Food in microgravity and beyond: How NASA scientists deliver ‘the right stuff’

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Space Food System Challenges

- No Cold Storage
- Five Year Shelf Life Challenge
- Fully Processed “Sterile” Food System
- No Capability to Transfer Food/Reuse Containers
- Limited Variety
- Limited Upmass/Waste Disposal

Food System Development
Mercury and Gemini 1961-1966

- Highly engineered
  - Cubes and Tubes
  - Freeze-dried
Apollo 1968-1972

- Addition of
  - Thermostabilized cans and pouches
  - Spoon bowls
  - Natural form foods
Skylab 1973-1979

- Continued to include freeze-dried and thermostabilized foods
- Only space missions to include frozen foods
Shuttle 1981-2011

- Higher quality food
- Lighter weight/flexible packaging
- Food trays
- Galley to heat/rehydrate food
International Space Station 1998-present
Space Food Evolution

**Mercury and Gemini**
Tubes and cubes, some rehydratables

**Apollo**
Hot water, utensils and canned foods
Limited, **consistent body mass loss**

**Shuttle**
Approximately 120 menu items
Crew preference menus
**Consistent body mass loss**
ISS Food System: E1-16

- Food packed to crew preference menus, 120 menu items available
- Resupply delays = menus did not coincide with correct crew
- Average **BODY MASS LOSS ~5%**. Results in **significant bone and muscle loss**, cardio deconditioning
ISS Food System: E16-current

8 Standard Menu Categories packed in BOBs

- Breakfast
- Beverages
- Side Dishes
- Vegetables and Soups
- Fruit and Nuts
- Desserts and Snacks
- Rehydratable Meats
- Meat and Fish

Bulk Overwrap Bag (BOB)

- Limited crew specific food, fresh food, condiments available

- New bags are opened every 7 to 9 days based on a crew’s calculated caloric needs.

With this food system and resistive exercise, many crew maintained body mass and bone density.
Humans in Space

HUMAN STATE IN SPACEFLIGHT

- Stress, Anxiety, Depression (Slack et al. 2009)
- Altered cytokine production (Crucian et al. 2014)
- Reduced immune cell function (Crucian et al. 2008)
- Increase in virulence of pathogenic bacteria (Wilson et al. 2007)
- Reduced microbial diversity

POSSIBLE OUTCOMES

- Withdrawal, Conflict
- Major Psychological Event
- Illness
- Performance Decrement
- Death

NEED FOR NONINVASIVE COUNTERMEASURES
Environmental Influences:
- Microgravity
- Sleep shift
- Temperature
- Air Quality
- Light
- Noise
- Exercise
- Antibiotics/Meds
- Pathogens

Food System

Daily environmental influence that is
Greatly Modifiable
and
Has Potential To Promote Health

Food, HUMAN GENETICS AND EPIGENETICS, MICROBIOME

90% of cells in the human are microbe, impacted by external factors.

Dinan and Cryan 2012 Nature Reviews Neuroscience
How do we design a food system that promotes crew health and performance on a mission to Mars?

Safe  
Nutritionally Stable  
Sensory acceptability and variety  
Balance with resource constraints
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
- Possibility of refrigerators or freezers for food storage
- No resupply; food may be prepositioned to accommodate high mass and volume
- Radiation impact is unknown
- Current food system is mass constraining and will not maintain nutrition/acceptability
WHY NOT USE A VITAMIN SUPPLEMENT?
Bioactive Compounds in a Processed Food System

Anthocyanins in Cherry Blueberry Cobbler Across One-Year of Indicated Storage

[mg/100g as gallic acid]

Initial, 3 mos, 35°C, 6 mos, 35°C, 12 mos, 35°C, 6 mos, 21°C, 12 mos, 21°C, 6 mos, 4°C, 12 mos, 4°C
Food Acceptability in a Processed Food System

(Catauro. JFS. 2011)
Food Mass for a Mission to Mars

- 3000 kcal a crewmember a day
- How much does this weigh?

**Mars Scenario:**
6 crewmembers
1095 days

12,023 kg

IF THEY EAT TO ZERO SCENARIO
Potential Long Duration Exploration Food Systems

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

Formulation
- Fortification
- Food Matrix
- Functional Foods
- Meal Replacement
- Variety

Processing
- Pressure Assisted Thermal Sterilization (PATS)
- Lyophilization
- Improvement
- Microwave Sterilization
- 3D Printing/bulk automated processing (SBIR)

Packaging
- Improve clarity
- Improve barrier
- Mass reduction
- In Suit Nutritional Delivery System

Environment
- Atmosphere
- Temperature
- Radiation
- Microgravity
- Partial Gravity
Contingency In-Suit Nutritional Delivery

- Scenario: Vehicle depressurizes, 144 hour crew return in pressurized suit
  - Requirement: Nutrition delivery system to overcome 4 psi suit pressure

- Solutions:
  - Bag-in-Bag Pressure Equilibration
  - Low-residue complete nutrition

Testing performed with the Launch/Entry Suit & Crew Protection Systems Laboratory
Human Exploration Research Analog (HERA)

Environment that simulates exploration mission scenarios

- Isolation / Confinement
- Environment
- Communication Delay

Evaluate food system scenarios

- Variety Limitations
- Controlled Menus
- Human Health and Performance Effects
Radiation

- Sources have drastically different effects on food.
- Food is frozen for treatment.
- The effect of deep space radiation on food is unknown.
Integrate Bioregenerative Foods

International Space Station
Supplement prepackaged with “Pick and Eat,” beginning with Veggie chamber.

Food Safety
Cold Plasma
ProSan Wipes

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