OBJECTIVES

Current spaceflight foods were evaluated to determine if their nutrient profile supports positioning as a functional food and if the stability of the bioactive compound within the food matrix over an extended shelf-life correlated with the expected storage duration during the mission. Specifically, the research aims were:

Aim A. To determine the amount of each nutrient in representative spaceflight foods immediately after processing and at predetermined storage time to establish the current nutritional state.

Aim B. To identify the requirements to develop foods that stabilize these nutrients such that required concentrations are maintained in the space food system throughout long duration missions (up to five years).

Aim C. To coordinate collaborations with health and performance groups that may require functional foods as a countermeasure.

KEY CONCEPTS

Functional foods, according to the American Dietetic Association, include whole foods and fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis, at effective levels.


The unavailability of fresh foods, fruits, and vegetables in the spaceflight food system makes it critical to understand the stability and capability to deliver bioactive compounds (carotenoids, flavonoids, phenolics, and tannins) in a shelf-stable food system over time.

Inira and Mohammadi (2012) showed that thermal processing degrades most flavonoids and that freeze-drying was less aggressive that hot air drying but still resulted in flavonoid losses.


METHODS

FOOD SYSTEM ANALYSES

A prospective list of spaceflight foods, thermo-stabilized and freeze-dried, was generated. The foods were pulled just after production, taken from inventory if the items were less than 3 months old, or specially produced in a smaller batch and freeze-dried to spaceflight specifications in the Space Food Systems Lab. The tested food items are listed in Table 1.

Food samples were sent to the Food Composition Laboratory of the Linus Pauling Institute at Oregon State University (Corvallis, OR) for bioactive compound analysis. The following tests were conducted:

- Vitamin K (HPLC)
- Vitamin E (HPLC)
- Vitamin C (HPLC)
- Carotenoids (HPLC)
- Sterols (HPLC)
- Phenolic, anthocyanins and antioxidants (Spectrophotometric, HPLC)
- Mineral analysis (ICP)

SHELF LIFE STUDIES

Duplicate samples of the food were placed in 4°C, 21°C, and 35°C environmental chambers within the Space Food Laboratory for storage. After 3 months of storage samples were pulled from the 35°C chamber for repeat analysis. After 6 months of storage, samples were pulled from all three chambers and submitted for repeat analysis.

The stability assessment of the bioactive compounds will proceed over the course of two years. At the one-year storage time point, the food will be pulled from the 4°C, 21°C and 35°C chamber and undergo repeat analysis. Food stored at 4°C and 21°C will be analyzed again at the two-year time point.

RESULTS

Table 1. Selected spaceflight foods for bioactive compound stability study

<table>
<thead>
<tr>
<th>Food</th>
<th>Carotenoids</th>
<th>Flavonoids</th>
<th>Sterols</th>
<th>Fatty acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherry Blackberry Cobbler</td>
<td>31.23</td>
<td>28.65</td>
<td>28.80</td>
<td>28.27</td>
</tr>
<tr>
<td>Wild Rice Noodles</td>
<td>31.00</td>
<td>28.50</td>
<td>28.60</td>
<td>28.50</td>
</tr>
<tr>
<td>Blueberries</td>
<td>31.50</td>
<td>28.00</td>
<td>28.70</td>
<td>28.30</td>
</tr>
</tbody>
</table>

The initial results showed that the flavonoid quantities are contributed as follows: Strawberries > Granola with Blueberries > Cherry Blackberry Cobbler > Sweet and Savory Kale.

Table 2. Sterol content of spaceflight food during storage at different temperature

<table>
<thead>
<tr>
<th>Food</th>
<th>EPA (mg/100g)</th>
<th>DHA (mg/100g)</th>
<th>4°C (mg/100g)</th>
<th>21°C (mg/100g)</th>
<th>35°C (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmon</td>
<td>1.72</td>
<td>0.96</td>
<td>1.84</td>
<td>1.85</td>
<td>1.79</td>
</tr>
<tr>
<td>Oatmega (Dark Mint Chocolate)</td>
<td>10.07</td>
<td>14.04</td>
<td>21.12</td>
<td>21.49</td>
<td>18.42</td>
</tr>
<tr>
<td>Oatmega Dark Mint Chocolate</td>
<td>4.53</td>
<td>6.16</td>
<td>26.82</td>
<td>24.84</td>
<td>21.49</td>
</tr>
<tr>
<td>Wild Rice</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Figure 3. Total Carotenoids content for spaceflight foods after processing and during shelf-life (3 and 6 months)

Figure 4. ALA (n-Linoleic acid) in spaceflight foods after processing and during shelf-life

Figure 5. EPA (Eicosapentaenoic acid) and DHA (Docosahexaenoic acid) fatty acids in spaceflight foods after processing and during shelf-life

CONCLUSIONS

The ability to provision high-phenolics, high-carotenoids, or high-omega-3 foods within the spaceflight food system was demonstrated by the identification of the target foods and their initial chemical analysis during the first months of storage. Samples continue under controlled storage and nutrient content will be assessed after one and two years of shelf-life.

- Fish products on the space menu are very limited, therefore omega-3 concentrations are limited.
- The use of foods for health benefit in space could be a challenge with the current menu.
- The identification of foods with high bioactive compound concentrations highlighted the fact that the ISS provisioning menu likely does not have a variety of foods with these compounds.