CHANGES IN SPACE FOOD OVER THE LAST 45 YEARS

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FIRST TRIP TO THE MOON – APOLLO MISSIONS

From 1969 through 1972, 12 U.S. astronauts made 6 landings on the Moon.[1] A variety of foods—dehydrated foods hydrated with hot water, food preserved in thermostablized pouched foods, some tube foods, and bite-sized foods— were available to the astronauts, but they did not take the time to consume the food and did not particularly like some of these items[1-3]. The nutritional values of the food reflected the Recommended Dietary Allowances of the time period. For instance, calcium intake was recommended at 800mg/d and the food system reflected that level. During the Apollo program the food system improved and many of the developments led to the Shuttle and International Space Station food systems.

THE MOST ADVANCED, U.S. SPACE FOOD SYSTEM—SKYLAB SPACE STATION

In the early 1970s, the US launched its first space station, Skylab, which was dedicated to solar astronomy and life sciences research.[4] Astronauts lived and worked on Skylab for 3 missions of 28, 59, and 84 days. They had a large interior living area with a dining room and table, and had eating utensils along with a pair of scissors for cutting open the food containers. The containers were similar to plastic bowls. The menu of 72 different foods included frozen and refrigerated foods. No other space vehicle before, or since, has had the capability to provide these. Skylab astronauts participated in metabolic studies and were strongly encouraged to consume all their foods. Consequently, Skylab is the only space program in which astronauts did not lose weight**.** Repeating these metabolic experiments with the current food program is not expected to occur for many years because of power and volume constraints as well as emphasis on other science objectives as opposed to metabolic studies.

SHUTTLE AND INTERNATIONAL SPACE STATION (ISS) FOOD SYSTEMS

In current space flight programs, the basic foods must be stored at ambient temperatures, survive acceleration and temperature gradients during launch, and meet safety and nutritional standards. Many of the foods used are commercially available, but are packed for individual consumption with protection such as oxygen barriers. The foods are reheated by radiant heat as convection currents do not occur in the microgravity of space flight. Packages are flat for ease of storage **(Fig. 1).** Food components are freeze-dried, thermostablized (made to be unaffected by heating), irradiated, or left in a natural form (nuts are an example of the latter). Infrequently, some fresh foods such as fruit are available. Crew members select their flight menu by tasting foods before launch and menus are determined to provide the nutritional requirements and variety **(Table 1)**.[5]

Shuttle foods and ISS foods differ in several major ways. The Shuttle can handle dehydrated foods better because water is readily available as a by-product of the fuel cells that provide the Shuttle's power. (**Fig 2**) ISS power comes from solar panels; hence water is a limited resource. Thus, ISS has a higher percentage of thermostablized foods, which already contain the necessary water.

Shuttle missions last about 2 weeks while ISS missions last 6 months. With the longer missions, acceptability of the food is much more important to the astronauts. Anecdotal reports from the crew have suggested that the sense of taste changes in microgravity. Since approximately 85% of what you taste is what you smell, it is not clear whether this phenomenon is due to fluid shift in the body, vehicle air currents where hot air does not rise, or that the food is not piping hot in temperature. The observed effect could also be related to the fact that the crew is far from home and the result may be the need for "comfort foods". Related to acceptability, the ISS crews require more variety in their menus. For the initial ISS flights, the menu cycle was six days where the menu repeated itself every six days. The menu cycle has gradually increased, and the crew currently experiences a ten-day menu cycle.

With both acceptability and variety increasing in importance, NASA food scientists have developed 65 new foods for the ISS menu. Because there is a need for more flavors to counteract the change in taste, and since the crewmembers train in Houston (known for its ethnic and spicy foods), the new food items are flavorful and spicy. In addition, the foods are ethnic in nature and include Chinese, Indian, Cajun, and Mexican menu items. However, the favorite among many of the astronauts is still the freeze-dried shrimp cocktail with its flavorful cocktail sauce.

The Shuttle launches with all the crew members' foods, including some fresh foods, but ISS food may be launched separately from the crew members and does not contain fresh foods. Supplies of fresh foods are provided to ISS crew members infrequently via the Russian Progress resupply vehicles or the Shuttles when they dock with the ISS. Sometimes, due to changes in launch dates of supply missions, ISS crew members do not have the food items they chose for their menus. On the ISS, food is stored in boxes and sorted by categories, like a kitchen pantry, allowing the crew members to select their foods of choice. This provides the crew with some choice on what to eat during each meal – another psychological boost during the long mission.

FOODS FOR RETURN TO THE MOON

Initially, sortie missions to the Moon will have a total duration of 2 weeks and astronauts will spend about 7 days on the surface. For these missions, the food system will be similar to that of the ISS. However, the sortie mission crew compartment will have less space than the ISS for heating and eating foods, as well as for trash containers. No waste disposal system will be available, so food packaging must be disposed of in some other way. Since the present plan is to return all waste to Earth, the packaging must not only provide a sufficient barrier to oxygen and water, but also do it with low mass and volume.[6]

There are plans for the establishment of a habitat on the lunar surface. A habitat would allow the food system to be expanded to include some *in situ*-grown foods such as salad crops (**3**) and provide a potential for some food preparation similar to that on Earth. If a long-duration Moon base is built, a greater variety of foods will be provided by growing, or bringing up in bulk, crops such as soybeans, wheat, peanuts, beans, and rice. This would lead to a more vegetarian-like diet. Most of these crops would require some food processing and cooking capabilities for long-duration extraterrestrial missions.

Although small amounts of green leafy foods such as lettuce have been grown on the Russian Space Station Mir, US Shuttle flights, and the ISS, technical issues may make it difficult to grow plants on the Moon. The atmosphere of the Moon base will probably have a higher percentage of oxygen and carbon dioxide (CO_2) than on Earth, at an atmospheric pressure between 8 and 10.2 psi rather than the 14.7 psi on Earth. The elevated CO_2 levels would tend to increase photosynthetic rates for many crops and improve yields [7, 8]. Although the percentage of oxygen might be high due to the reduced overall pressure, this should not interfere with photosynthesis so long as the absolute partial pressure of carbon dioxide is greater than ~ 0.1 kPa, or the equivalent of 1000 ppm at 14.7 psi total pressure [7, 8]. As with all gases, diffusion of water vapor at reduced pressures would increase, resulting in increased rates of transpiration [9, 10].

Plants for food production on the Moon would likely be grown in their own chambers so that the atmospheric mixture of oxygen, CO_2, and humidity, along with temperature, light levels, and light cycles, can be controlled. At the same time, the plants will be growing at 1/6 of Earth gravity. Although these gravitational forces are less than on Earth, they are greater than in space. Will this partial gravity affect crop growth compared to the growth in microgravity of space flight or the 1 gravity of Earth? Partial gravity of the Moon should at least allow the use of conventional watering techniques; similar to those on Earth, but clearly it will be a challenge to grow crops at sustainable levels on the Moon.

Crop processing and food preparation techniques will be limited on the Moon, even with the slight increase in gravity, more room, and potentially adequate power. The heating and processing of food will require food processing equipment that uses a limited amount of water (continuing to be a limited resource) and crew time. Since up-mass and volume will continue to be an issue, food processing equipment that is multifunctional will be required. By self-containing the equipment, the contamination from dust and the effects of lower atmospheric pressure on the processing of the food will be minimized.

SUMMARY

The space food system has improved over the last 45 years. With the advances for a Moon base, there is a potential that foods in space will be more like home cooked foods. However, until that happens, there will continue to be dehydrated and thermostablized foods providing the bulk of the astronauts' food. In order for the astronauts to have adequate macronutrients, a food system must be developed including raising plants and food preparation, both a major challenge given the limited water, volume, and power. The lunar kitchens will be very different, but good food is essential to maintain good health.

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Table 1. Example of space flight menus

Figure Legends

Figure 1 Example of foods

Figure 2 Astronaut James H Newman, PhD consuming foods on Space Shuttle

Figure 3 Illustration of Foods growing at a Moon base

Typical Menus For Astronauts On Orbit

Meal	Day 1	Day 2	Day 3
Breakfast	Blueberry/Raspberry Yogurt (T) Granola w/ Blueberries (R) Orange Drink (B) Kona Coffee w/Cream, Sugar (B)	Dried Peaches (IM) Oatmeal w/ Raisins (R) Orange Drink (B) Kona Coffee w/Cream, Sugar (B)	Blueberry-Raspberry Yogurt (T) Granola w/ Raisins (R) Orange Drink (B) Kona Coffee w/Cream, Sugar (B)
Lunch	Beef Fajitas (I) Tortilla (FF) x2 Applesauce (I) Almonds (NF) Lemonade (B) x2	Smoked Turkey (I) Tortillas (FF) x2 Dried pears (IM) Almonds (NF) Orange-Grapefruit Drink (B) x2	Chicken Strips in Salsa (T) Tortillas (FF) x2 Applesauce (T) Cashews (NF) Lemonade (B) x2
Dinner	Shrimp cocktail (R) Grilled Chicken (T) Macaroni & Cheese (R) Green Beans w/Mushrooms (R) Candy Coated Chocolates (NF) Lemonade (B) Tea w/Lemon and Sugar (B)	Vegetarian Vegetable Soup (T) Chicken Fajitas (T) Tortilla (FF) x2 Cherry-Blueberry Cobbler (T) Orange Drink (B) Tea w/Lemon and Sugar (B)	Chicken Noodle Soup (T) Beef Stroganoff w/ Noodles (R) Broccoli au Gratin (R) Dried Peaches (IM) Apple Cider (B) Tea w/Lemon & Sugar (B)
	Day 4	**Day 5**	**Day 6**
Breakfast	Dried Pears (IM) Oatmeal w/ Brown Sugar (R) Orange Drink (B) Kona Coffee w/Cream, Sugar (B)	Dried Peaches (IM) Oatmeal w/ Raisins (R) Orange Drink (B) Kona Coffee w/Cream, Sugar (B)	Blueberry-Raspberry Yogurt (R) Granola Bar (NF) x2 Dried Peaches (IM) Orange Drink (B) Kona Coffee w/Cream, Sugar (B)
Lunch	Peanut Butter (T) Grape Jelly (T) Tortilla (FF) x2 Trail Mix (IM) Grape Drink (B) x2	Beef Fajitas (I) Tortilla (FF) x2 Dried Pears (IM) Almonds (NF) Orange-Grapefruit Drink (B) x2	Chocolate Brownie Clif Bar (FF) Vanilla Breakfast Drink (B) Almonds (NF) Orange-Mango Drink (B)
Dinner	Shrimp Cocktail (R) Crawfish Etouffee (T) Vegetable Risotto (R) Creamed Spinach (R) Dried Peaches (IM) Apple Cider (B) Tea w/Lemon & Sugar (B)	Grilled Pork Chop (T) Mashed Potatoes (R) Broccoli au Gratin (R) Peach Ambrosia (R) Apple Cider (B) Tea w/Lemon & Sugar (B)	Split Pea Soup (T) Teriyaki Chicken (R) Rice Pilaf (R) Broccoli au Gratin (R) Peach Ambrosia (R) Apple Cider (B) Tea w/Lemon & Sugar (B)

B = Beverage FF = Fresh Food I = Irradiated IM = Intermediate Moisture NF = Natural Form R = Rehydratable T = Thermostabilized

Crackers
2/28/2003
1296
Крекеры
Candy Coated Peanuts
9/30/2003
2088
Арахис глазированный
Orange Ade
Creamed Spinach
50 mL hot water, 5-10 min
Протертый шпинат
CHEESE SPREAD
(FORTIFIED)
Cheddar Cheese Spread
Knead Before Opening
1/31/2004
1201
Паста из сыра чеддер
Размягчить перед открытием
Trail Mix
9/30/2003
2088
Сухофрукты и орехи
Beef Steak
Exp. 8/31/97
5234
4127303142
BEEF PATTIE
BML728
Cashews
9/30/2003
2088
Орехи кешью