DEEP SPACE FOOD CHALLENGE

Phase 2 Safety Workshop Q&A

April 5, 2022

12:00pm-3:00pm CT (GMT -6)

Workshop Recording

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RESOURCES

- **Challenge Website:** deepspacefoodchallenge.org
- **NASA P2 Rules Document:** https://www.deepspacefoodchallenge.org/challenge#register
- **Impact Canada Website:** https://impact.canada.ca/en/challenges/deep-space-food-challenge
- **Past Webinars:**
  - Phase 1 Informational (About the Challenge)
  - Space Food
  - Solving for Earth
- **Nutritional Needs of the Crew:**
  - https://www.nasa.gov/hhp/standards
  - https://www.nasa.gov/hhp/education
- **Food for ISS and Shuttle:**
  - Evolution of foods for ISS: https://www.nasa.gov/feature/space-station-20th-food-on-iss
  - Food for Space Flight: NASA - Food for Space Flight | NASA
  - Space Food & Nutrition (pdf): Space Food and Nutrition pdf (nasa.gov)
    - *Appendix A: Baseline Space Shuttle Food and Beverage List*
    - *Appendix B: International Space Station Daily Menu Food List*
  - Tasting Astronaut Food: Inside NASA's Space Food Systems Laboratory: https://www.youtube.com/watch?v=6vVle67Tfjc
- **Current systems & standards:**
  - NASA STD-3001: NASA Spaceflight Human-System Standard; Volume 2: Human Factors, Habitability, and Environmental Health: https://www.nasa.gov/hhp/standards
  - International Life Sciences Institute North America Mid-Year Meeting (2019): Developing a Safe, Nutritious & Palatable Food System in Space (Grace Douglas): https://www.youtube.com/watch?v=QY1Xyjsl70w
  - Microbial food safety in space production systems Lee JA, Brecht JK, Castro-Wallace S, Donovan FM, Hogan JA, Liu T, Massa GD, Parra M, Sargent SA, Settles AM, Singh NK, Justiniano YAV (2021)
  - Water on the Space Station: https://science.nasa.gov/science-news/science-at-nasa/2000/ast02nov_1
  - XROOTS Tech Demo: https://science.nasa.gov/biological-physical/investigations/xroots
- **Future Food Systems**
  - "Space Food for Thought: Challenges and Considerations for Food and Nutrition on Exploration Missions," Douglas, G.L, and Zwart, S.R., and Smith, S.M., The Journal of Nutrition [online journal], Vol. 150, Issue 9
- **NASA Human Research Roadmap**
  - Evidence Report: Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System

TOPIC 1: Crew & Environmental Safety

1. Have there been any documented cases of Norovirus or any of the ones mentioned in the presentation on the ISS, Skylab or Mir?

The panel did not know of any specific cases of Norovirus. There have been documented cases in earlier programs including Mercury and Gemini where bacteria was found in the capsule, and there were a few documented cases where astronauts had become infected. The source contaminant was not foodborne. But astronauts have become infected in space. This is a potential concern. The reason Norovirus was included in the workshop presentation as an example is because there have been recent reports in SpaceX rockets (for example) of problems with the waste systems, and in the past there have been problems on other missions where the waste systems have failed that has resulted in some cases where feces entered the capsule. If that happens, then you have a major problem because microorganisms in the feces can contaminate surfaces and could contaminate food and/or the food production systems. As a result, all these things need to be considered - it's not just the production system, but also considering is the production system enclosed? What are the changes to the external environment? And, if compromised, could the external environment contaminate the food? In foodborne outbreaks on earth, it's typically not a single breakdown in the food production process, but rather the contamination is usually a series of breakdowns. So, the goal is to try to decrease those from happening which would decrease the risk of a food contamination.

2. Could you please share the PCR kits which you use or recommend for pathogen detection?

There's a number of approved kits that can be used based on the different PCR platforms and a number of commercial kits available. It should also be noted, on Earth, any test that's used to test food for commercial consumption has to be approved by the Association of Analytical Chemists (AOAC) and that means the tests are actually tested independently and under strict criteria to make sure they work. Once a test has AOAC approval - in Canada it's Health Canada approval - they can be used to test food.

The methods and the kits are published on the Health Canada website in the Compendium of Analytical Methods. These are not just from AOAC, but there is a list there that teams could use. These are very official methods, but the kits are mentioned in these methods and can be requested from Health Canada through the Compendium of Analytical Methods (linked above)..

3. **Are swab tests acceptable for equipment testing in space?**

The issue comes down to the fact that we cannot detect low numbers of pathogens. If you're looking for a pathogen there has to be considerable thought put into that. For deep space missions like a lunar or mars base, there might be a specific area set aside for testing. But in a spacecraft the concern is if you take a swab to detect pathogens you'd have to then grow them. You'd have to put the swab into some kind of broth and grow it to a high number or put it onto a petri plate. And when you've done that you've increased the numbers of those factors. So, if then there was some kind of contamination event, the tube should open for example, now you've contaminated the whole environment with pathogens that are highly infectious and can cause serious illness.

In terms of space, any swabbing of environmental equipment should be restricted to indicator organisms that are nonpathogenic, so it reduces the risk.

TOPIC 2: Cleaning & Sterilization

1. **What is the sanitation method for viruses? Would ATP bioluminescence work?**

Those are two different questions - one refers to sanitation (process of removing the microorganism) and the other is testing.

First - sanitation - there are lots of well-known methods that will remove viruses. And the presentation at the workshop emphasized that this needs to be done repeatedly. You have to consider the fact that some chemicals that are used on earth will not be amenable to use in space. Also consider the interaction with the crew.

The second refers to ATP - which is found in living organisms (viruses are not living organisms) and detecting the presence of viruses. The utility of ATP is not a test for microorganisms; it is a test for organic material that could be microorganisms. Consider that fresh produce (such as lettuce cells) produce ATP, and human skin cells produce ATP. So, the idea of using ATP is to determine if a surface is clean or not. But if there is organic material present, then likely some of that will have ATP. If you use this method and determine it's dirty, after that you would re-clean, re-sanitize and test again.

2. **Do we include cleaning materials and water or soap or other solutions in our documentation and "byproduct" pages? Any limitations aboard the ship or shuttle we need to know about regarding cleaning?**

There are restrictions for water in the rules, and the team should share what is needed for cleaning. It is important to be aware that there is an option to use a variety of commodities for cleaning. There might be some that you want to steer away from because they might be problematic.

3. **Is the water source on the ISS sterilized? If so, how and what is the pH?**

The ISS uses filtration and temperature sterilization to ensure the water is safe to drink. Water is checked often to ensure it meets the water quality requirements and monitored closely for bacteria, pollutants, and proper pH. The recycled water on the ISS is required to be within the pH level range of 6.0 to 8.5.

4. **How is cleaning and sterilization done on the ISS?**

There are chemical biocides that are used. The crew is partially relied on to keep the ISS microbiome population under control. Every week astronauts are scheduled to wipe down surfaces with antimicrobial wipes and use a vacuum cleaner to suck-up any stray debris. Additionally, daily cleaning is done to keep kitchen areas clean and prevent sweaty exercise gear and equipment from going moldy. The life support systems are relied on to filter the air and keep the water clean.

5. **Are there existing cleaning techniques/interfaces available on planned transportation vessels and long-term space habitation structures?**

Using Prosan wipes for wiping down any of the plant material prior to crew consumption is the only thing that's specific when it comes to cleaning the actual plants.

Advanced Plant Habitat is a closed system and has a science carrier that is thrown out. There was a plan for wiping down the inside with liquid prosan, but it hasn't shown to be very effective. From a water system perspective, to flush this out will take too much water. It's not a sustainable process and the microbiological counts go up - which is also causing issues. This is something the program is wrestling with and is a challenge.

Later this year, NASA is holding a conference to set standards and approaches that are acceptable for future hardware systems.

6. **What is the current method for removing physical contaminants from the water on space stations? Is it just filtration or something like distillation?**

Information on the ISS water system can be found here:
https://science.nasa.gov/science-news/science-at-nasa/2000/ast02nov_1

7. **Is having chlorine bleach for sterilizing items (such as seed on board the ISS and other stations) an option granted there is proper handling, training, and documentation?**

For seed sanitation on ISS, Veggie and Advanced Plant Habitat, the seeds are sanitized before they fly and the seeds are all pre-planted. As part of the go-forward, we need to understand how we are going to accomplish this in the future when we start talking about taking seeds with us on long duration missions or growing plants seed-to-seed. Using commodities like bleach in a microgravity environment, even when it comes to mixing fertilizer solutions, would need to be carefully controlled and understood to make sure the flight safety ramifications of using those commodities is something we can work through. This is part of what NASA will be discussing later this summer at the conference mentioned in the answer to Question 5.

TOPIC 3: Safety Plan

1. **Is light a factor for pathogenic growth?**

No, light is not a factor. There are microorganisms that do require light; pathogens do not require light to grow.
UV light can be used for sterilization/sanitation, but the UV has to reach all parts of the surface that is being sanitized and that can be difficult. For example if you're trying to do seeds with cracks and crevices you might not get all the areas. There are some caveats, but yes, UV can be used.

If talking about fresh produce (microgreens and other veggies) prevention is the most important part. UV, blue light, and chemical sanitizers have been tried but none of them have completely removed/eliminated pathogens once they are present. It is really critical that pathogens are prevented from getting there in the first place.

2. **What about the risk of Methicillin-resistant staphylococcus aureus (MRSA) from cleaning solutions?**

Expanding on this to include antibiotic-resistance that are developed by antimicrobials. This is something that is being studied, but it has been an issue with use of some cleaning compounds and sanitizing compounds in food settings. If the cleaning/sanitizing process is done appropriately, this wouldn't be a concern. But teams have to be careful because space and earth are different and every chemical won't be appropriate.

3. **What about use of surfaces that are naturally antibacterial that inhibit bacterial growth indefinitely, in growth systems and across the spacecraft? Like brass, or silver coating, or titanium surfaces? Brass should not wear off.**

For materials and coatings, the challenge is the efficacy of coatings runs out over time.The cleanliness and sanitization levels of the surfaces will need to be maintained for periods of at least up to five years. Or will need to have some way to revitalize or replace them in a relatively straightforward and easy way with minimal consumables. The initial investigations show all these materials eventually wear to some degree in terms of efficacy over time and same goes with coatings. Specifically for brass and titanium coatings for a plant application, the focus is on how a biofilm builds up over continuous exposure to a water nutrient solution. There would need to be a better understanding of a brass or titanium coating, but a rule of thumb is microorganisms are naturally sticky and stick to things. Generally speaking, nobody has come up with a surface that is antimicrobial to the extent that nothing will grow or survive on it. Even if a surface is antimicrobial, if there's organic material, studies have shown if you put a bacteria or virus on it, it is activated. You start adding in real world examples where you mix that with organic material (as in food production) you start to see decreased efficacy. The principles - regardless of the material used - remain the same. You have to effectively clean and effectively sanitize. Without that, the risk of bacterial contamination greatly increases.

NASA is investigating a coating material now (tested at KSC) - the customer documentation implies durability and serves its function for up to 2-years. That's the challenge - it's not a long enough period of time. We really need to understand how to develop them to be longer lasting and how to demonstrate them in a real-world setting.

It's important to remember it's not either/or situation. If something is said to be antimicrobial, along with that is the reduction in the concentration of microorganisms. Typically you'll see a percentage reduction or log reduction. Most of these surfaces will reduce the concentration by 2-3 logs - keeping in mind pathogens can cause illness at very low concentrations (E Coli for example - 1-10 ingested cells have caused illness). Any solution still needs to be accompanied by proper cleaning and sanitation.

This is an area of current research, but it has not yet been developed. If you are in the field and have the expertise to develop some type of coating or surface material, it would be useful for the entire food processing industry - beyond just NASA.

4. **What do you consider effective cleaning and sanitization, short of heating the system for complete sanitization? Ozonated solutions as a cleaning solution?**

Ozone is a good example of something that is useful on earth but may not be useful in space. It has some efficacy, but the ozone has to be generated. Teams have to consider concentration and the enclosed space where the ozone is being generated - would that be appropriate for a deep space mission? Teams also have to consider human exposure and the off-gas.

For heating - there are many ways to clean and sanitize without using heat. Keep in mind if you're looking for additional infrastructure for heating or cold storage (for example), those are systems that are beyond the scope of the challenge and teams can't assume that those are going to be available. Gateway (for example) won't have this additional infrastructure. For the near future the ability to heat food and keep things cold is out later in the timeline. Even on ISS there is a food warmer, but not an oven or the ability to freeze or keep things cold. Be careful when you start looking at other system capabilities to compliment your system because they may not be available.

5. **Is it to be an important portion of the documentation to include bacterial test results? If so, how many tests per cycle would the DSFC ask for?**

The NASA Rules / CSA Phase 2 Instructions contain all the details you will need. These documents specify some of the required tests. Testing plans will be reviewed with Teams to confirm tests to be realized.

6. **Do we need to include the rapid test procedure in the submitting document or will the rapid test be generic for every team?**

The NASA Rules / CSA Phase 2 Instructions contain all the details you will need. These documents specify some of the required tests & procedures. Testing plans will be reviewed with Teams to confirm tests to be realized.

OTHER QUESTIONS

1. **Is the location of the food production system in the vehicle or on the surface of the Moon?**

The types and durations of future lunar missions are constantly evolving and maturing based on new technological advances and scientific input. Space agencies will need to address long-duration lunar missions and how to provide these future lunar crews with safe and nutritious food while in lunar orbit or on the lunar surface. At the same time, they are looking ahead to how a lunar food system can help enable a Mars mission for a crew traveling with their entire food system. Additionally, the speed at which technology is being developed is increasing. As such, space agencies are interested in flexible and modular food production technologies that adapt to changing needs and mission architectures. The intent is to use modular and flexible technologies and build them into systems that meet the unique needs of each mission type or specific mission. The Deep Space Food Challenge provides a set of performance criteria and asks Teams to produce the best food production technology they can within those criteria.

The scoring criteria recognize that a combination of technologies will be used together in an overall food system and rewards those technologies (submissions) that are likely to contribute to multiple mission scenarios. Examples of mission scenarios are included in Appendix A of the NASA Official Rules.

2. **Is it okay to participate with more than one idea?**

Yes, teams could submit more than one proposal.

3. **Are there resources that are publicly available that contain past tests that have been done at KSC to reference and compare what the teams are trying to do?**

There are no official websites but teams could search for research papers on the ISS water systems or microbial activity that was documented as samples were collected from experiments on Veggie or Advanced Habitat.

4. **Can you reference an article that describes the root medium or "pillows" currently used for vegetable growth?**

Regarding aeroponics for plant growth. The concept will be evaluated this summer on the ISS with the Sierra Space XROOTS tech demo. https://science.nasa.gov/biological-physical/investigations/xroots

5. **Are you, or are you planning on recycling the APH's argillite media?**

For the NASA Veggie program, there are plant pillows that have argillite media contained in them - that's discarded. For the NASA Advanced Plant Habitat program - the plant pillows have argillite media but there are porous tubes inserted in that media to help the uniform distribution of water near the root zone. In both cases, the science carrier and the pillows are single-use items but they are discarded. That's a challenge going forward. Because ISS is a research platform, this isn't a big deal because there is relatively easy access to low earth orbit. But when thinking about exploration activities, the weight penalty, the amount of material you have to send on a mission like that it makes it completely impractical to have single-use items. Current research is trying to get away from solid media and trying to see alternative approaches in the hydroponic realm - aeroponics or capillary-driven systems, etc. whatever we can do to make them more sustainable.

6. **What has been the safety experience with growing algae in space?**

Algae is one of those cells that's being explored for use in single-celled protein and more used as an ingredient than anything. There is some use of algae as food on earth. From a food perspective, NASA has not grown algae in space as a food source.

There are a lot of reasons for that, but part of it has to do with the palatability, the nature of the algae itself, and how you would consume it. Teams should consider that while there are technical hurdles, the team at NASA currently responsible for the food production systems are very conservative in their thinking. To give additional context, we are already exposing astronauts to isolation from home and asking them to be away from family on earth and away from things they are familiar with, and putting them in an environment they aren't used to. So bringing things along with them that bring comfort is important. From a larger perspective, not only is the food system the first line of defense in crew safety, but also the one area that reminds them of home and gives them the ability to be more human in that regard. Exposing them to novel technologies that might provide nutrition but take away some things they are familiar with and enjoy has a series of problems from a psychosocial benefit. This is something the NASA food system team are trying to avoid. In part this is why they've steered clear of algae.

Even though this hasn't been considered to-date, that doesn't mean over time algae can't be a valuable component of the diet with the crew enjoying it as part of some other food product. With anything novel we have to demonstrate it. That was the case with microgreens - when the idea first came up because of the benefits of turnaround, minimum resources, etc. - no one had heard of microgreens so the team at KSC had to socialize those. They managed to do that quickly, but some of these things that are more on the fringe of what people would consider to consume will take more work.

7. **How about the role of probiotic food supplements needed for a healthy body microbiota during the deep space journey?**

If we're talking about nutritional additives, one of the principles of the food system being worked on is having the nutrients consumed as part of the food they eat. It's about a foundational food system rather than adding nutrients to the foods available. They want to see the food the crew bring and grow to provide the nutritional content. They would be more interested in looking at different or enhanced foods that could be consumed to fill nutritional requirements.

8. **Has any type of fermentation been attempted in space?**

May have been attempted, but we are not aware of any for consumption.

9. **What life-support systems are available on-board vessels such as the ISS (i.e. CO2 scrubbing/reclamation, water recycling/reverse osmosis, humidity control, air filtering, etc)? To what extent could those existing systems be incorporated as support to our solutions?**

Information about the current life support systems on ISS can be found here: Life Support Systems | NASA. When designing and building your food production system,

8. **If a system included insect cultivation, does NASA have any reference cases for that and if so, how do you sanitize the insect's cultivation system?**

NASA has not investigated the use of insects as a potential supplement to crew diet. There is no official information on this. There have been talks about potentially using this material as a flour or converting it to an ingredient of a meal where it is more acceptable to the crew but that's further down the road than NASA has looked at simply because of the hurdles of getting crew members comfortable consuming materials from insects.

More generally, the place to start is what's already being done on earth. In terms of insect production - what's being done, what's the potential contaminants being dealt with on earth. Same with micro greens and any other type of food. Teams should consider what are the hazards, how are they being controlled, and can that be used or adapted for in-space? Everything has to be demonstrated in an earth setting, and once comfortable with that and addressed the challenges and technologies in a reliable way, then we talk about moving it forward into a space environment.