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Project Title:	Reheating and Sterilization Technology for Food, Waste and Water		
Division Name:	Human Research		
Program/Discipline:	ADVANCED HUMAN SUPPORT TECHNOLOGIES		
Program/Discipline--Element/Subdiscipline:	ADVANCED HUMAN SUPPORT TECHNOLOGIES--Advanced life support		
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Comments:			
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Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
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COI Name (Institution):	Marcy, Joseph E (Virginia Tech) Yousef, Ahmed E (The Ohio State University) Perchonok, Michele H (NASA JSC)		
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	Long-duration space missions require high-quality, nutritious foods, which will need reheating to serving temperature, or sterilization on an evolved planetary base. The package is generally considered to pose a disposal problem after use. We propose herein the development of a dual-use package wherein the food may be rapidly reheated in situ using the technology of ohmic heating. We propose to make the container reusable, so that after food consumption, the package is reused to contain and sterilize waste. This approach will reduce Equivalent System Mass (ESM) by using a compact heating technology, and reducing mass requirements for waste storage. Our objectives are to 1) develop and optimize a reusable container and system for processing food and waste products by ohmic heating; 2) test the device for efficacy in sterilizing plant foods and waste products; 3) test the device for efficacy in reheating packaged shelf-stable foods; 4) test the heating system for efficacy in heating water for crew use,		

Task Description:

when not being used for heating food; 5) establish the oxygen and moisture barrier requirements for longer-term food storage; and 6) develop procedures and test methods to ensure hermetic seal for thermostabilized food containers.

Our approach will involve the development of a package with two electrically conducting ends and an electrically insulating wall, which will serve as a combination package and ohmic heater. We propose to study properties of food and waste to ensure the appropriate process strategy; study the critical issues of elimination of electrolytic bubble formation and microgravity feasibility; verification via heat transfer and microbiological studies of the efficacy of sterilization; study the potential for using the same technology for heating water for personal use; and study the attributes of the container necessary for long shelf life. 1. Develop and optimize a reusable container and system for processing food and waste products by ohmic heating. This includes Optimization of package and enclosure to minimize ESM Optimization of power input conditions to eliminate gas production. Optimization of current density to eliminate arcing. Optimization for use under microgravity conditions.

2. Test the device for efficacy in sterilizing plant foods and waste products.

3. Test the device for efficacy in reheating packaged shelf-stable foods.

4. Test the heating system for efficacy in heating water for crew use, when not being used for heating food.

5. Establish the oxygen and moisture barrier requirements for longer-term food storage.

6. Develop procedures and test methods to ensure hermetic seal for thermostabilized food containers. Research will help address the following Critical Path Roadmap Risks and Questions:

Risk No. 38. Crew nutritional requirements may not be met and crew health and performance compromised due to inadequate food acceptability, preparation, processing and storage systems.

38d. What food processing technologies are required when using crops and stored staple ingredients to ensure a system that is nutritious, safe and acceptable?

This study is the first step in developing better quality products. We will conduct informal tests to determine if quality is superior. Indeed, prior experience with ohmically heated products indicates this to be the case. However, the scope of the present project's deliverables do not allow for Human Subjects testing, and this will have to be left for another project. 38e. What food packaging materials will provide the physical and chemical attributes, including barrier properties, to protect the food from the outside environment, and assure the 3-5 year shelf life?

We are currently working with military grade MRE pouches, which are designed to provide barriers compatible with a 3-5 year shelf life. We fully expect that a sterile product produced under these conditions will meet the shelf-life requirement.

38f. What food packaging will be biodegradable, easily processed, or be lighter in mass than the current packaging, and still provide the physical and chemical attributes including barrier properties to protect the food from the outside environment, and assure the 3-5 year shelf life?

In light of our current work, we believe that this question may be rephrased as:

What food packaging will be reusable, light in mass, still provide the physical and chemical attributes including barrier properties to protect the food from the outside environment, and assure the 3-5 year shelf life?

Risk No. 41. Crew health may be compromised due to inability of currently available technology to adequately process solid wastes reliably with minimum power, mass, volume. Inadequate waste management can also lead to contamination of planetary surfaces.

Specific questions addressed include:

41a. What system will meet the storage and/or disposal requirements for specified missions?

Our study indicates that a system for ohmic heating within packages will enable storage and disposal for long-duration (Mars) missions.

41e. What system will meet the requirements for managing residuals for planetary protection?

Biological residuals may be contained and sterilized within spent food packaging materials, as indicated by our preliminary studies. We expect to address this question further during the coming year.

41i How do partial and microgravity affect biological waste processing?

We will be addressing this subject in part within this study, but cannot verify it without a flight experiment. For the moment, we have been looking into bubble generation within our package/heater system.

41o. What resources are required to manage waste disposal as an environmental risk during long and remote missions (from EH)?

Capability for containment and sterilization is necessary. This capability may be met by reusable food packaging, and our system fits this need. The mass balance on a human being (Hanford and Ewert, 2002) also indicates that the total mass of fecal waste is far smaller than the total food intake. Thus, over time, we would expect a surplus of containers. Those containers not used for waste containment could be reused for packaging of food produced on an evolved planetary base.

41s. How should wastes be handled or stored to avoid perception such as bad odors or unsightly appearance that would adversely affect crew quality or life and consequent degradation in performance?

Our project addresses this issue, since we intend to contain and sterilize human wastes within reused packaging material. Since food packaging is designed with barrier properties in mind, it should be effective in waste containment as well. Our preliminary tests indicate that this is feasible, but further tests in the coming year will verify this finding.

41t. What waste management systems will prevent release of biological material (cells or organic chemicals that are signs of life) from contaminating a planetary surface, such as the Martian surface, and compromising the search for

	indigenous life? As discussed above. Our system offers this capability. Once adequately sterilized, the waste can no longer contaminate its environment. 41w. What is the probability that microorganisms in biological wastes such as food scraps or feces could be altered or mutated by the space environment radiation to become harmful or pathogenic? What can prevent this? Again, adequate containment and sterilization, both of which are being addressed in this project. If waste is sterile, no such problem will exist, and the question will no longer be relevant. 41x. What containment vessels will be sufficient to prevent escape of stored waste at various mission locations such as planetary surfaces or crew cabins? Containers of the MRE-type will answer such issues. Again, the assurance of sterility and container integrity are key.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	If a reusable package can be developed, which will serve as a sterilizing device, it will likely see earth-based applications long before its potential use in space applications. This may also have other spinoffs in terms of serving as a preheating technology for other earth-based food applications (e.g., high pressure processing).
Task Progress:	An ohmic heating package, enclosure and power supply system have been developed. The package has been optimized with respect to electrode configuration and materials. Electrode configuration chosen provides the most uniform heating possible within the package. This has been accomplished using computational heat transfer methods, for current ISS rations. The electrode material (stainless steel) also provides superior results to aluminum in terms of minimum electrolytic gas generation. Container integrity has been enhanced by etching one surface of stainless steel with ferric chloride and adhering to polyethylene surfaces by heat sealing. Results of sterilization tests indicate that the container retains its integrity through a sterilization treatment. We have conducted preliminary experiments for sterilization of waste, and have been successful in heating waste to sterilization temperatures, with satisfactory container integrity. Our next steps will involve sterilization microbiology tests, and shelf-life studies.
Bibliography Type:	Description: (Last Updated: 08/08/2019)
Abstracts for Journals and Proceedings	Sastry, S.K, Marcy, J.E., Yousef, A.E. and Perchonok, M.H. "Reheating and sterilization technology for food, waste and water" Habitation 2004 Conference, Orlando, FL, Jan. 4-6, 2004. Abstract No. HLS-20 , Jan-2004
Abstracts for Journals and Proceedings	Sastry, S. K., Marcy, J. E., Yousef, A. E., and Perchonok, M. H. "Reheating and sterilization technology for food, waste and water." IFT Annual Meeting, Las Vegas, NV, July 12-16. Abstract No. 90-3 , Jul-2004
Papers from Meeting Proceedings	Jun, S.,Heskitt, B., Mahna, R., Sastry, S.K., Marcy, J.E., and Perchonok, M. "Reheating and sterilization technology for food, waste and water: design and development considerations for package and enclosure. " Paper No. 05ICES299. ICES 35 Meeting, Rome, Italy Jul-2005
Presentation	Jun, S.,Heskitt, B., Mahna, R., Sastry, S.K., Marcy, J.E., and Perchonok, M. "Reheating and sterilization technology for food, waste and water: design and development considerations for package and enclosure. " . Presentation scheduled for ICES 35 Rome, Italy, July 11-14 Jul-2005