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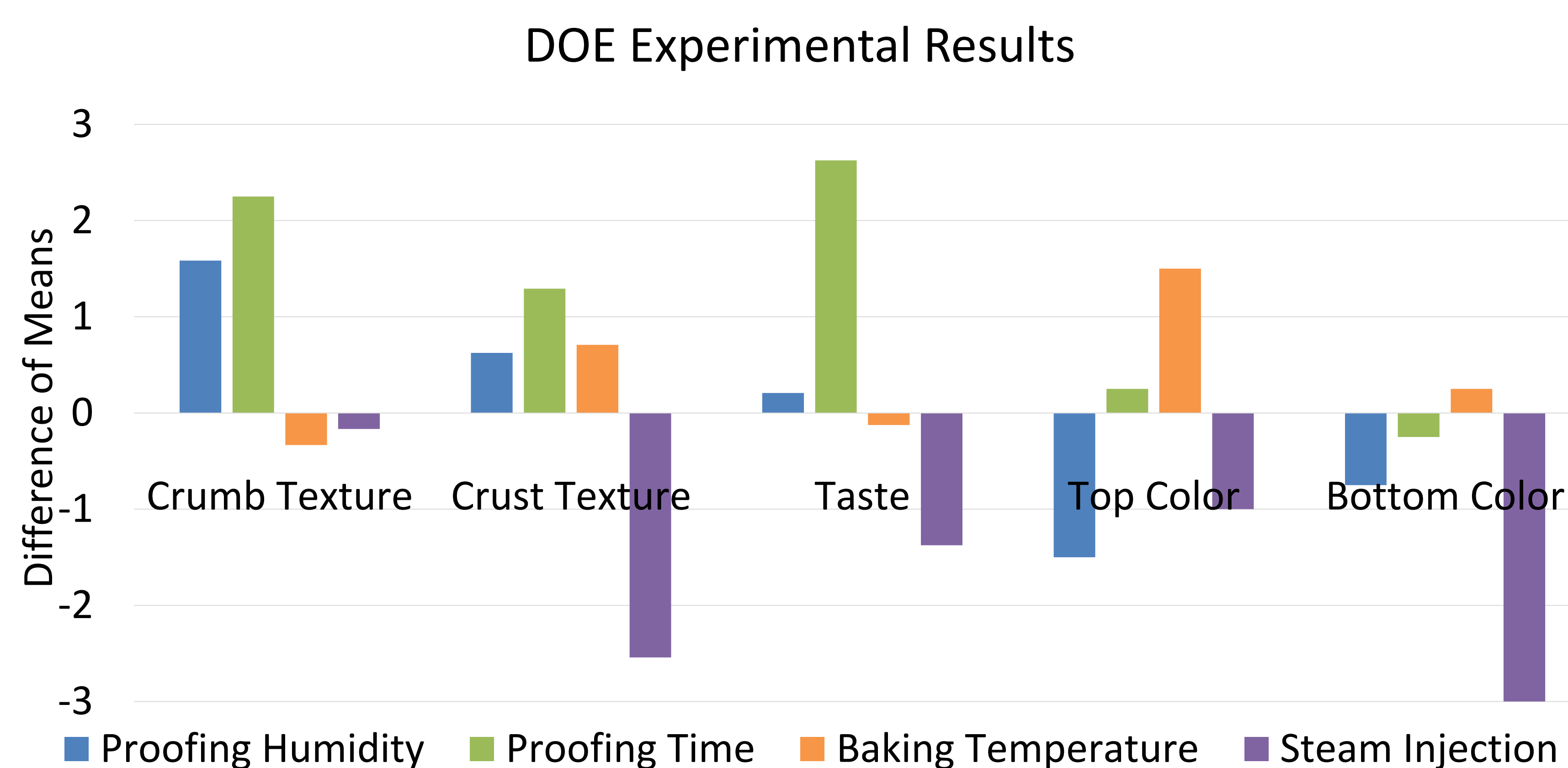
**Introduction**

- **It is all about the bubbles:** Sourdough is fermented with a live culture of yeast and lactobacillus bacterium that must be fed water and flour daily.
- **Simple Ingredients:** Flour (54%), water (42%), active sourdough culture (2.6%), and salt (1.4%). That's it!
- **Partial Baking and Freezing:** A long shelf-life means fresh bread with a crisp crust straight out of the oven every time
- **Objective:** To design and optimize the production line for artisan, par-baked, and frozen sourdough loaves in order to generate profit



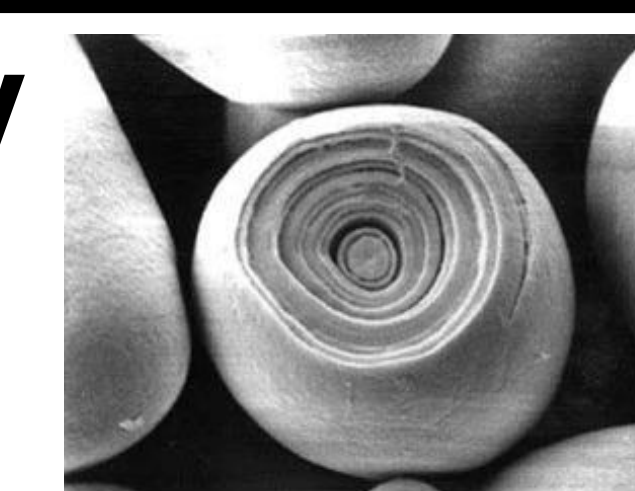
**Design of Experiment**

- Four factor, full factorial design
- Tested proofing humidity and time, and baking temperature and steam injection
- Color analysis using scale to the right and sensory preference test
- **Conclusions:** Quality decreased with steam injection and increased with increased proofing time and humidity



**Bread Chemistry**

- Maillard Browning
- Starch Gelatinization
- Moisture Migration
- Microbial Conversions
  - Yeast CO<sub>2</sub> production
  - Lactic Acid Fermentation



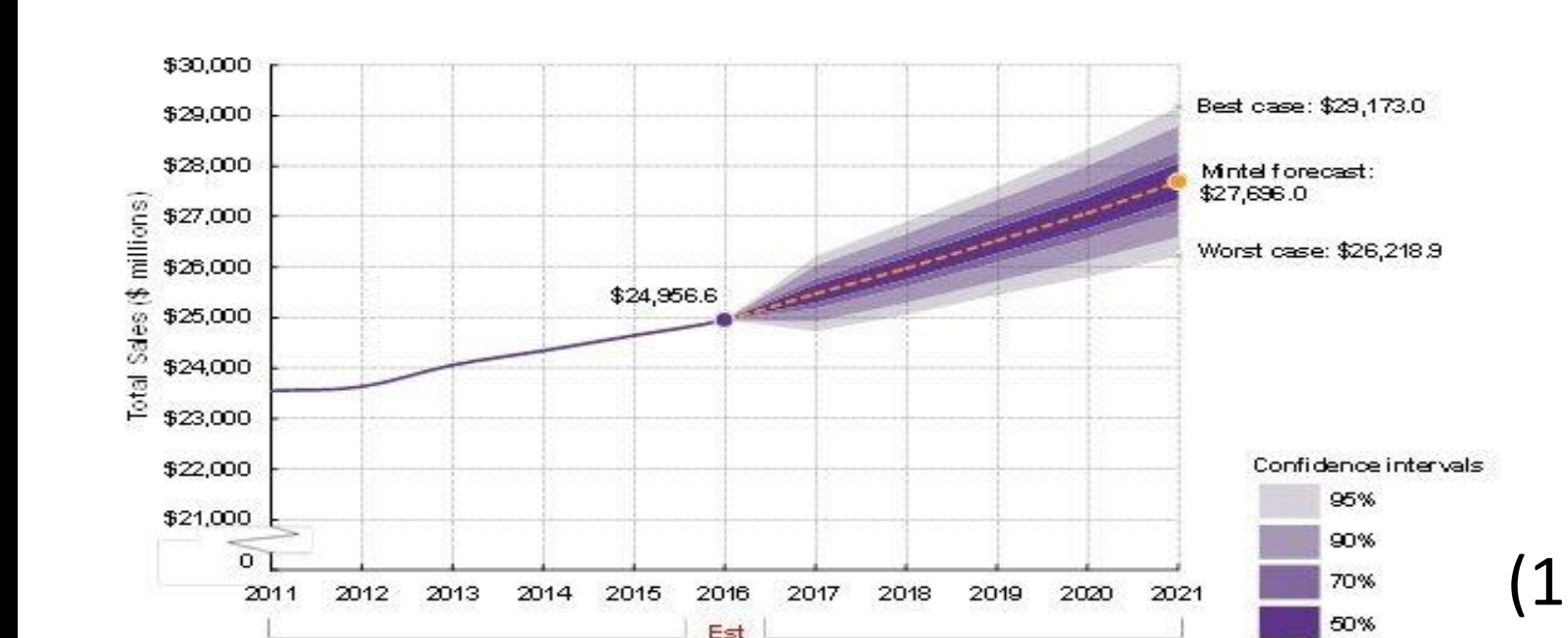
**Annual Material Cost**

- 300 day per year continuous process with production rate of 670 loaves/hour (100 kg/hour)
- 720,000 kg/year production or 6,259,680 packs
- 4 rolls/pack at \$12.00
- Income Tax: 35%
- Equipment Lifespan: 10 years
- Return on Investment: 20%

Annual Sale Revenue	\$75,116,160
Material Costs	\$385,196
Total Annual Utilities	\$73,880,690
Fixed Capital Percent of TCI	85%
Total Capital Investment	\$506,752
Annual Cash Flow	\$491,848

**Market Size**

- Consumer preferences for bakery products have been shifting from basic to artisan<sup>1</sup>
- Demand is high for all natural products



**Global and Societal Impact**

**Health Benefits**

- Fermentation reduces starch availability and gluten formation giving sourdough a low glycemic index<sup>2</sup>
- Improves bioavailability of nutrients compared to white bread<sup>2</sup>

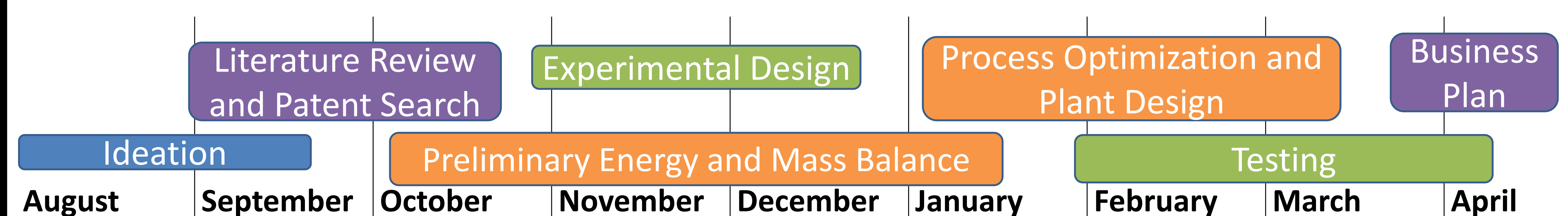
**Economic Benefits**

- Fermentation reduces pH to allow for longer shelf-life and reduced food waste<sup>2</sup>

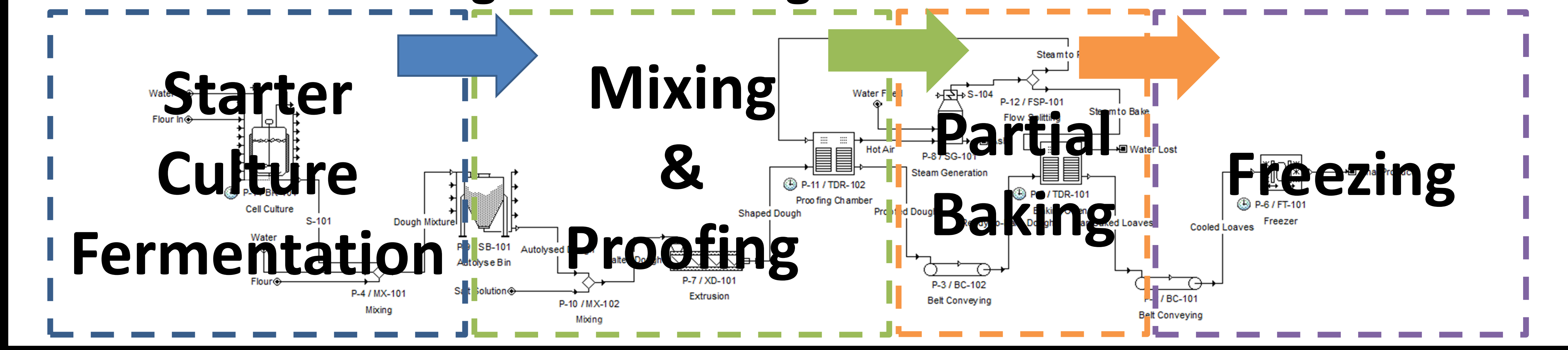
**Historical Impact**

- First historical records are 6000 years old<sup>2</sup>
- Nourished western US settlers<sup>2</sup>

**Project Timeline**



**Industrial Sourdough Processing**



**Alternative Solutions Evaluation**

**Steam Injection:**

- Common baking practice used to decrease pore size in the crust
- However, experimentally reduced the bread quality

**Culture Type:**

- Can be natural (Type I), liquid (Type II), or spray-dried (Type III)
- Natural cultures are cheap and self-sustaining.
- However, the concentration of lactobacilli in the region is low
- Batches came out dense and tough, thus a spray-dried sample was used to start the culture.

**Continuous vs. Batch:**

- Typically a batch production because of starter culture kinetics
- Emerging technologies allow continuous processes.

**Recommendations**

- Determine better simulation for steam injection
- Attempt proofing at higher temperatures to decrease proofing time to improve processing time
- Design experiment on re-baking time and temperature
- Evaluate possibility of CO<sub>2</sub> recovery from fermentation tanks
- Use of natural additives to improve crumb/crust sensory quality

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<sup>1</sup>Packaged Bread - US - July 2016. (n.d.). Retrieved April 13, 2018, from <http://academic.mintel.com/display/780300/>

<sup>2</sup>Poutanen, K., Flander, L., & Katina, K. (2009). Sourdough and cereal fermentation in a nutritional perspective. *Food Microbiology*, 26(7), 693-699. doi:10.1016/j.fm.2009.07.011