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CHAPTER 1
APOLLO FOOD TECHNOLOGY

by

Malcolm C. Smith, D.V.M.
N.D. Heidelbaugh, V.M.D.
Paul C. Rambaut, Sc.D.
R.M. Rapp
Harry O. Wheeler, Ph.D.

Lyndon B. Johnson Space Center

C.S. Huber, Ph.D.
C.T. Bourland, Ph.D.

Technology, Inc.

Introduction

Before man ventured into space for the first time, there was concern that he might choke while attempting to swallow food in zero gravity. Foreign body pneumonia from aspiration of food particles and droplets was feared by some. The ability of man to digest and absorb food in a weightless environment was also seriously debated. These concerns for man's physiological well-being during weightlessness were augmented by fears that the unfamiliar and austere limitations imposed by the space vehicle and flight plans might place unacceptable constraints on the food system. Some food technologists doubted that edible foods could be prepared to withstand conditions of temperature, pressure, and vibration which were characteristic of unmanned space flight vehicles. Limitations on allowable weight and volume would also have direct impact on the food system.

Despite early concerns, restrictions, and technological hurdles surrounding space food development, adequate and acceptable diets were formulated and made available in sufficient time to accommodate the needs of man in space. The earliest food systems used in the Project Mercury flights and the short duration Gemini Program flights resembled military survival rations. For the first long term flight, the two-week Gemini 7 mission, nutritional criteria became important considerations and began to constrain food system designers. Adequate provisions for energy and nutrients had to be made within an exceedingly small weight and volume envelope. This food system envelope, about .77 kg per man per day (1.7 pounds) and 1802 cm^3 per man per day (110 cubic inches), also had to allow for all packaging materials needed to protect foods.

Because water produced as a by-product of fuel cell operation in the Gemini spacecraft could be made available, it became highly attractive from a food acceptance and weight savings standpoint to use dehydrated foods that could be reconstituted in flight. This was the departure point for the development of the Apollo food system, and systematic improvements were subsequently made as technology became available and the application was feasible. The results of these efforts are described in this chapter.

The Apollo Food System

The overall objective of the Apollo food system development program was to provide adequate and safe nutrition for man during the most ambitious space explorations ever attempted. This objective had to be achieved within many critical biological, operational, and engineering constraints. Considerations from which specific constraints were developed are listed in table 1. Details concerning the constraints are described in the *Apollo Experience Report – Food Systems* (NASA TN D-7720, July 1974).

Table 1
Sources of Constraints
on Apollo Food System Development

Biological	Operational	Engineering
Safety	Vehicle interface	Weight
Nutrition	Stability	Volume water for rehydration
Organoleptics	Packaging	
Personal hygiene	Storage	Pressure
Ingestion	Preparation	Temperature
Digestion	Servicing	Relative humidity
Absorption	Waste disposal	Acceleration
Gastroenterology	Schedules	Vibration
Crew idiosyncracies	Crew time	Power

Apollo food system technology evolved over a considerable period of time, with the aid of efforts from the U.S. Air Force Manned Orbiting Laboratory Program, the U.S. Army Natick Laboratories, industry, and universities. The earliest "space foods" were bite-sized foods suitable for eating with one's fingers, and pureed foods, squeezed directly into the mouth from flexible metal toothpaste-type tubes. Extensive modifications in food and food packaging were made throughout Project Mercury and the Gemini and Apollo Programs. Modifications of the food system were especially necessary during the Apollo Program for the following reasons.

1. Inflight food consumption proved inadequate to maintain nutritional balance and body weight.
2. Inflight nausea, anorexia, and undesirable physiological responses experienced by some crewmen were believed to be partly attributable to the foods.

3. Meal preparation and consumption required too much crew time and effort.
4. Water for reconstitution of dehydrated foods was unpalatable initially and contained undesirable amounts of dissolved gases.
5. Functional failures occurred in the rehydratable food packages in the early Apollo flights.

Stepwise modifications of food system technology improved system capability to deliver adequate nutrients in a form that enhanced food acceptance and convenient use. This general trend of increased acceptance was reported by each successive Apollo flight crew.

An overall impression of the evolution of the Apollo food system can be gained by comparing the flight menus for the Apollo 7, 11, and 17 missions (tables 2, 3, and 4). The similarity of the menus for each Apollo 7 astronaut should be compared with the high degree of individuality achieved for each Apollo 17 astronaut. This difference resulted from increased personal selection of food items by the astronauts as the program progressed. Table 4 also indicates the greatly increased variety of foods available for Apollo 17 crewmen.

Increased variety of foods was important, but more important was the improvement in quality of individual foods. Improved food quality is not apparent from the listing of foods. For example, fruit cocktail was reformulated because the original product became crushed by the effects of atmospheric pressure on the package and it was then difficult to rehydrate.

Details of the evolution in space food science and technology, from the first days of planning for manned space flight to the end of the Apollo Program, can be traced in reports cited in the chronological bibliography at the end of this chapter.

Each mission in the Apollo series had different objectives and requirements, and the scope of the Apollo food system was modified to fit the needs of each. The primary mission phases, from the vantage point of food provision, included times during which the crewmen occupied the Command Module (CM) and the Lunar Module (LM), and times when they were being transported in various vehicles from the recovery site to the NASA Lyndon B. Johnson Space Center in Houston, Texas. A contingency food system also was provided to be used if emergency decompression of the space vehicle occurred. For the Apollo 11 through 14 missions, a postflight quarantine period required a food system for use in the Mobile Quarantine Facility (MQF) and the Lunar Receiving Laboratory (LRL). Each of these environments presented a different set of constraints and requirements for the food system. Inflight metabolic balance studies were conducted on the Apollo 16 and 17 missions. These studies imposed unique requirements on the food system for preflight, inflight, and postflight measurements and control of dietary intake.

Before an Apollo launch, each prime and backup crewmember evaluated available flight foods and selected the food items he preferred. Then the foods were assembled into nutritionally balanced menus which were reviewed by crewmembers and nutritionists for maximum acceptability within nutritional constraints. Finally, the astronauts were briefed on spacecraft food stowage, preparation, and waste disposal.

Table 2
Typical Menu, Apollo 7-10

A. Commander (CDR)			
Day 1	Day 2	Day 3	Day 4
Meal A			
Peaches (R) Bacon squares (IMB) Cinnamon bread cubes (DB) Breakfast drink (R)	Applesauce (R) Sausage patties (R) Apricot cereal cubes (DB) Breakfast drink (R)	Fruit cocktail (R) Bacon squares (IMB) Cinnamon bread cubes (DB) Breakfast drink (R)	Ham and apple-sauce (R) Peanut cubes (DB) Strawberry cereal cubes (DB) Breakfast drink (R)
Meal B			
Corn chowder (R) Chicken sand-wiches (DB) Coconut cubes (DB) Sugar cookie cubes (DB) Cocoa (R)	Tuna salad (R) Cinnamon bread cubes (DB) Chocolate cubes (DB) Cocoa (R)	Corn chowder (R) Beef pot roast (R) Graham cracker cubes (DB) Butterscotch pudding (R) Cocoa (R)	Pea Soup (R) Salmon salad (R) Cheese sand-wiches (DB) Cocoa (R)
Meal C			
Beef and gravy (R) Brownies (IMB) Chocolate pudding (R) Pineapple-grapefruit drink (R)	Spaghetti with meat sauce (R) Cheese sand-wiches (DB) Banana pudding (R) Pineapple fruit cake (IMB) Grapefruit drink (R)	Potato soup (R) Chicken salad (R) Beef sandwiches (DB) Gingerbread (IMB) Orange drink (R)	Shrimp cocktail (R) Chicken and gravy (R) Cinnamon bread cubes (DB) Date fruit cake (IMB) Orange-grapefruit drink (R)
B. Command Module Pilot (CMP)			
Meal A			
Peaches (R) Bacon squares (IMB) Cinammon bread cubes (DB) Breakfast drink (R)	Applesauce (R) Sausage patties (R) Apricot cereal cubes (DB) Breakfast drink (R)	Fruit cocktail (R) Bacon squares (IMB) Cinnamon bread cubes (DB) Breakfast drink (R)	Ham and apple-sauce (R) Peanut cubes (DB) Strawberry cereal cubes (DB) Breakfast drink (R)

R = Rehydratable
DB = Dry bite
IMB = Intermediate moisture bite

Table 2 (Continued)
Typical Menu, Apollo 7-10

B. Command Module Pilot (CMP) (Continued)			
Day 1	Day 2	Day 3	Day 4
Meal B			
Chicken sandwiches (DB) Coconut cubes (DB) Sugar cookie cubes (DB) Cocoa (R)	Tuna salad (R) Cinnamon bread cubes (DB) Chocolate cubes (DB) Cocoa (R)	Beef pot roast (R) Graham cracker cubes (DB) Butterscotch pudding (R) Cocoa (R)	Pea soup (R) Salmon salad (R) Cheese sandwiches (DB) Cocoa (R)
Meal C			
Beef and gravy (R) Brownies (IMB) Chocolate pudding (R) Pineapple-grapefruit drink (R)	Spaghetti with meat sauce (R) Cheese sandwiches (DB) Banana pudding (R) Pineapple fruit cake (IMB) Grapefruit drink (R)	Potato soup (R) Chicken salad (R) Beef sandwiches (DB) Gingerbread (IMB) Orange drink (R)	Shrimp cocktail (R) Chicken and gravy (R) Cinnamon bread cubes (DB) Date fruit cake (IMB) Orange-grapefruit drink (R)
C. Lunar Module Pilot (LMP)			
Meal A			
Peaches (R) Bacon squares (IMB) Cinnamon bread cubes (DB) Breakfast drink (R)	Applesauce (R) Sausage patties (R) Breakfast drink (R) Peanut cubes (DB)	Fruit cocktail (R) Bacon squares (IMB) Cinnamon bread cubes (IMB) Breakfast drink (R)	Ham and applesauce (R) Strawberry cereal cubes (DB) Apricot cereal cubes (DB) Breakfast drink (R)
Meal B			
Corn chowder (R) Chicken sandwiches (DB) Coconut cubes (DB) Sugar cookie cubes (DB) Cocoa (R)	Tuna salad (R) Cinnamon bread cubes (DB) Chocolate cubes (DB) Cocoa (R)	Corn chowder (R) Beef pot roast (R) Graham cracker cubes (DB) Butterscotch pudding (R)	Salmon salad (R) Cheese sandwiches (DB) Peanut cubes (DB) Cocoa (R)

Table 2 (Continued)
Typical Menu, Apollo 7-10

C. Lunar Module Pilot (LMP) (Continued)			
Day 1	Day 2	Day 3	Day 4
Meal C			
Beef and gravy (R) Brownies (IMB) Chocolate pudding (R) Pineapple-grapefruit drink (R)	Spaghetti with meat sauce (R) Cheese sandwiches (DB) Banana pudding (R) Pineapple fruit cake (IMB) Grapefruit drink (R)	Potato soup (R) Chicken salad (R) Beef sandwiches (DB) Gingerbread (IMB) Orange drink (R)	Potato salad (R) Chicken and gravy (R) Cinnamon bread cubes (DB) Date fruit cake (IMB) Orange-grapefruit drink (R)

The initial Apollo inflight food system consisted of two basic food types: (1) lightweight, shelf-stable, dehydrated foods that required rehydration prior to consumption, and (2) ready-to-eat, dehydrated bite-sized foods. Dehydrated foods were selected because of shelf life and because weight was critical in the Apollo vehicle. Approximately 80 percent of the weight of fresh food is water; therefore, the removal of water resulted in a substantial reduction of food system weight. As was previously noted, water for rehydration was available as a by-product of fuel cell operation, wherein hydrogen is combined with oxygen to release electrical energy.

Freeze Dehydrated Foods

The optimal method of dehydrating food is freeze dehydration, a technique preferred because of the remarkable preservation of quality in the resulting product. Color, texture, flavor, nutrient content, and reconstitution of foods which are properly freeze-dried closely approximate the original food. However, as with any other method of preservation, the food which is preserved cannot be of higher quality than the original.

The high quality of freeze-dried food derives largely from the technique of removing the water by sublimation directly from ice to vapor with minimum exposure of the food to heat. The food is frozen rapidly in circulating air at a temperature of approximately 233°K (-40°C). The frozen food is then placed in a vacuum chamber, where the pressure is reduced to less than 270 N/m^2 ($\approx$2 mm Hg). Energy in the form of heat is applied by means of heating plates maintained at temperatures of 298° to 303°K ($\approx$25° to 30°C), depending on the product. Under vacuum, this heat source provides the energy required to sublime the ice while the temperature of the food is maintained below the eutectic point. The heat input is carefully controlled to provide optimum removal of water vapor, which is collected on condensers within the vacuum chamber. The core of ice in the food completely disappears when the food reaches a moisture content of approximately two percent. This residual moisture remains bound to the food, and the energy level required to free it is greater than that of sublimation.

Table 3
Typical Menu, Apollo 11-16

A. Command Module – CDR and CMP			
Day 1,* 5	Day 2	Day 3	Day 4
Meal A			
Peaches (R) Bacon squares (8) (IMB) Strawberry cubes (4) (DB) Grape drink (R) Orange drink (R)	Fruit cocktail (R) Sausage patties (SBP) Cinnamon toasted bread cubes (4) (DB) Cocoa (R) Grapefruit drink (R)	Peaches (R) Bacon squares (8) (IMB) Apricot cereal cubes (4) (DB) Grape drink (R) Orange drink (R)	Canadian bacon and applesauce (R) Sugar coated corn flakes (R) Peanut cubes (4) (DB) Cocoa (R) Orange-grapefruit drink (R)
Meal B			
Beef and potatoes (WP) Butterscotch pudding (R) Brownies (4) (IMB) Grape punch (R)	Frankfurters (WP) Applesauce (R) Chocolate pudding (R) Orange-grapefruit drink (R)	Cream of chicken soup (R) Turkey and gravy (WP) Cheese cracker cubes (6) (DB) Chocolate cubes (4) (DB) Pineapple-grapefruit drink (R)	Shrimp cocktail (R) Ham and potatoes (WP) Fruit cocktail (R) Date fruit cake (4) (IMB) Grapefruit drink (R)
Meal C			
Salmon salad (R) Chicken and rice (SBP) Sugar cookie cubes (6) (DB) Cocoa (R) Pineapple-grapefruit drink (R)	Spaghetti with meat sauce** (SBP) Pork and scalloped potatoes (SBP) Pineapple fruit cake (4) (IMB) Grape punch (R)	Tuna salad (R) Chicken stew (SBP) Butterscotch pudding (R) Cocoa (R) Grapefruit drink (R)	Beef stew (WP) Coconut cubes (4) (DB) Banana pudding (R) Grape punch (R)

*Day 1 consisted of meals B and C only
**CMP substituted potato soup (R)
R = Rehydratable
I = Irradiated
DB = Dry bite
WP = Wet pack
IMB = Intermediate moisture bite
SBP = Spoon-bowl packet

Table 3 (Continued)
Typical Menu, Apollo 11-16

B. Command Module – LMP			
Day 1,*	Day 2	Day 3	Day 4
Meal A			
Peaches (R) Bacon squares (8) (IMB) Strawberry cubes (4) (DB) Grape drink (R) Orange drink (R)	Fruit cocktail (R) Sausage patties (SBP) Cinnamon toasted bread cubes (4) (DB) Cocoa (R) Grapefruit drink (R)	Peaches (R) Bacon squares (8) (IMB) Apricot cereal cubes (4) (DB) Grape drink (R) Orange drink (R)	Canadian bacon and applesauce (R) Sugar coated corn flakes (R) Peanut cubes (4) (DB) Cocoa (R) Orange-grapefruit drink (R)
Meal B			
Beef and potatoes (WP) Butterscotch pudding (R) Brownies (4) (IMB) Grape punch (R)	Frankfurters (WP) Applesauce (R) Chocolate pudding (R) Orange-grapefruit drink (R)	Cream of chicken soup (R) Turkey and gravy (WP) Cheese cracker cubes (6) (DB) Chocolate cubes (4) (DB) Pineapple-grapefruit drink (R)	Shrimp cocktail (R) Ham and potatoes (SBP) Fruit cocktail (R) Date fruit cake (4) (IMB) Grapefruit drink (R)
Meal C			
Salmon salad (R) Chicken and rice (SBP) Sugar cookie cubes (6) (DB) Cocoa (R) Pineapple-grapefruit drink (R)	Potato soup (R) Pork and scalloped potatoes (R) Pineapple fruit cake (4) (IMB) Grape punch (R)	Tuna salad (R) Chicken stew (SBP) Butterscotch pudding (R) Cocoa (R) Grapefruit drink (R)	Beef stew (SBP) Coconut cubes (4) (DB) Banana pudding (R) Grape punch (R)

*Day 1 consisted of meals B and C only.

Table 3 (Continued)
Typical Menu, Apollo 11-16

C. Lunar Module	
Meal A	Meal B
Bacon squares (8) (IMB)	Beef stew (R)
Peaches (R)	Cream of chicken soup (R)
Sugar cookie cubes (6) (DB)	Date fruit cake (4) (IMB)
Coffee (R)	Grape punch (R)
Pineapple-grapefruit drink (R)	Orange drink (R)

Additional Items	Units
Extra beverage (R)	8
Dried fruit (IMB)	4
Candy bar (IMB)	4
Bread (I)	2
Ham salad spread (tube food)	1
Turkey and gravy (WP)	2

D. Pantry Stowage

Accessories	Units	Breakfast	Units
Chewing gum	15	Peaches	6
Wet skin cleaning towels	30	Fruit cocktail	6
Oral hygiene kit	1	Canadian bacon and applesauce	3
3 toothbrushes		Bacon squares (8)	12
1 edible toothpaste		Sausage patties*	3
1 dental floss		Sugar coated corn flakes	6
Contingency feeding system	1	Strawberry cubes (4)	3
3 food restrainer pouches		Cinnamon toasted bread cubes (4)	6
3 beverage packages		Apricot cereal cubes (4)	3
1 valve adapter (pontube)		Peanut cubes (4)	3
Spoons	3		
Germicidal tablets (20)	3		
Total Units	53	Total Units	51

Rehydratable Desserts	Units
Banana pudding	6
Butterscotch pudding	6
Applesauce	6
Chocolate pudding	6
Total Units	24

*Spoon bowl package

Table 3 (Continued)
Typical Menu, Apollo 11-16

D. Pantry Stowage (Continued)

Beverages	Units	Bites	Units
Orange drink	6	Cheese cracker cubes (6)	6
Orange-grapefruit drink	3	BBQ beef bites (4)	6
Pineapple-grapefruit drink	3	Chocolate cubes (4)	6
Grapefruit drink	3	Brownies (4)	6
Grape drink	6	Date fruit cake (4)	6
Grape punch	3	Pineapple fruit cake (4)	6
Cocoa	6	Jellied fruit candy (4)	6
Coffee (B)	15	Nutrient defined food	
Coffee (S)	15	sticks (4)	
Coffee (C & S)	15		6
Total Units	75	Total Units	48

Salads/Meats	Units	Salads/Meats	Units
Salmon salad	3	Chicken and rice*	6
Tuna salad	3	Chicken stew*	3
Cream of chicken soup	6	Beef stew*	3
Shrimp cocktail	6	Pork and scalloped	
Spaghetti and meat sauce*	6	potatoes*	6
Beef pot roast	3	Ham and potatoes (wet)	3
Beef and vegetables	3	Turkey and gravy (wet)	6
		Total Units 57	

Bread	Units	Dried Fruits	Units
Rye	4	Apricots	6
White	4	Peaches	6
Cheese	4	Pears	6
Total Units	12	Total Units	18

Sandwich Spread	Units
Ham salad (226.8 gm [8 oz])	1
Tuna salad (226.8 gm [8 oz])	1
Chicken salad (226.8 gm [8 oz])	1
Cheddar cheese (56.7 gm [2 oz])	3
Total Units	6

*Spoon-bowl package.

Table 3 (Continued)
Typical Menu, Apollo 11-16

E. Low Residue Diet, One Day Before Flight

Breakfast	Lunch	Dinner
Strained grapefruit 113.4 gm (1/2 c) Cream of rice 113.4 gm (1/2 c) Scrambled eggs (2) Breakfast steak 170.1 gm (6 oz) Toast (1 slice) Butter 9.45 gm (2 tsp) Grape jelly (or substitute) Coffee Sugar	Beef with rice soup 113.4 gm (1/2 c) Crackers (4 squares) Sliced chicken sandwich 113.4 gm meat (4 oz); 2 slices of bread Cottage cheese-pear salad 1 pear half; 113.4 gm cheese (1/2 c) Angle food cake with rum sauce Coffee or tea Sugar	Tomato juice cocktail 170.1 gm (3/4 c) Roast beef au jus 170.1 gm (6 oz) Buttered noodles 113.4 gm (1/2 c) Pureed beets 113.4 gm (1/2 c) Hard roll (1) Butter 9.45 gm (2 tsp) Sherbet 113.4 gm (1/2 c) Coffee or tea Sugar

F. Low Residue Diet, Two Days Before Flight

Breakfast	Lunch	Dinner
Tomato juice 113.4 gm (1/2 c) Canadian bacon (2 slices) Soft cooked eggs (2) Toast (1 slice) Butter 9.45 gm (2 tsp) Cream of rice 113.4 gm (1/2 c) Sugar Grape jelly Coffee	Apple juice 113.4 gm (1/2 c) Broiled flounder 170.1 gm (6 oz) Paprika potatoes 113.4 gm (1/2 c) Pureed green beams 113.4 gm (1/2 c) Hard roll (1) Butter 9.45 gm (2 tsp) Lime sherbet 113.4 gm (1/2 c) Vanilla wafers (2) Coffee	Beef consomme 113.4 gm (1/2 c) Baked chicken 170.1 gm (6 oz) Buttered rice 113.4 gm (1/2 c) Pureed carrots 113.4 gm (1/2 c) Whipped strawberry gelatin dessert Lady fingers (2) Tea or coffee

Critical relationships exist between pressure and temperature during the drying process, and criteria were developed for each food employed in the system. These criteria were developed to assure the most rapid method of processing while maintaining organoleptic quality and preventing destruction of nutrients.

Bite-Sized Foods

Bite-sized, ready-to-eat foods supplemented rehydratable foods for the first Apollo manned flight. These bite-sized foods were either dehydrated (moisture less than two percent) or prepared so that water in the product would be bound and, therefore, not available for microbial growth. The latter category is generally referred to as intermediate-moisture food to differentiate it from fresh foods at one extreme and dehydrated food at the other. The intermediate-moisture foods (moisture less than 40 percent) are highly acceptable since they closely approximate the texture of fresh foods and are ready to eat without reconstitution. Even with this combination of foods, however, the range of texture and tastes was fairly limited for early Apollo astronauts, a situation that was gradually rectified throughout the program.

Table 4

Apollo 17 Menu

A. Command Module – Commander			
Day 1,* 5, 9,** 13	Day 2, 6,*** 10, 14***	Day 3, 11	Day 4, 12
Meal A			
Bacon squares (8) (IMB) Scrambled eggs (RSB) Corn flakes (RSB) Peaches (RSB) Orange beverage (R) Cocoa (R)	Spiced oat cereal (RSB) Sausage patties (R) Mixed fruit (WP) Cinnamon toast bread (4) (DB) Instant breakfast (R) Coffee (w/K) (R)	Scrambled eggs (RSB) Bacon squares (8) (IMB) Peaches (WP) Pineapple-grapefruit drink (R) Cocoa (w/K) (R)	Sausage patties (R) Apricot cereal cubes (4) (DB) Fruit cocktail (R) Pears (IMB) Cocoa (w/K) (R) Coffee (R)
Meal B			
Chicken and rice soup (RSB) Meatballs and sauce (WP) Fruit cake (NC) (WP) Lemon pudding (WP) Orange-pineapple drink (R)	Corn chowder (RSB) Frankfurters (WP) White bread (2) (I) Catsup (WP) Apricots (IMB) Orange-grapefruit drink (R)	Lobster bisque (RSB) Peanut butter (WP) Jelly (WP) White bread (1) (I) Chocolate bar (IMB) Orange-grapefruit drink (w/K) (R)	Chicken soup (RSB) Ham (I) Cheddar cheese spread (WP) Rye bread (1) (I) Cereal bar (IMB) Orange beverage (R)
Meal C			
Potato soup (RSB) Beef and gravy (WP) Chicken stew (RSB) Peach ambrosia (RSB) Gingerbread (4) (IMB) Citrus beverage (R)	Turkey and gravy (WP) Pork and potatoes (RSB) Brownies (4) (IMB) Orange juice (R) Lemonade (R)	Shrimp cocktail (RSB) Beef steak (WP) Butterscotch pudding (RSB) Peaches (IMB) Orange drink (w/K) (R)	Tomato soup (RSB) Hamburger (WP) Mustard (WP) Vanilla pudding (WP) Date fruit cake (4) (IMB) Orange-pineapple drink (w/K) (R)

*Meal C only
**Meals B and C only
***Meal A only

R = Rehydratable
I = Irradiated
DB = Dry bite
WP = Wet pack (thermostabilized)

NC = Nutrient complete
w/K = Fortified with 10 mEq of potassium
IMB = Intermediate moisture bite
RSB = Rehydratable spoon-bowl

Table 4 (Continued)
Apollo 17 Menu

B. Command Module – Command Module Pilot			
Day 1,* 5, 9, 13	Day 2, 6, 10, 14**	Day 3, 7, 11	Day 4, 8, 12
Meal A			
Bacon squares (8) (IMB) Scrambled eggs (RSB) Corn flakes (RSB) Apricots (IMB) Orange juice (R)	Spiced oat cereal (RSB) Sausage patties (R) Mixed fruit (WP) Instant breakfast (R) Coffee (w/K) (R)	Scrambled eggs (RSB) Bacon squares (8) (IMB) Peaches (WP) Cinnamon toast bread (4) (DB) Orange juice (R) Cocoa (w/K) (R)	Sausage (R) Grits (RSB) Fruit cocktail (R) Orange beverage (R) Coffee (w/K) (R)
Meal B			
Chicken and rice soup (RSB) Meatballs with sauce (WP) Fruit cake (NC) (WP) Butterscotch pudding (WP) Orange-pineapple drink (R)	Frankfurters (WP) White bread (2) (I) Catsup (WP) Pears (IMB) Chocolate pudding (RSB) Grape drink (w/K) (R)	Lobster bisque (RSB) Peanut butter (WP) Jelly (WP) White bread (1) (I) Cherry bar (1) (IMB) Citrus beverage (w/K) (R)	Ham (I) Cheddar cheese spread (WP) Rye bread (1) (I) Peaches (RSB) Cereal bar (IMB) Orange-pineapple drink (w/K) (R)
Meal C			
Potato soup (RSB) Beef and gravy (WP) Chicken stew (RSB) Ambrosia (RSB) Brownies (4) (IMB) Orange-grapefruit drink (R)	Corn chowder (RSB) Turkey and gravy (WP) Chocolate bar (IMB) Orange beverage (R)	Shrimp cocktail (RSB) Beef steak (WP) Butterscotch pudding (RSB) Orange drink (w/K) (R)	Tomato soup (RSB) Hamburger (WP) Mustard (WP) Vanilla pudding (WP) Sugar cookies (4) (DB) Caramel candy (IMB) Grape drink (w/K) (R)

*Meal C only
**Meal A only

Table 4 (Continued)

Apollo 17 Menu

C. Command Module – Lunar Module Pilot			
Day 1,* 5, 9,** 13	Day 2, 6,*** 10, 14***	Day 3, 11	Day 4, 12
Meal A			
Bacon squares (8) (IMB) Scrambled eggs (RSB) Corn flakes (RSB) Apricots (IMB) Cocoa (w/K) (R)	Sausage patties (R) Cinnamon toast bread (4) (DB) Mixed fruit (WP) Instant breakfast (R) Coffee (w/K) (R)	Scrambled eggs (RSB) Bacon squares (8) (IMB) Peaches (WP) Orange-pineapple drink (w/K) (R) Cocoa (R)	Sausage patties (R) Grits (RSB) Peaches (RSB) Pears (IMB) Pineapple-grapefruit drink (R) Coffee (w/K) (R)
Meal B			
Chicken and rice soup (RSB) Meatballs with sauce (WP) Fruit cake (NC) (WP) Lemon pudding (WP) Citrus beverage (R)	Corn chowder (RSB) Frankfurters (WP) White bread (1) (I) Catsup (WP) Chocolate pudding (RSB) Orange-grapefruit drink (w/K) (R)	Potato soup (RSB) Peanut butter (WP) Jelly (WP) White bread (1) (I) Cherry bar (1) (IMB) Orange-grapefruit drink (w/K) (R)	Chicken soup (RSB) Ham (I) Cheddar cheese spread (WP) Rye bread (1) (I) Cereal bar (IMB) Orange drink (w/K) (R)
Meal C			
Lemonade (R) Beef and gravy (WP) Chicken stew (RSB) Ambrosia (RSB) Gingerbread (4) (IMB) Grapefruit drink (w/K) (R)	Turkey and gravy (WP) Pork and potatoes (RSB) Caramel candy (IMB) Orange juice (R)	Shrimp cocktail (RSB) Beef steak (WP) Butterscotch pudding (RSB) Peaches (RSB) Orange drink (w/K) (R)	Tomato soup (RSB) Hamburger (WP) Mustard (WP) Vanilla pudding (WP) Chocolate bar (IMB) Grape drink (w/K) (R)

*Meal C only
**Meals B and C only
***Meal A only

Table 4 (Continued)

Apollo 17 Menu

D. Lunar Module – Commander			
Day 6	Day 7	Day 8	Day 9
Meal B	Meal A	Meal A	Meal A
Corn chowder (RSB)	Scrambled eggs (RSB)	Sausage patties (R)	Bacon squares (8) (IMB)
Frankfurters (WP)	Bacon squares (8) (IMB)	Apricot cereal cubes (6) (DB)	Scrambled eggs (RSB)
White bread (2) (I)	Peaches (IMB)	Fruit cocktail (R)	Corn flakes (RSB)
Catsup (WP)	Peanut butter (WP)	Pears (IMB)	Beef and gravy (WP)
Apricots (IMB)	Jelly (WP)	Cereal bar (IMB)	Fruit cake (NC) (WP)
Orange-grapefruit drink (R)	White bread (1) (I)	Cheese cracker cubes (4) (DB)	Peaches (RSB)
Tea (R)	Chocolate bar (IMB)	Ham (I)	Cocoa (R)
Lemonade (R)	Pineapple-grapefruit drink (R)	Cocoa (R)	Orange beverage (R)
	Orange-grapefruit drink (w/K) (R)	Tea (R)	Tea (R)
	Cocoa (w/K) (R)	Spiced oat cereal (RSB)	
	Tea (R)	Lemonade (R)	
Meal C	Meal B	Meal B	
Spaghetti and meat sauce (RSB)	Chicken and rice (RSB)	Lobster bisque (RSB)	
Turkey and gravy (WP)	Shrimp cocktail (RSB)	Hamburger (WP)	
Pork and potatoes (RSB)	Beef steak (WP)	Mustard (WP)	
Brownies (4) (IMB)	Beef sandwiches (4) (DB)	Cheddar cheese spread (WP)	
Orange beverage (R)	Butterscotch pudding (RSB)	Rye bread (1) (I)	
Tea (R)	Graham cracker cubes (6) (DB)	Date fruit cake (4) (IMB)	
	Orange drink (w/K) (R)	Orange-pineapple drink (w/K) (R)	
	Tea (R)	Orange beverage (R)	
		Tea (R)	

Table 4 (Continued)
Apollo 17 Menu

E. Lunar Module – Lunar Module Pilot			
Day 6	Day 7	Day 8	Day 9
Meal B	Meal A	Meal A	Meal A
Corn chowder (RSB)	Scrambled eggs (RSB)	Sausage patties (R)	Bacon squares (8) (IMB)
Frankfurters (WP)	Bacon squares (8) (IMB)	Spiced oat cereal (RSB)	Scrambled eggs (RSB)
White bread (2) (I)	Peaches (IMB)	Peaches (RSB)	Corn flakes (RSB)
Catsup (WP)	Peanut butter (WP)	Pears (IMB)	Apricots (IMB)
Chocolate pudding (RSB)	Jelly (WP)	Cereal bar (IMB)	Cocoa (R)
Orange-grapefruit drink (R)	White bread (1) (I)	Gingerbread (6) (IMB)	Tea (R)
Tea (R)	Orange-grapefruit drink (w/K) (R)	Ham (I)	Beef and gravy (WP)
Lemonade (R)	Cocoa (w/K) (R)	Pineapple-grapefruit drink (R)	Fruit cake (NC) (WP)
	Tea (R)	Tea (R)	
	Fruit cocktail (R)		
Meal C	Meal B	Meal B	
Turkey and gravy (WP)	Chicken and rice (RSB)	Potato soup (RSB)	
Pork and potatoes (RSB)	Shrimp cocktail (RSB)	Hamburger (WP)	
Caramel candy (IMB)	Beef steak (WP)	Mustard (WP)	
Orange beverage (R)	Beef sandwiches (4) (DB)	Cheddar cheese spread (WP)	
Tea (R)	Butterscotch pudding (RSB)	Rye bread (1) (I)	
	Graham cracker cubes (6) (DB)	Chocolate bar (IMB)	
	Orange drink (w/K) (R)	Banana pudding (RSB)	
	Orange-pineapple drink (R)	Orange drink (w/K) (R)	
	Tea (R)	Grape drink (w/K) (R)	
		Tea (R)	

Table 4 (Continued)

Apollo 17 Menu

F. Pantry Stowage Items

Beverages (R)	Qty.	Accessories	Qty.	Accessories (Continued)	Qty.
Coffee	20	Contingency beverages (R) (for contingency use only)		In-suit food bar assembly	
Tea	20			In-suit drinking device	
Grape drink	10	Instant breakfast	15	Spoon assembly (2)	
Grape punch	10	Orange drink	5	Germicidal tablets pouch (42)	1
		Pineapple-orange drink	5	Germicidal tablets pouch (20)	1
		Lemonade	5		

Snack Items	Qty.	Snack Items (Continued)	Qty.
Bacon squares (4) (IMB)	9	Sugar cookies (4) (DB)	6
Apricot cereal cubes (DB)	6	Apricots (IMB)	3
Brownies (4) (IMB)	3	Peaches (IMB)	3
Gingerbread (4) (IMB)	3	Pears (IMB)	3
Graham crackers (4)	6	Chocolate bar (IMB)	3
Jellied candy (IMB)	6	Tuna salad spread (WP) (small cans)	2
Peach ambrosia (RSB)	3		
Pecans (6) (IMB)	6	Catsup (WP)	3
Fruit cake (WP) (NC)	3	Salt packets	6

Packaging

Packaging, like food items themselves, underwent substantial modification during the Apollo Program. Flexible packaging protected each individual portion of food and made handling and consumption easier. A series of redesign cycles finally resulted in a rehydratable food package that had (1) an improved, transparent barrier-film of laminated polyethylene-fluorohalocarbon-polyester-polyethylene; (2) a water injection port consisting of a one-way, spring-loaded valve; and (3) an improved opening that permitted food consumption in weightlessness with a conventional tablespoon.

Cold [$\approx$283°K (10°C)] and hot [$\approx$333°K (60°C)] water were available for food preparation. Following water injection with the Apollo water dispenser, the food package was kneaded to rehydrate the food and then opened for consumption. Early packages, shown in figure 1, were fitted with plastic tubes through which rehydrated food was extruded into the mouth. This configuration was changed by the introduction of a spoon-bowl package, pictured in figure 2 and described in greater detail in the following sections.

Figure 1. Apollo rehydratable food packages

Bite-sized, ready-to-eat foods were contained in packets made from the same plastic laminate material used for packaging rehydratable foods. These packets were opened simply by cutting with scissors (figure 3). The food was eaten directly from the package or by use of the fingers.

Figure 2. Apollo rehydratable food spoon-bowl package shown opened with spoon inserted.

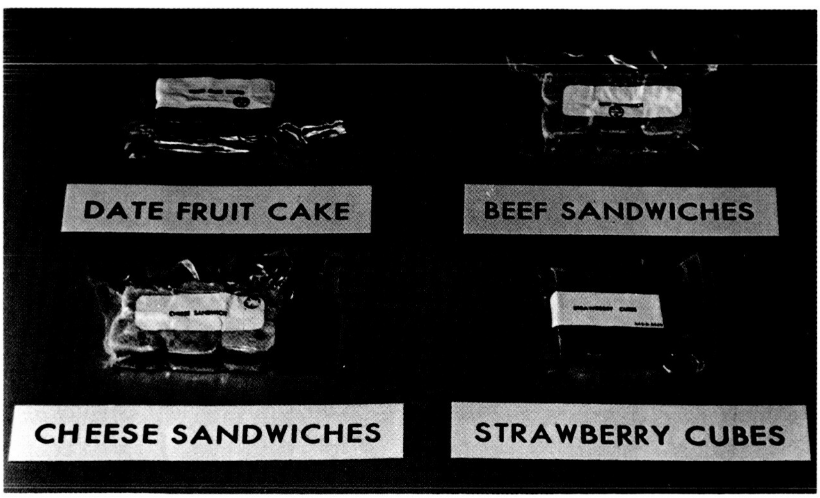

Figure 3. Bite-sized, ready-to-eat, intermediate-moisture and dry foods shown in Apollo flight packages.

Evolution in Apollo Food Technology

Improvements in the food system were aimed at maintaining astronauts in the best possible physiological condition and with a high level of morale. Modifications to improve ease of consumption, stowage weight, and nutrient intake were reviewed and implemented as dictated by changes in mission objectives, new activities, and medical, operational, and experimental requirements.

Apollo 7

The food system for the first manned Apollo mission was basically that provided in the Gemini Program but featured a wider variety of foods. However, while the availability of 96 food items for the Apollo 7 flight contributed to better acceptance and increased consumption relative to Gemini foods, the time and trouble required for meal preparation was increased.

Apollo 8

The first departure from heavy reliance on rehydratable foods occurred during the Apollo 8 flight. On Christmas day, 1968, during the first lunar orbital mission, the Apollo 8 astronauts opened packages of thermostabilized turkey and gravy and ate with spoons. This turkey entree required no water for rehydration because the normal water content (67 percent) had been retained. The thermally stabilized, ready-to-eat meal in a flexible can became known as a "wetpack," a term used to differentiate this package from the dehydrated space foods that required the addition of water before consumption. The flexible packs were made from a laminate of polyester, aluminum foil, and polyolefin.

Wet-type foods had not been used previously because of the disadvantages associated with high moisture content, particularly the requirement for sterility and the weight penalty associated with this type of food. The improved crew acceptance of the product justified the weight increase. Technology for heat sterilization in flexible packages was sufficiently advanced by the time of Apollo 8 to assure a high quality product with minimal chance for failure.

The Apollo 8 crew also used a conventional teaspoon to eat some foods, and found that this mode of food consumption in weightlessness was quite satisfactory. This finding led to food package redesign which made the use of spoons much more convenient.

Apollo 9

Beginning with the Apollo 9 mission, more wetpack items were added to the food system. The variety of foods provided for this flight made crew diets more typical of those consumed on Earth. The extensive use of wetpack containers without difficulty during this mission confirmed the potential for eating a substantial portion of food from open containers. The Apollo 9 crewmen experimented further by cutting open a rehydratable food package and eating its contents with a spoon; the experiment was successful.

During Apollo 9, the Lunar Module Pilot experienced nausea and vomiting. Menu manipulation in flight to reduce the tendency for nausea represented the first use of real-time food selection for countering undesirable physiological responses to vestibular stimuli. The Apollo 9 mission also included the first use of the Lunar Module food system.

Apollo 10

Evolution of the Apollo food system was continued with the Apollo 10 flight, during which the spoon-bowl package (see figure 2) was introduced. The spoon-bowl package permitted convenient use of a spoon for consuming rehydrated foods. This modified package had a water inlet valve at one end and a large plastic-zippered opening on the other, which provided access to the rehydrated food with a spoon. Large pieces of dehydrated meat and vegetables could now be included to provide a more familiar and acceptable texture. As a result of this modification, some Apollo crewmen expressed a preference for selected foods in rehydratable form over the wetpack equivalent.

The feasibility of eating from open containers with spoons in weightlessness was first tested in aircraft flight, and subsequently verified during the flights of Apollo 8 and Apollo 9. Using jet aircraft flying parabolic patterns, numerous foods, packages, and utensils were tested. While these flights produced only brief periods of near-weightless conditions, the results indicated that spacecraft application of the spoon-bowl concept could be made successfully without dispersal of food particles throughout the vehicle.

Apollo 10 also marked the first successful use of conventional slices of fresh bread and sandwich spreads. This bread had a shelf life at Apollo vehicle temperatures for at least four weeks when packaged in a nitrogen atmosphere (figure 4). Provision of the bread allowed crewmen to make sandwiches using meat salad spreads provided in separate containers. The sandwich spreads were preserved by thermal processing and final package closing in a hyperbaric chamber. The process enhances preservation of natural flavor and texture by reducing thermal processing time and temperature.

An additional modification for the Apollo 10 mission was the introduction of the pantry concept. Locker space was reserved for an assembly of food to provide *ad libitum* selection of meal components. This method allowed for some versatility in menu planning and for inflight dietary modification. In all subsequent Apollo flights, pantry-stocked foods augmented prepackaged meals. Even though most astronauts expressed a desire prior to flight for real-time food selection, they typically reported that this often proved to be more trouble than it was worth.

The Apollo 10 crewmen reported some discomfort from a feeling of fullness and gastric awareness immediately after eating. This was troublesome to individual astronauts throughout the Apollo Program. Many causes for this condition have been suggested. Among these are (1) aerophagia; (2) undissolved gases (oxygen and hydrogen); (3) reduced atmospheric pressure; (4) changes in gastrointestinal motility; and (5) shifts in intestinal microflora. Moreover, removal of water during the process of food dehydration is a complex phenomenon that causes many physical-chemical shifts at the cellular level. It is conceivable that, during the rehydration process, continued occurrence of microscopic phenomena could cause osmotic displacements sensed by the cells of the gastric or intestinal mucosa.

Apollo 11

New food items for the Apollo 11 flight included thermostabilized cheddar cheese spread and thermostabilized frankfurthers. Sandwich spreads were packaged in "401" aluminum cans, which featured a pull-tab for easy removal of the entire top of the can. This can proved successful and eventually became the nucleus for the development of the open-dish eating concept implemented in the Skylab Program.

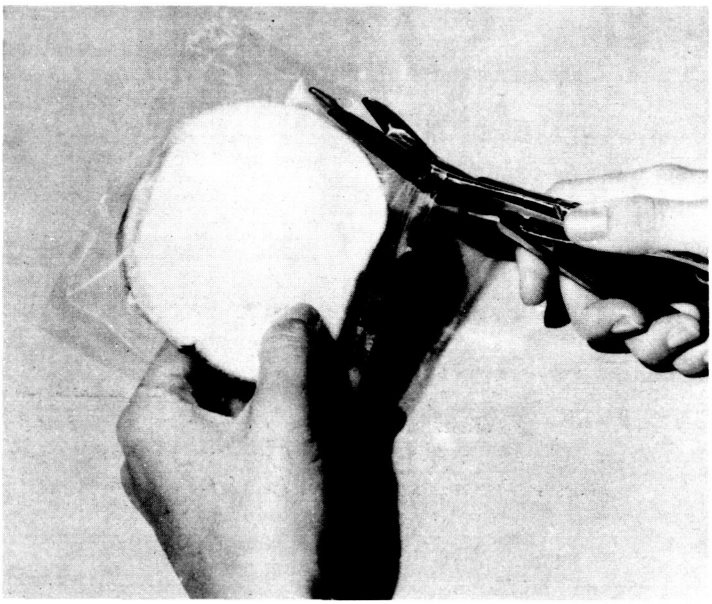

Figure 4. Irradiated bread packaged for use on Apollo missions.

Command Module food for the first five days of the Apollo 11 mission was assembled in nominal meal packages (figure 5). Forty-two man-meals (starting with day 1, meal B), an oral hygiene kit, and spoons were contained in a Command Module food locker. Command Module menus for each Apollo 11 astronaut are presented in tables 3 (A, B). Because the wetpack food items included did not require reconstitution in flight, the menu was planned for consumption of wetpack foods during the midday meal when crew activity was highest. The wetpack foods were stowed separately from nominal meal packages.

A six-day supply of food and accessory items were stowed in pantry fashion (figure 6) to permit some food selection based on real-time preference and appetite and to supplement the meal packages if more food was desired by an individual. The foods included beverages, salads, soups, meats, breakfast items, desserts, and bite-sized foods [see table 3(D) for listing]. Primary food packages were placed in nonflammable overwraps, which served to keep food groups together and to partition the spacecraft food container for ease of retrieval in flight. Germicide tablets were provided for stabilization of any food residue remaining in the primary food packages.

Four lunar surface meal periods were scheduled. The Apollo 11 Lunar Module menu is outlined in table 3(C). Foods for the four nominal meals (two each of meals A and B), spoons, wetpack food, extra beverages, and tubed ham sandwich spread were stowed in the Lunar Module food box. The remaining items (bread, candy, and dried fruit) were stowed in the utility-light compartment of the flight data file.

Figure 5. Apollo meal pack.

Another major component of the Apollo 11 food system was the system employed on the prime recovery ship in the Mobile Quarantine Facility (MQF) and, subsequently, at the Lunar Receiving Laboratory (LRL) at Johnson Space Center. A typical MQF menu is shown in table 5. The MQF foods were used from time of splashdown until the crewmen entered the LRL. The menu contained primarily precooked, frozen entrees, which were reconstituted in a microwave oven in the MQF. The LRL system used the same type of entrees with the addition of a wider variety of frozen vegetables, salads, and snacks. The LRL food system also included a "first class" restaurant service, complete with table linens, china, and silverware which was available to the flight crew, their support team, and the lunar quarantine staff of approximately 20 scientists and technicians.

Apollo 12

The food system for Apollo 12 was quite similar to that which had proven successful for Apollo 11. Freeze dehydrated scrambled eggs were introduced and were well accepted by the crew. Other changes in the menu were directed toward meeting individual crewmember nutrient requirements.

Table 5

Typical Menu for Apollo Mobile Quarantine Facility*

Day 1	Day 2	Day 3	Day 4	Day 5
		Breakfast		
Crepes Georgia Cheese omelette Crisp bacon strips Breakfast roll Jelly	Crepes Normandie Link sausage Pancakes Maple syrup	Crepes Diane Cheese omelette Crisp bacon strips Breakfast roll Jelly	Crepes Georgia Plain omelette Breakfast ham Breakfast roll Jelly	Crepes Normandie French toast Crisp bacon strips Maple syrup
		Lunch		
Roast beef sandwich Corn relish Mixed fruit compote Vanilla ice cream Assorted cookies	Beef stew Dinner roll Plums	Spaghetti with meat sauce Green beans amandine Dinner roll Vanilla ice cream Oatmeal-raisin cookies	Roast beef au jus Duchess potatoes Glazed carrots Dinner roll Fudge brownies	Braised beef tips Tiny whole potatoes with green peas Dinner roll Vanilla ice cream
		Dinner		
Strip steak Baked potatoes Asparagus spears Dinner roll Apple cobbler	Chicken Kiev White rice Mixed vegetables Dinner roll Fudge cake	Baked ham with pine-apple glaze Potatoes au gratin Buttered green peas Dinner roll Cherry cobbler	Short ribs of beef Buttered peas with mushrooms Whole kernel corn Dinner roll Pecan pie	Lobster Newburg White rice French style green beans Dinner roll Almond torte

*Instant coffee, tea, butter and sterilized canned whole or fresh milk available at each meal. Otherwise all foods shown were frozen.

Apollo 13

The Apollo 13 inflight explosion and loss of fuel cell systems tested the food system in an emergency situation in which fluid and electrolyte intakes were critical for life support. After the accident, crew nutrient consumption was limited by the amount of available water. Beverage bags proved to be extremely useful as an emergency means of storing water that was rapidly being depleted. The use of these packages and the availability of wetpack foods for providing fluids for the Apollo 13 crewmen has been largely credited with maintaining the health of the astronauts throughout the emergency.

Figure 6. Apollo food and accessory items.

The beverage packages found other uses during Apollo missions and proved to be versatile, durable, and reliable. They were used in experiments on the separation of gas from liquids in weightlessness and also served as head supports on the couch during reentry of the Command Module in at least one mission.

The Apollo 13 food system included the first dehydrated natural orange juice. Orange juice had not been employed in space food systems previously because the dehydration methods available failed to prevent fusion of natural sugars with the formation of an insoluble mass. The provision of fruit juices further improved the quality and nutritional value of the food system.

Apollo 14

The Apollo 14 flight marked the first time space crewmen returned to Earth without a significant change in body weight. The Commander and the Lunar Module Pilot had consumed essentially all of their programmed food supply.

The Apollo 14 food system included an in-suit drinking device. This allowed the astronauts to better maintain fluid balance during extensive lunar surface operations.

The food safety regimen throughout the Apollo Program included the production and final packaging of all food items in a Class 100 000 filtered-air cleanroom to maintain low microbiological counts of Apollo foods. Foods were also examined for the presence of heavy metals. The only deviation from perfect performance in the food safety area was a failure in the early detection of mercury contamination in the Apollo 14 tuna fish salad. The mercury content ways in excess of maximum limits established by the U.S. Food and Drug Administration. The tuna fish was removed from the food system shortly prior to launch, and a nutritionally equivalent substitute from the pantry was used to supplement the menu.

Apollo 15

Apollo 15 crewmen consumed solid food while working on the lunar surface. High nutrient density food bars were installed inside the full pressure suit (figure 7). Figure 8 shows a view of the neck ring area of the Apollo lunar surface pressure suit with the in-suit food bar and the in-suit drink device installed. The in-suit drink device was designed to provide water or fruit flavored beverages. This crew was the first to consume all of the mission food provided. Negligible weight losses, after equilibration for fluid losses, reaffirmed that the diet provided adequately for the crew's energy requirements. The typical Apollo menu ultimately provided energy equivalent to 155 ± 17 kJ/kg (37 ± 4 kcal/kg) of body weight. Sliced fresh bread that had been pasteurized by exposure to 50 000 rads of cobalt-60 gamma irradiation was first used for the Apollo 15 flight.

Apollo 16

Electrocardiographic recordings for Apollo 15 crewmen indicated occasional arrhythmias believed to be possibly linked to a potassium deficit. In an effort to prevent recurrence of a similar situation in the Apollo 16 crew, a requirement was levied to provide 140 ± 5 milliequivalents of potassium in the Apollo 16 diets daily during flight and for 72 hours both before and after flight. In addition, nutrient intake and absorption for each Apollo 16 crewman was monitored during the entire period, beginning 72 hours before flight and ending 72 hours after flight. This control of nutrient intake afforded maximum opportunity to detect physiological changes accompanying transition to and from the weightless state.

The requirement for 140 ± 5 mEq of potassium could not be met by menu manipulations using unmodified flight-qualified Apollo foods. Therefore, potassium fortification of qualified inflight foods was investigated, and the development of modified preflight and postflight foods was undertaken. It was found that Apollo 16 beverages and soups could be modified by the addition of 10 mEq per serving of potassium in the form of potassium gluconate (2.35 gm per serving).

The physiological safety of potassium gluconate for food fortification and supplementation was verified by a search of the literature concerning its use and effects and by three studies involving human volunteers. The compatibility of this level of potassium with individual flight crewmembers was tested by providing each individual with fortified foods for consumption and evaluation.

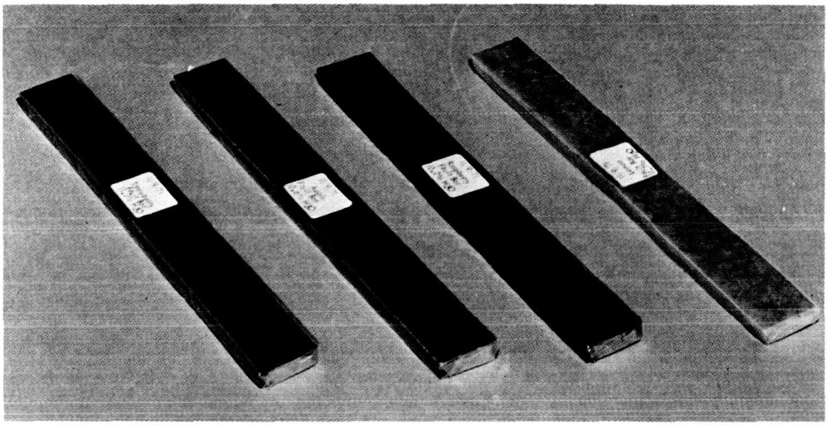

Figure 7. High-density food bars for use in pressure suits on the lunar surface.

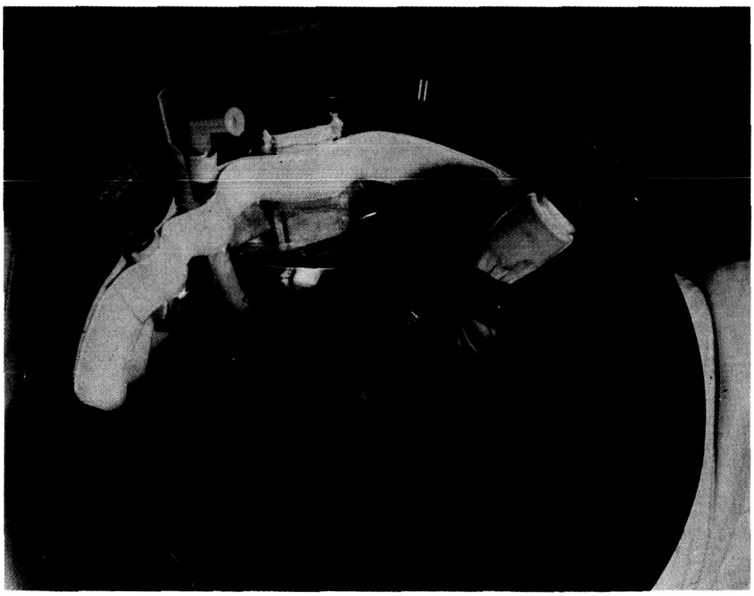

Figure 8. Neck ring of the Apollo lunar surface pressure suit showing in-suit food bar and drink device.

Apollo 16 grape drink, orange drink, pineapple-orange drink, pineapple-grapefruit drink, grapefruit with sugar, and cocoa were fortified with potassium gluconate, for an average daily inflight potassium intake of approximately 100 mEq. Real-time adjustments in nutrition were applied by menu rearrangements to counteract the gastrointestinal awareness reported by one crewmember and believed to be associated with dietary potassium intake.

Apollo 17

In addition to a liberal usage of previously described improved foods, the Apollo 17 system was modified by the inclusion of shelf-stable ham steak that had been sterilized by exposure to cobalt-60 gamma irradiation (3.7 megarads). The Apollo 17 food system also incorporated a fruit cake that provided complete nutrition in shelf-stable, intermediate-moisture, ready-to-eat form. Both proved to be highly acceptable to the crewmen. This type of intermediate-moisture food was included in the Skylab contingency food system and is being evaluated for use in the Space Shuttle food program.

Conclusions

Large improvements and advances in space food systems were achieved during the Apollo food program. Nevertheless, the majority of Apollo astronauts did not consume sufficient nutrients. Loss of body weight, fluids, and electrolytes was the rule, with few exceptions. The Apollo food program showed that man and his eating habits are not easily changed. Adequate nutrition begins with appropriate food presented to the consumer in familiar form.

A space food system must fulfill program requirements and provide proper nutrition to maintain physiological well-being during the specific environments and stresses imposed by the mission. Such a system must ultimately rely on nutritious foods that are easy to prepare, that have familiar flavor and texture, and that provide diversion, relaxation, security, and satiety.

Modifications of the Apollo food system were directed primarily toward improving delivery of adequate nutrition to the astronaut. Individual food items and flight menus were modified as nutritional countermeasures to the effects of weightlessness. Unique food items were developed, including some that provided nutritional completeness, high acceptability, and ready-to-eat, shelf-stable convenience. Specialized food packages were also developed.

The Apollo Program experience clearly showed that future space food systems will require well-directed efforts to achieve the optimum potential of food systems in support of the physiological and psychological well-being of astronauts and crews. The accomplishments of the Apollo food program provide a significant beginning.

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