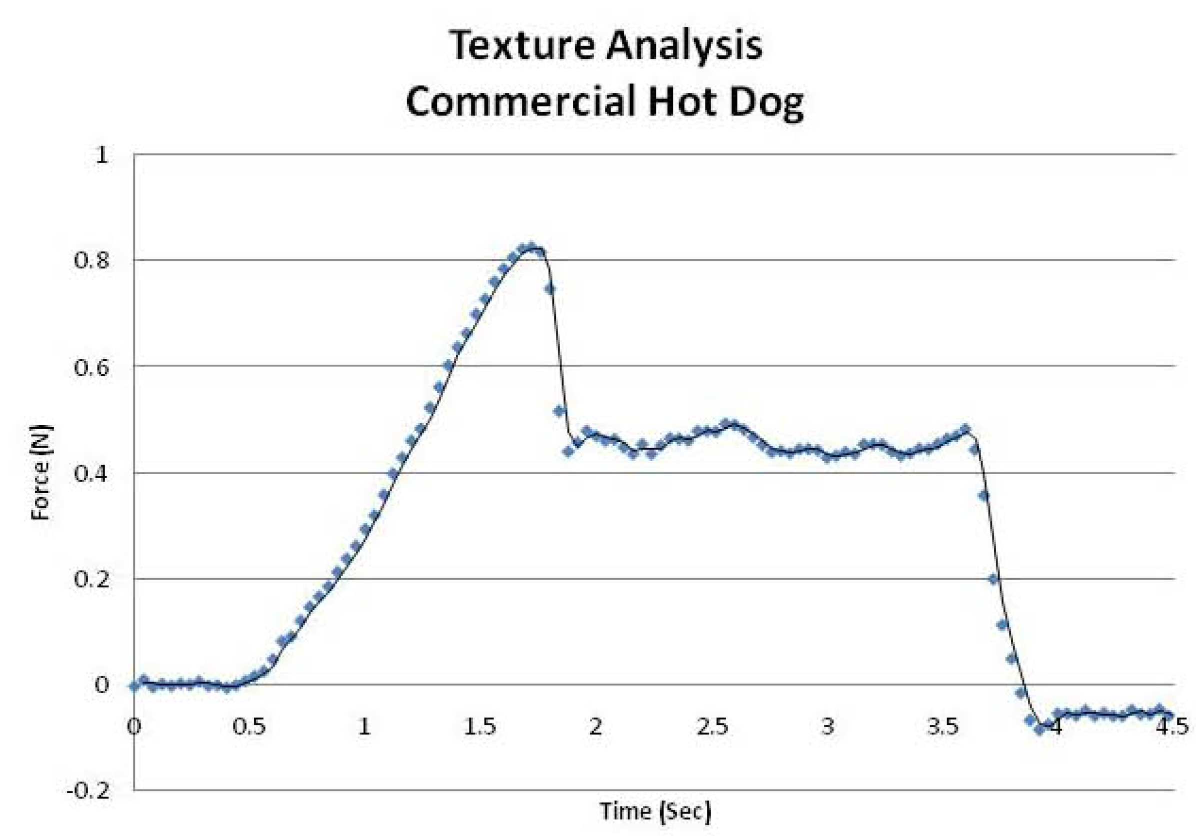
Experiment #	A	B	C	D	E	F	G	Result
1	+	-	-	+	-	+	+	3.3
2	+	+	-	-	+	-	+	6.3
3	+	+	+	-	-	+	-	3.3
4	-	+	+	+	-	-	+	2.7
5	+	-	+	+	+	-	-	7.0
6	-	+	-	+	+	+	-	5.3
7	-	-	+	-	+	+	+	5.7
8	-	-	-	-	-	-	-	4.7

Factor	Effect Level	SS	DOF	MS	F Statistic	P value
E	2.58	26.6256	1	26.6256	14.8101	0.94
B	-0.75	2.25	1	2.25	1.25153	0.62
A	0.42	0.7056	1	0.7056	0.39248	0.41
D	-0.42	0.7056	1	0.7056	0.39248	0.41
C	-0.25	0.25	1	0.25	0.139059	0.25
Error	-0.67	0.9556	2	0.4778		

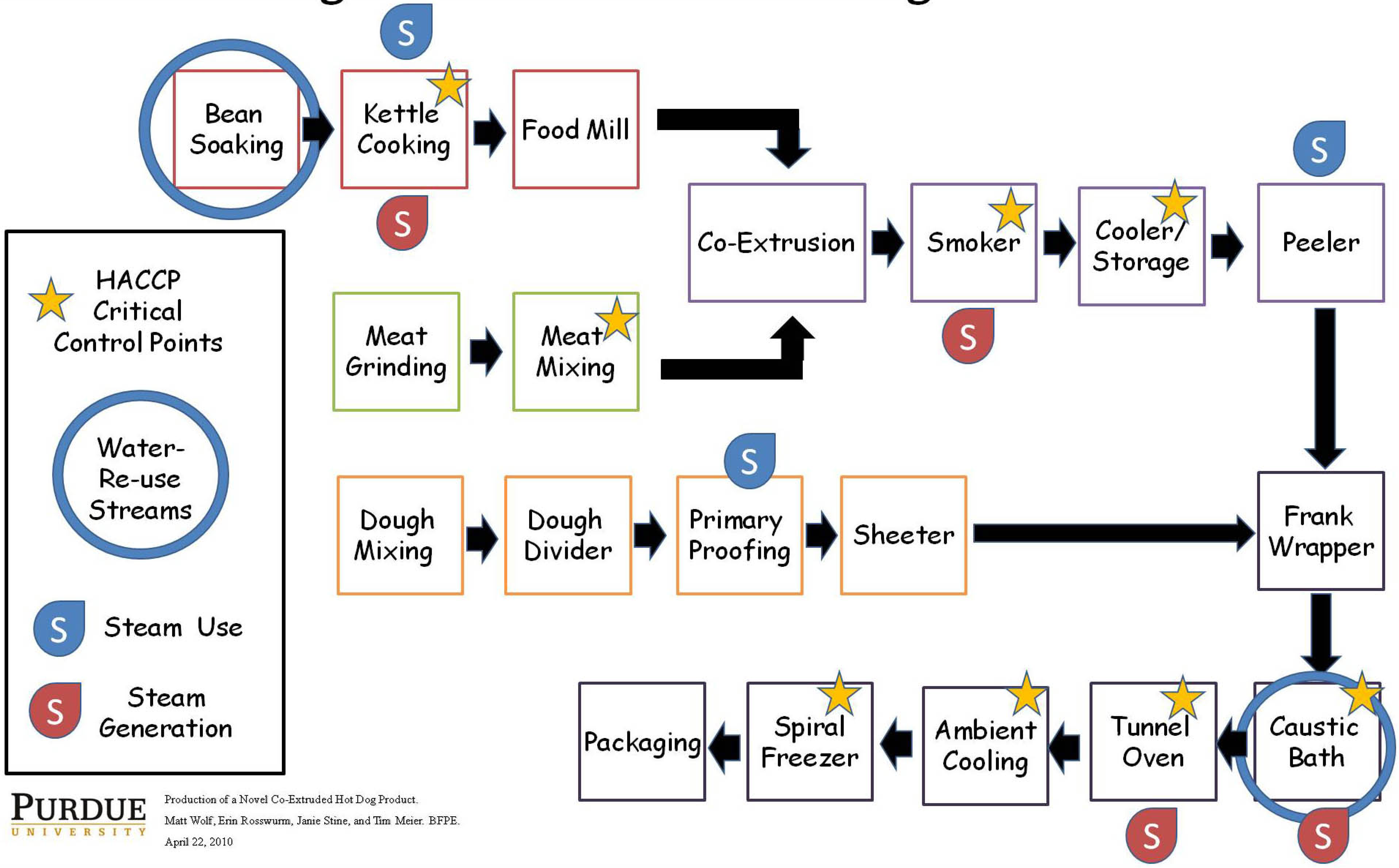
Results and Conclusions

Based on the statistical analysis of the five factors on hot dog texture, the only significant variable was Pre-gelatinized Starch Level (P = 0.94). Flavor analysis demonstrated that starch addition has no significant effect on overall flavor. Therefore, starch will be added to the product formulation.





Process Flow Diagram for Co-Extruded Hot Dog



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Energy Balance Calculations

To determine the total energy consumptions for our process, we utilized several analysis methods. Finite difference and lumped capacitance heat transfer models were developed for three unit operations, and estimates from equipment manufacturers were used for the others.

Total electricity requirements are 292.64 kW (998,529 btu/hr); total natural gas requirements are 65.77 kW (224416 btu/hr). The total energy cost of this process is estimated at $21.34 per hour, based on US Energy Administration Association commercial averages from 2009.

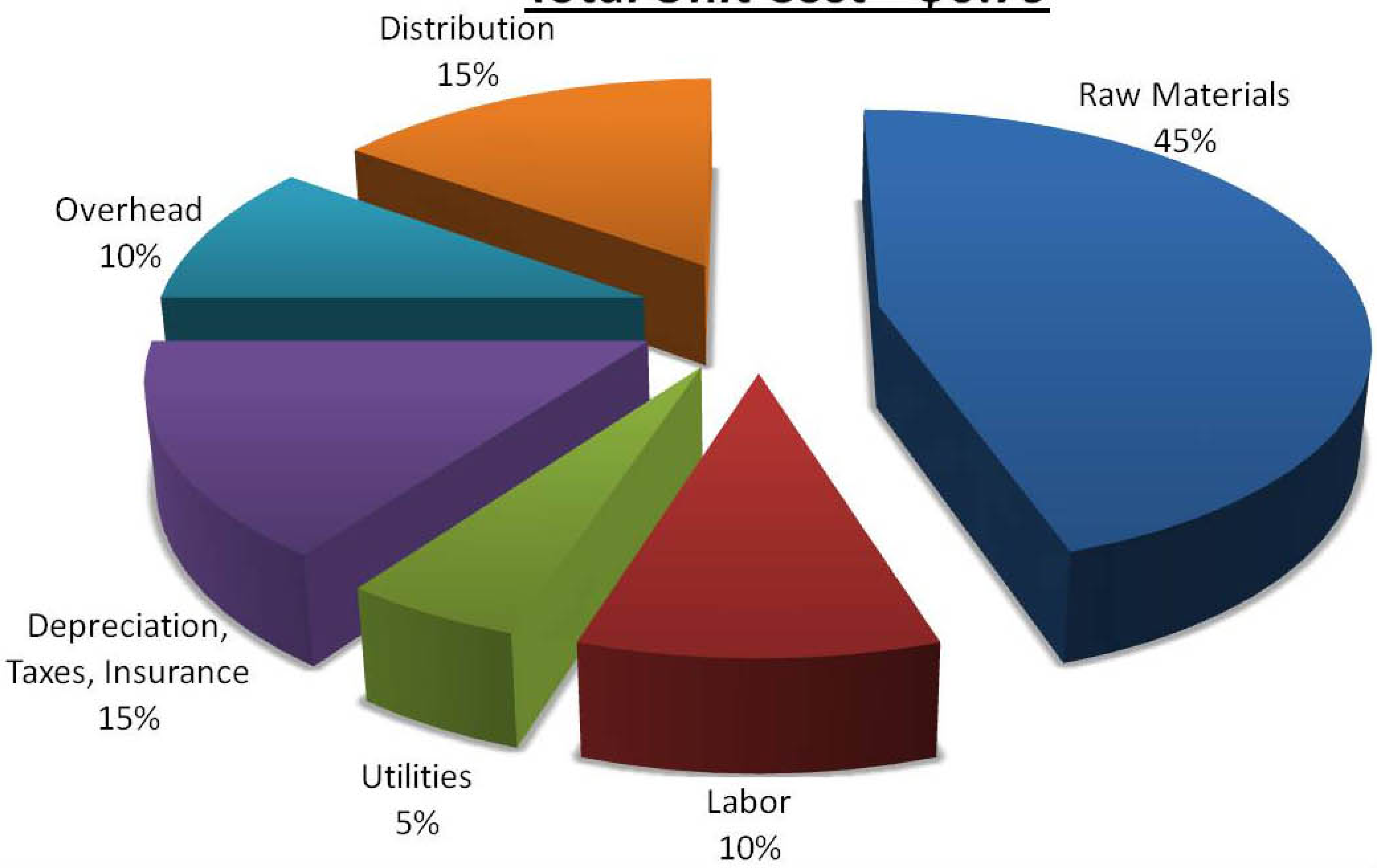
Energy Calculations

Equipment	kW Usage/hour	Natural Gas Consumption(BTU/hr)	Operational Assumptions (running time in 1hr)	$/hr
Meat Grinding	15.70	N/A	0.45	1.08
Meat Mixing	84.76	N/A	0.45	5.81
Chili Mixing	0.96	123416.83	0.68	0.75
Chili Blending	72.97	N/A	1	5.00
Co-extrusion	8.59	N/A	1	0.59
Smoking	-	-	1	-
Peeling	0.75	N/A	1	0.05
Dough Mixing and Kneading	24.39	N/A	0.81	1.67
Dough Chunker	3.21	N/A	0.81	0.22
Proofing Chamber	4.05	N/A	1	0.28
Dough Sheeter	2.40	N/A	1	0.16
Frank Wrapper	-	-	1	-
Caustic Bath	48.50	N/A	1	3.32
Tunnel Oven	N/A	101000.00	1	0.60
Spiral Freezer	26.36	N/A	1	1.81
			Total $/hour	21.34

*BTU Price based on Dec. 09' National Average from U.S. Energy Administration (assume 5.958E-6$/BTU)

*kWh price based on 2009 commercial energy estimate from U.S. Energy Administration Assoc. (assume .0685$/kWh)

Total Unit Cost = $0.79



Cost Analysis

Equipment costs were based on current prices for used equipment obtained from estimates provided by equipment vendors. Raw materials prices were taken from vendors, as well as USDA commodity prices (Ag. Marketing Service).

Using these known values for equipment and raw materials costs, we calculated the remaining cost factors constituting the total unit cost. Standard percentages were taken from *Plant Design and Economics for Chemical Engineers* (Peters and Stone).

Design Alternatives and Future Work

Rather than a co-extruded meat/sauce component in series with a dough wrapper, a triple extrusion process could also be used. Additionally, several batch processes could be converted to continuous processes to increase overall efficiency. Current convertible batch processes include dough mixing and proofing, bean soaking, and sauce mixing and blending.

Future work could be focused in two areas: the product and process. For the product, sodium/fat contents could be reduced, while fiber/nutrient content could be increased. Whole wheat could be incorporated into the dough, and other filling options (cheese, jalapeño, barbeque, relish, etc.) could be explored. For the process, work could be done to optimize and refine the co-extrusion technology. Also, the process could be reduced from low discharge to zero discharge with the addition of recycle streams and an in-house water treatment plant.

Nutrition Facts

Serving Size 1 chili dog (225 g)
Servings Per Container 1

Amount Per Serving

Calories 440 — Calories from Fat 130

	% Daily Value*
Total Fat 14g	**22%**
Saturated Fat 4.5g	**23%**
Trans Fat 0g	
Polyunsaturated Fat 3g	
Monounsaturated Fat 5g	
Cholesterol 85mg	**28%**
Sodium 1180mg	**49%**
Potassium 450mg	**13%**
Total Carbohydrate 47g	**16%**
Dietary Fiber 2g	**8%**
Soluble Fiber 0g	
Insoluble Fiber 0g	
Sugars 6g	
Sugar Alcohol 0g	
Other Carbohydrate 0g	
Protein 29g	

Vitamin A 10% • Vitamin C 15%

Calcium 10% • Iron 25%

Acknowledgements

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