FOOD QUALITY DESIGN FOR GEMINI AND APOLLO SPACE PROGRAMS

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The Food Division of U. S. Army Natick Laboratories functions as the research and development center for Military rations. Our interest in space feeding dates back to the middle 50's when the Air Force requested our predecessor, The Armed Forces Food and Container Institute, to develop foods for high altitude feeding. Initial efforts for the Air Force produced two systems that do not fit the familiar food approach selected by NASA, but offer promise for special situations. The first, canned liquid foods that drain by gravity through a flexible tube into the mouth, requires adaptation. Powdered foods might be rehydrated or suspended in water and fed, as a liquid, to astronauts outside the spacecraft through a feeding port. The second, semi-solid or pureed foods that are squeezed from a tooth paste-like tube through a rigid pontube into the mouth, was used for the first manned space flights-Project Mercury. This system is particularly suited to contingency or emergency feeding and to the extra-vehicular excursions on the lunar surface scheduled as part of the Apollo program.

As the space program was accelerated, NASA increased the tempo of space feeding research and development. The Food Division developed most of the Gemini and Apollo food items in-house or by contract monitoring. Actual development of the integrated feeding system, including production of the foods, is performed by industry under NASA contract. Occasional production to meet emergency demands, develop food items, furnish specifications, and act as technical consultant to NASA have been Food Division's contributions to the space program.

Space food manufacture is still very much an art. The end item of research and development is not the food, but a specification that can be used to satisfactorily procure the food. Effecting procurement requires a clear picture of what is wanted, the quality needed, and an industrial capability to produce the food. One must necessarily precede the other, and space foods are not yet in this final stage of refinement. Food specifications for both the Gemini and Apollo programs are not true specifications, but rather production guides which tell the producer how to make the product and delineate certain essential requirements. Eventually, procurement will require that a product and a quality level be specified leaving all the manufacturing details up to the producer. However, the state of the art does not permit this as yet, and food quality is largely dependent on the design of the food itself. In fact, in the Gemini and Apollo space programs, food quality design must be defined as design of the foods themselves. Adequate quality design depends upon understanding the conditions under which the food will be consumed and orienting the food item, the food formulation and the food packaging to these conditions. For convenience, these considerations have been divided into six areas:

1. Morale
2. Weight and available space
3. Weightlessness
4. Stability
5. Mechanical Stress
6. Health

The morale value of food in stress situations is a much debated subject.

Stefansson,(1) the famous Artic explorer, advocated the austere approach maintaining that the food should be functional and not so well liked that personnel would "snack" on it or overeat. On the basis of military experience, NASA made their decision the other way - that food is a positive morale factor, one of the few that can be offered sedentary astronauts during lengthy space voyages. This decision was basic to design, dictating that the foods be as close to "home cooked" as possible in taste and texture although visual appearance might be compromised. The formulated diets, familiar to many "weight watchers", and the tin can would have been much easier to design and control.

Once the decision to use familiar foods was made, weight and available space made it obvious that primary dependence would have to be on precooked, low and intermediate moisture foods. Food must be stored, prepared and consumed in the spacecraft where

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room is already at a premium, and every pound of weight requires approximately 1,000 pounds of lift-off thrust. There is no room for preparation utensils, refrigeration devices, or even the 60 to 90 percent water present in most foods as consumed. Water is a by-product of the spacecraft fuel cells, and NASA decided to use it for food rehydration. Access to water, a major problem limiting the use of some dried foods in military survival situations, is not a consideration for space feeding since water can be produced or recycled. Storage is carefully engineered by overwrapping the packaged food items into meal units and stowing in reverse order of withdrawal.

Weightlessness is, of course, a condition completely unique to space. Originally, there was some question as to whether man could swallow properly when weightless, but this turned out to be no problem.[2] However, crumbs do not drop onto the floor. Fluids do not stay in open containers. They become free floating and are potential hazards to automatic controls, electronic equipment and, particularly, to breathing of the astronauts. Foods that are normally consumed in a fluid or semi-fluid state must be reconstituted in, and fed from, a closed system. Foods that are consumed dry must not crumb, dust or fracture.

Stability is a traditional problem to food systems. Space foods must withstand test temperatures up to 136°F., and perspiration and breathing add moisture to a cabin atmosphere that is also high in oxygen content. Usual techniques of vacuum packaging, food additives, special packaging materials, careful quality control, low moisture and rapid turnover did prove effective. However, a new problem, surface greasiness, popped up. Greasiness or tackiness is aggravated by high temperature and is greatly magnified in space feeding situations. Except for wet and dry towels intended to clean the hands, spacecrafts are not equipped with clean-up facilities. Slight tackiness that normally goes unnoticed provides an ideal medium for bacterial growth when transferred to and from the astronaut's hands and gloves, and must be avoided.

Mechanical stress must be considered in design of foods and food packages. Accelerating a spacecraft sufficiently to escape the earth's gravity creates a great deal of shock, noise and vibration. The assembled Gemini food system[3] is subjected to tests of 37½ to 4800 cycles per second random vibration, 1 G to 7¼ G linear acceleration, 135 decibels acoustic noise, and several G's shock. Cushioning within the spacecraft container aids the foods in withstanding this stress.

The health consideration has several facets. Adequate nutrition is, of course, basic, and the work that NASA is doing in this area[4] through contracts, simulator studies, etc. is developing a wealth of knowledge. But the point of most concern and interest to the quality design is that there is no family doctor and no corner grocery store in space. The food must not represent a health hazard, and the Gemini and Apollo microbiological requirements are stringent. At first thought, the microbiologists would like to set up zero tolerances, and, although costly, modern aseptic techniques and white rooms can effectively reduce counts to approximate zero. However, an interesting question is posed: Are zero tolerances desirable? After all, bacterial flora in the lower intestinal tract produce many essential nutrients. Present in-house research with germ-free environments is providing an insight into this area. Although no broad proven statements can be made, it may be that future long flights will require bacterial supplements in the diet.

When all six factors are considered, the direction of design for space foods becomes clear. Barring development of a new technology, freeze dried foods will have to be the dietary mainstay supplemented by other low and intermediate moisture foods. The Armed Forces have been working on freeze drying since the early 1950's, primarily for operational rations. Possessing all the logistical advantages of other dried foods, these foods rehydrate to a quality very close to that of the original wet food. Futhermore, many of them have fairly high acceptability when eaten dry. The foods for both Gemini and Apollo are basically precooked dehydrated foods[5,6&7] which are eaten after rehydration and bite size foods which are eaten as is, rehydrating in the mouth. Rehydratable items cover the spectrum from cereals or soups to salads to meat and vegetable entrees to fruits, puddings and beverages. Freeze dried meats, sandwiches and toasts, compressed cereals and confections, and high calorie-low moisture bakery items comprise the bite size grouping. All items are designed specifically for space use, and are carefully combined into meal units according to planned menus which assure adequate nutrition.[8]

The developmental sequence generally consists of preparation of a new item by a technologist, screening by a technical panel of members of the Food Division staff, evaluation by a formal consumer taste panel at intervals during a 6-month storage period, and presentation to NASA for simulator and feeding studies. Once a new item has been accepted by NASA, a processing description or production guide must be written so NASA can buy the product from industry. As performance data and production information becomes available, a specification containing quality assurance provisions will be prepared. In a sense, a specification is our final product, and it should be emphasized that food science still has enough art in it to make specification writing a headache. How do you specify and control the flavor and texture of beef stew? After all, flavor and texture are the two most important aspects to the consumer.

The actual food items are governed first by what is acceptable, and second by what will meet the limitations imposed either by the space conditions themselves or the package dictated by these conditions. First, it must be a familiar food - one which is acceptable to Americans and, in particular, acceptable to the individual astronauts who, quite logically, are given a voice in what foods go on board with them. Acceptability is easily determined. Taste panels will furnish considerable information, and the astronauts are capable of stating what they do or do not like. One problem with the Gemini feeding system is that the temperature of water used for rehydration is at or below 80°F. Foods that are customarily eaten hot are not appetizing at this temperature. A limited amount of water at 155°F., the boiling point at the 1/3 of an atmosphere spacecraft pressure, is expected to be available for Apollo use.

The second condition that dictates the individual items, depends on food-package-use compatability. Packages for the rehydratable foods must have some way of admitting the water, and some way of getting the rehydrated food into the mouth.[9] Weightlessness rules out pouring the water in and spooning food out. A pressurized tank is provided to force water in thru a valve. The food rehydrates by capillary action helped by the astronaut kneading or shaking the packages. Then, the astronaut squeezes the food through a tube into his mouth. The rehydrated foods have pieces small enough to go through the feeding tube (a 1½ inch wide polyethylene tube) yet large enough to give the eater some good, solid food to chew on. Furthermore, the food pieces must be strong enough to withstand kneading during rehydration, yet tender enough so the eater doesn't think he is chewing shoe leather. Also, the food must be fluid enough to pass through the feeding tube.

Bite size items, present quite different problems. Here the packaging does not need to be as fancy as with the rehydratables since bites are transferred directly to the mouth. In this case, crumbling and dusting are much more important. Freeze dried foods are by nature very brittle, and it is necessary to coat freeze dried bite items. Bakery and confectionery bite items must be coated, not only to prevent crumbling, but also to overcome surface tackiness. A good deal of effort has been devoted to coatings,[10] and not all of those used to date are completely satisfactory. Either they coat the mouth, are greasy to the touch, crack, or have some other defect that limits their usefulness. Another factor with bites is size. Decreasing the size increases the costs. Increasing the size gives rise to questions such as how big a piece can an individual comfortably place in his mouth? Individuals, vary considerably in mouth capacity.

The contract for procurement of the Apollo feeding system integrated space foods into the NASA space systems quality program. NASA's quality program aims at producing high reliability using such tools as: component qualification, quality control, quality assurance, design verification, flight qualification and failure analysis. Space food manufacture still depends heavily on component qualification and tight quality control. Quality assurance was not introduced to food until well after the Gemini program was underway, but it is an integral part of the Apollo program.

The quality assurance provisions added to the production guides are based on MIL-STD-105D because most of the requirements are expressed as attributes. Where requirements lend themselves to variables inspection, such a system is used. However, there are problems. The rules of statistics often do not apply. Lot sizes are very small necessitating a large portion of production to be by hand. As is often true with hand operations, the hands destroy the randomness. For example, picking out the off-size foods and having to add a few of the best ones at the end to meet the delivery quantity raises havoc with sampling plans. Food weights behave mysteriously. Production data shows uniformity to about 5%. Yet, studies of assembled feeding prototypes have recorded 10 to 20% weight variation in packaged foods from these same lots.

We do not feel that the items being used for Gemini and Apollo are the last word in foods for space. A cursory examination of a few cook books can result in literally hundreds of ideas for other items. In turn, and within a few limitations, almost all of these items can be prepared. It takes a number of formulations to arrive at the correct spicing level, ingredient composition, and hardness to be acceptable without slowing rehydration or being excessively brittle. However, it is still mostly "trial and error." We are conducting investigations aimed at improving present products as well as developing new feeding concepts.[11] We also feel that the quality of space foods cannot continue to depend on art. The production guides were prepared without quality assurance provisions. Now these have been added. NASA's failure analysis provides traceability by which critical design points are being located. Careful study always identifies the cause of failure and establishes the necessary control procedure. It is likely that end item specifications containing all the necessary requirement, quality and reliability criteria will be available before the Apollo program is completed.

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