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IMPROVEMENT OF SHELF LIFE FOR SPACE FOOD THROUGH A HURDLE APPROACH

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INTRODUCTION

The processed and prepackaged spaceflight food system is a critical human support system for manned space flights. As missions extend longer and farther from Earth over the next 20 years, strategies to stabilize the nutritional and sensory quality of food must be identified. For a mission to Mars, the space foods themselves must maintain quality for up to 5 years to align with cargo prepositioning scenarios. Optimizing the food system to achieve a 5-year shelf life mitigates the risk of an inadequate food system during extended missions.

Because previous attempts to determine a singular pathway to a 5-year shelf life for food were unsuccessful, this investigation combines several approaches, based on science, technological advancement, and past empirical evidence, that will define the prepackaged food system for long duration missions. This study supports the Advanced Food Technology strategic planning process by identifying food processing, packaging, and storage technologies that will be required for exploration missions and the extent that they must be implemented to achieve a 5-year shelf life for the entire food system.

OBJECTIVES

- Determine the ability of a 2-hurdle combination to prevent loss in food quality and nutrition in representative space foods. The first hurdle is either a processing, preparation, ingredient, formulation, or packaging hurdle and the second is reduced-temperature storage (2 or 3 temperatures, depending on the product). Each product will also be stored at 21°C as a control.

Hurdles Examined:
Formulation: Minimally Processed Ingredients for Freeze Drying
Formulation: Percentage of Sodium in Formulation
Preparation: Poultry Cook Process Prior to Freeze Drying
Packaging: Packaging Vacuum Level
Packaging: Desiccant within the Secondary Package
Processing: Microwave-Assisted Thermal Sterilization (MATS),
Processing: Irradiation Processing
Reduced Temperature Storage:
- 80°C storage
- 20°C storage
4°C storage

- Determine the singular impact of reduced temperature storage on select space foods and condiments.

- Determine the impact of processing (retort, irradiation, MATS, vacuum packaging) and storage temperature (-80°C, -20°C, 4°C, 21°C) on the film barrier and seal integrity of current and proposed space food packaging materials.

REPRESENTATIVE FOODS

Twenty-four foods (whole and component) and 9 condiments will be examined in this study (Tables 1 and 2); the results attained on the representative foods will be applied to extrapolate the shelf life of other foods in the space food system and to predict the stability of an alternate, component-based food system.

Table 1: These foods are being evaluated for a formula, preparation, packaging, or processing modification in combination with reduced temperature storage.

	Formulation	Preparation	Packaging	Processing
Italian Vegetables (FD)	X			
Strawberries (FD)			X	
Rice and Chicken (FD)	X			
Turkey Tetrazzini (FD)		X		
Peaches (T)				X
Carrot Coins (T)				X
Indian Fish Curry (T)				X
Grilled Chicken (T)				X
Beef Steak (T)				X

Table 2: These foods are being evaluated under reduced temperature storage.

Single Component Foods	Multi-Component Foods	Condiments
Green Beans (FD)	Vanilla Breakfast Drink (B)	Ketchup
Broccoli (FD)	Sweet & Savory Kale (FD)	Mayonnaise
Shrimp (FD)	Wheat Flat Bread (NF)	Mustard
Chicken Breast (T)	Apricot Cobbler (T)	Barbecue Sauce (Reconstituted)
Quinoa (T)	Tomato Basil Soup (T)	Strawberry Spread
Noodles (FD)		Chili Pepper Paste
Spinach (FD)		Soy Sauce
Potatoes (FD)		Olive Oil
Dried Apricots (NF)		Cheese Sauce
Macadamia Nuts (NF)		

Current processing is indicated as: Freeze Dried (FD), Retort Thermostabilized (T), Natural Form (NF); Beverage Powder (B)

KEY CONCEPT

Hurdle approach is the deliberate combination of several empirically-derived preservative factors – like temperature, water activity, preservatives, nonthermal processing techniques, pH, and removal of oxygen – to improve the microbial stability and safety as well as the sensory and nutritional quality of foods.

Leistner, L. and Gould, G.W., 2002. *Hurdle Technologies: Combination Treatments for Food Stability, Safety, and Quality*. New York, NY: Academic/Plenum Publishers, 194 p.

ANALYSIS METHODS

Samples are being evaluated at 0, 1, 3, and 5 years.

Color analysis is being conducted using the Hunter D25LT Colorimeter (HunterLab, Reston, VA).

Shear force and firmness analyses is being performed on the Texture Technologies TA.HDPlus Texture Analyzer (Texture Technologies, Hamilton, MA).

Nutritional analysis is being performed by a reference laboratory following the Official Methods of Analysis of AOAC International for each micronutrient. Vitamin analyses selection is based on previous nutritional analyses of the selected foods.

Sensory evaluation is being completed within the Space Food Systems Laboratory sensory evaluation center using the untrained sensory volunteers at Johnson Space Center (n ≥ 25). Each sample will be rated on appearance, color, aroma, flavor, texture, and overall acceptability on a 9-point hedonic scale.

Rehydration ratio is being determined by adding the prescribed amount of water for the food (50-100 grams of water at 66°C) to one package and allowing absorption for 15 minutes. The rehydration ratio will be calculated as

$$\text{Rehydration ratio} = \frac{\text{Weight of hydrated sample} - \text{weight of freeze–dried sample}}{\text{weight of freeze–dried sample}}$$

Packaging: Oxygen and water vapor barrier analysis will be tested using MOCON Ox-tran 2/21 (MOCON, Minneapolis, MN) at 50% RH and 73.4°F and MOCON Permatran 3/33 at 90% RH and 100°F, respectively. Mechanical properties, such as Young's modulus and tensile strength, will be analyzed in accordance with ASTM D882 using an Instron®5965 Tensile Testing Machine (Instron, Norwood, MA). Seal integrity and burst strength will be analyzed in accordance with ASTM F88 and ASTM F2054, respectively.

The **end of shelf life** shall be defined for a given product as the point at which (1) the overall acceptability from the volunteer sensory panel declines to below 6.0 on the 9-point hedonic scale and represents at least a 20% decline from the original acceptability rating, (2) any single quality attribute (appearance, odor, flavor, texture) declines below 4.0 on the 9-point hedonic scale, (3) finished goods microbiological hurdles fail to be met for consumption, or (4) package failures compromise ability to safely consume the product. Nutrient data will not be used in shelf-life determination.

STATUS

SFSL PRODUCED FOODS					
	Shelf Life Start	Year 1	Year 3	Year 5	Year 7
Wheat Flat Bread	■	■			
Dried Apricots	■	■			
Macadamia Nuts	■	■			
Vanilla Breakfast Drink	■	■			
Rice and Chicken	■	■			
Italian Vegetables	■	■			
Turkey Tetrazzini	■	■			
Strawberries	■	■			
Sweet and Savory Kale	■	■			
Apricot Cobbler	■	■			
Tomato Basil Soup	■	■			
Component – Chicken	■				
Component – Green Beans	■				
Component – Shrimp	■				
Component – Broccoli	■				
Component – Quinoa	■				
Component – Potatoes	■				
Component – Noodles	■				
Component – Spinach	■				
Condiments (8 total)	■	■			
AMERIQUAL FOODS -- WET PACK FOODS					
	Shelf Life Start	Year 1	Year 3	Year 5	Year 7
Peaches	■	■			
Carrot Coins	■				
Indian Fish Curry	■				
Beef Steak	■				
Grilled Chicken	■				

PRELIMINARY RESULTS

Most products passed sensory evaluation after one year of storage (Fig 1). Mayonnaise (-20°C) was excluded from sensory evaluation due to emulsion separation during freezing. Of the hurdle variables studied, storage temperature, processing technique, and ingredient selection all caused notable changes to food quality. Reduced temperature storage did appear to positively impact some color and nutritional changes. However, some quality shifts were exacerbated by reduced temperature storage (highlighted below).

FIG 1

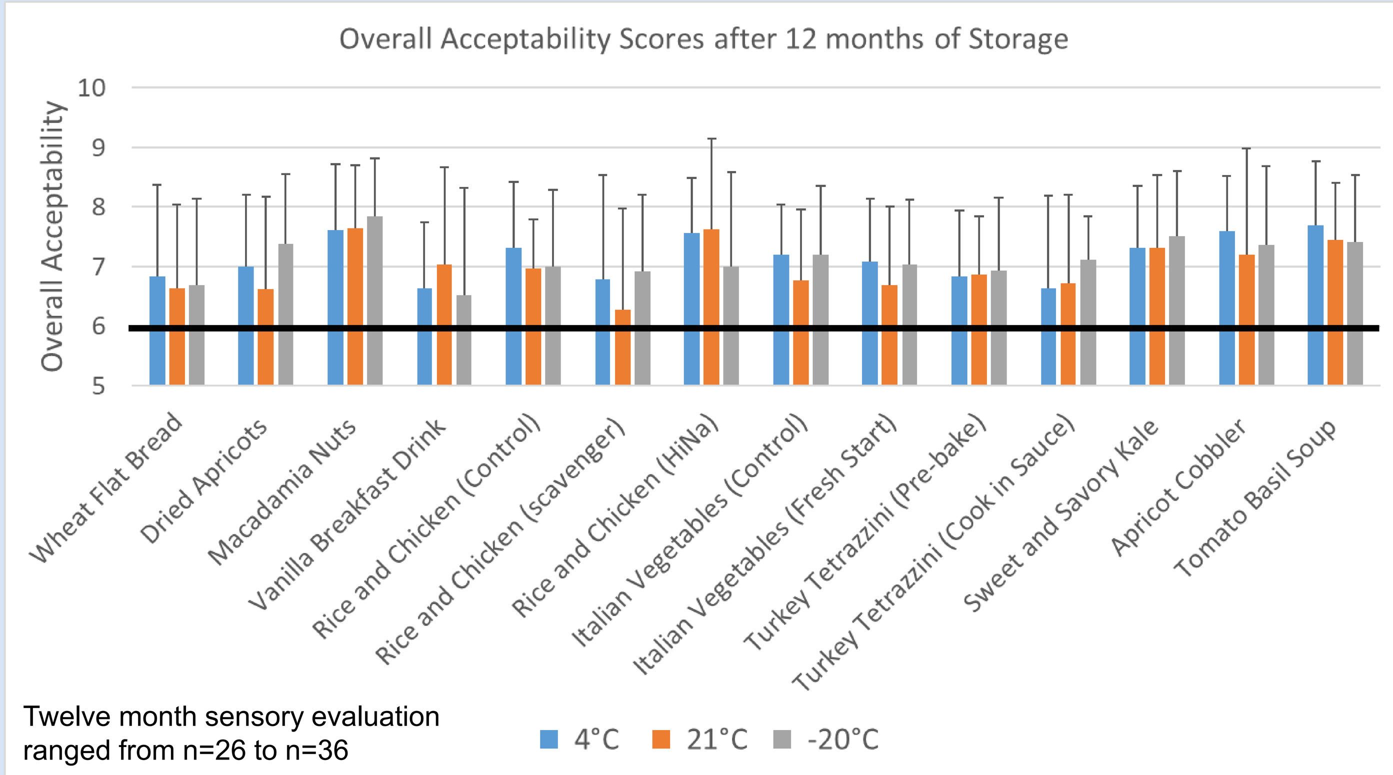
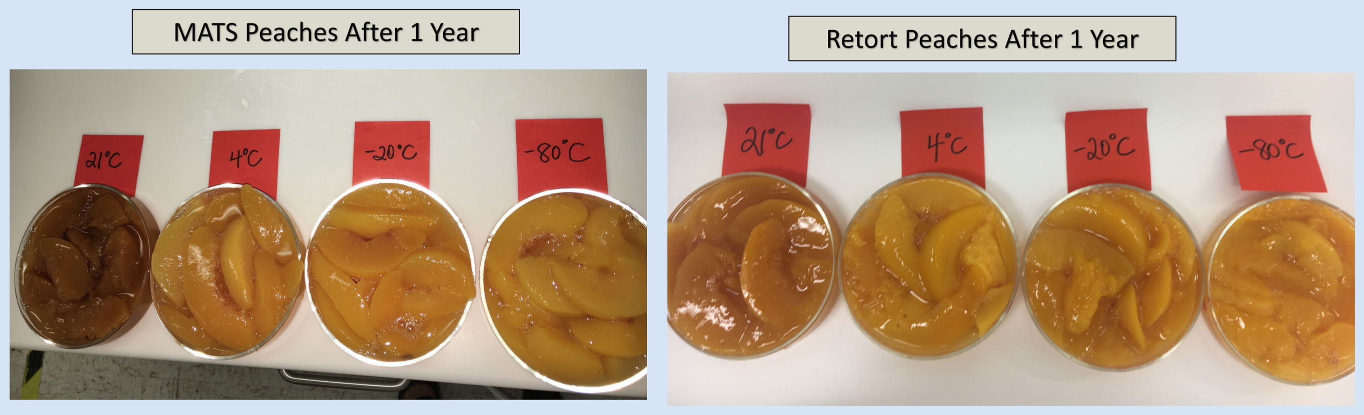
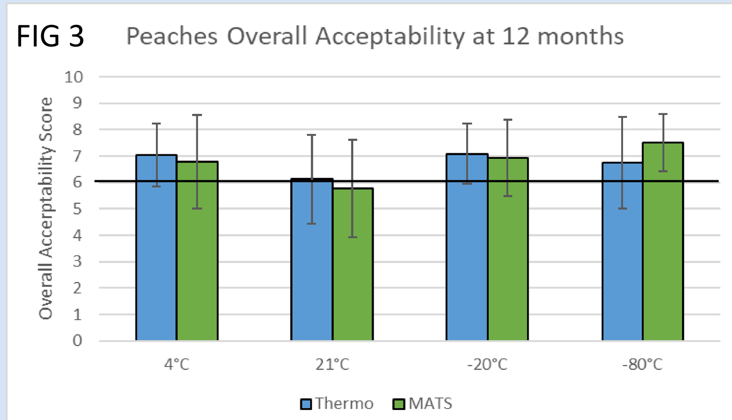
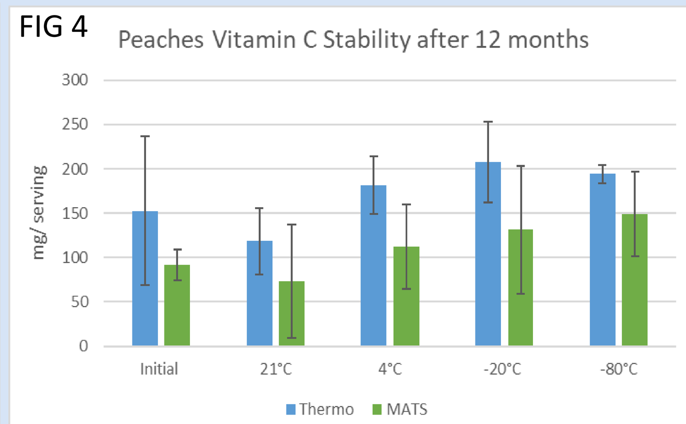
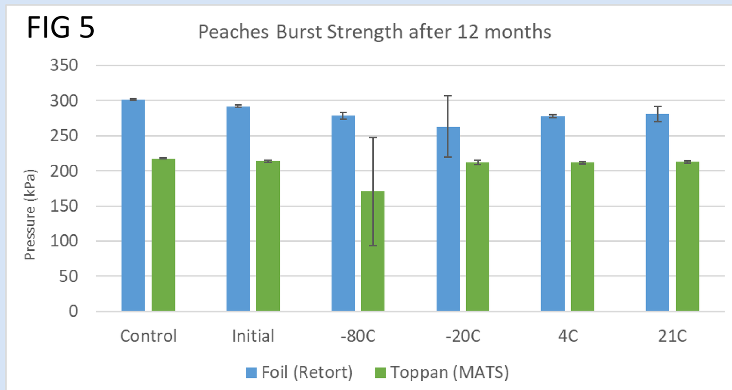


FIG 2









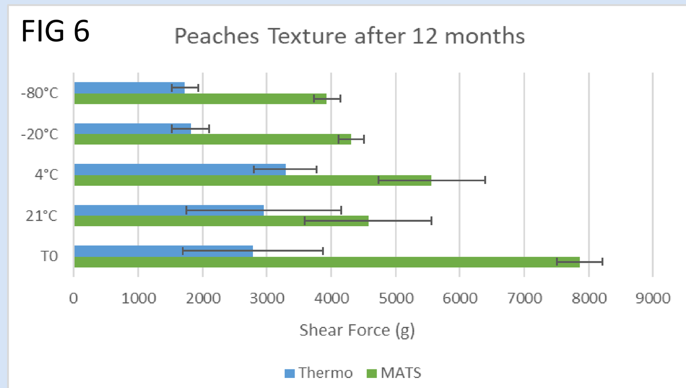


FIG 2: Peaches: Color (top) - Temperature storage and processing method (MATS vs thermo) both impacted color stability over time. In both cases, items stored at ambient temperature experienced the greatest degree of browning, which correlates to diminished sensory acceptability after 12 months of storage (FIG 3). Nutrient Stability (FIG 4) – Retorted items appear to retain higher amounts of vitamin C, despite concerns of heat-induced degradation. Items stored at ambient temperature show higher degrees of degradation, regardless of processing method. Package integrity (FIG 5) – Burst strength of foil pouches is roughly 25% higher than Topan pouches. However, burst strength was not significantly impacted by processing or storage temperature. Texture (FIG 6) – Retort processing resulted in diminished texture initially and after 12 months of storage. Low and ultra-low temperature storage (-20°C and -80°C, respectively) resulted in notable texture degradation.

FIG 7

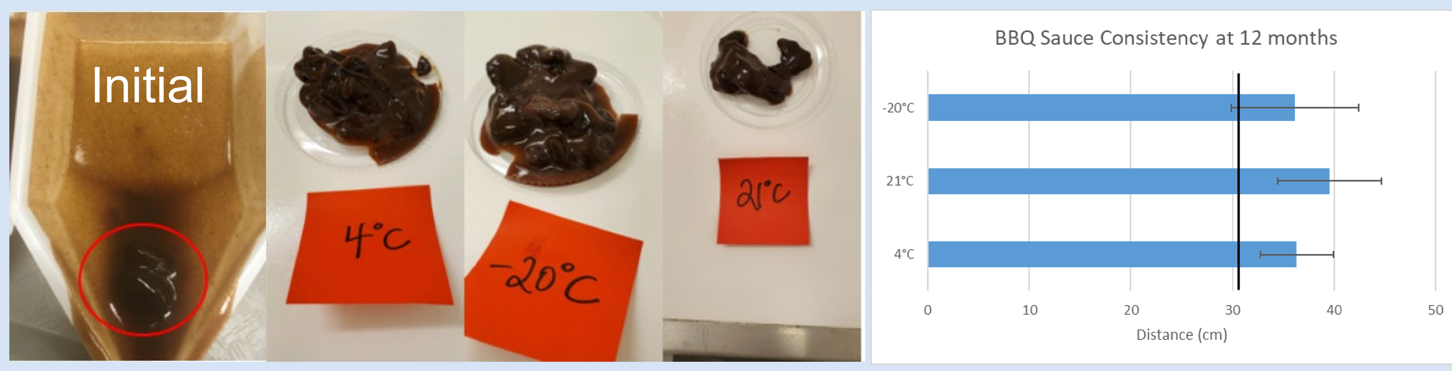


FIG 7. BBQ sauce rehydration was negatively impacted by low temperature storage. However, all items maintained acceptable sensory ratings of 6.00 or higher (out of 9.00 possible points), indicating that panelists did not detect differences in flavor intensity due to poor rehydration. Changes in product consistency progress, regardless of storage temperature.

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