NASA-STD-3001 Technical Brief

Food and Nutrition

OCHMO-TB-013
Rev C

Executive Summary

Nutrition has been critical in every phase of exploration on Earth, from the time when scurvy plagued seafarers to the last century when polar explorers died from malnutrition or, in some cases, nutrient toxicities.
The space food system must provide food that is safe, nutritious, and acceptable to the crew, to maintain crew health and performance during space flight. Nutritional standards in NASA-STD-3001 are based on National Institutes of Health (NIH) standards with modifications for spaceflight environment. Achieving and maintaining food system acceptability, nutrition, and safety for spaceflight is complex and influenced by factors such as duration isolated from Earth, menu development, suitability in microgravity, palatability, packaging, and stowage.

NASA astronaut Kjell Lindgren (left) and Japan Aerospace Exploration Agency (JAXA) astronaut Kimiya Yui, participate in a food tasting session.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev B

[V1 3002] Pre-Mission Preventive Health Care
[V1 3003] In-Mission Preventive Health Care
[V1 3004] In-Mission Medical Care
[V1 3016] Post-Mission Health Care
[V1 3018] Post-Mission Long-Term Monitoring
[V1 4019] Pre-Mission Nutritional Status
[V1 4020] In-Mission Nutrient Intake
[V1 4021] In-Mission Nutritional Status
[V1 4022] Post-Mission Nutritional Assessment and Treatment

NASA-STD-3001 Volume 2, Rev C

[V2 3006] Human-Centered Task Analysis[1]
[V2 6026] Water Quality
[V2 6039] Water Dispensing Rate
[V2 6040] Water Dispensing Increments
[V2 6109] Water Quantity
[V2 6110] Water Temperature
[V2 7001] Food Quality
[V2 7002] Food Acceptability
[V2 7003] Food Caloric Content
[V2 7004] EVA Food Caloric Content
[V2 7007] Food Microorganism Levels
[V2 7008] Food Preparation
[V2 7009] Food Preparation and Cleanup
[V2 7010] Food Contamination Control

(continued on next page)

1. Human-in-the-Loop (HITL) Technical Brief

Executive Summary (continued)

Risks of Inadequate Food & Nutrition

Performance decrement

- Strength and Endurance
- Cognition
- Behavior
- Sleep

Crew health

- Nutritional deficiencies or toxicities
- Bone loss[1]
- Changes in immune function
- Cardiovascular performance
- Gastrointestinal function
- Severe dehydration
- Nausea
- Diarrhea
- Endocrine function
- Ocular
- Behavioral health[2]
- Renal stones
- Ability to mitigate oxidative damage
- Weight loss

Long-term health effects

- Cancer
- Musculoskeletal changes
- Ocular health
- Cardiovascular diseases (SANS and cataracts)
- Neuropathy
- Dementia

Drug/nutrient interactions

- Oral Contraceptives (B vitamins, zinc, copper)
- Proton Pump Inhibitors (B12, vitamin C, iron, calcium, magnesium)
- Antibiotics (iron)

Relevant Technical Requirements

NASA-STD-3001 Volume 2, Rev C
[V2 7011] Food and Beverage Heating
[V2 7012] Dining Accommodations
[V2 7014] Food Spill Control
[V2 7015] Food System Cleaning and Sanitizing
[V2 7100] Food Nutrient Composition
[V2 7052] Stowage Location
[V2 8001] Volume Allocation
[V2 11025] Suited Nutrition
[V2 11029] LEA Suited Hydration
[V2 11030] EVA Suited Hydration

Skylab Food System

1. *Bone Loss and Prevention Technical Brief*
2. *Behavioral Health and Performance Technical Brief*

Background

> "An army marches on its stomach." – *Napoleon Bonaparte*

Throughout history, one of the performance-affecting factors for explorers on Earth was the availability of an adequate food supply. Even with tremendous gains in scientific knowledge, the need for adequate and acceptable food is underestimated. In space, inadequate food and nutrition provisions and intake has led to weight loss, bone and muscle loss, cardiovascular deconditioning, and impaired immune function, among other likely health and performance decrements.

Historical Events

1897-1899 Belgica Expedition (Cook)

Beri beri (thiamine deficiency) that led to death, shortness of breath, irregular heart rate and edema

1910-1913 Terra Nova Expedition (Scott)

Weight loss due to inadequate caloric intake that was 1500-3000 kcal less than expended

Inadequate wound healing due to Vitamin C deficiency that led to skin rotting, loss of nails and a hand wound that began to suppurate

Gemini, Apollo, Skylab, ASTP, and ISS flights

Weight loss occurred even during the short durations due, in part, to food acceptability

Biosphere 2

Weight loss of 14-21% due to inadequate food availability

Mars 500

Food became probably the greatest problem in isolation (Šolcová et al 2016)

Food System Evolution

Mercury – Semi-solid, sterile, tubed foods, fruits, and meat combinations packaged in collapsible aluminum tubes. Supplementing the semi-solid foods were special dry bite-size foods.

Gemini – More complex, all dehydrated food system with more meals per person per day. Some of the bite-size foods had to be altered to control crumb problems.

Apollo – Greater attention was focused on astronaut preferences which resulted in greater menu variation of both bite-sized and rehydratable foods. Hot water was available for food rehydration and "wet packs" were introduced.

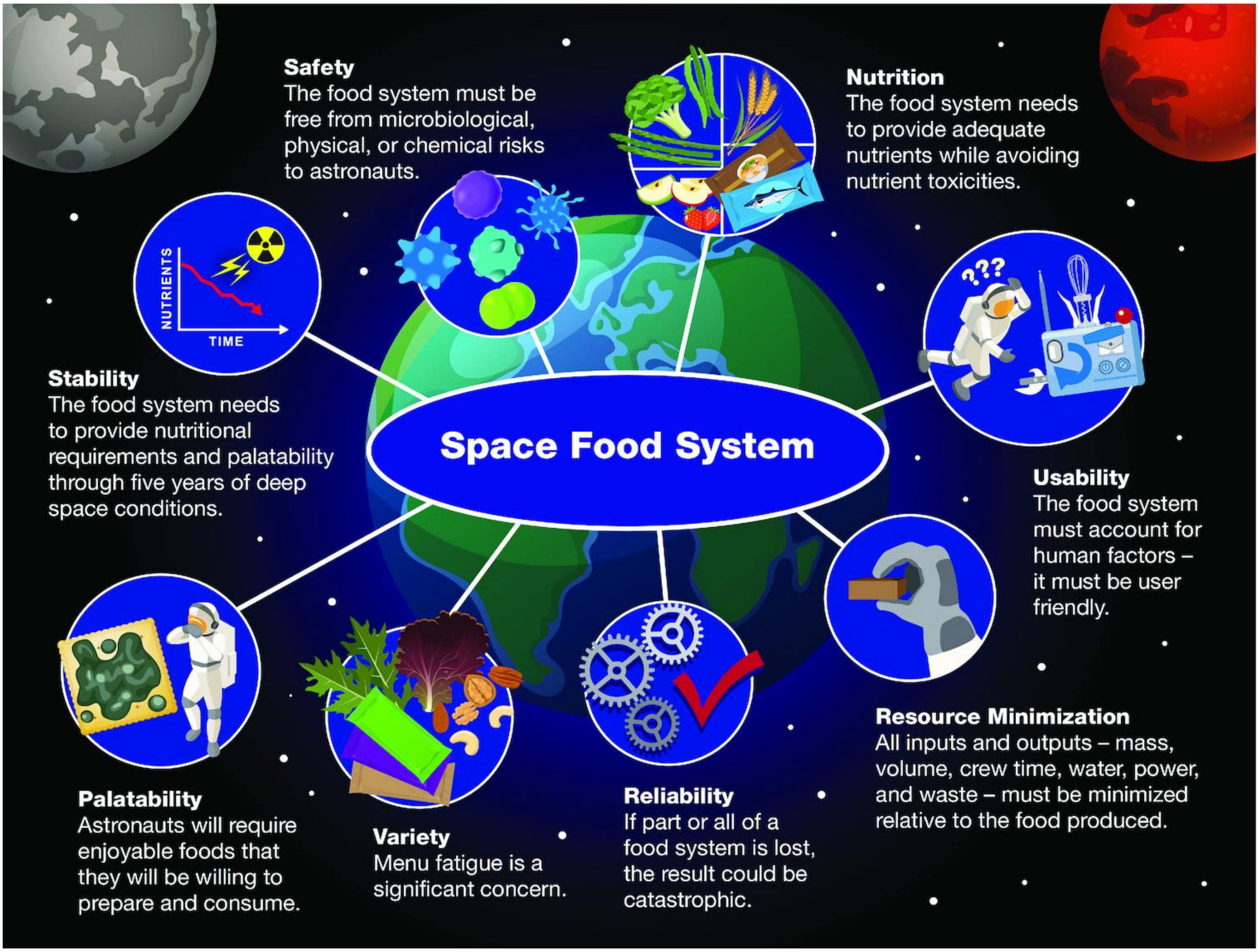
Skylab – Efforts were focused on making food a positive morale factor by including variety and acceptance. Menus were on a 6-day cycle with more consistent nutrient content. A food warmer for canned and freezer foods were provided.

Apollo-Soyuz Test Project (ASTP) – Introduction of freeze-dried foods and redappertized meats. No freezer or food warmer available, along with limited water.

Shuttle – Redesigned packaging of rehydratables and improved galley that included convection oven and rehydration unit with hot and cold water.

ISS – Standard menu which provides eight Standard Categories that the crew can choose food from typically for a 7- to 9-day usage rate. Crew Specific Containers are allotted to each crew member, typically one container per 20 days. Other supplemental containers include condiments, nutrition bars and periodic fresh foods. ISS has hot metered water, ambient water, food warmers and small chiller to aid in food preparation. However, there is currently no refrigeration for foods.

Reference Information



Requirements of space food systems. A depiction of the many facets of and requirements for space food systems. As described in the text, each element is critical for the ultimate success of a space mission, and failure of any aspect could imperil the mission and the crew. The moon and Mars are also depicted here, reflecting two likely destinations for future human space exploration.

Source: J Nutr, Volume 150, Issue 9, September 2020, Pages 2242–2244, [*https://doi.org/10.1093/jn/nxaa188*](https://doi.org/10.1093/jn/nxaa188)

Reference Information

Food Acceptability Considerations

Past experience and personal preference – The ability to choose and consume foods that are familiar, and the availability of personal favorites becomes more important in isolation and confinement; considerations are needed for international crews.

Variety – Food can lose its acceptability if eaten too frequently. Additionally, individuals will have favorite foods and avoid foods they do not like. In closed systems, a wide variety of foods helps support preferences that lead to intake of adequate nutrition.

-The US military limits the use of MREs to 21 consecutive days to prevent health and performance impacts due to inadequate food consumption.

Availability – Snacks should be available with a minimum of preparation, which is particularly important for high-energy-output tasks such as extravehicular activity (EVA) operations. Food overage is necessary in a closed system to help support preferences that lead to intake of adequate nutrition.

Food form – Food quality that is more familiar and "Earth-normal" will facilitate acceptability of the food and subsequent consumption.

Meal scheduling – Lack of consistent meal periods in the crew schedule can lead to skipped meals and undernourishment.

-Crew days are planned to ensure there is adequate time for meals, as well as time for dining together as a team.

-Meal scheduling will likely be impacted on days with EVAs and the specific needs of those activities.

Meal Preparation Time and Capability – Complexity of preparation, or availability of preparation equipment, including rehydration and heating, can lead to skipped meals or incomplete consumption due to time constraints from crew day scheduling, and are highly requested by crew to increase acceptability and intake.

Microgravity environment – Anecdotally, some crewmembers have reported that changes occur in their taste and odor perception of foods during spaceflights, which may be influenced by factors such as bodily fluid shift, changes in air circulation, and competing odors in the closed spacecraft. Condiments are flown to allow the crewmembers to individually alter the flavors of the foods.

-Some crew have noted that spicier foods are desired due to the lack of smell or taste.

Waste management facilities – Inadequate body waste management facilities have discouraged food consumption.

-Previous crew comments have noted that the smell from the waste management system has caused appetites to be affected from smells.

Space adaptation sickness (SAS) – Control of SAS is essential for a healthy appetite.

-Crew have medications available to them to help mitigate this occurrence, as well as having the flexibility to consume less solid food while maintaining hydration with the available water quantities.

Atmospheric contaminants – Buildup of background odors during missions could contribute subliminally to a decrease in appetite and consumption.

-This could include the stowage of trash, as well as the off-gassing from various chemicals used or payloads.

Reference Information

> "The soldier who is well fed is not only in better bodily health and better able to resist disease, but he is more cheerful in difficulties and therefore more equal to any strain he may be called upon to endure." – *Surgeon-Lieutenant-Colonel GS Robinson*

Spaceflight Standards

NASA utilizes the appropriate age and gender matched macronutrient and micronutrient Dietary Reference Intakes (DRIs) as suggested by the National Academies, except Vitamin D is increased to counter the limited UV exposure from sunlight and protein intake may be modified based on individual crewmember needs.

- The DRIs may be tailored based on mission design architecture and individual crewmember needs.

Estimated Energy Requirement

NASA utilizes the terrestrial energy requirements and considers mission operations (such as EVAs) to determine additional caloric content.

Estimated Energy Intake

EER for men 19 years old and older

$$\text{EER (kcal/day)} = 662 - 9.53 \times \text{Age [y]} + \text{AF} \times (15.9 \times \text{Body Mass [kg]} + 539.6 \times \text{Height [m]})$$

EER for women 19 years old and older

$$\text{EER} = 354 - 6.91 \times \text{Age [y]} + \text{AF} \times (9.36 \times \text{Body Mass [kg]} + 726 \times \text{Height [m]})$$

Considerations for Off-Nominal Events

- Contingency food and water supplies will need to account for the needs of the crew in the event of a delayed or unplanned rescue
- For example, plans for a change in consumed calories, fats and carbs to conserve O_2 use and CO_2 production during events where the ECLSS is strained

Technical Challenges

Use of alcohol on the ISS is prohibited due to impacts to the ISS ECLSS[1] and Body Waste Management Systems[2]. Use of any ingredients containing even minor levels of alcohol, in the form of ethanol's such as extracts, vinaigrettes, or cooking wine, should be considered in the ECLSS and waste management system designs.

1. *ECLSS Technical Brief*
2. *Body Waste Management Technical Brief*

8 Standard Categories – feeds a crew of three for 7-9 days

1. Breakfast
2. Rehydratable Meats
3. Meat and Fish
4. Side Dishes
5. Vegetables and Soups
6. Fruits and Nuts
7. Desserts and Snacks
8. Beverages

Supplemental Categories

9. Personal Preference
10. Condiments
11. Fresh foods (periodic)

Current Average Consumption

Calories 2365
Fat 29% / Sat Fat 10%
Carbs 51%
Protein 20%
Sodium 2573mg

Food Prep Equipment

Hot metered water
Ambient water
Food warmer
Small chiller

Current ISS Standard Food System

Reference Information

Food and Water Intake for Previous Spaceflight Programs and Expeditions

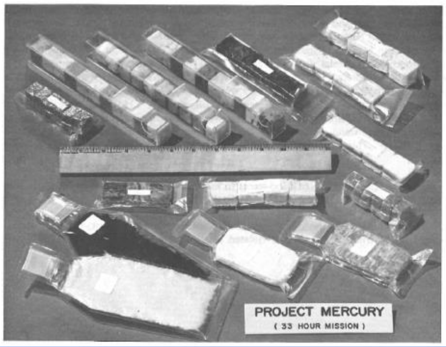
Updated nutrient intake data for several space programs are reported below. For ISS, we report the data on nutrients available from the Food Frequency Questionnaire analysis. Data on planned ISS menu content and information on a wider range of nutrients are available online at https://www.nasa.gov/hhp/education.

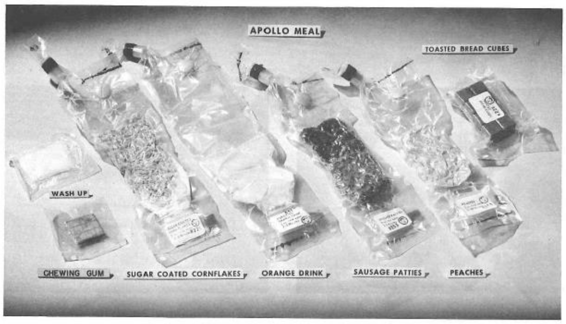
	Apollo	Skylab	Shuttle	ISS (E1-13)	ISS (E14-25)	ISS (E26-34)
N	33	9	32	19	19	17
Energy, kcal/d	1880 ± 415[a]	2897 ± 447	2090 ± 440	2313 ± 514	2317 ± 591	2444 ± 536
Energy, %WHO	64.2 ± 13.6	99.1 ± 8.2	74.2 ± 16.0	79 ± 18	83 ± 17	84 ± 15
Protein intake, g/d	76.1 ± 18.7	111.0 ± 18.4	78.0 ± 18.8	102 ± 25	96 ± 34	109 ± 30
Protein intake, % of kcal	16.3 ± 2.1	15.7 ± 2.1	14.9 ± 2.4	18 ± 2	16 ± 2	18 ± 2
Carbohydrate intake, g/d	268.9 ± 49.1	413.3 ± 59.3	304.0 ± 67.3			
Carbohydrate intake, % of kcal	58.1 ± 7.1	57.5 ± 9.1	58.4 ± 5.0			
Fat intake, g/d	61.4 ± 21.4	83.2 ± 13.8	64.0 ± 17.8			
Fat intake, % of kcal	28.9 ± 5.5	26.8 ± 8.6	27.2 ± 4.4			
Calcium, mg/d	774 ± 212	894 ± 142	826 ± 207	878 ± 274	944 ± 258	1074 ± 205
Phosphorus, mg/d	1122 ± 325	1760 ± 267	1216 ± 289			
Magnesium, mg/d		310 ± 58	294 ± 74			
Iron, mg/d			15.0 ± 3.9	18 ± 5	18 ± 5	20 ± 5
Zinc, mg/d			12.0 ± 2.9			
Sodium, mg/d	3666 ± 890	5185 ± 948	3984 ± 853	4601 ± 1239	4658 ± 1593	3823 ± 785
Potassium, mg/d	2039 ± 673	3854 ± 567	2391 ± 565	3315 ± 513	3214 ± 863	3559 ± 784
Water, g/d	1647 ± 188[b]	2829 ± 529	2223 ± 669	2012 ± 462	2142 ± 387	2320 ± 581

Source: Human Adaptation to Spaceflight: The Role of Nutrition, 1st Ed by Smith, Zwart and Heer.

[a] All data are mean ± SD. Empty cells show where data were not available.

[b] n=3 for water intake during Apollo missions.





See the OCHMO Water Technical Brief for additional information.

Reference Information

Food Safety
Food safety is important pre-flight to prevent any food borne illness from impacting the crew and mission during the ascent phase of flight and for preventing any infectious disease prior to or during the mission. Post-flight food safety is important for the health of the crew as they may return with impaired immune systems.

Staging of food should consider long duration storage and temperatures to ensure food quality and acceptability.

- Contingency planning
- Prepositioning of foods
- Available fresh fruits/vegetables
- Crew preferences
- Stability of food micro- and macronutrients
- Preservation of food quality

Food Safety Modernization Act (FSMA)
FoodSafety.gov

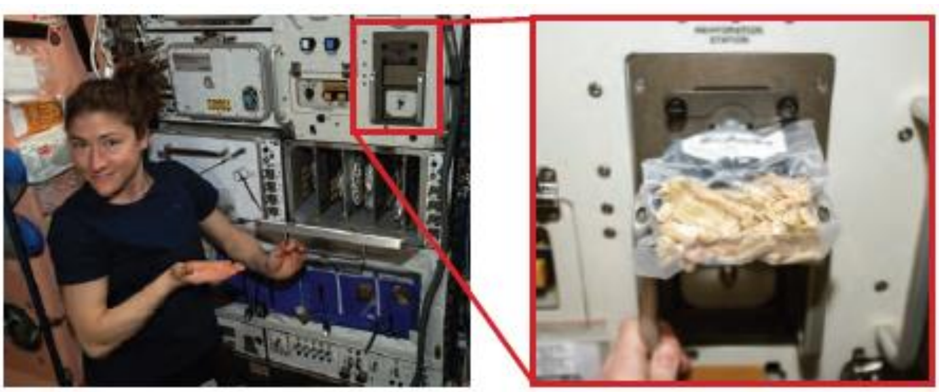
Contamination Sources
Waste and Hygiene Areas[1] – microbes that can lead to gastrointestinal illnesses
Air – odors that are not properly contained
Water Sources – microbial contamination, leeching or biocides
Packaging – must be food grade

- Primary packaging will need to be uncompromised

Eating Utensils – forks, spoons, scissor, straws, etc.
Chemical Sources – cleaning materials used in the same area that leave a residue or have off-gassing
Physical Debris – dirt, regolith, wood, plastic and other small objects
Fresh fruits and vegetables – direct shipment from the ground, items that are picked and then eaten

- Recommendation of 30-second dip in a 200 parts per million chlorine solution (or approved equivalent), followed by a final potable water rinse and thorough air drying prior to stowage/storage, which should include a wrapping to maintain cleanliness

1. Body Waste Management Technical Brief



The ISS Galley in the USOS includes a conduction food warmer and a Potable Water Dispenser with metered hot or ambient temperature water. NASA astronaut Christina Koch is heating pizzas, part of the limited shelf-life foods that may be included in some resupply provisions to the ISS. Inset: Example of a food package during rehydration. Photo Credits: NASA.

Reference Information

Food Safety During Production

Food safety is defined by the absence of a health risk due to physical, chemical and microbiological contamination. Shelf stable food products will need to be processed in compliance with local, state, and federal codes and laws and NASA specific requirements including visual inspections, vacuum integrity and microbial testing. This can also include testing items prior to or during use, empty pouches at receiving, septum adapter assemblies at receiving, and straw assemblies after cleaning.

Area/Item	Microorganism Tolerances	
Food Production Area	**Samples Collected**	**Limits**
Surfaces	3 surfaces sampled per day[a]	3000 CFU/ft^2 (total aerobic count)
Packaging Materials	Before use	3000 CFU per Pouch, Septum, 25 cm^2 or base
Air	1 sample of 320 L monthly	113 CFU/320 L (Total aerobic count)
Food Product	**Factor**	**Limits**
Non-Thermostabilized[b]	Total aerobic count	20,000 CFU/g for any single sample (or if any two samples from a lot exceed 10,000 CFU/g)
	Enterobacteriaceae	100 CFU/g for any single sample (or if any two samples from a lot exceed 10 CFU/g). No detected serious or severe hazard human enteric pathogenic organism
	Salmonella	0 CFU/g for any single sample
	Yeasts and molds	1000 CFU/g for any single sample (or if any two samples from a lot exceed 100 CFU/g or if any two samples from a lot exceed 10 CFU/g Asperfillis flavus)
In-House Thermostabilized Products	Package integrity inspection	100% inspection for package integrity
	Incubation test	Test package must remain intact with no gas production following 10-day incubation at 35 ± 3°C
Commercial Thermostabilized Products	Package integrity inspection	100% inspection for package integrity
Irradiated Sterile Products	Package integrity inspection	100% inspection for package integrity
	Total aerobic count	<10 CFU/g Note: test conducted on samples following incubation at 35°C for 10 days
	Yeasts and molds	<10 CFU/g Note: test conducted on samples following incubation at 35°C for 10 days

a. Samples collected before food processing on days that the food facility is in operation. Environmental samples will be collected when there is a 1-hour break in activity, or after five hours of continuous work.

b. Food samples that are considered "finished" products that require no additional repackaging are only tested for total aerobic counts.

Source: NASA-STD-3001 Volume 2, Revision C, Table 15 – Food and Production Area Microorganism Levels

Application

Food/Packaging Type	ISS Example	Parameters
Thermostabilized – heating food to a temperature that renders it free of pathogens, spoilage microorganisms, and enzyme activity	Beef stew, Chocolate Pudding, Split Pea Soup, Tuna casserole, Red beans & rice	**Shelf life:** 2 years **Packaging:** Multilayer aluminum-containing laminate pouch **Preparation:** None or heating **Mass:** 3.07 to 8.32 oz (87 to 236 g)
Irradiated – use of gamma rays, X rays, or electrons, and uses energy levels that ensure negative induction of radioactivity in the irradiated product. Irradiation controls naturally occurring processes such as ripening or senescence of raw fruits and vegetables, and is effective to inactivate spoilage and pathogenic microorganisms	Beef fajitas, Smoked turkey	**Shelf life:** 2 years **Packaging:** Multilayer aluminum-containing laminiate pouch **Preparation:** None or heating **Mass:** 3.03 to 6.94 oz (86 to 197 g)
Rehydratable – are drying with heat, osmotic drying, and freeze drying	Vegetables, Chicken salad, Cornbread dressing, Sausage patty, Shrimp cocktail	**Shelf life:** 1.5 years with overwrap; 1 year with no overwrap **Packaging:** Multilayer laminiate pouch with, vacuum packaged with gas flush, adapter for rehydration **Preparation:** Rehydration using hot or cold Water **Mass:** 0.88 to 3.40 oz (25.0 to 96.6 g)
Natural form – these foods rely on reduced water activity to prevent microbial activity	Cookies, Brownies, Nuts, Granola bars	**Shelf life:** 1.5 years with overwrap; 1 year with no overwrap **Packaging:** Multilayer laminiate pouch **Preparation:** None **Mass:** 0.74 to 2.43 oz (21 to 69 g)
Extended-shelf-life bread products – the products must be specially formulated to a water activity level low enough to prevent the growth of anaerobic pathogenic bacteria	Tortillas, Wheat flat bread	**Shelf life:** 1 year **Packaging:** Multilayer aluminum-containing laminate or packaged by Department of Defense **Preparation:** None
Fresh food – foods with a short shelf life and no processing	Fresh fruit, Raw vegetables, Fresh tortillas	**Shelf life:** 1 week **Packaging:** Vacuum packaged with gas flush, protection of structure and contamination **Preparation:** None
Beverages – either freeze-dried beverage mixes (e.g., coffee or tea) or flavored drinks (e.g., lemonade, orange drink, etc.)	Freeze-dried (coffee or tea), Drink mix (lemonade), Water	**Shelf life:** 3 years **Packaging:** Multilayer aluminum-containing laminate pouch, adapter for rehydration, straw **Preparation:** Rehydration using hot or cold water **Mass:** 0.42 to 1.90 oz (12.0 to 54.0 g)

Source: Human Integration Design Handbook, Table 7.2-6: Types of Food and Packaging for Spaceflight

Application

<u>**Space Food System Design**</u>

Food Development – Foods must be developed to be safe, nutritious, and acceptable, and to meet mission requirements.

Mission Requirements – Missions up to three days in length may have mass and power constraints that do not support certain types of foods, such as rehydratables and heated foods. As mission length increases (> that 30 days) menu cycle length must increase (over an eight-day menu) menu cycle length must increase (over an eight-day menu) to provide variety, which promotes consumption. Sufficient supply will also need to be considered for planning. For example, the reserve for ISS USOS crewmembers is 4-month worth of food for 4 crewmembers.

Development of Food Products – Food products are developed with consideration for nutritional content, safety, and acceptability, as well as:

- storage duration (based on mission duration plus the time required to process, test, and ship the foods for launch) and shelf life (based on each food's composition, preparation and processing method, packaging, and storage conditions)
- packaging type is essential for maintaining safety, nutritional quality, and acceptability throughout shelf life – food packaging must meet safety and gaseous barrier specifications
- suitability for use in microgravity, for example, foods that produce crumbs (such as crackers) should be provided in bite-sized pieces to minimize debris and foods that easily break and crumb should not be used; meal items should contain enough moisture to stay in the package or on a utensil through surface tension

Food Stowage – Food may be stowed in various configurations, as long as the packages are protected from puncture or damage during transport and in mission.

Expertise – NASA utilizes the following expertise to develop and provide a food system:
food scientists develop food specifications, confirm safety, confirm shelf life, and suitability registered dietitians develop menus and confirm nutritional content packaging engineers develop and test package integrity (sealing and vacuum) of packaged foods logistics specialists develop stowage procedures and monitor food inventory food system engineer design food processing equipment to rehydrate and heat food

Facilities – Proper facilities such as an analytical lab, food processing plant, packaging room, sensory facility and stowage room are needed to maintain the food quality and safety.

Product Packaging on System Compatibility and Crew Safety – Other consideration should include flammability of the packaging, avoiding the use of frangible materials, off-gas testing and limiting foreign object debris (FOD).

Menu Development (personal preference vs standard menu) – Personal preference coupled with providing a standard menu for use by all crew is considered based on launch and crew selection timelines. Preference menus may not be suitable if food launches ahead of crew selection. The overall menu needs to ensure that the total nutrient requirements are met while providing acceptable foods with enough and variety for the crew to avoid menu fatigue, and underconsumption that could lead to impacts on crew health and performance.

Application

Additional Considerations

Packaging – The food packaging needs to provide the capability to maintain food safety and limit environmental contamination during all nominal and contingency phases of the mission.

Personnel – All personnel working directly with food intended for human consumption will need to receive food handling training equivalent or exceeding the requirement for obtaining a food handler's permit from the local health authority (ServSafe® certification, or the equivalent). Additionally, the personnel need to avoid personal behaviors that can contaminate food, properly wash and care for hands, wear proper PPE (e.g. disposable lab coat, hair nets, face mask, gloves, and beard nets when applicable are required when handling exposed food and packaged food for flight).

Facility – The facility where food is prepared, processed, packaged, stowed, and stored will need to:

- Comply with applicable federal/state/local laws and regulations and industry Good Manufacturing Practice standards.
- Limit access to prevent food adulteration
- Have temperature and FOD control
- Control for microbial and particulate contaminants

Crew Training – Crewmembers will need to have understanding and training of in-flight food safety (proper food preparation, consumption, and clean up; food hardware's reuse frequency; etc.).

Documentation – Maintain records that demonstrate compliance with federal food regulations and laws for inspection at any time. Documentations such as standard operation procedure technical specifications of food, applicable drawings are to be in place to ensure consistent and quality work.

Technical Challenges

- Nutrient-dense, shelf stable foods that meet overall nutritional, safety, and sensory acceptability metrics
- Menu items with at least a 5-year shelf life
- Partial gravity cooking processes that minimize microbial risk
- High-barrier, low-mass, & process compatible packaging materials that help extend shelf-life to five years
- Packaging that can withstand vibration, acceleration loads, radiation, various environmental factors (i.e., temperature, humidity, zero-pressure and decompression)

Sourcing – Typically, it is preferred that all food and ingredients are sourced from a major chain grocery store or food companies with a quality assurance system in place that audits their suppliers for compliance with federal, state, and local food regulations and laws including but not limited to FSMA, Current Good Manufacturing Practices (CGMP), and Hazard Analysis, and Risk-Based Preventive Controls in accordance with the Code of Federal Regulations (CFR) Title 21 and Title 9 as applicable. Any items that are imported into the United States will need to meet all of the requirements of the FDA FSMA rule on the Foreign Supplier Verification Program (FSVP), according to the federal government import requirements.

Processing – Shelf-stability is the standard used product type and should be used when possible. This can include the processing methods of freeze drying, thermostabilizing, and irradiation.

Inventory Control –This includes maintaining, tracking, tracing, and recalling all food items that can be subject to a recall.

Back-Up

Major Changes Between Revisions

Rev B → Rev C

- Modified layout to be consistent with new formatting
- Additional content added for clarity and guidance throughout
- Corrected Food and Production Area Microorganism Levels table

Rev A → Rev B

- Updated information to be consistent with NASA-STD-3001 Volume 1 Rev B and Volume 2 Rev C

Original → Rev A

- Modified Dietary Reference Intakes (DRIs) exceptions
- Added protein and deleted B6 adjustment
- Added note that DRIs may be tailored
- Added Considerations for Off-Nominal Events
- Added Packaging Considerations to "Technical Challenges" section on slide 8
- Added Back-Up slides to include Standard details

Referenced Technical Requirements

NASA-STD-3001 Volume 1 Revision B

[V1 3002] Pre-Mission Preventive Health Care Pre-mission preventive strategies shall be used to reduce in-mission and long-term health medical risks, including, but not limited to: (see NASA-STD-3001, Volume 1 Rev B for full standard).

[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA) that takes into account the needs and limitations of each specific design reference mission (DRM), and parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. The term "in-mission" covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001, Volume 1 Rev B for full standard).

[V1 3004] In-Mission Medical Care All programs shall provide training, in-mission medical capabilities, and resources to diagnose and treat potential medical conditions based on epidemiological evidence-based PRA, clinical practice guidelines and expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses should consider the needs and limitations of each specific DRM and vehicles. The term "in-mission" covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, are to include, but are not limited to: (see NASA-STD-3001, Volume 1 Rev B for full standard).

[V1 3016] Post-Mission Health Care Post-mission health care shall be provided to minimize occurrence of deconditioning-related illness or injury, including but not limited to: (see NASA-STD-3001, Volume 1 Rev B for full standard).

[V1 3018] Post-Mission Long-Term Monitoring Crewmembers returning from space flight shall be monitored longitudinally for health and well-being parameters in a standardized manner.

[V1 4019] Pre-Mission Nutritional Status Pre-mission nutritional status shall be assessed and any deficiencies mitigated before launch.

[V1 4020] In-Mission Nutrient Intake In-mission nutrient intake shall be no less than 90% of the calculated nutrient requirements, based on an individual's age, sex, body mass (kg), height (m), and an activity factor of 1.25.

[V1 4021] In-Mission Nutritional Status In-mission nutritional status shall be assessed and recommendations/countermeasures applied for any decrements below predetermined values.

[V1 4022] Post-Mission Nutritional Assessment and Treatment Post-mission nutritional assessment and treatment shall be aimed at returning to baseline.

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision C
[V2 3006] Human-Centered Task Analysis Each human space flight program or project shall perform a human-centered task analysis to support systems and operations design.

[V2 6026] Water Quality At the point of crew consumption or contact, the system shall provide potable water that is safe for human use, including drinking, food rehydration, personal hygiene, and medical needs and is aesthetically acceptable.

[V2 6039] Water Dispensing Rate Water shall be dispensed at a rate that is compatible with the food system.

[V2 6040] Water Dispensing Increments To prevent overflow, water shall be dispensable in specified increments that are compatible with the food preparation instructions and time demands of the allotted meal schedule.

[V2 6109] Water Quantity The system shall provide a minimum water quantity as specified in Table 4, Water Quantities and Temperatures, for the expected needs of each mission, which should be considered mutually independent.

[V2 6110] Water Temperature The system shall provide the appropriate water temperature as specified in Table 4, Water Quantities and Temperatures, for the expected needs of each mission and task.

[V2 7001] Food Quality The food system shall provide the capability to maintain food safety and nutrition during all phases of the mission.

[V2 7002] Food Acceptability The system shall provide food that is acceptable to the crew for the duration of the mission.

[V2 7003] Food Caloric Content The system shall provide each crewmember with an average of 12,698 kJ (3,035 kcal) per day, else an average energy requirement value is determined using Table 13, EER Equations and applying an activity factor appropriate to the mission gravity and planned level of physical activity.

[V2 7004] EVA Food Caloric Content For crewmembers performing EVA operations, the food system shall provide an additional 837 kJ (200 kcal) per EVA hour above nominal metabolic intake as defined by [V2 7003] Food Caloric Content, of this NASA Technical Standard.

[V2 7007] Food Microorganism Levels Microorganism levels in the food and production area shall not exceed those specified in Table 15, Food Microorganism Levels.

[V2 7008] Food Preparation The system shall provide the capability for preparation, consumption, and stowage of food.

[V2 7009] Food Preparation and Cleanup The food system shall allow the crew to unstow supplies, prepare meals, and clean up for all crewmembers within the allotted meal schedule.

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision C (continued)

[V2 7010] Food Contamination Control The food storage, preparation, and consumption areas shall be designed and located to protect against cross-contamination between food and the environment.

[V2 7011] Food and Beverage Heating The system shall provide the capability to heat food and beverages to a temperature appropriate for the given item.

[V2 7012] Dining Accommodations Crewmembers shall have the capability to dine together.

[V2 7014] Food Spill Control The system shall provide the ability to contain and remove food particles and spills.

[V2 7015] Food System Cleaning and Sanitizing The system shall provide methods for cleaning and sanitizing food facilities, equipment, and work areas.

[V2 7100] Food Nutrient Composition The system shall provide a food system with a diet including the nutrient composition that is indicated in the Dietary Reference Intake (DRI) values as recommended by the National Institutes of Health, with the exception of those adjusted for space flight as noted in Table 14, Nutrient Guidelines for Space flight.

[V2 7052] Stowage Location All relocatable items, e.g., food, EVA suits, and spare parts, shall have a dedicated stowage location.

[V2 8001] Volume Allocation The system shall provide the defined habitable volume and layout to physically accommodate crew operations and living.

[V2 11025] Suited Nutrition The system shall provide a means for crewmember nutrition in pressure suits designed for surface (e.g., Moon or Mars) EVAs of more than 4 hours in duration or any suited activities greater than 12 hours in duration.

[V2 11029] LEA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 2 L (67.6 fl oz) per 24 hours for the LEA suit.

[V2 11030] EVA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 240 mL (8.1 fl oz) per hour for EVA suited operations.

[V2 11037] Suited Metabolic Rate Measurement The system shall measure or calculate metabolic rates of suited EVA crewmembers.

[V2 11038] Suited Metabolic Rate Display The system shall display metabolic data of suited EVA crewmembers to the crew.

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