Applications of Food Technology: Lessons from the Space Program

by

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Development of space food in the United States has evolved over a series of manned missions into space in various types of vehicles with a wide variety of objectives and goals. Man's first ventures into space were in small space craft with a crew of one or two. Food development for space flight has always been from a systems approach, since the food has so many intricate interfaces in the closed environment of a space craft.

The design goals, from the consumer point of view, have always been basically the same and are not any different from those of the general public. These goals are:

- High Acceptability
- Minimum Preparation
- Nutritious
- Easy Clean-up
- Free Choice

Engineered Foods

The initial approach to developing food to meet the constraints of the small space craft was to produce highly engineered foods. Examples of these are shown in Figures 1 and 2. Tube foods were the first to be consumed in space by U.S. astronauts. Astronaut John Glenn was the first to eat in space when he had applesauce in a tube. Tubes were later supplemented with cubes. Both types of foods were highly engineered and met all the constraints imposed by the vehicle, such as pressure changes, high oxygen content, etc. There were virtually no crumbs associated with consumption, no possibility of water escaping into the cabin, and the food provided a balanced diet. But there was a problem. Lesson number one: In order for food to be nutritious and provide psychological well being, it must be eaten. Food in tubes could not be seen or smelled and the texture was not normal in most cases. Cubes were made from crackers and cookies. The flavor was unchanged, but the texture was significantly different from the original product. Even though astronauts on taste panels in the test kitchen thought they tasted great, a majority of the cubes were returned after each mission. Concentrated food or the meal-in-a-pill concept was not acceptable for space food systems.

Heating Food

As food systems evolved from cubes and tubes to dehydrated foods, the need for hot water or a method of heating food in space became apparent. Hot water was available on the early space craft and methods were devised to add hot water to food for rehydration. However, the water was seldom hot enough to provide a "hot" meal, especially after it was transferred to a package with ambient temperature food and then allowed to sit for up to ten minutes while the food rehydrated. A food warmer was first introduced on the Skylab program in 1973. With mission length lasting up to 84 days, the ability to heat food became an important factor in the acceptability of the food. The Skylab food warmer was built into the serving tray with three food cavities having the ability to warm foods (Figure 3).

A food heater was not used again until the Shuttle program, which began in 1981. The first food warmer used on the Shuttle was a portable carry-on suitcase heater. Hot water was not available from the tap, so in order to get hot water, the astronauts had to fill a beverage package with ambient temperature water and place it in the food warmer for 15 to 20

Figure 1

Tube food developed for and used on the Mercury, Gemini and early Apollo missions. The first food eaten in space by a U.S. Astronaut was from this type container.

Figure 2

Cubed foods used on Mercury, Gemini and early Apollo missions.
Each cube was coated to prevent crumbs in the space craft.

Figure 3

Skylab heating and serving tray.
The three wells in the front had heaters to warm the food to serving temperatures.
The heaters were connected to a timer which could be preset to warm the food.

minutes. The galley was introduced on STS-9 in 1983. In addition to having the capability to heat foods in the forced-air convection oven, the galley also provided measured quantities of hot and cold water, and a food preparation area (Figure 4).

Plans for the Space Station galley include a forced-air convection oven with the capability to reach 350°F. Lesson number 2: The ability to heat food significantly improves the acceptability.

Refrigerators and Freezers

A passive freezer, which used liquid nitrogen as the coolant, was developed for the Apollo program, but was never used due to weight and volume restrictions. Freezers and refrigerators were first used by the U.S. on the Skylab program, which began in 1973. Frozen and refrigerated foods enhanced the Skylab food system, which tended to be bland and lacked variety due to the metabolic studies which controlled food intake. Only a limited quantity of frozen and refrigerated food could be included, so the astronauts were involved in the decision as to which foods would be frozen. The refrigerator was used as a chiller for food preparation. The two most popular frozen foods were steaks and ice cream.

Food freezers and refrigerators were not included in the design of the Shuttle food system due to limited weight and volume allocations. Three servings of vanilla ice cream and one steak were sent up in a laboratory experimental freezer on STS-4. No other frozen food has been used on U.S. missions since the Skylab program.

Frozen and refrigerated foods have been included in the plan for Space Station food. Current plans call for around 50 percent frozen food for the 90-day missions. Lesson number 3: Food freezers and refrigerators are essential for long duration missions.

Thermo-stabilized Retort Pouches

The first retort pouches were used by NASA in 1968 on the Apollo Missions, long before they were approved for the general public. Even though the pouches added more weight and volume to the food system, the variety and minimum preparation efforts made the retort pouches a favorite. Retort pouches have continued to be used in space food systems from Apollo through the current Shuttle program. Lesson number 4: Acceptability and ease of preparation are more important to crew members than weight savings.

Irradiated Food

Some irradiated foods offer a distinct advantage for use in space food systems. They require no freezer or refrigerator space and allow the processor to control the amount of free liquids and doneness in meat products. Shelf life of bakery goods is significantly improved with irradiation.

Irradiated ham was first used on Apollo 17 in 1972. Irradiated flour was used to make shelf stable bread for Skylab, and irradiated steak, ham, and corned beef were used on the Apollo-Soyuz Test Project in 1975. Irradiated bread and breakfast rolls were used on the early Shuttle missions, but were discontinued when permission was granted to load perishable foods on the Shuttle at 16 hours before launch. Irradiated steak, corned beef and smoked turkey have been used on Shuttle missions. Lesson number 5: Some irradiated foods are a viable alternative to frozen foods.

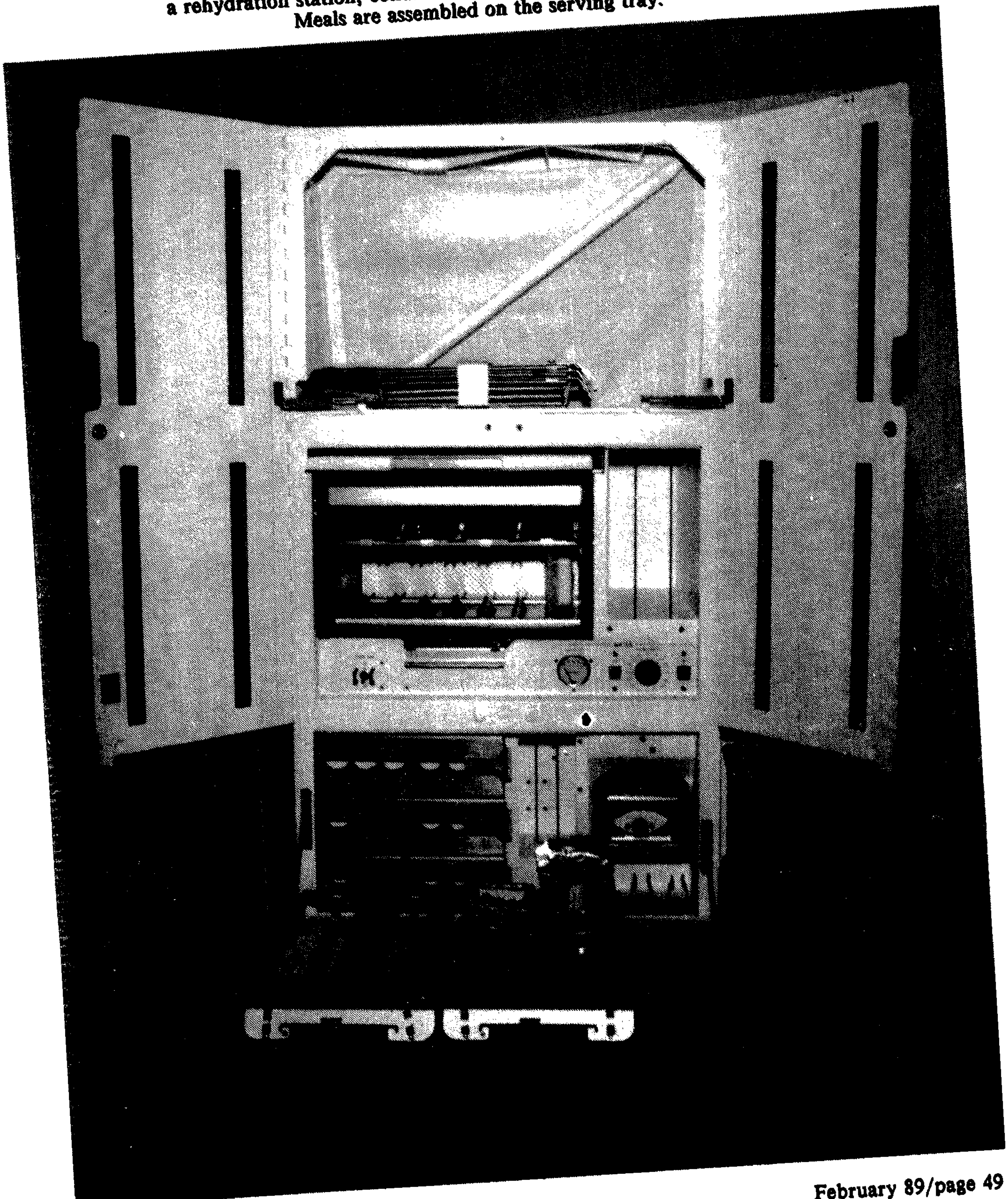
Use of Commercial Foods

Prior to the Shuttle program, almost all space food was specially processed from ingredients which met rigid requirements. The food was processed and packaged under strict environmental constraints and constant inspection. Each lot of food was documented for traceability. The commercial image of the Shuttle program encouraged the use of commercial foods in the system. The food system was designed to make maximum use of commercial products in order to reduce cost by avoiding the expense of producing small lots of food and to take advantage of the reduced costs of mass produced products.

Several problems occurred with this approach. In order to be qualified for flight use, food must undergo a series of tests to verify that it does indeed meet the criteria established, such as rehydration, susceptibility to vacuum packaging, microbiological tests, etc. Most Shuttle foods are purchased yearly, or maybe every two years, depending upon the product. The problem encountered with commercial foods was that the product purchased last year was not always available the next time it was needed. Commercial manufacturers tend to reformulate and change their products. Many of these changes are not detectable to the consuming public, but can cause problems in space applications. Commercial products

Figure 4

Shuttle Galley.
The galley consists of a forced air convection oven which warms food to 170°F, a rehydration station, condiment dispenser, and meal assembly area. Meals are assembled on the serving tray.



required more testing than did those produced to a strict specification. Lesson number 6: In some cases, the advantages of using commercial foods are negated by the additional testing required to ensure that they are still qualified for flight.

Menu Selection

Early space voyagers were allowed to select their own personal menu from a limited number of flight-qualified foods. During the design phase of the Shuttle food system, it was determined that a universal menu would be more appropriate, due to the larger crew sizes and increased flight rate. A universal menu was selected after a series of sensory evaluations by representative astronauts. Each meal was overwrapped in a plastic bag to keep everything together. Experience with more flights resulted in more complaints about the universal menu and the bagged meal. Each astronaut wanted to select his or her own menu prior to the mission and did not want to be restricted to a sacked meal. Even though a few commanders have dictated use of the universal menu for the convenience of food preparation, the majority of flight crews prefer the personal preference menu. The system was changed early in 1984 to allow crews the option of choosing the universal menu or their own. Lesson number 7: There is no universal menu and crews must have options for menu selection with some real-time decision capability.

Fresh Food

Fresh fruits and vegetables were introduced on the Shuttle food system in 1983 on STS-6. Permission to load perishable foods on the Orbiter 16 hours before launch allowed the use of fresh fruits, vegetables, and bakery products. Types of items stowed as "fresh food" included oranges, apples, bananas, celery and carrot sticks, cheese, bread, and breakfast rolls. The availability of fresh fruits and vegetables made a significant improvement in the acceptability of the food system even though most of the foods were only good for a few days due to the high storage temperature (90°F+) of the Shuttle food lockers. Odors from the fresh fruits tend to permeate the cabin atmosphere and a few crew members have objected to the smell. Lesson number 8: Fresh fruits and vegetables are an essential part of a space food system.

Lessons to be Learned

There are many more lessons to be learned for the application of food technology to space food. Hopefully, we will have a microwave oven on Space Station, a first for the United States.

We need to learn more about cooking and mixing in space. We would like to be able to bake bread in space. We should be able to make great emulsions without gravity. The atmosphere control people want to know exactly what chemicals we are placing in their atmosphere when we cook.

For extended duration missions, we will need alternative sources of food. It is virtually impossible to launch and carry enough food for extended missions. Solutions may be found in growing food with such techniques as microbial fermentation, plant genetics, biotechnology, and physical/chemical reactions. Expendables will have to be recycled in a closed loop system, which presents problems as well as solutions. Closed loop systems tend to concentrate some toxic substances and may limit intake of essential nutrients by limiting the variation of food and water sources.

We have learned many other lessons from the space food program, but I hope I have covered some of the more important ones. We have many more challenges to meet, especially to support extended duration missions such as trips to Mars and a Lunar base colony.