Fiscal Year:	FY 2017	**Task Last Updated:**	FY 09/06/2016
PI Name:	Barrett, Ann Ph.D.		
Project Title:	Stabilized Foods for Use in Extended Spaceflight: Preservation of Shelf-Life, Nutrient Content and Acceptability		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Space Human Factors Engineering		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	(1) **HHC**:Human Health Countermeasures		
Human Research Program Risks:	(1) **Food and Nutrition**:Risk of Performance Decrement and Crew Illness Due to Inadequate Food and Nutrition		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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PI Organization Type:	GOVERNMENT	**Phone:**	508-233-4516
Organization Name:	United States Department of the Army		
PI Address 1:	NSDREC, CFD/PORT, RDNS-CFP		
PI Address 2:	U.S. Army Natick Soldier Systems Center		
PI Web Page:			
City:	Natick	**State:**	MA
Zip Code:	01760-5018	**Congressional District:**	7
Comments:			
Project Type:	GROUND	**Solicitation / Funding Source:**	2011 Crew Health NNJ11ZSA002NA
Start Date:	11/01/2012	**End Date:**	10/31/2017
No. of Post Docs:	0	**No. of PhD Degrees:**	1
No. of PhD Candidates:	1	**No. of Master' Degrees:**	5
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	1
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Douglas, Grace	**Contact Phone:**	
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Flight Program:			
Flight Assignment:	NOTE: Element change to Human Health Countermeasures; previously Space Human Factors & Habitability (Ed., 1/19/17) NOTE: End date changed to 10/31/2017 per G. Douglas/JSC (Ed., 12/14/15) NOTE: Changed from NSBRI to NASA-monitored project, per M. Perchonok/NASA JSC (Ed., 2/25/2013)		
Key Personnel Changes/Previous PI:	N/A		
COI Name (Institution):	Froio, Danielle (United States Department of the Army) Richardson, Michelle (United States Department of the Army)		
Grant/Contract No.:	NNJ13HA911		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	The objective of this effort is to develop shelf stable, highly acceptable, food with increased nutrient (vitamins) stability for extended space missions utilizing innovative processing and packaging technologies. There will be two research thrusts. For the first thrust area, we will formulate, test, and optimize the quality and nutrient content of a range of fortified shelf-stable foods. The focus will be on extruded/pressed low-water activity bar-type products. Advances in innovative pre-treatment technologies (encapsulation) for vitamins will be assessed, as well as synergy with matrix chemical character. For the second thrust area, different packaging technologies will be investigated with research focused on the interaction of packaging material with various innovative sterilization processes such as microwave heating, irradiation, and high pressure treatment. The availability of highly nutritious and health-promoting food is a factor that is a significant prerequisite for prolonged space travel. The design of feeding and nutritional strategies for multi-year, non-resupplied flights is an undertaking requiring substantial research and development; it is also an endeavor and that could be founded upon our existing, considerable knowledge and experience base at Natick Soldier RD&E (Research, Development and Engineering) Center.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The proposed study will yield strategies for the development of extremely stable, nutrient-dense foods and the development of packaging materials compatible with new quality-preserving sterilization techniques. While this work is specifically important to the health of astronauts, its significance also extends to the research that is critical to the mission of the Natick Soldier Research Development and Engineering Center: to support and promote the nutritional health of the Warfighter on extended missions with little or no means of resupply.
Task Progress:	FY16 Progress – Vitamin Stabilization for Long Term Space Flight Effort 1 (Matrix Effects) VITAMIN LOSSES AFTER 2 YEARS AT 70F Vitamin levels in relatively low and high fat content compressed bars and dispersed drink mixes, fortified with twice the Space Flight Requirement for vitamins A, B1, B9, C, and E, were analyzed after two years storage at 70F. Vitamins in relatively low fat products had been encapsulated in a lipophilic coating; Vitamins in relatively high fat products had been encapsulated in a starch-based coating. Vitamin contents were measured by Covance Co., with n=6. Losses for the vitamins after 2 years storage at 70F are as follows. Vitamin A: low fat and high fat bars—18%: low fat beverage base—24%; high fat beverage base—22%; Vitamin B1: low fat bar—2%; high fat bar—3%; low fat beverage base—1%; high fat beverage base—25%; Vitamin B9: low fat bar—5%; high fat bar—3%; low fat beverage base—35%; high fat beverage base—49%; Vitamin C: low fat bar—9%; high fat bar—2%; low fat beverage base—8%; high fat beverage base—0%; Vitamin E: low fat bar—0%; high fat bar—3%; low fat beverage base—3%; high fat beverage base—1%. Results show that vitamin loss susceptibility after 2 years storage, on average, followed the sequence, B9 > A > B1 > C > E. Vitamins, on average,were more stable in compressed bars (which were vacuum packed) rather than in dispersed beverage bases, especially for vitamin B9/folic acid. KINETIC ANALYSIS OF VITAMIN DEGRADATION IN NASA PRODUCTS: Kinetic analysis of vitamin losses in the fortified foods, using all pulls to date and data from both high and low temperature storage (70F: 1 and 2 year pulls, and 100F: 6 month and 1 year pulls), was completed. Vitamin levels at the endpoint storage times were first statistically tested for differences from Time 0 levels by a two sample t-test. Vitamins/systems showing significant degradation at $p < 0.05$ were then fitted to the first order kinetic equation, [ln(C/Co) = -kt], where C and Co are vitamin content at storage time t (in months) and vitamin content at time zero, respectively, and k is the degradation rate constant (in reciprocal months). Vitamins exhibiting appreciable degradation (i.e., exhibiting rate constants greater than 0.004 month-1) were: A, in all systems; B1, in the high fat beverage and in the low fat bar (high temperature only); B9, in both beverages and in the low fat bar (high temperature only); and C, in the low fat bar and in all products stored at high temperatures. Vitamin E had no discernible loss in any system. Data for Vitamin A, for which rate constants for both products at both temperatures were above the 0.004 month-1 threshold, were furthermore fitted to the Arrhenius model, [ln(k2/k1) = Ea/R[(1/T1)-(1/T2)], in which the constant R is in (J/mol-Ko), T is temperature (Ko), subscripts 1 and 2 respectively refer to low and high storage temperatures, and Ea is activation energy (J/mol). A relatively higher activation energy indicates relatively greater dependence of degradation rate on temperature. Vitamin A demonstrated an appreciable temperature sensitivity, with Ea >50 KJ/mol in both bars and beverages; reaction rate was increased by a factor of 2-3 by a temperature increase of 30o. Effort 2 (Processing/Packaging Effects) The objective of this effort is to investigate innovative multilayer packaging materials for compatibility with novel food sterilization methods and assess food quality as a function of processing method and package type. In this effort food processing methods including Microwave Assisted Thermal Sterilization (MATS), Irradiation, and Retort were studied to determine the effect on a down-selected non-foil pouch utilizing a novel high barrier coating technology and a control aluminum foil (AF) Retort Pouch. The pouches were filled with Creamy Cajun Chicken, and subjected to the various processing methods. Pre- and post-processing pouch integrity was analyzed. During FY16, mechanical, bust, and barrier testing were conducted on the packaging materials, and water activity, color analysis, and sensory acceptance were used to evaluate the food. Previous years' research led to the down-selection of 3 pouch/processing combinations based on mechanical integrity, barrier performance, seal strength, layer analysis, and sensory data. The down-selected pouch/process combinations include (1) Pouch A/MATS, (2) Pouch A/Irradiated, (3) Pouch A/Retort, and (4) Pouch B/Retort. Pouch A employs an aluminum oxide coated film, and Pouch B is the control aluminum foil based Retort Pouch. The second phase of a contract with Ameriqual was executed during FY16, which included processing of the down-selected pouch/process combinations mentioned above, with Creamy Cajun Chicken. A total of 2000 pouches were produced and processed. All samples passed microbiological testing, indicating that the processing methods were successful in achieving commercial sterilization. Pouches were received by NSRDEC and inspected prior to being placed into short term (12 months @100F) and long term (36 months @70F) storage. Testing of pouches and food product at time zero and 3 months at 100F has been completed. Pouch integrity testing shows that Pouch B/retort shows a 10-14% decrease in seal strength after processing, whereas Pouch A shows no change in seal strength after processing or 3 month storage at 100F. Burst testing showed no change in burst strength for Pouch A; however, burst data could not be collected for Pouch B, as it exceeded the maximum pressure limits of the

	equipment. Modulus of the pouches decreases by approximately 30% after processing for all pouches except Pouch A/Irradiated. However, Pouch A/Irradiated does show a drop in modulus of 37% after 3 months storage. Barrier testing is currently ongoing, but initial data shows that water vapor transmission rate (WVTR) is comparable to results obtained in the first down-selection phase of the project, where minimal changes in WVTR were observed before and after processing. With respect to changes in the food product, water activity, color analysis, and sensory analysis were performed. There is decrease in water activity for food packaged in Pouch A, between time zero and 3 months at 100F. The decrease is small, but a consistent trend is seen for all Pouch A samples. Pouch B shows consistent water activity readings for time zero and 3 months. Color analysis showed minor darkening/yellowing of the Pouch A/Irradiated samples after 3 months at 100F. This sample was the lightest and least yellow initially, and is still considerably lighter than the other samples. Sensory analysis reveals a significant difference in Appearance Quality at time zero, with Pouch A/Irradiated having scores of 6.23 and all other samples having scores in the range of 5.44-5.83, with Pouch A/Retort scoring the lowest. Sensory data at 3 months indicated a significant difference in Flavor Quality, with Pouch A/Irradiated showing the lowest score for flavor of 5.42, and Pouch A/Retort showing the highest score of 6.09. Vitamin analysis of vitamins A (retinol), C (ascorbic), E (a-tocopherol), B1 (thiamin), and B9 (folic acid) is currently underway at Covance.
Bibliography Type:	Description: (Last Updated: 08/25/2020)
Abstracts for Journals and Proceedings	Barrett A, Richardson M, Froio D, Anderson D, O'Connor L. "Influence of food matrix and storage temperature on vitamin stability." IFT16, Institute of Food Technologists Annual Meeting, Chicago, IL, July 16-19, 2016. Published Abstracts, IFT16, Institute of Food Technologists Annual Meeting, Chicago, IL, July 16-19, 2016. , Jul-2016