Seminar report

SPACE NUTRITION

By

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DECLARATION

I, Meera P. M (2018-16-002) hereby declare that the seminar entitled ‘Space nutrition’ has been prepared by me, after going through various references cited at the end and has not copied from any of my fellow students.

Vellanikkara
25/ 01/ 2020

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CERTIFICATE

This is to certify that the seminar report entitled ‘Space nutrition’ has been solely prepared by Meera P. M (2018-16-002) under my guidance and has not been copied from fellow students.

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SPACE NUTRITION

1. INTRODUCTION

Space food is a type of food product created and processed for consumption by astronauts in outer space. The food has specific requirements of providing balanced nutrition for individuals working in space, while being easy and safe to store, prepare and consume in the machinery-filled weightless environments of crewed spacecraft.

The first space missions only lasted for a few minutes, so there was no need for the crews to eat, but as missions became longer, astronauts had to be fed. Gherman Titov was the first person to have food in space in a mission called Vostok, 1961.He confirmed that human could eat, swallow and digest food in space.The main problem with eating and drinking in space is the microgravity condition in space flight. Food crumbs and drops of water could float around the spacecraft, make a mess or even damage the space craft itself. Unscientific evidence also suggests that microgravity may have an effect on the taste of food, or the sensory perception of food. The extreme environment and stress of isolation cannot be overlooked. Psychological effects of isolation may affect appetite and consumption. Since food developers cannot force astronauts to eat, their solution has been to make the food more palatable, hoping this would encourage consumption (Bourland, 1993).

"Space foods are those food products specially created and processed for consumption of astronauts in outer space" (NASA, 1999). The food has specific requirements of providing balanced nutrition for individuals working in space.

Nutrition plays multifaceted roles in space flight. Providing high quality palatable foods also is important to ensure adequate nutritional intake. The realization of the full role of nutrition will be critical for the success of extended duration space missions.

2. Challenges during space flight

2.1 Radiation

Space radiation can penetrate habitats, spacecraft, equipment, spacesuits, and can harm astronauts. Minimizing the physiological changes caused by space radiation exposure is one of the biggest challenges in keeping astronauts fit and healthy as they travel through the solar system. Ionizing radiation is a serious problem that can cause damage to all parts of the body including the central nervous system, skin, gastrointestinal tract, skeletal system, and the blood forming organs. Biological damage due to radiation can be mitigated through implementation of counter measures that are designed to reduce radiation exposure and its effects.

Dietary counter measures are drugs, that when ingested by an astronaut, may have the potential to reduce effects of ionizing radiation. These supplements can be broadly categorized into two groups. The first group includes specific nutrients that prevent the radiation damage. For example, antioxidants like vitamins C and A may help by soaking up radiation-produced free-radicals before they can do any harm. Research has also suggested that pectin fiber from fruits and vegetables, and omega-3-rich fish oils may be beneficial counter measures to damage from long-term radiation exposure (Cucinotta *et al*., 2008). Other studies have shown that diets rich in strawberries, blueberries, kale and spinach prevent neurological damage due to radiation. In addition, drugs such as Radiogardase (also known as Prussian blue) that contain Ferric (III) hexacyanoferrate (II) are designed to increase the rate at which radioactive substances like cesium-137 or thallium are eliminated from the body.

The second group of dietary agents currently being considered for protection against ionizing radiation includes drugs that can facilitate faster recovery from radiation damage. These dietary agents offer protection by stimulating the growth of surviving stem and progenitor cells, or by lengthening the duration of the cell cycle segment that checks for and repairs damaged genes. Although these types of drugs (radioprotectants) are now used to treat people exposed to radiation contamination on Earth, they may be good candidates for use on long duration space missions. However, that when administered in effective concentrations, some radioprotectants also have limiting negative side effects such as nausea, hypotension, weakness and fatigue (Rask *et al*., 2008).

2.2 Isolation and confinement

Human psychology and physiology are significantly altered by isolation and confinement. In interplanetary missions, the related adverse effects on the human body need to be explored and defined as they have a large impact on a mission's success. Pagel and Chouker (2016) concluded that terrestrial space analogs offer an excellent controlled environment to study some of these stressors during a space mission in isolation without the complex environment of the International Space Station. Participants subjected to these space analog conditions can encounter typical symptoms ranging from neurocognitive changes, fatigue, misaligned circadian rhythm, sleep disorders, altered stress hormone levels and immune modulatory changes.

2.3 Microgravity

Microgravity is the condition in which people or objects appear to be weightless. The effects of microgravity can be seen when astronauts and objects float in space. Microgravity can be experienced in other ways, as well. "Micro-" means "very small," so microgravity refers to the condition where gravity seems to be very small. In microgravity, astronauts can float in their spacecraft - or outside, on a spacewalk. Heavy objects move around easily. For example, astronauts can move equipment weighing hundreds of pounds with their fingertips (Sandra, 2017). Prolonged exposure to weightlessness also increases the risks of kidney stones and bone fractures, which are both associated with bone demineralization. In addition, studies suggest that microgravity alters the ability of bones to heal after fractures.

Long stays in space also impact muscles. There is loss of muscle mass, strength and endurance, especially in the lower extremities. Changes in muscle performance, coupled with the effects of microgravity on connective tissues and the demands of activities of varying intensities, place astronauts at risk of fatigue and injury.

The heart is a unique muscle, and diminished cardiac function and the possible occurrence of heart rhythm disturbances are concerns faced during space flight. In microgravity, body fluids are redistributed away from the extremities, which results in puffiness in the face during flight as well as changes in cardiovascular physiology. Upon return to Earth, some astronauts experience impaired orthostatic response, which means that their blood pressure drops abnormally low when they move from lying down to a sitting or standing position (Drummer *et al*., 2000).

2.4 Hostile/closed environments

The ecosystem inside the spacecraft plays a big role in everyday astronaut life. Microbes can change characteristics in space, and microorganisms that naturally live on body are transferred more easily from person to person in closed habitats like the space station. The stress hormone levels are elevated and the immune system is altered, which could lead to increased susceptibility to allergies or other illnesses, and disease. Every inch and detail of living and working quarters must be carefully thought-out and designed. It is important to monitor the air quality of the space station to ensure the atmosphere is safe to breathe and not contaminated with gases like formaldehyde, ammonia, and carbon monoxide. Various parts of the body and the space station are swabbed for analysis of the microbial population that inhabits the environment. Effective monitoring techniques are in place to identify how immune system changes in space by analyzing blood, saliva, and urine samples.

The other challenges that occur during space flight are distance from earth, physiological changes *etc*. which adversely affect the body.

3. History

Early in history, humans discovered that food would remain edible longer if it were dried and stored in a cool dry place until it was time to be consumed. Food dehydration was achieved by cutting meat, fish, and certain fruits into thin strips and drying them in sunlight. Rubbing food with salt or soaking it in salt water, an early form of curing food, also helped preserve it. Later techniques were developed for cooking, processing, preserving, and storing food in sealed containers (Watson, 2008). With the developments of pasteurization and canning, a much larger variety of foods could be stored and carried on long journeys. More recently, refrigeration and quick-freezing have been used to help preserve food flavor and nutrients and prevent spoilage.

While these forms of packaged food products are fine for travel on Earth, they are not always suitable for use on space flights. There are limitations to weight and volume when traveling and the microgravity conditions experienced in space also affect the food packaging. Currently, there is limited storage space and no refrigeration. To meet these challenges, special procedures for the preparation, packaging, and storing of food for space flight were developed

3.1 Mercury (1961-63)

In project Mercury, space flights lasted from a few minutes to a full day. Because of the short duration, complete meals were not needed. The major meal was consumed prior to the flight. These first astronauts found themselves eating bite-sized cubes, freeze-dried foods, and semi-liquids in aluminum toothpaste-type tubes. Dry bite-sized snacks were covered with gelatin coating, which was necessary to control crumbling. Food was unappetizing, and there were problems when they tried to rehydrate the freeze-dried foods. The tube foods offered many challenges to food development.

Special materials were developed to coat the inner surface of the aluminum tubes to prevent the formation of hydrogen gas as a result of contact between metal and the acids contained in some foods, such as applesauce. This aluminum tube packaging often weighed more than the food it contained. Because of this, a lightweight plastic container was developed for future flights. NASA (1999) during the later Mercury test flights, bite-sized foods were developed and tested. These were solid foods processed in the form of compressed, dehydrated bitesized cubes. The cubes could be rehydrated by saliva secreted in the mouth as food was chewed. These foods were vacuum-packed into individual serving-sized containers of clear, four-ply, laminated plastic film for storage. This packaging also provided protection against moisture, loss of flavor and spoilage.

Plate 1. Food products of Mercury mission

3.2 Gemini (1965-67)

The major advancements in food items during the Gemini period were more variety and improved packaging. The dehydration process provided foods that were similar in appearance including color, taste, shape and texture to freshly prepared food products. Adequate nutrient intake became a health concern with extended space flights in the Gemini program. Each crew member was supplied with 0.58 kilograms of food per day. These included dehydrated juices, freeze-dried and dehydrated foods, and compressed, noncrumbling, bite- sized foods. These made up the three meals a day that the astronauts ate. Meals were planned in advance, and the menu was repeated every 4 days. The advantages of freeze-dried foods were paramount in their development. The food is lightweight because the water has been removed. The food has a longer shelf life and can be stored at room temperature. The food also has flavors and textures more closely resembling that of the original fresh food items (NASA, 1999).

Plate 2. Food products of Gemini mission

3.3 Apollo (1968- 75)

The Apollo program used food packages similar to those used on Gemini, but the variety of foods was considerably greater.The preparation, handling, and consumption of space foods during the Mercury and Gemini missions provided valuable experience for the further development of space foods for future space flights. Rehydratable food was encased in a plastic container referred to as the spoon bowl. Water was injected into the package through the nozzle of a water gun. After the food was rehydrated, a pressure-type plastic zipper was opened, and the food was removed with a spoon. The moisture content allowed the food to cling to the spoon, making eating more like that on Earth.

Another new package, the wet pack or thermostabilized flexible pouch, required no water for rehydration because water content was retained in the food. There were two types of thermostabilized containers: a flexible pouch of a plastic and aluminum foil laminate and a can with a full panel pull out lid. Apollo astronauts could see and smell what they were eating as well as eat with a spoon for the first time in space. The storage space for the new packaging allowed for 1 week worth of rations for one astronaut to fit in a pressure resistant container the size of three shoe boxes (NASA, 1999).

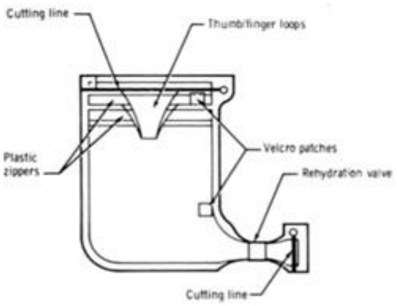

Plate 3. Wet packs used in Apollo mission

3.4 Skylab (1973)

The dining experience on Skylab was unlike any other space flight. The Skylab laboratory had a freezer, refrigerator, warming trays, and a table. Eating a meal on Skylab was more like eating a meal at home. The major difference was the microgravity environment. The supply of food onboard was sufficient to feed three astronauts for approximately 112 days. The menu was designed to meet each individual astronaut's daily nutritional requirements based on age, body weight, and anticipated activity. Each astronaut's caloric intake was 2,800 calories a day. These nutritional requirements were part of the life science experiments conducted on Skylab.

Skylab foods were packaged in specialized containers. The rehydratable beverages were packaged in a collapsible accordion-like beverage dispenser. All other foods were packaged in aluminum cans of various sizes or rehydratable packages. To prepare meals, the Skylab crew placed desired food packages into the food warmer tray. This was the first device capable of heating foods (by means of conduction) during space flight. Foods consisted of products such as ham, chili, mashed potatoes, ice cream, steak and asparagus.

Plate 4. Food warmer tray

3.5 Space Shuttle (1981- 86)

For the Space Shuttle program, a more Earth-like feeding approach was designed by updating previous food package designs and hardware items. Food variety expanded to 74 different kinds of food and 20 kinds of beverages. The changes were driven by the relatively large crews and regularly scheduled space flights. A standard Shuttle menu is designed around a typical 7-day Shuttle mission. Astronauts may substitute items from the approved food list to accommodate their own tastes or even design their own menus, but these astronaut-designed menus are checked by dietitians to ensure that they provide a balanced supply of nutrients.

On the Shuttle, food is prepared at a galley installed in the orbiter s middeck. This modular unit contains a water dispenser and an oven. The water dispenser which can dispense hot, chilled, or ambient water is used for rehydrating foods, and the galley oven is used to warm foods to the proper serving temperature. The oven is a forced-air convection oven and heat food in containers different in size, shape, and material. A full meal for a crew of four can be set up in about 5 minutes. Reconstituting and heating the food takes an additional 20—30 minutes. A meal tray is used as a dinner plate. The tray attaches to the astronaut's lap by a strap or can be attached to the wall. Eating utensils consist of a knife, a fork, a spoon and a pair of scissors to open food packages.

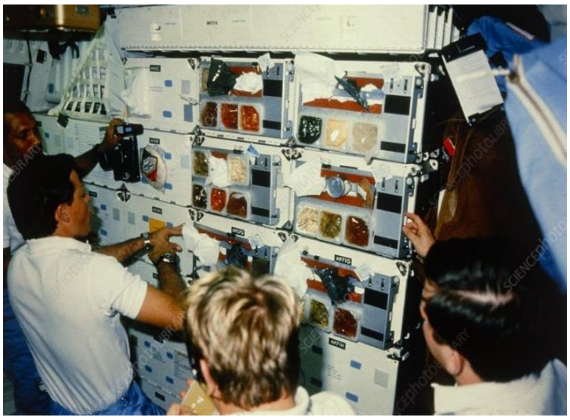

Plate 5. Galley of Space shuttle

3.6 International Space Station (1998)

The International Space Station (ISS) was operational on a full-time basis with a crew of three. Later, the crew size grow to a maximum of seven people. The crew reside in the Habitation Module (HAB). Food and other supplies was resupplied every 90 days by the Multi-Purpose Logistics Module (MPLM). The MPLM is a pressurized module carried in the Space Shuttle payload bay that is used to transport materials and supplies. The food system described here is for the completed ISS and will be considerably different from the Space Shuttle food system.

Water was recycled from variety of sources, but was not enough for use in the food system. Therefore, most of the food planned for the ISS was frozen, refrigerated, or thermostabilized (heat processed, canned, and stored at room temperature) and require the addition of water before consumption. Although many of the beverages was in the dehydrated form, concentrated fruit juices was added to the beverages offered and was stored in onboard refrigerator. ISS beverage package was made from foil and plastic laminate to provide for longer product shelf life. An adapter located on the package was connected with the galley, or kitchen area, so that water may be dispensed into the package. This water will be mixed with the drink powder already in the package. The adapter used to add water also holds the drinking straw for the astronauts. The food package is made from a microwaveable material. The top of the package is cut off with a pair of scissors, and the contents are eaten with a fork or spoon.

Plate 6. Storage area

Plate 7. Microwave oven

According to Cooper *et al*, (2017) post-production analysis indicated that vitamin D, vitamin K, potassium, and calcium were not adequate to meet recommended nutrient daily intake, assuming dietary compliance to the standard spaceflight food menu. Vitamin D is generally low in food. The deficit of vitamin D, largely due to lack of exposure to sunlight, has been mitigated with a supplement on ISS. Both potassium and calcium concentrations were approximately 20 per cent lower than recommended intake levels and vitamin K had a projected 13 per cent daily shortfall.

The vitamins in spaceflight food degraded during 21 °C temperature storage over a 3-year storage period. Vitamins B and C declined rapidly, but several vitamins (including A, B61, and B_{12}) only showed minor degradation or were available in enough foods that nutrient delivery remained adequate. The nutritional stability trends did not support a difference between processing methods after 3 years for most vitamins. However, the stability of several vitamins varied with food formulation or matrix. The vitamin C content in most fruit products degraded between 32 and 83% after 3 years of storage, with no attributable differences to ascorbic acid fortification status. Vitamin C appeared to be more stable in freeze-dried products that offered protection against oxidation (products with sauces) and in powdered fortified beverages

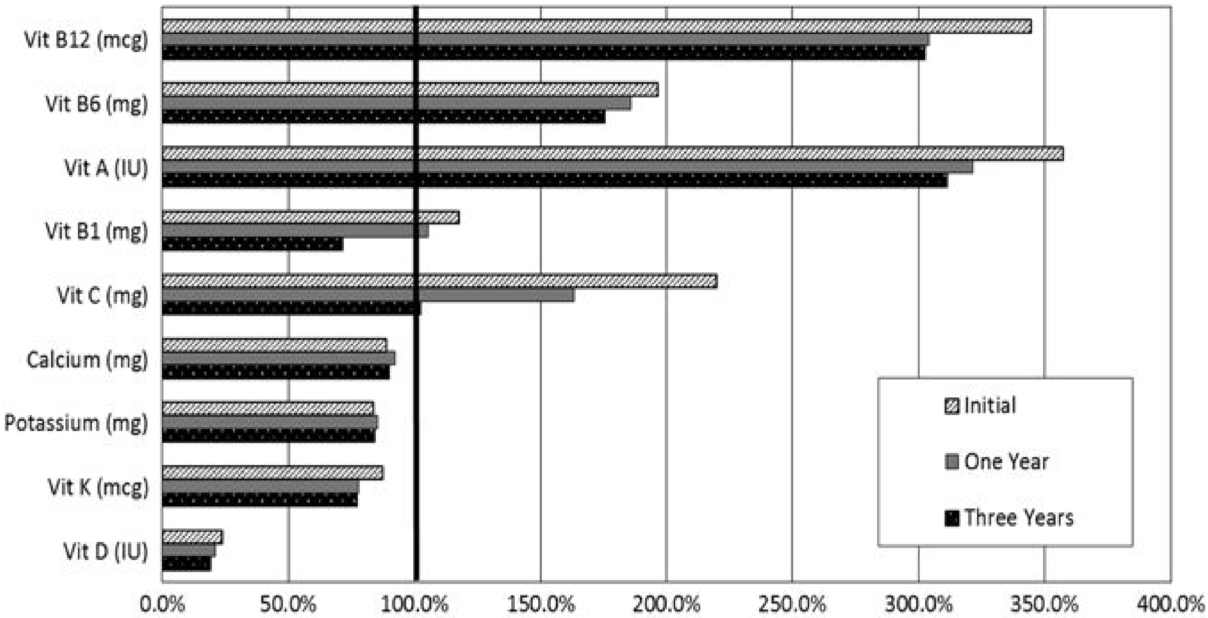

Figure 1. Nutritional quality of ISS standard menu over 3 years of ambient storage

3.7 Space Idli Mission (2012)

The first Indian items of the space menu are tiny idlis, the size of Rs 2 coins, accompanied by flaming orange sambhar powder and creamy coconut chutney dust developed by Defence Food Research Laboratory (DFRL). The idlis are cooked and dried using infrared radiation at a temperature of 700º C, and then further dried by microwaving. The moisture is zapped out of them, but not the taste, smell or nutrients.They do, however, lose some of their colour. It is slightly browned. Idlis and sambhar are to be eaten after adding hot water; the coconut chutney needs only cold water. Each idli is 12 gm and swells to 25 gm when soaked in water. The desiccation makes it impossible for micro organisms like bacteria to grow and increases the idlis' shelf life to more than a year. The removal of moisture also reduces the weight of food sharply, something crucial to the needs of both ISRO and the armed forces. The sambhar and chutney are also dried completely with infrared radiation, a technology that has been used in the preparation of food over the past six years or so.

Plate 8. Mini Idlis

4. Major Physiological Changes

4.1 Space motion sickness

Space motion sickness is experienced by 60 to 80 per cent of space travellers during their first 2 to 3 days in microgravity and by a similar proportion during their first few days after return to Earth. Space motion sickness symptoms are similar to those in other forms of motion sickness; they include: pallor, increased body warmth, cold sweating, malaise, loss of appetite, nausea, fatigue, vomiting, and anorexia. These are important because they may affect the operational performance of astronauts.

Two hypotheses have been proposed to explain space motion sickness: the fluid shift hypothesis and the sensory conflict hypothesis. The fluid shift hypothesis suggests that space motion sickness results from the cranial shifting of body fluids resulting from the loss of hydrostatic pressure gradients in the lower body when entering microgravity. The cranial fluid shifts lead to visible puffiness in the face, and are thought to increase the intracranial pressure, the cerebrospinal-fluid pressure or the inner ear fluid pressures, altering the response properties of the vestibular receptors and inducing space motion sickness. The sensory conflict hypothesis suggests that loss of tilt-related otolith signals upon entry into microgravity causes a conflict between actual and anticipated signals from sense organs subserving spatial orientation. Such sensory conflicts are thought to induce motion sickness in other environments (Heer and Paloski., 2006). Space motion sickness is usually treated using pharmaceuticals, most of which have undesirable side effects.

4.2 Bone and muscle loss

During spaceflight, bone resorption increases significantly, and formation either remains unchanged or decreases slightly. The net effect of this imbalance is loss of bone mass. Bone loss, especially in the legs, is increased during spaceflight. This is most important on flights longer than thirty days, because the amount of bone loss increases as the length of time in space increases. Weightlessness also increases excretion of calcium in the urine and the risk of forming kidney stones. Both of these conditions are related to bone loss. Increased bone resorption and largely unchanged bone formation result in the loss of calcium and bone mineral during space flight, which alters the endocrine regulation of calcium metabolism.

According to Smith *et al,* (2013), the reason for concern about chronic inadequate energy intake is that weight loss could occur over an extended period, along with possible accelerated muscle and bone loss. Although many crewmembers have lost weight during flight, many others have maintained body weight during flight, indicating that it is possible to maintain weight.

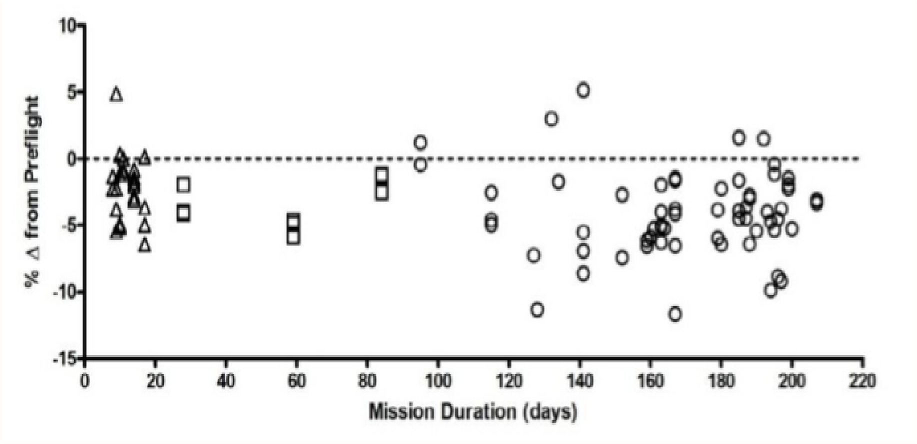

Figure 2. Body weight loss of astronauts in several space programs

Another study done by Matsumoto *et al*. (2011) indicates that space missions of greater than 1-yr duration are likely to be associated with physiologically significant weight loss for some astronauts.

Several factors are identified that vary directly or inversely with weight change. Such associations offer clues as to the nature and underlying mechanisms of weight change. Pre-flight predictors of weight loss include an astronaut's first mission, exercise levels, and exercise type. This analysis is the first report of biological predictors of weight loss during spaceflight, including baseline serum cholesterol, potassium, and chloride levels.

4.3 Fluid redistribution

Acclimation of the cardiovascular system to weightlessness is complex and not completely understood. Control mechanisms involving the autonomic nervous system, cardiac functions and peripheral vasculature all play a role. The primary cause of these acclimations can be attributed to a re-distribution of body fluids toward the head. The supine prelaunch position with the lower limbs raised above the thoracoabdominal coronal plane initiates a fluid shift, which continues during orbit, with blood and other fluids moving from the lower limbs to the torso and head.

During space flight, the volume in the lower limbs decreases by about 10% (1–2 L of fluid from the legs' vascular and tissue space) compared with preflight. The facial fullness and unique puffy appearance of the head coupled with reduced volume in the lower limbs associated with this fluid redistribution is referred to anecdotally as the "puffy face–bird leg" syndrome (Watenpaugh, 2001).

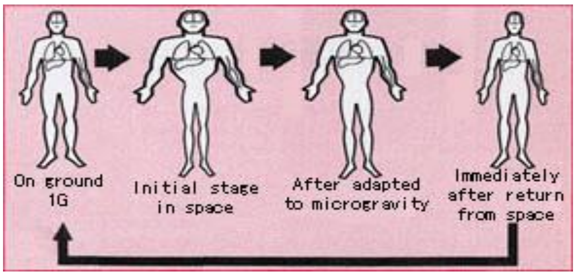

Plate 9. Fluid redistribution in body during space flight

Leach *et al*, (1988) confirmed that both fluid intake and urine output decrease significantly on the first day in flight and remain relatively low during space flight. The reductions in thirst and fluid intake occur regardless of space motion sickness. For example, none of the four studied SLS-2 crew members experienced motion sickness.

4.4 Changes in endocrine system

The endocrine system appears to be sensitive to the conditions of space flight. Hormones are important effectors of the body's response to microgravity in the areas of fluid and electrolyte metabolism, erythropoiesis, and calcium metabolism. Several hormones may increase in the circulation as part of the stress response to microgravity conditions, including epinephrine and norepinephrine, adrenocorticotropin, cortisol. These hormones play a role in the elevation of plasma glucose and fatty acids, in increased lipolytic activity in adipose tissue, in reducing lipogenesis and in raising glycogen content in the liver (Lane *et al.*, 1998).

Several hormones are known to participate in regulation of body fluid volume and blood levels of electrolytes. Antidiuretic hormone (ADH), cortisol, and aldosterone have been considered the most important hormones performing these functions. Levels of two metabolites of vitamin D, 25-hydroxyvitamin D 3 and 24,25-dihydroxyvitamin D 3, did not change significantly during flight. The metabolite l~t,25-dihydroxyvitamin D3, which is produced by the kidney and increases intestinal calcium absorption and resorption of calcium from bone, increased substantially in the first 2 days of flight. During the postflight recovery period, however, when l~t,25- dihydroxyvitamin D3 was only slightly decreased, plasma calcium exhibited its greatest change, a 5 per cent decrease, which was probably associated with changes in other plasma electrolytes measured after the flight. (Leach *et al*., 1988).

4.5 Blood volume changes

Plasma volume contraction occurs quickly in microgravity, probably as a result of transcapillary fluid filtration into upper-body interstitial spaces. No natriuresis or diuresis has been observed in microgravity, such that diuresis cannot explain microgravity-induced hypovolemia. Reduction of fluid intake occurs irrespective of space motion sickness and leads to hypovolemia (Lane *et al*., 1998). The fourfold elevation of urinary antidiuretic hormone (ADH) levels on flight day 1 probably results from acceleration exposures and other stresses of launch. Nevertheless, it is fascinating that elevated ADH levels and reduced fluid intake occur simultaneously early in flight.

Extracellular fluid volume decreases by 10 to 15 per cent in microgravity, and intracellular fluid volume appears to increase. Total red blood cell mass decreases by approximately 10 per cent within 1 week in space. Inflight Na^+ and volume excretory responses to saline infusion are approximately half those seen in pre-flight supine conditions. Fluid volume acclimation to microgravity sets the central circulation to homeostatic conditions similar to those found in an upright sitting posture on Earth. Fluid loss in space contributes to reduced exercise performance upon return to 1g, although not necessarily in flight. In-flight exercise training may help prevent microgravity-induced losses of fluid and, therefore, preserve the capacity for upright exercise post-flight. Protection of orthostatic tolerance during space flight probably requires stimulation of orthostatic blood pressure control systems in addition to fluid maintenance or replacement (Diedrich *et al*., 2007).

5. Nutritional requirements

Maintaining adequate nutrient intake during space flight is important not only to meet nutrient needs of astronauts but also to help counteract negative effects of space flight on the human body. The longer space station missions have included semi- closed food system, with periodic resupply and transient exposure to unique and fresh foods (Altman and Talbot, 1987).

Determining the nutritional requirements for travelers on short, medium and long-duration exploration missions will be crucial for ensuring health.

5.1 Energy

Energy itself is not readily stored in the body, but the substrates for energy are stored in the body. Energy in the form of heat is obtained by oxidising carbohydrates, fats, proteins and alcohol. Fat provides the most energy of these sources, at about 9 kcal/g. Carbohydrates and proteins provide about 4 kcal/g and alcohol about 7kcal/g. The energy requirements are similar before and during flight and energy intake during flight is commonly lower than the estimated requirements for individual crew member. Food palatability is reported as a cause of reduced in-flight intake and changes in taste and aroma of food during flight. The fluid shifts and congestion associated with the first days of microgravity can alter taste and odor perception. Other possibilities including effects of atmospheric contaminants, stress, radiation, and psychological factors.

5.2 Protein

Protein is one of the most important limiting factors when the body is deprived of energy, because essential amino acids are not stored in the body. A complete depletion of energy and protein reserves is the cause of death from starvation (Altman and Talbot, 1987). Maintaining a proper protein intake is vital, as both low-protein and high-protein diets can cause harm. Space flight requirement for protein intake is 50 g/kg per day, not to exceed 35% of the total daily energy intake. About 2/3 of the total amount of protein is to be provided in the form of animal protein, and 1/3 of the total should be in the form of vegetable protein.

5.3 Carbohydrate

Carbohydrates play an important role in the body because they supply the primary source of energy as well as a readily available source. This energy is oxidized and used by various organs and cells in the body, particularly the brain and red blood cells, which depend solely on carbohydrate for energy. Carbohydrate intake during space flight is 50 – 55 per cent of the total daily energy intake. The acceptable macronutrient distribution range for dietary carbohydrate is defined as 45 – 65 per cent of the total dietary energy intake. A minimum intake of 320 g/d is required to maintain the needs of organs that require carbohydrate for energy production.

5.4 Fat

Fat is the most energy-dense of all the nutrients, and therefore is a major energy source for the body. Chemically, dietary fat is mainly in the form of triacylglycerols, which contain a glycerol backbone with as many as 3 fatty acids attached. Body stores of fat are located mainly in adipose tissue as triacylglycerols. Adipose tissue is dispersed throughout the human body, its distribution differing slightly between genders.

Space flight requirement is for dietary intake of fat to make up 25 – 30 per cent of the total daily energy intake. Dietary intake of n-6 and n-3 fatty acids is 14 g/d and 1.1 to 1.6 g/d, respectively. Saturated fat should be < 7 per cent of total calories, trans fatty acids < 1 per cent of calories, and cholesterol intake < 300 mg per day. Deficiency of fat leads to essential fatty acid deficiency and ultimately death. Toxic levels of fat lead to high serum cholesterol, obesity, atherosclerotic plaques, and ultimately coronary heart disease, and ultimately death.

5.5 Fluid

Adequate fluid intake is necessary to maintain the body's normal hemodynamic state and normal fluid osmolality, which is important for cardiovascular health and for maintenance of fluid and electrolyte homeostasis. Water is a structural component of the body and the solvent for transportation of nutrients and waste. Total intake of water (including that contained in food, beverages, and drinking water) is 2 L/day (Desanto *et al*., 2001). Fluid intake during flight is typically less than preflight intake and often below the recommended quantity.

5.6 Sodium

Sodium is the major cation of extracellular fluid. sodium is utilized by the body to maintain normal water distribution, osmotic pressure, and anion-cation balance in the extracellular fluid compartment. Increases in blood sodium levels can be caused by diabetes, renal polyuria, diarrhea, insufficient water intake, excessive sweating, or increased dietary sodium intake. Sodium levels decrease with edema, excessive water intake, vomiting, diarrhea, diuretic therapy, renal tubular damage, hyperaldosteronism, or lower dietary intake. space flight requirement for dietary sodium is 1500 to 2300 mg/d (1.5 to 2.3 g/d) for both women and men (Dewardener and Macgregor, 2002). High sodium intakes in flight can exacerbate bone loss and lead to increased risk of renal stone formation. deficiency of sodium electrolyte during flight could lead to hyponatremia, hypotension and even death.

5.7 Calcium

Calcium is essential for maintaining the body's structural and mechanical functions, and it makes up 37 – 40 percent of the bone mineral hydroxyapatite in the body. Deficiency of calcium leads to reduced bone mass and osteoporosis. An excess of absorbed calcium leads to kidney stones, hypercalcemia, and ultimately renal insufficiency or even death. Intakes upto 2500 mg/d are considered safe under normal conditions. space flight requirement for dietary intake of calcium during flight is 1200 to 2000 mg/d (Heaney, 2008). The ability to understand and counteract weightlessness-induced bone mineral loss will be vital to crew health and safety during and after extended-duration space station and exploration missions.

5.8 Iron

Iron is an essential element involved in oxygen transport, oxidative phosphorylation in carbohydrate and lipid metabolism, and electron transport in cytochromes and cytochrome oxidase. Deficiency of iron leads to anemia, fatigue, reduced work capacity, impaired behavior and intellectual performance, cognitive deficits and memory loss, heart palpitations, impaired thermoregulation, decreased immune function, or even death. Toxicity of iron may lead to tissue damage or cancer. High iron intakes have also been related to gastrointestinal distress. space flight requirement for dietary intake of iron is 8 to 10 mg/d for men and women. the RDA for men 19 to 70 years is 8 mg/d, and for women aged 19 to 50 years it is 18 mg/d, dropping to 8 mg/d in women over 50 (Alfrey *et al*., 1996). Dietary iron provided by the space food system has always exceeded the requirement and intakes have often been much higher. This gives reason for concern because of the potential for elevated tissue iron to cause deleterious effects, including oxidative damage.

Nutrients	**Normal requirements**	**Space flight requirements**
Carbohydrate	225- 325 g/ day	320g/ day
Protein	46- 56 g/ day	50 g/ day
Fat	20 – 35 % of calories	25 – 30 % of calories
Fluid	2.7 – 3.7 L/ day	2 L/ day
Sodium	1.5 – 2.3 g/ day	1.5 – 2 g/ day
Calcium	1.2 g/ day	1.2 - 2 g/ day
Iron	18 – 20 mg/ day	8 – 10 mg/ day

Table 1. Nutritional requirements during normal and space flight condition

6. Characteristics of space food

Space foods usually have the following characteristics

- Nutritious
- Light weight
- Compact
- Easily digestible
- Palatable
- Physiologically appropriate
- Well packed
- Quick to serve
- Easy to clean-up
- High acceptability with minimum preparation.

7. Types of space food

7.1 Rehydratable Food

Moisture is removed from the food during packaging food materials like Soups, casseroles, scrambled eggs and breakfast cereals are packaged in this manner. As the time passed technology grew more advanced and by the time Gemini mission (1965) was launched the food became tastier. The astronauts got this choice of selected from a wide variety of food which included seafood, turkey meat and cream of chicken soup with a dessert. The pre requisites for this include the storage and receiving section for raw materials, a food cooking area and finally a large area with lots of large freezing and drying chambers followed by a packaging section. The facility also includes a research and development lab where in new improved methods of freeze drying are discovered the food is then finally sent to a test kitchen where in it is checked for the final quality parameters (Bourland, 1999).

7.1.1. Testing and preparation of freeze dried foods

The food is first checked for bacterial counts and spoilage. Some food items must be cooked before freeze drying. Thus they are usually bought in small cut pieces. Already cut, pitted, and peeled, fruits and vegetables are usually purchased. These fruits and vegetables are washed by spray of water. Some quickly scalded or blanched vegetables, like peas and corn are used before freezing. Pre-brewed concentrated liquid for coffee is purchased as the aroma of coffee is what is most appealing in the product. To improve the aroma a small amount of coffee bean oil is added to the liquid and the oil is not removed when the product is dried (Bourland, 1993).

7.1.2. Freezing

The food pieces are then spread out on a even metal trays that are staked over each other 20 to 30 at a time in a wheeled trolley for the food that is already precooked and frozen the trays are pre chilled to prevent thawing of the frozen material. For material like coffee, it is poured in a shallow pan. These trolleys are then led into a large, walk in cold freezer where the temp is -40^{0} C in this temp the food quickly freezes, these trolleys are kept their till the time to dry them into the drying chamber reaches (Hui., 1992)

7.1.3. Drying

The trolleys are then led into a vacuum drying chamber. For liquids like coffee, the frozen coffee is first grinded into small particles in a low-temperature grinder machine. With semi-elliptical ends, the drying chamber is a large, long, horizontal cylinder one end of which is closed and the other open. This procedure is called as Sublimation. In sublimation, a solid material is transformed into gaseous state without changing into liquid state.

In case of freeze dried food, the ice crystals present in the frozen food material are transformed into water vapor without changing into liquid water. In the chamber, drying is done by removing the air with a help of a vacuum pump to decrease the pressure till about 0.036 psi (0.0025 bar). The temperature of the food is increased to about 100°F (38°C) by conduction heating passing through the bottom of the trays, radiation is absorbed from heat lamps, or microwave heating.

7.2 Thermostabilized Food

These foods are processed by heat at high temperature to destroy bacteria and other micro organisms so they can be stored at ambient growth temperature. Foods like fruits, pudding and tuna fish are preserved in this. Dehydrated foods are the most well known space food groups thermo stabilized foods rank second in the preference, these are heated to destroy harmful bacteria and enzymes that cause food spoilage, the biggest advantage of these food is that they don't use any of the water available on the shuttle which is in a limited quantity. These foods are fast, easy and less time consuming to cook because they only need to be warmed (re heated) before eating (Cooper, 2011).

7.3 Intermediate Moisture Food

These are those types of foods in which some moisture is removed and the rest is not. Foods like dried peaches, pears and apricots are examples of intermediate moisture foods. (IMF) is regarded as one of the oldest food preserving method tested by man. In this method the mixing of various ingredients to attain a given A that allows a safe storage for a long time but at the same time it maintains the eating quality of the food, but this work was only done on an empirical basis (Morris *et al*., 2007).

This work done by food scientists and technologist approximately 30 years ago, in the search for convenient stable shelf life products by removing water, resulted in the modern intermediate moisture foods (IMF). These foods have a high dose of preservative and humectants added to stop the growth of microorganisms. It is since then; this category of foods is subjected to continuous research and development.

7.4 Natural Form Food

Nuts, Granola bars and cookies are examples of food with a naturally long shelf-life. They are simply packaged in ready-to-eat pouches.

7.5 Irradiated Food

Like thermo stabilized foods, these foods have been preserved by killing harmful bacteria and organisms. They come in flexible pouches having food that is ready to eat. The only difference is the process that is used to sterilize the food. Irradiated food is exposed to ionizing radiation from gamma rays or electron beams for a specific length of time determined by the type and content of food. Irradiated food can include any food group from fruits and vegetables to meat. Despite the use of radiation, these food do not raise the risk of cancer for those eating it (Bui and Small, 2007).

7.6 Fresh Food

These are the foods available for space flight for some initial days of the mission. Fruits and vegetables that are sanitized by chlorine are packaged in a simple plastic bags to preserve their freshness are loaded in the shuttle. But since there is no refrigeration onboard in the shuttle, these foods must be consumed within the first two to three days of the mission to prevent them from spoilage.

8. Space food development institutions

8.1 Space Food Systems Laboratory (SFSL)

It is a multipurpose facility where teams research and process space food. It also plans menus, packaging and food-related hardware (such as space-friendly utensils and reheating devices) for the space shuttle, International Space Station and Advanced Life Support systems. All foods used to support NASA ground tests and/or missions must meet the highest standards before they are 'accepted' for use on actual space flights. The foods are evaluated for nutritional content, sensory acceptability, safety, storage and shelf life, and suitability for use in micro-gravity. The food packaging is also tested to determine its functionality and suitability for use in space. Food Scientist, Registered Dieticians, Packaging Engineers, Food Systems Engineers, and Technicians staff the Space Food Systems Laboratory (NASA, 1999).

Activities

- Food product development
- Food preservation technology
- Sensory evaluation
- Menu planning
- Freeze dehydration
- Blast freeze
- Package development

8.2 Defence Food Research Laboratory

Defence Food Research Laboratory (**DFRL**) is an Indian defence laboratory of the Defence Research and Development Organisation (DRDO). Located in Mysore, Karnataka, it conducts research and development of technologies and products in the area of food science and technology to cater the varied food challenges for the Indian Armed Forces. DFRL is organised under the Life Sciences Directorate of DRDO.

Areas of work

- Research and development in food science and technology
- Studies in the development of convenience foods, preservation of foods, food safety, food packaging, and studies in the spoilage of foods and safety of processed foods
- Production and supply of processed foods on a limited scale to the Armed Forces and other bodies for national missions
- Toxicological, nutritional, and biochemical studies
- Development of pack rations, their quality assurance methods
- Preservation and packaging methods for long distance transportation of perishable products
- Evaluation of nutritional requirements of troops deployed under different climatic conditions
- List of space food under research - rice, lentils and millets, energy-filled nuggets *etc.*

The other institutions which are involved in the development of space food are Russian Space food Institute and China National Space Administration.

9. Packaging of space food

All space foods are stored under ambient storage conditions and must safely maintain a shelf life of nine months to five years.

- Shuttle foods are required to have a minimum shelf life of nine months.
- International Space Station (ISS) foods require a one year shelf life.
- All rehydratable and bite-sized foods destined for ISS are overwrapped with an aluminum foil laminate and vacuum sealed to improve barrier properties, increasing shelf life.
- The food system for planetary outposts will require a five year shelf life because of planned mission lengths.

9.1 Packaging of bite-sized foods

Many of the foods used for the Shuttle and ISS are freeze dried and packaged into rehydratable containers. These packages are made from a 5 layer co-extrusion of nylon/ethylene vinyl alcohol/tie layer of polyethylene/linear low density polyethylene (Cooper *et al.*, 2011). NASA packages both rehydratable and bite-sized foods in Combitherm Paxx packaging materials made by Wolff Walsrode of Burr Ridge, Illinois, a division of Bayer Corporation.

Bite sized food packaging methods and materials that are necessary for ensuring the extended shelf life and safety of space foods for consumption in microgravity. All space foods are stored under ambient storage conditions and must safely maintain a shelf life of nine months to five years.

Packaging for bite-sized foods is procured from the vendor sealed on three sides. NASA adds the food product and seals the fourth side.

- Rehydratable and bite-sized foods are packaged using modified atmosphere techniques.
- Each package is flushed with nitrogen three times before the final seal at 21 to 29 inches of Hg vacuum.
- The amount of vacuum used varies depending upon the food product (a hard vacuum will destroy the texture of some food products).

9.2 Packaging of rehydratable foods

Rehydratable packages are procured from the vendor in the shape of a cup and a lid. They are made of a flexible material to aid in trash compression. The vendor forms the flexible cup by thermoforming the five layer co-extruded film over a mold. The thermoforming process decreases the barrier properties of the original film as the material is stretched thinner to form the cup (Han, 2003).

- The food product in the cup, places the lid on top, and seals the lid.
- The septum adapter is an injected, molded device. The septa is made from silicon rubber and is inserted into the septum adapter with a special tool. The septa provides an entry for a needle to inject water into the package during rehydration. The septum foil laminate seal is pierced by the galley needle when rehydration takes place and seals off when the needle is withdrawn.
- The package is flushed three times with nitrogen and sealed.

9.3 Packaging of beverages

Beverage package is a modified Capri Sun package made from a foil laminate. The NASA version is longer than the commercially available package. Packaging of beverages for spaceflight following these steps:

- Dry beverage powder is placed in the package.
- The package is flushed three times with nitrogen.
- The septum is inserted and the beverage package is sealed

9.4 Other packaging materials

- Commercial pouches are used for thermostabilized and irradiated food
- A small amount of commercial plastic pudding containers, commercial full-panel pullout aluminum cans, and single-serving commercial condiment pouches are also used for the Shuttle and ISS.

Plastic can   Thermostabilised retort pouches

Plate 10. Different packaging materials

9.5 Food packaging weight

Food packaging weight and waste are critical issues for NASA. For Shuttle the food package weight is about 0.5 pounds per person, per day. The weight of ISS food packaging waste is greater, because rehydratable and bite sized foods packaged for Shuttle are overwrapped with an aluminum foil laminate for ISS to increase shelf life. Also, thermostabilized pouches are used more frequently on the ISS, adding additional food package weight.

10 Ongoing researches

10.1 Space farming

The use of agriculture for human life support in space has been one of the longest standing areas of space research, and has provided an intellectual and collegial bridge between the aerospace and agricultural communities. Numerous ground studies have shown that crops can regenerate air, recycle water, and produce much of the needed food for humans living in closed systems. But to succeed, space agricultural systems must be highly closed and efficient, where energy use is minimized, and air, water, and nutrients are recycled as much as possible.

Studies for space agriculture have documented crop yields far greater than yields reported from the even most productive field settings, suggesting there is still untapped potential from our field crops. Recirculating hydroponics with efficient water use and minimal nutrient discharge have been demonstrated for multiple crops, including crops like potato and sweetpotato.

Volume constraints of space have driven selection and development of shorter crops with high harvest indices, which along with the hydroponic advances and use of energy efficient LEDs have applications for vertical agriculture and plant factories on Earth. The ability to control CO and closed systems has provided insights into what the future might hold for terrestrial agriculture with rising CO. This decades-long effort has come from a global community of dedicated and enthusiastic researchers, who will one day literally have the seeds and fruits of their labor growing on other planets (Berkovich *et al*., 2009).

10.2 3D printing

3D printed food is a way of preparing a meal in an automated additive manner. 3D printing food works much like a regular fused filament fabrication 3D printer in the sense that a print head extrudes material onto a surface. The piece can be any shape the designer wants, as long as it does not extend past the spacial limitations of the printer. The main difference between 3D printed food and non-3D printed food is the texture, it will be in an easily extrudable form. It can be healthy and good for the environment because it can help to convert alternative ingredients such as proteins from algae, beet leaves, or insects into tasty products

11 Conclusion

Without an adequate food system, it is possible that space crew members' health and performance would be compromised. Nutrition will be the key factor for the next phases of exploration beyond this planet. Realisation of the full role of nutrition during spaceflight is critical for the success of extended duration missions. It is clear that in developing adequate food systems for future missions, a balance must be maintained between use of resources (such as power, mass, and crew time), and the safety, nutrition, and acceptability of the food system. In short, the food must provide the nutrients to sustain crew health and performance, must be acceptable throughout the course of the mission, must be safe even after cooking and processing, and must be formulated and packaged in such a way that the mass and volume are not restrictive to mission viability. It is this delicate balance that frames the food system needs for our next mission and charts the work for advanced Food Technology.

12. Discussion

1. What is Multi Purpose Logistic Module?

   A Multi-Purpose Logistics Module was a large pressurized container used on Space Shuttle missions to transfer cargo to and from the International Space Station.

2. Indian human spaceflight programme

   The Indian Human Spaceflight Programme (IHSP) was initiated in 2007 by the Indian Space Research Organisation (ISRO) to develop the technology needed to launch crewed orbital spacecrafts into low Earth orbit. The first crewed flight is planned with a spacecraft called *Gaganyaan* for December 2021 on a GSLV Mark III rocket.

3. Whether food get spoiled during spaceflight?

   Yes, it just takes longer for it to spoil. While most of the oxygen is removed, there's still trace amounts of oxygen left within the food. This will allow foods to spoil, but at a lot slower rate.

4. What are the space food research going on at DFRL?

   DFRL, Mysuru, the food research centre of the Defence Research and Development Organisation(DRDO) geared to feed Indian astronauts with tasty ready to eat and ready to make foods. Minute idli-sambhar, ready to eat courses made of rice, lentils and millets, kichdi, beaten rice delicacies, energy filled nuggets, munches, bars *etc*., even specially toasted potato chips are different products developed by DFRL.

5. How products are rehydrated during space flight?

   A freeze-dried meal would be rehydrated using a water gun to inject cold water into the package. After cutting the package open with scissors, the meal was then ready to eat. Astronauts used a water gun to reconstitute the food and scissors to open the package.

13. Reference

Alfrey, C. P., Udden, M. M., Leach, H.C., Driscoll, T. and Pickett, M. H. 1996. Control of red blood cell mass in spaceflight. *J Appl. Physiol*. 81: 98-104.

Altman, P. L. and Talbot, J.M. 1987. Nutrition and metabolism in spaceflight. *J. Nutr*.117: 421-7.

Berkovich, Y.A., Smolyanina, S.O., Krivobok, N.M., Erokhin, A.N., Agureev, A.N. and Shanturin, N.A., 2009. Vegetable production facility as a part of a closed life support system in a Russian Martian space flight scenario. *Adv. Space Res*. 44(2): 170-176.

Bourland, C. T. 1993. The development of food systems for space. *Trends Food Sci Tech*. 4: 271–6.

Bourland, C.T., 1999. Food systems for space travel. *Life Support Biosphere Sci*. *6*(1): 9-12.

Bui, L.T. and Small, D.M., 2007. Folates in Asian noodles: I. Microbiological analysis and the use of enzyme treatments. *J. Food Sci*. *72*(5): 276-282.

Cooper, M., Perchonok, M. and Douglas, G.L., 2017. Initial assessment of the nutritional quality of the space food system over three years of ambient storage. *npj Microgravity*, 3(1): 1-4.

Cooper, M., Douglas, G. and Perchonok, M., 2011. Developing the NASA food system for long-duration missions. *J. Food Sci*. 76(2): 40-48.

Cucinotta, F.A., Kim, M.H., Willingham, V. and George, K.A., 2008. Physical and biological organ dosimetry analysis for international space station astronauts. *Radiat. Res*. 170 (1): 127–38.

Diedrich, A., Paranjape, S.Y. and Robertson, D., 2007. Plasma and blood volume in space. *Am. J. Med. Sci. 334*(1): 80-86.

Desanto, N. G., Christensen, N. J. and Drummer, C. 2001. Fluid balance and kidney function in space: introduction. *Am. J. Kidney Dis*. 38(3): 664-7.

Drummer, C., Hesse, C., Baisch, F., Norsk, P., Elmann-Larsen, B., Gerzer, R. and Heer, M., 2000. Water and sodium balances and their relation to body mass changes in microgravity. *Eur. J. Clin. Investigation,* 30(12): 1066-1075.

Dewardener, H. E. and Macgregor, G.A. 2002. Harmful effects of dietary salt in addition to hypertension. *J. Hum. Hypertens*. 16(4): 213-23.

Han, J.H., 2003. Antimicrobial food packaging. *Novel Food Packaging Tech*. 8(2):50-70.

Heaney, R. P. 2008. Calcium supplementation and incident kidney stone risk: a systematic review. *J. Am. Coll. Nutr*. 27(5): 519-27.

Heer, M. and Paloski, W.H., 2006. Space motion sickness: incidence, etiology, and countermeasures. *Autonomic Neuroscience*, 129(1-2): 77-79.

Horneck, G., Klaus, D. and Mancinelli, R. L. 2010. Space microbiology. *Microbiol Mol Biol Rev.*74(1):121–56.

Hui, Y. H. 1992. Freeze dried food. *How products are made,* 2. Available: http://www.madehow.com/Volume-2/Freeze-Dried-Food.html [Accessed 8 Nov. 2019].

Lane, H.W., Gretebeck, R.J. and Smith, S.M., 1998. Nutrition, endocrinology and body composition during space flight. *Nutri. Res.* 18(11) :1923-1934.

Leach, C.S., Johnson, P.C. and Cintron, N.M., 1988. The endocrine system in space flight. *Acta Astronautica*. 17 (2): 161-166.

Matsumoto, A., Storch, K.J., Stolfi, A., Mohler, S.R., Frey, M.A. and Stein, T.P., 2011. Weight loss in humans in space. *Aviation Space Environ. Med.* 82(6): 615-621.

Morris, C., Brody, A.L. and Wicker, L., 2007. Non-thermal food processing/preservation technologies: A review with packaging implications. *Packaging Tech Sci.: Int. J*. 20(4): 275-286.

NASA (National Aeronautics Space Administration). 1999. *Space Food Nutrition*. National Aeronautics Space Administration, Washington D. C, 62p.

Pagel, J.I. and Chouker, A., 2016. Effects of isolation and confinement on humans-implications for manned space explorations. *J. Appl. Physiology*, 120(12): 1449-1457.

Rask, J., Vercoutere, W., Navarro, B.J. and Krause, A., 2008. Space Faring: The Radiation Challenge. *Nasa Module*, 3 (8): 9.

Sandra, M. 2017. What is microgravity?. *NASA knows!* 5. Available: https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-microgravity-58.html [Accessed 20 Jan. 2020].

Smith, S. M., Rice, B. L., Dlouhy, H. and Zwart, S. R. 2013. Assessment of nutritional intake during space flight and space flight analogs. *Procedia Food Sci*. 2: 27-34.

Watenpaugh, D.E., 2001. Fluid volume control during short-term space flight and implications for human performance. *J. Exp. Biology*, 204 (18): 3209-3215.

Watson, S. 2008. How space food works? *How stuff works*. Available: https://science.howstuffworks.com/space-food.html [Accessed 20 Jan. 2020].

14. Abstract

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FN 591: Master's Seminar

Name	: Meera P. M	Venue	: Seminar Hall
Admission no.	: 2018-16-002	Date	: 06-12-2019
Major advisor	: Dr. Sharon C. L	Time	: 11:30 am

Space Nutrition

Abstract

Space foods are those food products specially created and processed for consumption of astronauts in outer space (NASA, 1999). Maintaining adequate nutrient intake during space flight is important, not only to meet the nutrient needs of astronauts but also to counteract negative effects of space flight on human body.

The major challenges during space flight are microgravity, adaptation, radiation, isolation and confinement and extreme temperature which negatively affects the body by causing different physiological disorders.

Gherman Titov in 1961, was the first person to have food in a weightless environment in the mission Vostok. Initially the food provided in space was less appetizing. In the subsequent missions from Mercury, Gemini *etc,* the quality and shelf life of space foods improved. Food improved from liquid paste to bite sized cubes covered with gelatin and later food produced by technologies like freeze drying were provided. Further, fresh food and improved menus were provided to astronauts.

Major physiological changes occurring during flight are space adaptation syndrome, bone and muscle loss, fluid redistribution, changes in endocrine system and blood volume. Space adaptation syndrome symptoms are similar to those in other forms of motion sickness like nausea, vomiting, headache and lethargy. Deterioration of bones and muscles is another problem during space flight which is mainly due to bone calcium resorption and muscle atrophy (Smith *et al*., 2013). Calcium is provided in lower quantity to reduce accumulation in the serum. High sodium intake in flight can exacerbate bone loss and lead to increased risk of renal stone formation (Smith *et al.,* 2009). In microgravity condition fluid shifts to the upper portion of the body causing bulging neck veins, puffy face, sinus and nasal congestion. Elevation in plasma glucose and fatty acids due to the variation in different hormones increases the glycogen content of the liver (Lane *et al.,* 1998).

It took years for scientists and technologists to understand the practical problems of space foods. Space foods should be nutritious, light weight, compact, easily digestible, palatable, physiologically appropriate, well packed, quick to serve, easy to clean-up and highly acceptable with minimum preparation. Considering these facts, space foods are generally divided into rehydratable foods, intermediate moisture foods, thermostabilised foods, irradiated foods, natural form foods and fresh foods (NASA, 1999).

The main institutions that focus on space food development are Space Food Systems Laboratory and Defence Food Research Laboratory. Indian contribution to space food is the development of ready - to - eat food like coin sized idlis, products of rice, lentils and millets. DFRL have also developed edible cutleries to reduce the trash in space shuttle.

Packaging for space food serves the primary purpose of preserving and containing the food. Rehydratable and bite-sized foods are wrapped with an aluminium foil laminate and vacuum sealed to improve barrier properties thereby increasing shelf life. Commercial pouches like retort pouches are used for thermostabilised and irradiated foods.

Nutrition will be the key factor for the next phases of exploration beyond this planet. Realisation of the full role of nutrition during spaceflight is critical for the success of extended duration missions.

References

Lane, H.W., Gretebeck, R.J. and Smith, S.M., 1998. Nutrition, endocrinology and body composition during space flight. *Nutri. Res.* 18(11) :1923-1934.

NASA (National Aeronautics Space Administration). 1999. *Space Food Nutrition*. National Aeronautics Space Administration, Washington D. C, 62p.

Smith, S.M., Zwart, S. R., Kloeris V. and Heer, M. 2009. *Nutritional Biochemistry of Space Flight (Space Science, Exploration and Policies Series)*. Nova Science Publishers Incorporated, New York, 176p.

Smith, S. M., Rice, B. L., Dlouhy, H. and Zwart, S. R. 2013. Assessment of nutritional intake during space flight and space flight analogs. *Procedia Food Sci*. 2: 27-34.