

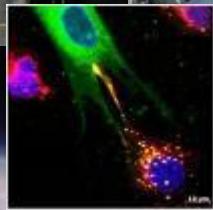
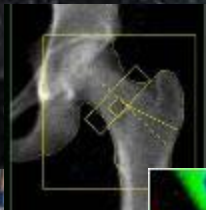
# The Sky Is Not The Limit: Taking Sensory Into the Final Frontier

Grace Douglas, Ph.D.

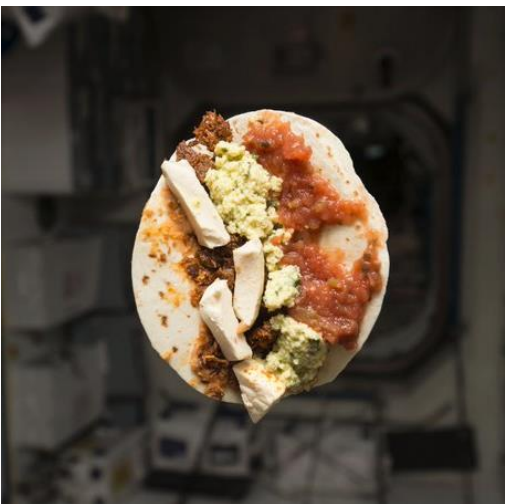
Advanced Food Technology Lead Scientist

Human Research Program

NASA Johnson Space Center

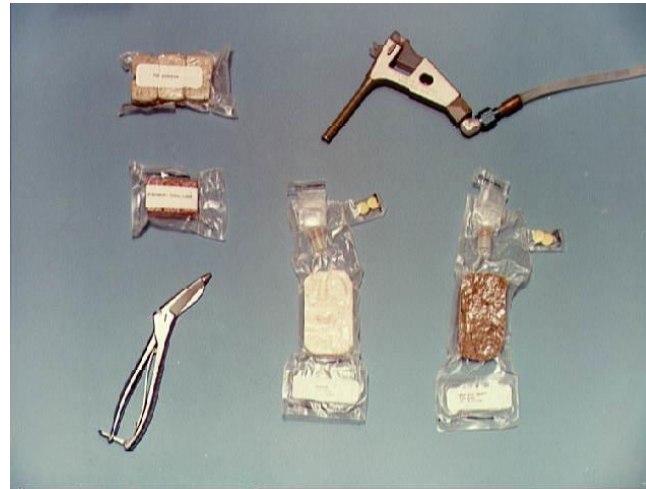


# Space Food System Challenges



- 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



ISS020E007188

SKYLAB

SHUTTLE

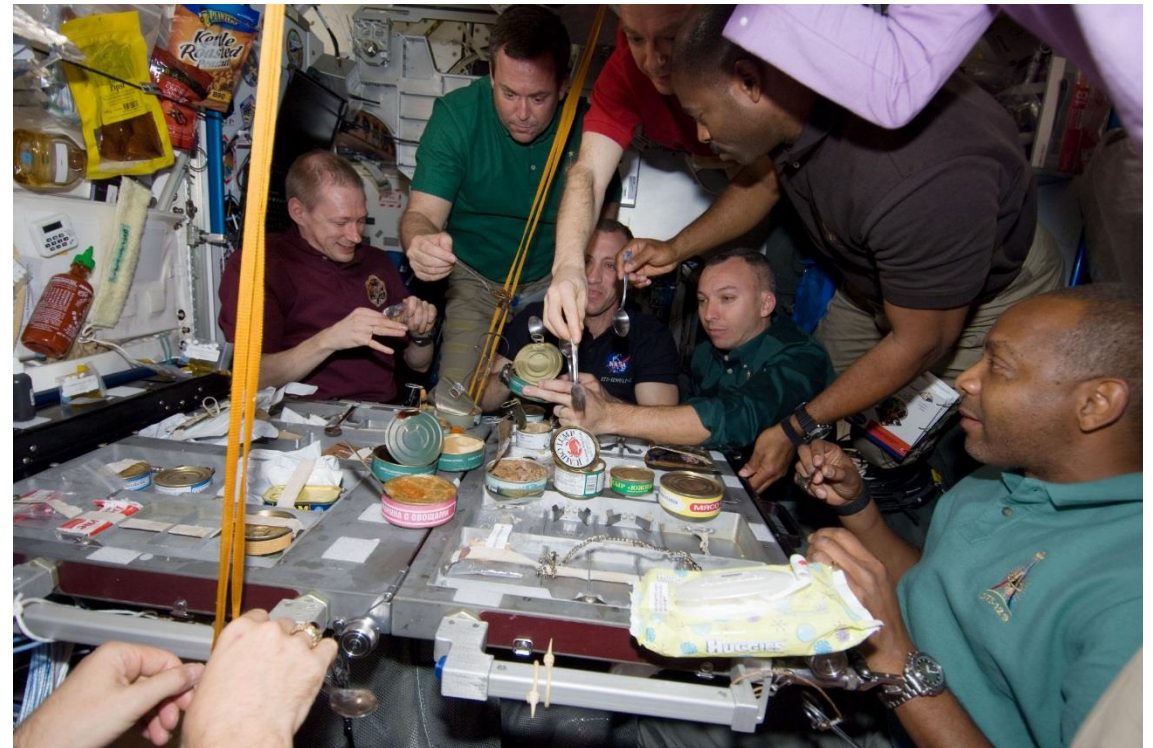
INTERNATIONAL SPACE  
STATION



# 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**

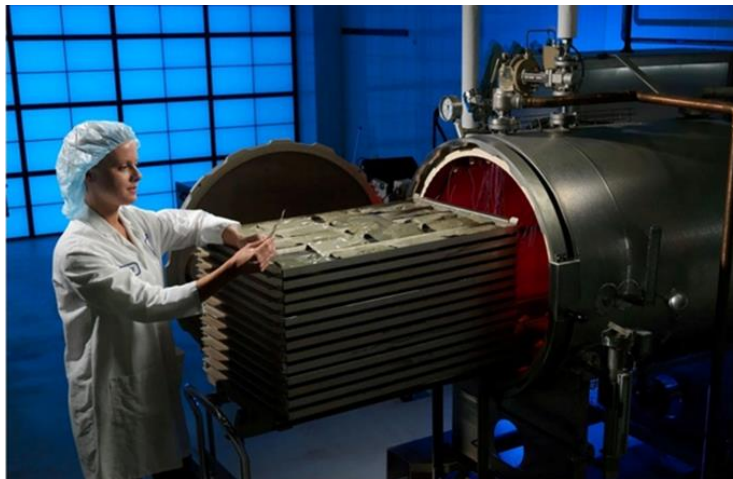
**Reduce Resource Use**



# Types of Food



- Freeze-Dried
- Retort Pouches
- Irradiated Meats



- Low Moisture/Natural Form
- Powdered Beverages





- 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

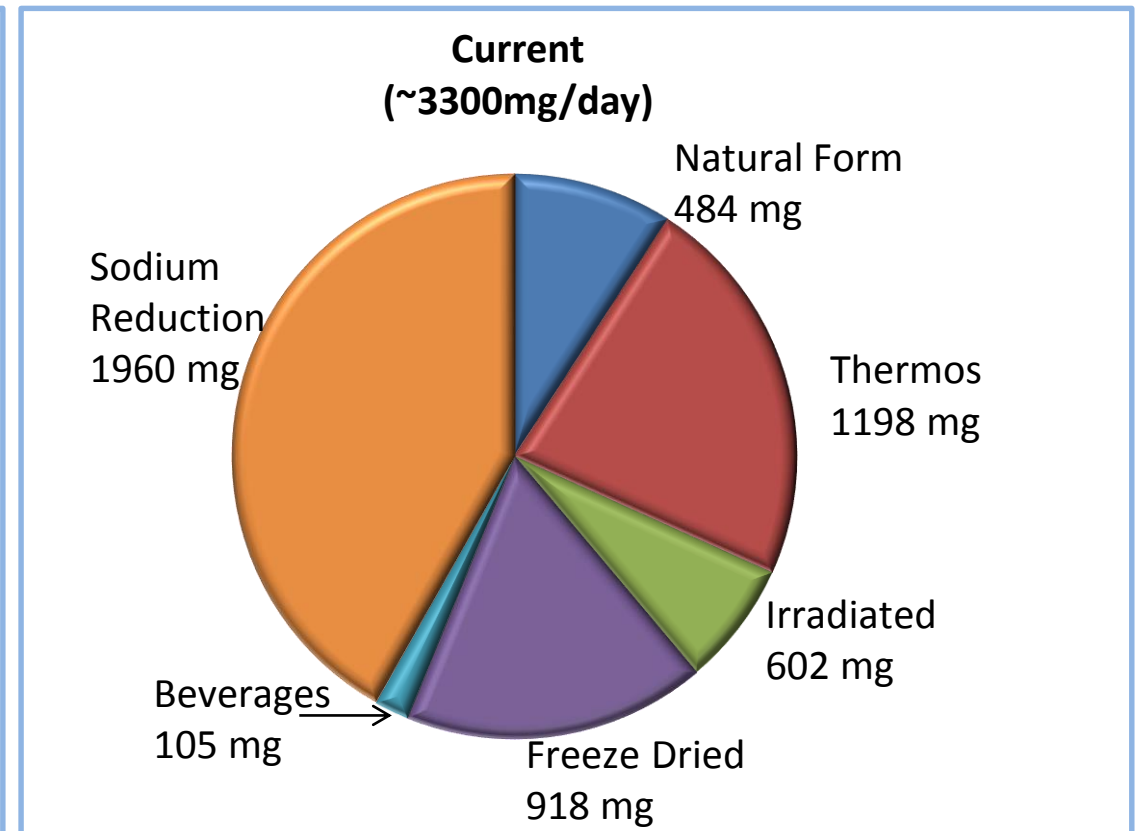
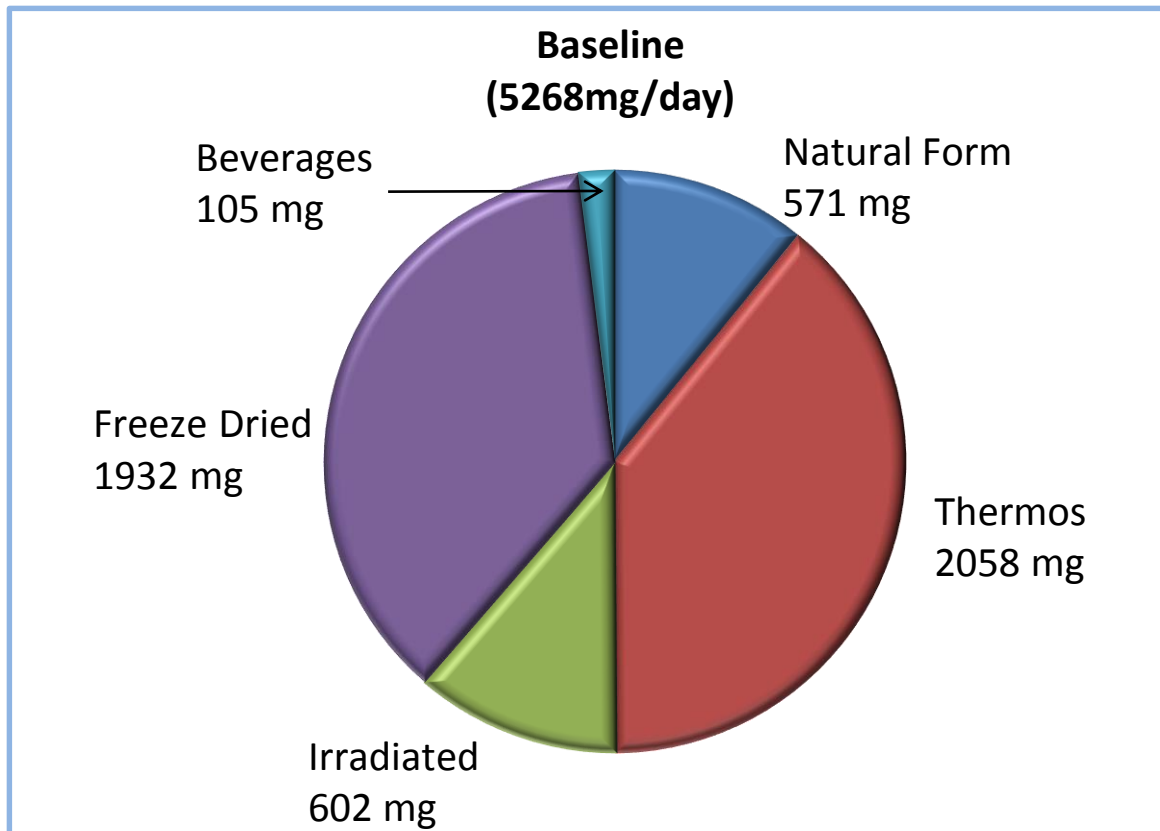




# Prepackaged Food Strategies: Sodium Reduction



- 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:

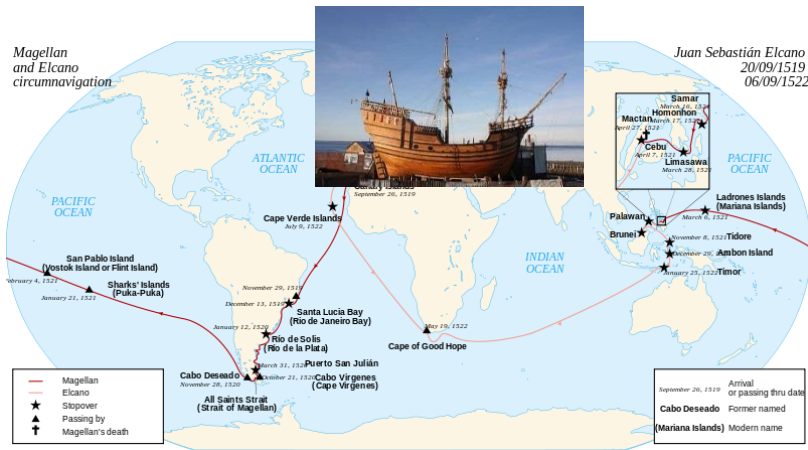
- 6 month microgravity missions
- Radiation impact understood
- Regularly scheduled resupply
- No refrigerators or freezers for food storage, all food processed and prepackaged
- 7-9 day standard menu cycle augmented by crew preference foods



## 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](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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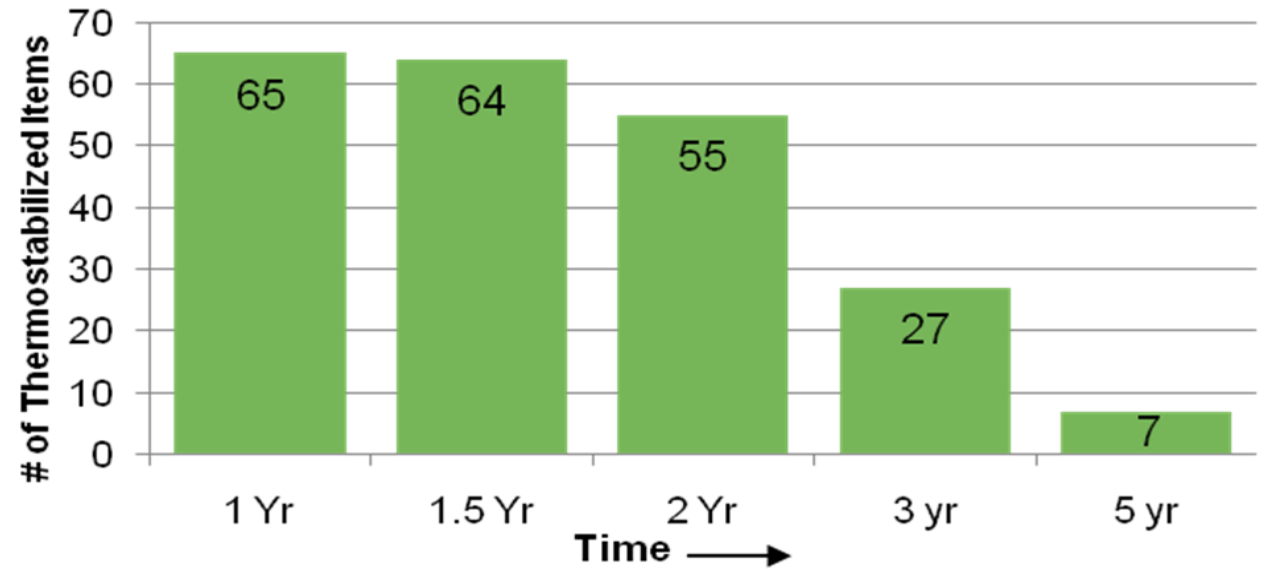
Modern US Military



# 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

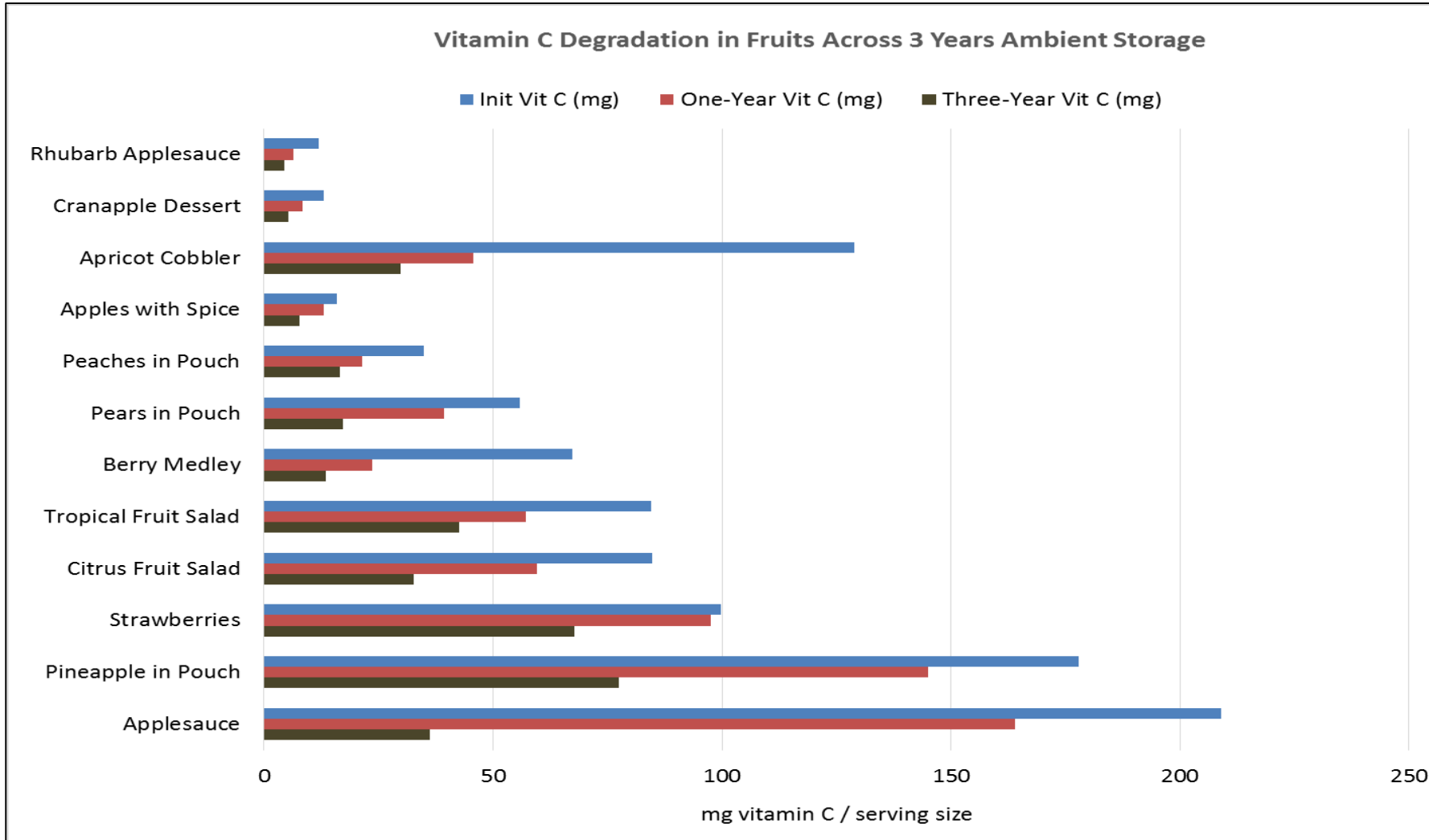


(Catauro. Journal of Food Science. 2011)





# 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**

