Challenges and strategies for developing a complete food system for long duration space exploration missions

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Space Food System Considerations

The goal of AFT is to:

Mitigate the Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System during all mission phases

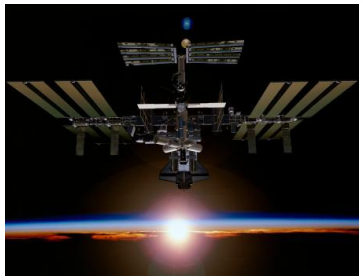
- Nutritional stability that meets spaceflight requirements
- Sensory acceptability and variety compatible with spaceflight challenges
- Processing and packaging to prevent foodborne illness
- Balance with resource constraints

Flexible Path to Mars

http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf

www.nasa.gov/exploration/humanresearch

Food System Constraints



International Space Station:

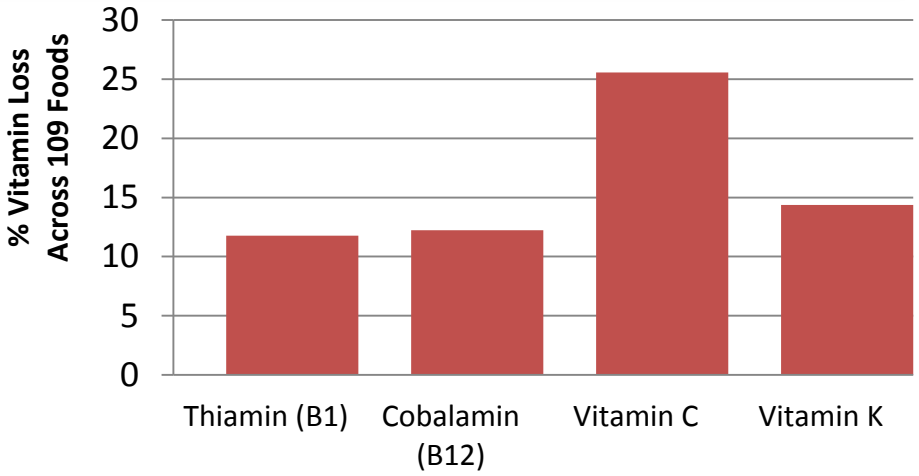
- 6 month microgravity missions
- No refrigerators or freezers for food storage, all food processed and prepackaged
- Regularly scheduled resupply
- Eight to eleven day standard menu cycle augmented by crew preference foods

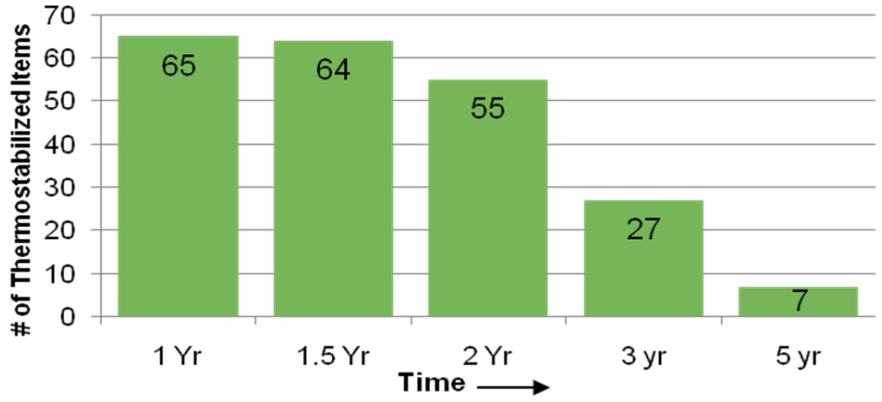
Mars Expedition Scenario:

- 2.5 year mission; microgravity and reduced gravity
- No refrigerators or freezers for food storage
- No resupply; food may be prepositioned to accommodate high mass and volume
- Current food system is mass constraining and will not maintain nutrition/acceptability

Nutrition and Acceptability Impacts of Room Temperature Storage

- Critical micronutrients show concerning degradation in space food system after 1 year of storage.
- Only 7 out of 65 thermostabilized foods are expected to be palatable after 5 years of storage. (Catauro. JFS. 2011)
- Current mass requirement for 3000 kcal per crewmember per day is 1.83 kg. Total mass for a Mars scenario (6 crewmembers, 1095 days) is 12,023 kg.





Potential Food Systems for Mars

Prepackaged

Less Infrastructure
Reduced Micro Risk
Less Crew Time
No Risk of Food Scarcity

Nutrient Degradation
Quality Loss
High Mass and Volume
No customization

Bioregenerative

Lower Food Stowage Mass
Agri-Therapy
Higher Nutrient Density
Fresher Food
Variety / Customization

High Crew Time
Microbiological Risk
Infrastructure
Risk of Food Scarcity

Prepackaged Food – 5 Year Shelf Life Challenge

Focus on nutritional stability, acceptability, health promotion, and mass reduction

Processing

Pressure Assisted Thermal Sterilization (PATS)

Lyophilization Improvement

Microwave Sterilization

3D Printing Technology (SBIR)

Packaging

Improve clarity

Improve barrier

Mass reduction

In Suit Nutritional Delivery System

Formulation

Fortification

Food Matrix

Functional Foods

Meal Replacement

Environment

Atmosphere

Temperature

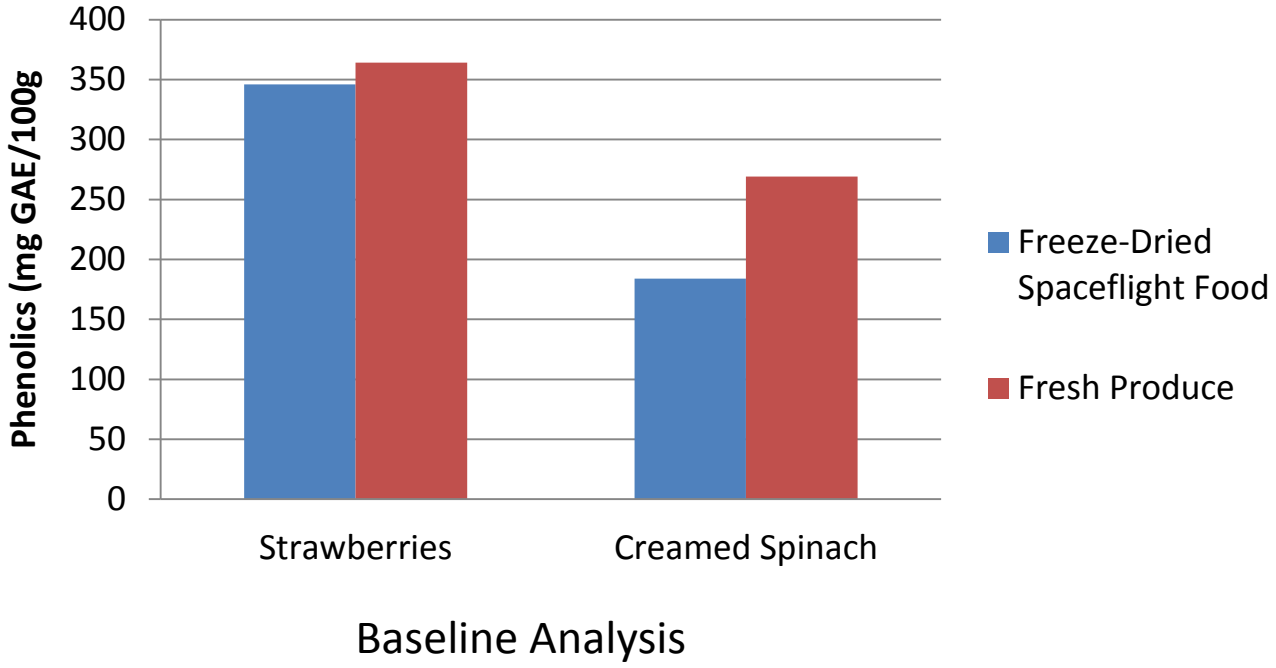
Radiation

Stability of Bioactive Compounds

- Phenolics
- Carotenoids
- Omega-3

- Freeze dried
- Retort Stabilized
- Reduced Moisture

- Current spaceflight packaging
- 4°C, 22°C, limited 35°C
- 2 years

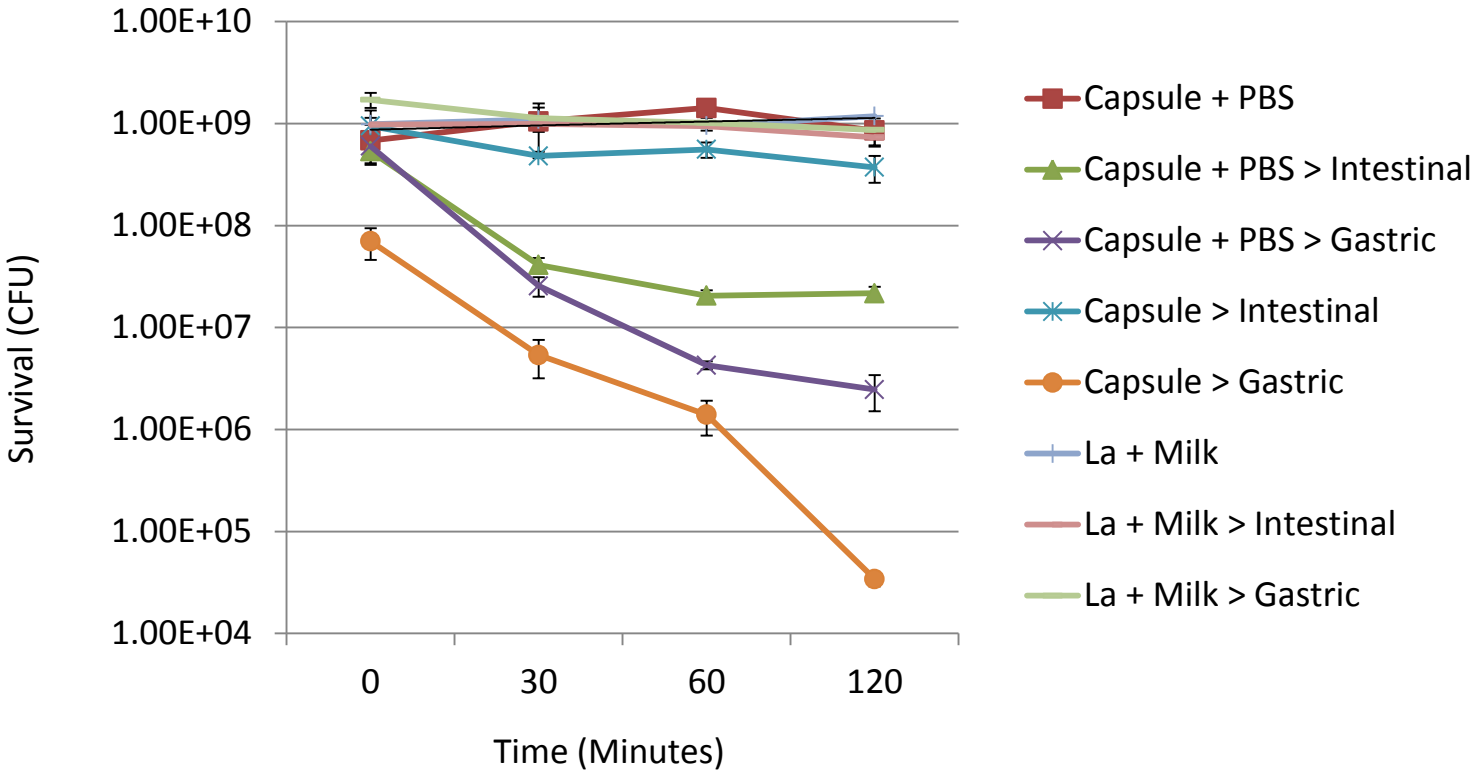


Baseline Analysis

Spaceflight Foods Analyzed at Oregon State University, Linus Pauling Institute
Fresh Produce –Lin et al. 2007. Food Chemistry.

Stability of Probiotics

Nonfat Dry Milk as a Delivery Vehicle



Contingency In-Suit Nutritional Delivery

- Contingency requirement - 144 hour in-suit event:
  - Beverage delivery system and compatible beverage to overcome 4 psi suit pressure and provide nutrition to crew
- Preliminary work:
  - Bag-in-Bag (BiB) prototype equilibrated pressure between suit and pouch
  - Beverage prototype – compatible viscosity, solubility, and macro-nutritional parameters

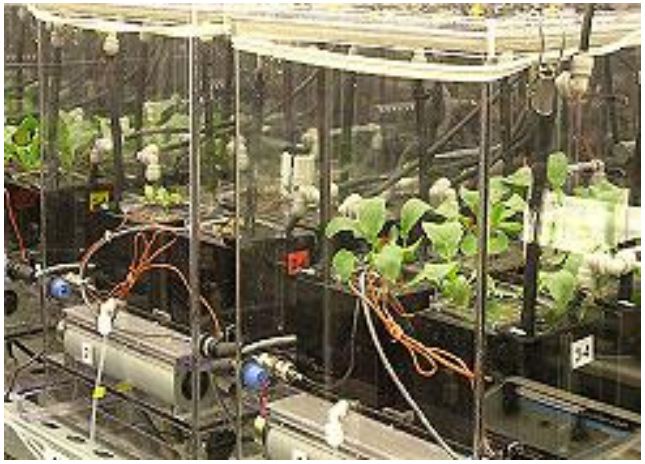
Integrate Bioregenerative Foods

International Space Station

Supplement prepackaged with “Pick and Eat” in microgravity transit

Mars

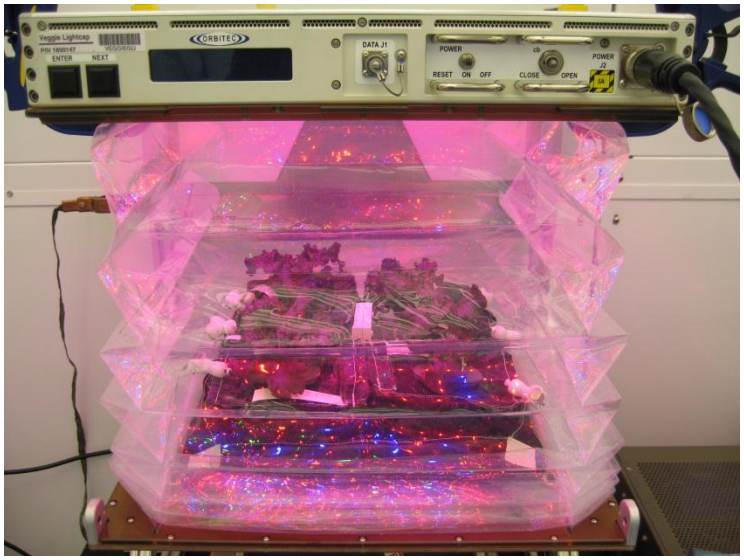
Optimize mission specific phased implementation and balance with prepackaged foods – based on nutrition, acceptability, resources



Research gaps

Infrastructure, resource use, radiation effects, safe handling/micro procedures, system integration, crew time usage

Pick and Eat – VEGGIE chamber



Chamber developed by ORBITEC through Small Business Innovative Research grant –NASA Space Biology

- Initial experiment – validate protocols in flight
- Future experiments – focus on nutrition, acceptability, safety, biomass, resources, crew time and establish pick and eat system on ISS

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Questions