NSBRI Summer Apprenticeship Program

Advanced Food Technology
Space Food Systems Laboratory

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About Me

Education

• Biological and Agricultural Engineering, Food Engineering concentration
  
  o B.S. from Michigan State University
  
  o M.S. and Ph.D. (in progress) from Washington State University
About Me

Work Experience

• Cornell University Food Science Summer Scholar
• Campbell Soup Company Co-op
• PepsiCo Intern
Goals

• Shadow scientists and engineers in food lab and across NASA

Project 1

• Mini trade study on food processing equipment for a Mars habitat galley

Project 2

• ISS production process for Italian Herb Flat Bread

Project 3

• Feasibility of omega-3 supplementation for space food
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Project 1: Background

Food Processing vs. Packaged Food System Trade Study (Cooper 2012)

**Key Question:** Is it better to take food to Mars or grow it on the surface?

**Answer:** Ambiguous, yes, a combination of both
Project 1: Objective

Key Question: What is the optimal number of burners and ovens needed for a Mars habitat galley?

Objective: Complete a mini trade study to optimize the number of burners and ovens

- Food system 3 (Cooper 2012) for a 6-member crew on a 600-day Mars habitat mission
- Factors: active crew time, total preparation time, crew flexibility, mass, volume, power
Project 1: Methods

1. Select equipment combinations
2. Analyze the menu for equipment use and time
3. Calculate Equivalent System Mass (ESM)
4. Select the optimal combination
### Equipment Combinations

Based on an initial evaluation of the 10-day menu

<table>
<thead>
<tr>
<th>Equipment combination</th>
<th>Burners</th>
<th>Ovens</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1" alt="Burner Image" /></td>
<td><img src="image2" alt="Oven Image" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image1" alt="Burner Image" /></td>
<td><img src="image2" alt="Oven Image" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="image1" alt="Burner Image" /></td>
<td><img src="image2" alt="Oven Image" /></td>
</tr>
<tr>
<td>4</td>
<td><img src="image1" alt="Burner Image" /></td>
<td><img src="image2" alt="Oven Image" /></td>
</tr>
<tr>
<td>5</td>
<td><img src="image1" alt="Burner Image" /></td>
<td><img src="image2" alt="Oven Image" /></td>
</tr>
<tr>
<td>6</td>
<td><img src="image1" alt="Burner Image" /></td>
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</table>
Project 1: Results

Selection of Optimal Combination

- Decreasing total time (increasing time savings)
- Increasing mass penalty

Hypothesized trend

Best case

Diagram: Flowchart showing the process of selecting optimal equipment combinations, including steps such as selecting equipment combinations, analyzing the menu for equipment use and time, calculating ESM, and selecting the optimal combination.
Project 1: Results

Selection of Optimal Combination

![Graph showing change in total time per day vs. change in ESM for different burner combinations.]

- 1 burner
- 2 burners
- 3 burners
Project 1: Results

Selection of Optimal Combination

Best 2 combinations:
- 2 burners, 1 oven
- 2 burners, 2 ovens

Highest ratio:
\[
\frac{\% \text{ Change in total time}}{\% \text{ Change in ESM}}
\]
**Project 1: Results**

**Selection of Optimal Combination**

- Combine total time/ESM data with crew flexibility index
- Crew flexibility index: return on investment (potential value obtained from additional resources)

<table>
<thead>
<tr>
<th>Best equipment combinations</th>
<th>% Change in total time</th>
<th>% Change in ESM</th>
<th>Crew flexibility index</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (2 burners, 1 oven)</td>
<td></td>
<td>0.78</td>
<td>2.75</td>
</tr>
<tr>
<td>4 (2 burners, 2 ovens)</td>
<td></td>
<td>0.73</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Project 1: Results

Selection of Optimal Combination

• Combine total time/ESM data with crew flexibility index
• Crew flexibility index: return on investment (potential value obtained from additional resources)

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Optimal combination: 2 burners, 2 ovens
Project 1: Conclusions

Optimal Equipment Combination

- 2 burners
- 2 ovens

- 2nd highest ratio of total time: ESM
- 2nd highest crew flexibility index

Compared to 1 burner, 1 oven
  - Total time saved: 59 min per day (7%)
  - ESM increased: 866 kg (9%)

- Results can be used in planning and optimizing food systems for long duration missions

- Future work: equipment design, recipe simplification, food system logistics and feasibility
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Project 2: Background

Mass Reduction Technology Development task
(Monica Leong, in progress)

**Key Question:** Is it possible to develop recipes that are high calorie, nutritious, good tasting, safe to eat, and have a reduced mass?

**Answer:** Yes! One example: Italian Herb Flat Bread
Project 2: Objective

Key Question: What production process could be used to make Italian Herb Flat Bread on a larger-scale for the ISS?

Objective: Propose a lab-scale, ISS production process for Italian Herb Flat Bread

- Ability to produce 200 servings in one 8-hour period
- Consistent weight: <5% variation from target
- Consistent quality: equivalent sensory overall acceptability, texture, and water activity as prototype
- Use Space Food Systems Laboratory personnel and equipment (minimize capital investment)
Project 2: Methods

- Determine main unit operations and scale-up options
  
  1. Ingredient preparation
  2. Mixing
  3. Rolling, cutting into single-serving
  4. Baking

- Test the scale-up options to select the most feasible ones
- Develop a production process
Project 2: Production Process

1. Ingredient preparation
   - Yeast, sugar, warm water (105–110°F)
   - Rest for 5 min

   ![Ingredient preparation images]

   - Dry ingredients: bread flour, salt, dough conditioners, gum, preservative, herbs
   - Mix for 0.75 min, speed setting 1

   ![Mixing ingredients images]

   - Wet ingredients: shortening, preservative, glycerine
Project 2: Production Process

2. Mixing to form dough
   - Combine dry, wet ingredients
   - Mix for 3.75 min at speed setting 1

3. Rolling and preparing single servings
   - Weigh out one serving (200 calories, ~64 g) and roll into circle (1/16” thick)
   - Poke holes in a star pattern using a fork
Project 2: Production Process

4. Baking
   - Temperature: 325°F
   - Time: 15 min
   - Rotate tray in the middle of baking time

5. Quality Control
   - Water activity, moisture content
   - Texture
   - Color
   - Sensory
Project 2: Production Process

5. Quality Control
   - **Texture analysis**: blade/cut compression test
   - Measure maximum force, work due to shear
   - 6 replicates
Project 2: Time Management

- 4 people on 2 teams, will rotate jobs to reduce fatigue
- Batch size 50 servings (~7.7 lbs), each team rolls 25 servings/batch
- Perform process 4 times to reach 200 servings (total ~6 hours)

<table>
<thead>
<tr>
<th>Team 1</th>
<th>Team 2</th>
<th>Total time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person 1</td>
<td>Person 3</td>
<td></td>
</tr>
<tr>
<td>Person 2</td>
<td>Person 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weigh ingredients (50 serv.)</td>
<td>Weigh out pieces (25 serv.)</td>
<td>30</td>
</tr>
<tr>
<td>Mixing to form dough (50 serv.)</td>
<td>Roll out pieces (25 serv.)</td>
<td>5</td>
</tr>
<tr>
<td>Weigh out pieces (25 serv.)</td>
<td>Poke holes with fork (25 serv.)</td>
<td></td>
</tr>
<tr>
<td>Roll out pieces (25 serv.)</td>
<td>Poke holes with fork (25 serv.)</td>
<td></td>
</tr>
<tr>
<td>Poke holes with fork (25 serv.)</td>
<td>Bake bread (50 serv.)</td>
<td></td>
</tr>
<tr>
<td>Bake bread (50 serv.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Project 2: Conclusions

Key process steps:
1. Weigh, prepare ingredients
2. Mix ingredients to form dough
3. Weigh and roll single serving pieces
4. Bake the bread pieces
5. Quality control tests

200 servings can be produced in 8 hours with 4 people
- Process steps 1–4: ~6 hours
- Key quality control tests for each batch (water activity, texture): ~1 hour
- Breaks for workers: ~1 hour (30 min lunch and two 15 min breaks)

Results can be used in creating a refined ISS production process for the bread in the future

Future work: production process test, packaging study to optimize vacuum level, sensory (in progress)
Acknowledgements

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Thank You!