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Effect of Reduced Temperature Storage on Nutrient & Quality Stability in Space Food

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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, to determine their potential to extend the shelf life of the prepackaged food system for long duration missions. This study may identify 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 [-80°C, -20°C, 4°C], depending on the product). Each product will also be stored at 21°C as a control.
- Determine the singular impact of reduced temperature storage on select space foods.
- Extrapolate the shelf life of other foods in the space food system based on the results attained on the representative foods.

FOODS

	Stabilization	Variants
Wheat Flat Bread	Reduced water activity, oxygen scavenger	Storage temperature only
Dried Apricots	Nitrogen-purged vacuum package	Storage temperature only
Macadamia Nuts	Nitrogen-purged vacuum package	Storage temperature only
Apricot Cobbler	Thermostabilized	Storage temperature only
Tomato Basil Soup	Thermostabilized	Storage temperature only
Rice and Chicken	Freeze-Dried	Sodium level, desiccant in package layers, storage temperature
Strawberries	Freeze-Dried	Package vacuum level, storage temperature
Italian Vegetables	Freeze-Dried	Starting ingredients, storage temperature
Turkey Tetrazzini	Freeze-Dried	Cook process for turkey, storage temperature

ANALYSIS METHODS

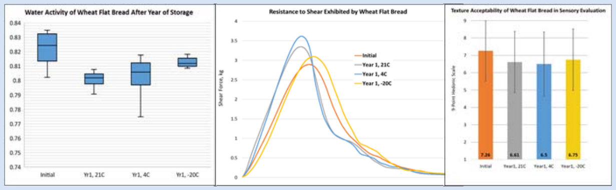
Samples are being evaluated at 0, 1, 3, and 5 years.

Color Analysis	Hunter D25LT/Aeros Colorimeter
Shear Force	Texture Technologies TA.HDPlus Texture Analyzer with blades, probes, and knives compatible with each food
Nutritional Analysis	Reference lab using AOAC approved methods
Sensory Evaluation	Untrained JSC volunteer panel using 9-point hedonic scale for appearance, color, aroma, flavor, texture, and overall acceptability. 1 corresponds to "dislike extremely" and 9 corresponds to "like extremely." 25-40 panelists per evaluation.
Rehydration Ratio	Calculated as the weight of water absorbed under prescribed rehydration conditions divided by the weight of the freeze-dried sample.

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 be used to inform final shelf-life decisions.

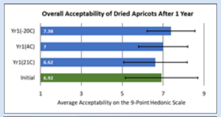
RESULTS / CONCLUSION

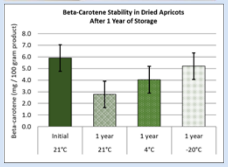
All of the foods achieved and maintained an overall acceptability greater than 6.0 in both initial and year one sensory evaluation. Reduced temperature storage did appear to positively impact some food color and nutritional changes. The benefit of reduced temperature on beta-carotene stability was clearer for Tomato Basil Soup and Dried Apricots than for Apricot Cobbler. However, quality shifts regarding texture progressed in storage regardless of storage temperature. Error bars on the bar graphs reflect the standard deviation between replicates or sensory panelist ratings.

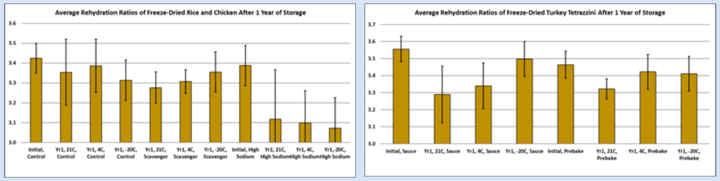


Above: The Wheat Flat Bread water activity decreases with storage time, impacting both required shear force and panelist texture acceptability. The next evaluation, at three years of storage, may clarify if frozen conditions retain a higher water activity.

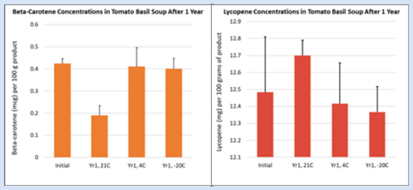
Right: The storage temperature slightly influenced the overall acceptability, but greatly influenced the color and the stability of beta-carotene concentrations in Dried Apricots in the first year of storage.







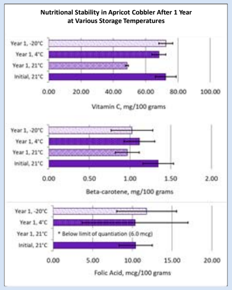
Above: The rehydration ratios of the freeze-dried rice and chicken products indicates directionally lower water-holding capacity with storage time and increased sodium but no clear correlation between rehydration ratio and storage temperature. Despite apparent variations in average rehydration ratios for the Turkey Tetrazzini, the evidence does not support significant differences in these rehydration ratios. Lowered rehydration ratios are indicative of portions of the food remaining dry and hard, eventually causing the product to become texturally unacceptable.

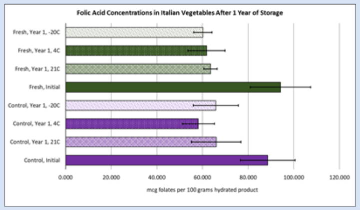


Left: The carotenoids in Tomato Basil Soup exhibited varying stability after one year of storage. Beta-carotene substantially declined in concentration at ambient temperature while no clear temperature effect was noted with lycopene concentrations.

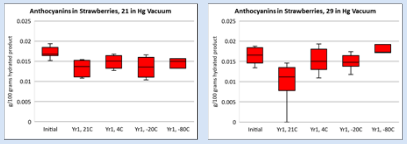
No evidence of change in Macadamia Nuts attributes after one year of storage.

Right: After one year of storage, the vitamin C, beta-carotene, and folic acid concentrations in thermostabilized Apricot Cobbler showed greater stability with lower temperatures though beta-carotene was not fully protected at any temperature condition.





Above: After one year of storage, the vitamin concentrations were not significantly different for vitamin C, beta-carotene, or vitamin K in the Italian Vegetables. However, folic acid concentrations were substantially lower, independent of the storage temperature or vegetable ingredients.



Left: After one year of storage, anthocyanins declined in Strawberries. Higher package vacuum and colder storage temperature resulted in some improved anthocyanin stability.

FUTURE WORK

For the next five years, researchers will continue to evaluate these nine foods along with five additional retort thermostabilized foods, two additional dry foods, eight condiments, and nine single-component food items. Microwave assisted thermal sterilization (MATS) and irradiation will be evaluated against steam retort thermostabilization along with reduced storage temperatures for the effect on shelf life of space foods. Packaging will also be evaluated for material stability over time. Data will inform the requirements for the food system for extended duration missions.

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