Advanced Food Technology
Space Food Systems Laboratory

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Mentors: Vickie Kloeris, Maya Cooper

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About Me

Education

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

Hometown: Houghton, MI
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
### Project 1: Results

#### 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>![Burner Image]</td>
<td>![Oven Image]</td>
</tr>
<tr>
<td>2</td>
<td>![Burner Image]</td>
<td>![Oven Image]</td>
</tr>
<tr>
<td>3</td>
<td>![Burner Image]</td>
<td>![Oven Image]</td>
</tr>
<tr>
<td>4</td>
<td>![Burner Image]</td>
<td>![Oven Image]</td>
</tr>
<tr>
<td>5</td>
<td>![Burner Image]</td>
<td>![Oven Image]</td>
</tr>
<tr>
<td>6</td>
<td>![Burner Image]</td>
<td>![Oven Image]</td>
</tr>
</tbody>
</table>

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**Flowchart:**
- Select equipment combinations
- Analyze the menu for equipment use and time
- Calculate ESM
- Select the optimal combination
Project 1: Results

Selection of Optimal Combination

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

Hypothesized trend

Best case
Project 1: Results

Selection of Optimal Combination

[Graph showing change in total time per day (%) against change in ESM (%)]

- 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>0.78</td>
<td></td>
<td>2.75</td>
</tr>
<tr>
<td>4 (2 burners, 2 ovens)</td>
<td>0.73</td>
<td></td>
<td>3.5</td>
</tr>
</tbody>
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Project 1: Results

Selection of Optimal Combination

- Combine total time/ESM data with crew flexibility index
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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
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°F–110°F)
   - Rest for 5 min

   ![Ingredient preparation](image1)

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

   ![Dry ingredients](image2)

   - Wet ingredients: shortening, preservative, glycerine

   ![Wet ingredients](image3)
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
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 2</td>
<td>Person 3</td>
</tr>
<tr>
<td>Weigh ingredients (50 serv.)</td>
<td>Mixing to form dough (50 serv.)</td>
<td>Weigh out pieces (25 serv)</td>
</tr>
<tr>
<td>30</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Roll out pieces (25 serv)</td>
<td>Poke holes with fork (25 serv)</td>
<td>Roll out pieces (25 serv)</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Bake bread (50 serv)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</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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