



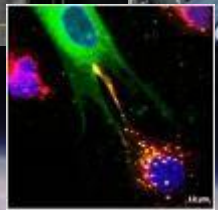
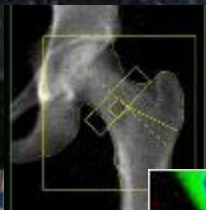
The Sky Is Not The Limit: Taking Sensory Into the Final Frontier

Grace Douglas, Ph.D.

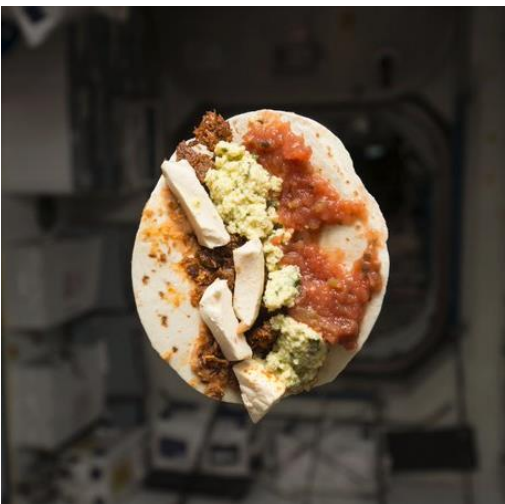
Advanced Food Technology Lead Scientist

Human Research Program

NASA Johnson Space Center

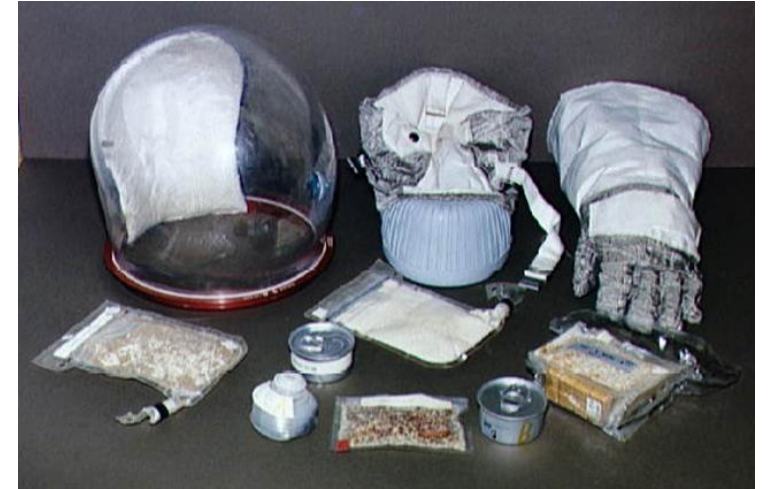
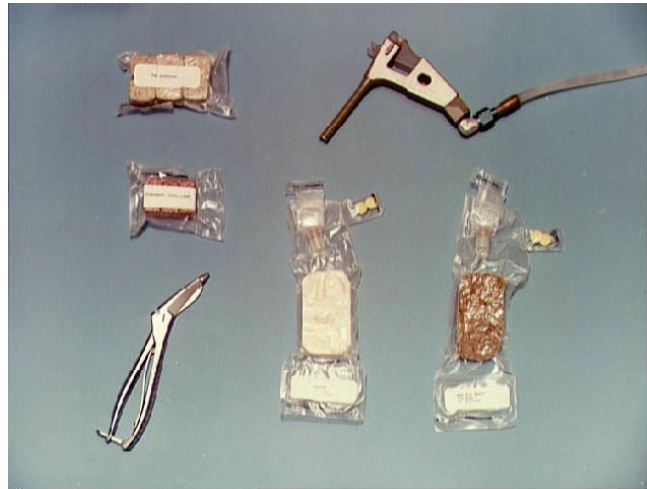


Space Food System Challenges



- Closed System
- Multi-year shelf stability
- No cold storage
- No cooking
- Limit crumbs and free liquid
- Minimal food transfer
- No washing or reuse of containers
- Minimal crew time for food preparation
- Resource Restricted – e.g. 2.5 L water per person per day

Food Systems: Mercury to Apollo



MERCURY

GEMINI

APOLLO



Food Systems: Skylab to early International Space Station



SKYLAB

SHUTTLE

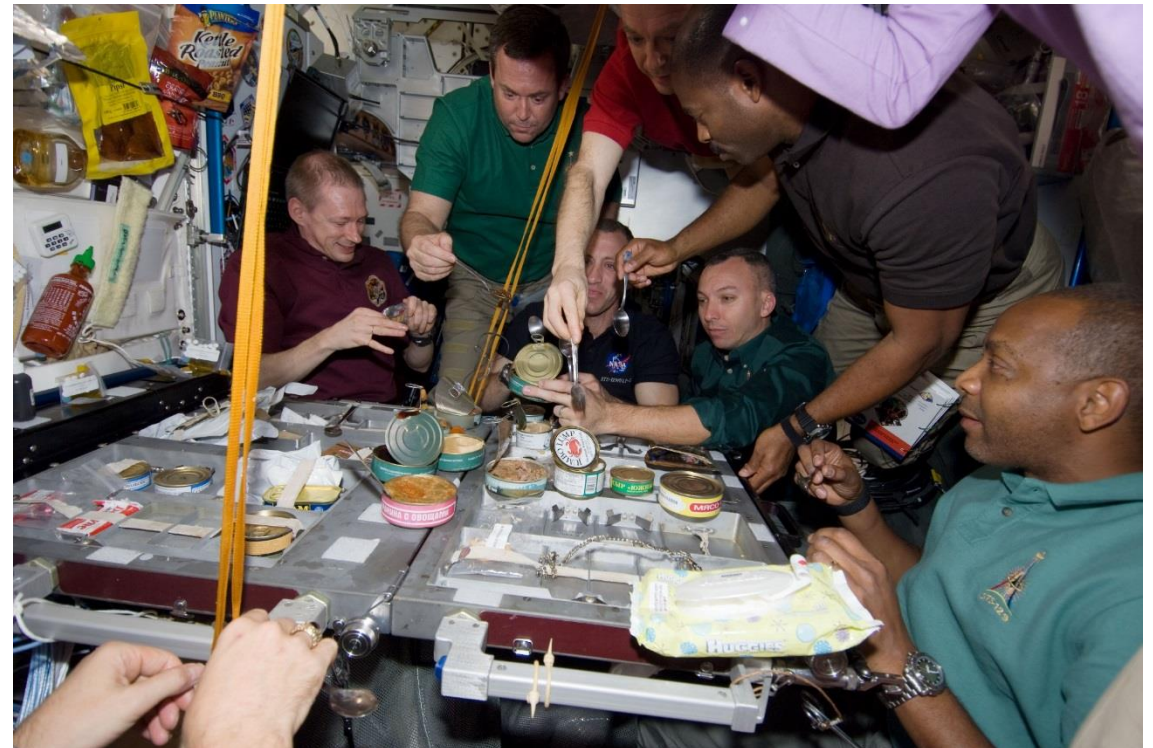
INTERNATIONAL SPACE
STATION



International Space Station 2000-2008



- 130 options, 6 month missions
- Resupply delays = preference menus did not coincide with correct crew
- Average BODY MASS LOSS ~5%.
Results in significant bone and muscle loss, cardio deconditioning
(Smith et al. 2015)





International Space Station 2008-Current



200 options in 8 Standard Menu Categories

1. Breakfast
2. Rehydratable Meats
3. Meat and Fish
4. Side Dishes
5. Vegetables and Soups
6. Fruits and Nuts
7. Desserts and Snacks
8. Beverages



Bulk Overwrap Bag (BOB)

A set of 8 BOBS (one per menu category) will feed a crew of 3 for 7-9 days

Limited crew specific food, fresh food, condiments

No food refrigeration available on ISS

Shelf life of 1-3 years under room temperature storage



Development of Prepackaged Foods



Goal: Exploration Food System that Promotes Crew Health And Performance

Safe

Nutritious

Acceptable

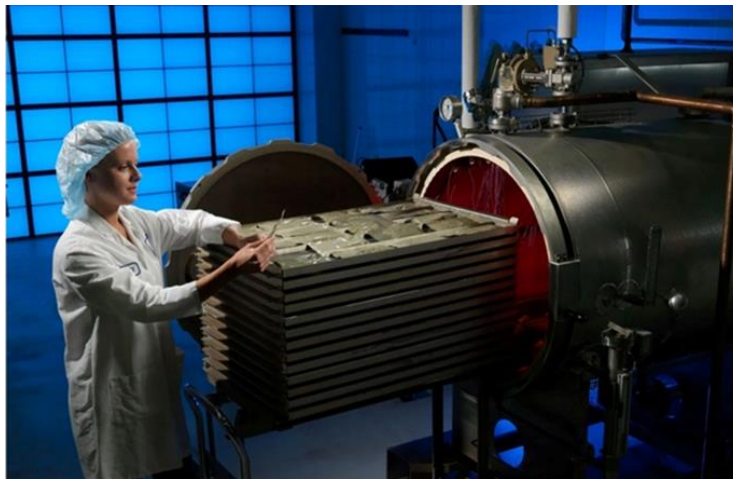
Reduce Resource Use



Types of Food



- Freeze-Dried
- Retort Pouches
- Irradiated Meats



- Low Moisture/Natural Form
- Powdered Beverages



Sensory

- Product Development
 - Meat/fish, fruits, vegetables, sides, desserts
 - Sodium reduction
 - Mass reduction
- Shelf Life
 - Up to 5 years
- Scales
 - 9-pt hedonic scale, general attributes
 - Just about right
 - Difference from control
- Volunteers include end user astronauts





Does Taste Change in Flight?



- Anecdotal
- Limitations to spaceflight experiment
- Potential Contributing Factors:
 - Limited pre-mission food evaluations
 - Fluid shift in microgravity
 - Aroma dissipation in microgravity
 - No cooking
 - Eat out of a package
 - Competing odors

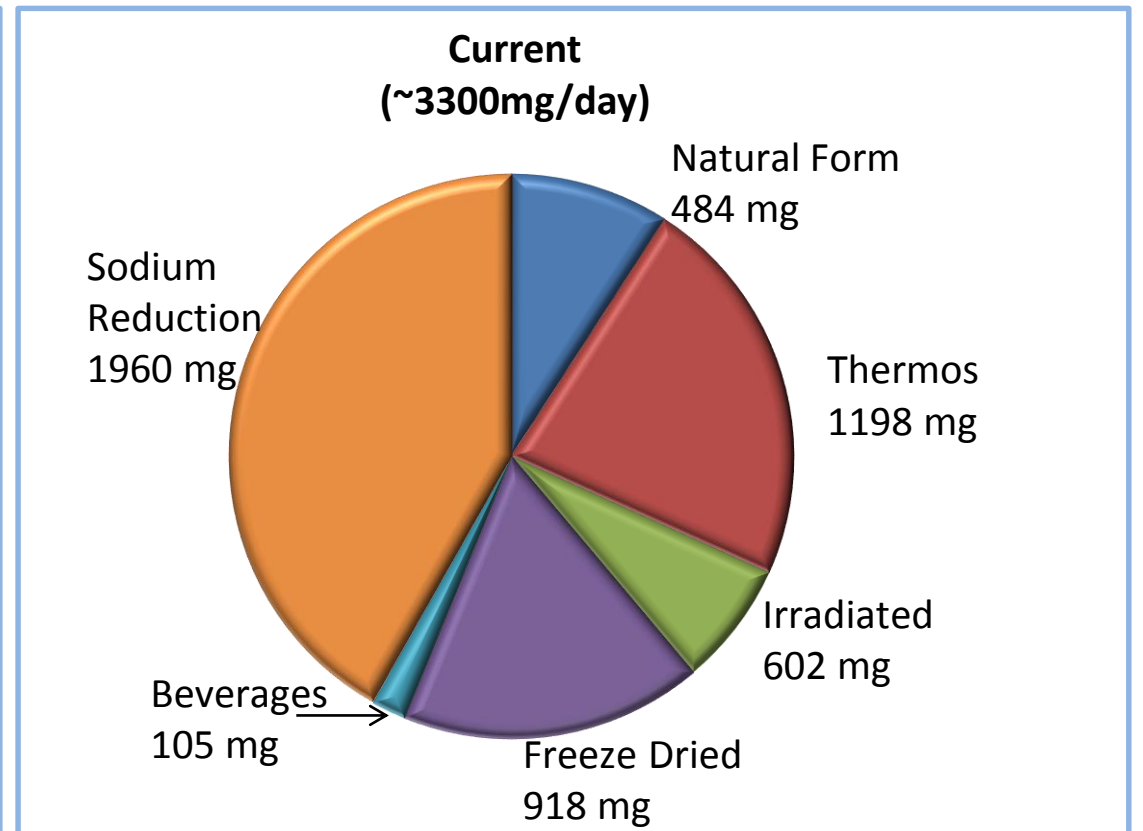
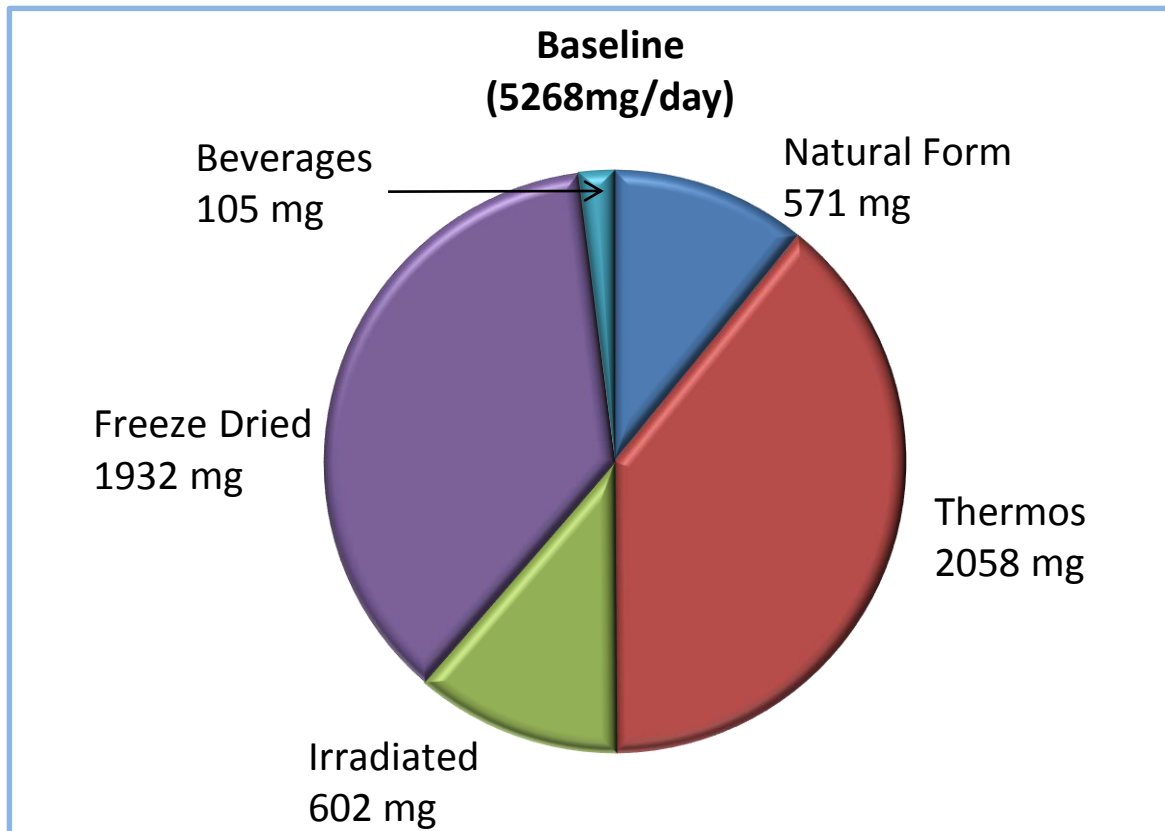




Prepackaged Food Strategies: Sodium Reduction



- Sodium exacerbates bone loss and may be a factor in intracranial pressure induced visual changes
- Reformulated 90 foods on current menu





Salt Reduction Strategy

Before Reform

- Commercial frozen products
- Salted snacks
- Salt added during processing

After Reform

- More products made from scratch; utilized herbs/spices/natural flavoring enhancers to compensate for reduced sodium
- Advantage: Space food does not have to meet a “brand” flavor profile
- Challenge: Food needs to be acceptable to a wide range of consumers because the system is closed/limited choice.

Food Product	% Sodium Reduction
Broccoli Au Gratin (FD)	70
Mexican Scrambled Eggs (FD)	59
Creamed Spinach (FD)	64
Tomatoes and Artichoke (FD)	72
Grilled Chicken (T)	91
Meatloaf (T)	43

Include compounds such as:

- Flavonoids
- Lycopene
- Lutein
- Sterols
- Omega-3 fatty acids

Minimum 2 year Shelf Life:

- Rehydration
- Flavor, texture, color



Freeze-Dried Mango Salad

Mangoes, kiwis, peaches,
walnuts, cranberries



Freeze-Dried Fish Tacos

Barramundi Fish
Mangoes
Green Peppers
Tomatoes



Thermostabilized Pickled Beets

Beets
Olive Oil
Apple Cider Vinegar



Exploration Constraints



International Space Station:

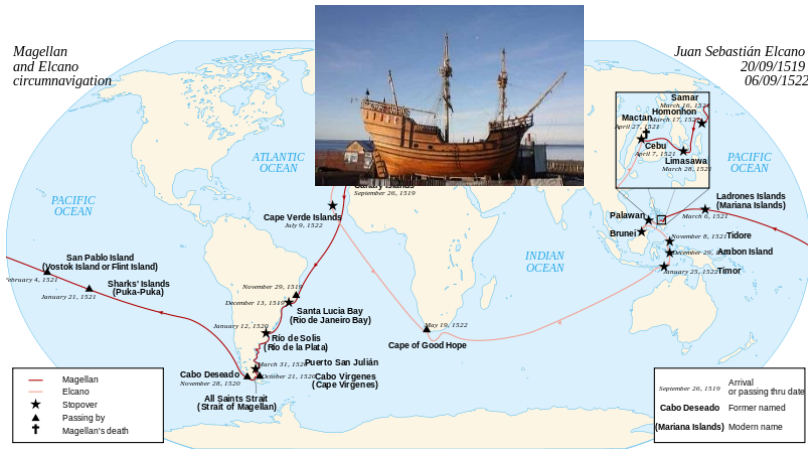
- 6 month microgravity missions
- Radiation impact understood
- Regularly scheduled resupply
- No refrigerators or freezers for food storage, all food processed and prepackaged
- 7-9 day standard menu cycle augmented by crew preference foods



Mars Expedition Scenario:

- 2.5 year mission; micro- and reduced gravity
- Radiation impact is unknown
- No resupply; food may be prepositioned
- Availability of refrigerators or freezers for food storage is undecided
- Current food system is mass constraining and will not maintain nutrition/acceptability

No Precedent for Five Year Shelf Life



https://en.wikipedia.org/wiki/Ferdinand_Magellan



<http://www.scottslastexpedition.org/expedition/journey-to-the-south-pole/>



<https://www.defense.gov/Photos/Photo-Gallery/igphoto/2001323110/>

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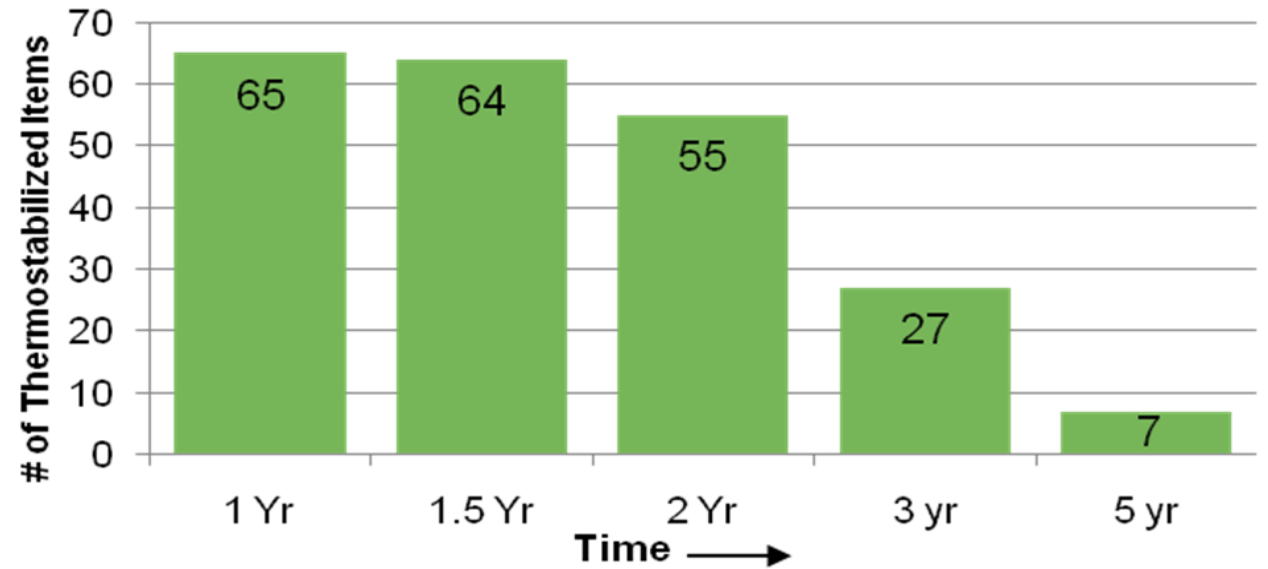
Modern US Military



Exploration Food System Challenge: Acceptability and Variety



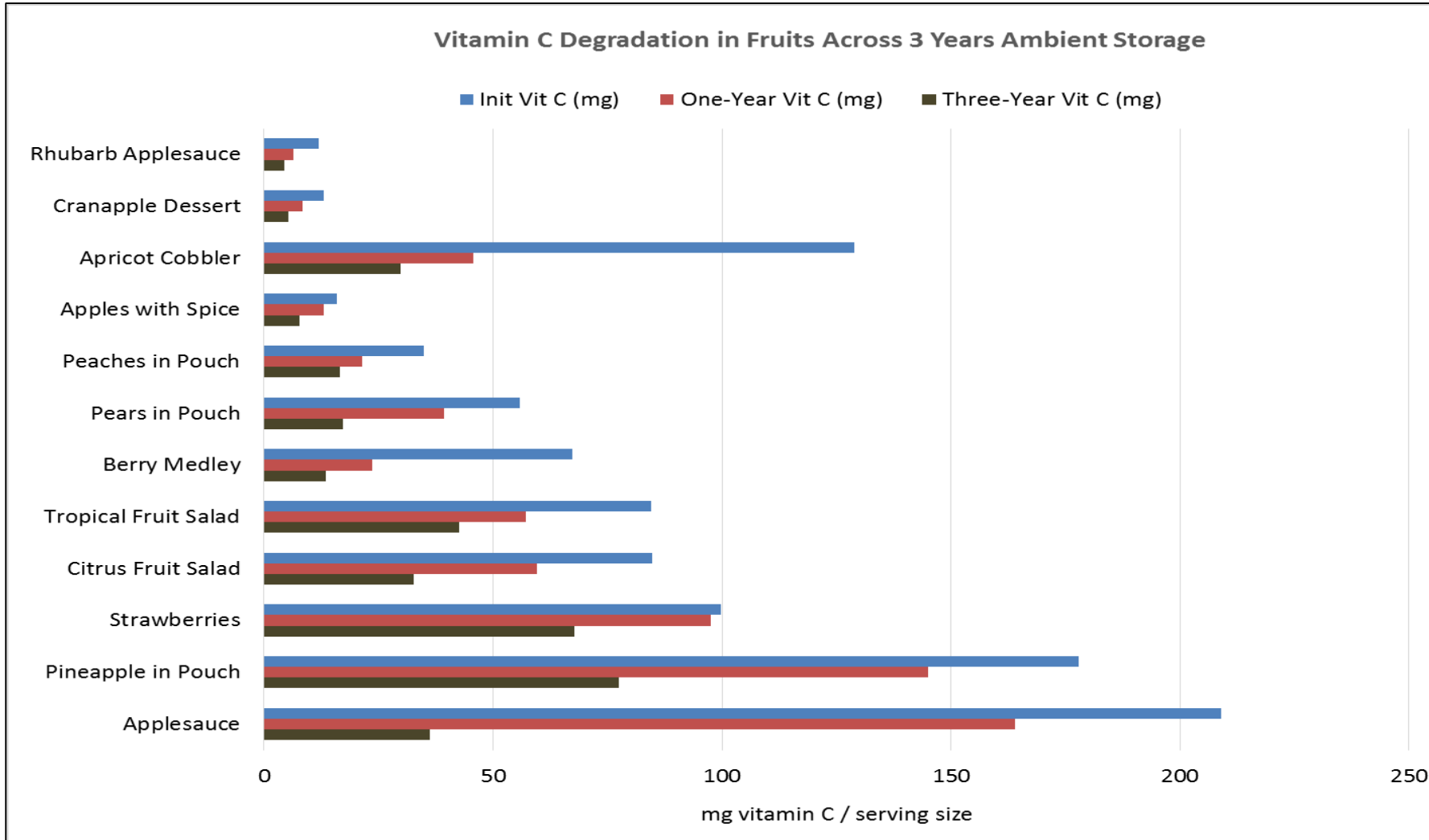
- Food quality relates to health and performance
- Food variety is limited in a closed system
- Food becomes more psychologically important with increasing mission duration



(Catauro. Journal of Food Science. 2011)



Exploration Food System Challenge: Micronutrient Degradation



Cooper et al. npj Microgravity (In Press). 2017.



Prepackaged Food Strategies: 5 Year Shelf Life



Focus on nutritional stability, acceptability, health promotion

Formulation



Fortification
Ingredients and Matrix
Functional Foods
Variety

Processing



Microwave Assisted Thermal Sterilization (MATS)
Lyophilization Improvement
Reduced Moisture

Packaging



Improve barrier
Reduce Mass
Improve Method
Improve Processing Compatibility

Environment



21°C -80°C
Temperature
Atmosphere
Radiation
Microgravity
Partial Gravity

- Orion requires 10% mass reduction
- Meal replacements
 - Nutritional requirements
 - Meet mass and volume requirements
- Mass Reduction Strategies must consider long term acceptability and variety





Nutrition, Acceptability, and Variety Validation



- Shelf Life
 - Nutritional Degradation
 - Sensory Degradation
 - Analytical Changes
- Analog Evaluation
 - Variety Impacts
 - Psychosocial Impacts
 - Physiological Impacts





Food System Key Points



- Establish Safety
- Stabilize Nutrition and Acceptability
 - Ensure Variety
- Reduce Resource Use
- **Promote Human Health and Performance**

