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Evolution of space food, category, challenges and packaging

Rahul Wadhwani

Abstract
The current level of technology and the problems in developing space food that can be rehydrated in space. The study focuses on innovative drying processes, such as vacuum drying and freeze-drying, that have been utilized to preserve food's nutritional content and texture. The paper also addresses the significance of packaging in safeguarding food from the extreme conditions of space flight, such as radiation and microgravity. One of the most challenging issues in designing space cuisine is ensuring that it can be quickly rehydrated and digested by astronauts, given the lack of availability to water in space. Furthermore, the report emphasizes the necessity for food to be lightweight and compact to reduce the amount of space and resources necessary for storage and transportation. The paper also give information about the freeze drying technology and the packaging which help in preserving food. Overall, the article presents a thorough review of the current state of technology and issues in the subject of rehydratable space food, emphasizing continuous attempts to create new and improved ways for preserving and packing food for space flight.

Keywords: Space food, freeze-drying, rehydratable food, preserving, packing, Types of space food

1. Introduction
Space food is a type of food that astronauts eat when in space due to the weightlessness of the environment. Dietary nutrition is critical to astronaut life security not only because correct nutrition can be maintained through the consumption of suitable nutrients, but also because appropriate food plays a key role in social psychology during long-term space flight. Rehydratable space food is a type of food that is designed for use by astronauts during space missions. It is typically freeze-dried or dehydrated to reduce its weight and volume and can be rehydrated with water on-demand. Future long-term human space missions will go from Earth to the Moon and then on to Mars. While missions to Mars are anticipated to take longer (between 800 and 1100 days), with roughly 500 days to be spent on the Martian surface missions to the Moon are likely to take between 20 and greater than 30 days (P Watkins *et al*. 2022) [30]

One of the key challenges in developing rehydratable space food is ensuring that it is nutritious and safe to eat, while also being able to withstand the extreme conditions of space travel. This includes exposure to high levels of radiation, changes in temperature and pressure, and long periods of storage. There are several different food items that have been prepared and designed specifically for use during space travel. Food should be able to readily and securely be made, stored, and consumed in low gravity locations while also meeting certain standards to assure adequate nutrition for individuals working in harsh circumstances. Despite the broad range of foods and drinks that astronauts consume; it is crucial that they be given a nutritional formula that contains all the vitamins and nutrients required and ensures the crews' working capacity and nervous system and psychological resilience. (Getsov P *et al*. 2020) [14].

The spaceflight environment causes a variety of physiological changes, including bone loss, reduced muscle mass, and impaired immunological function, as well as delayed intestinal transit time and gastrointestinal motility, which may diminish food absorption (Jiahui Jiang *et al*. 2020; Sun *et al*. 2014) [18, 34]. The first-time food was consumed in space was in 1962, when John Glenn, the first American to eat in space. Various tasks were completed to improve the food and beverage innovation methodologies. While today's astronauts enjoy high-quality meals prepared by some of the world's top chefs on Earth, future space travel will necessitate totally new ways for growing enough food in space to supply astronaut crews on multiyear interplanetary journeys with enough calories and nutrients. As a result, space agencies in the United States, Canada, Japan, and other countries are increasingly interested in developing new and creative food system concepts that will give our astronauts a balance and a delicious diet. One of the longest-standing fields of space study has been the use of agriculture for human life support in space, which has offered an intellectual and collegial bridge between the aerospace and agricultural industries (Wheeler 2017) [36]. But until we completely get success on space agriculture development program, the best way to provide good nutrient to our astronauts is by making food from earth itself. The creation of space food should have two goals: one is to fulfil astronauts' physiological demands to sustain life, and the other is to meet astronauts' psychological freshness and enjoyment throughout lengthy and challenging space missions (Jiahui Jiang *et al*. 2020; Katayama *et al*. 2009) [18, 20]. To address these challenges, food scientists and engineers use a variety of techniques, such as vacuum packaging, aluminum foil lamination, and the use of preservatives to extend the shelf life of the food. They also use scientific tests and analysis to ensure the food remains safe to eat and retains its nutritional value over time. Rehydratable food come in many forms, such as powders, chunks, and pastes. They are often high in calories, protein, and carbohydrates to provide astronauts with the energy they need to perform their duties in space. Some of the most common types of rehydratable space food include fruits, vegetables, meats, and grains. In terms of taste, the food usually have mixed reviews, as the astronaut are often looking for similar taste as their normal earth food and many of them have commented that the food can be bland, especially after eating it for extended periods of time. But some efforts have been done to improve the taste, by adding flavors and spices, or developing new food items that mimic the texture and taste of traditional Earth foods. Overall, the development of rehydratable space food is an ongoing process that involves significant research and collaboration between scientists, engineers, and astronauts.

The effects of microgravity on the look and packaging of food are a topic of research for scientists at the Space Food Systems Laboratory. When they build new product packaging, meal options, and in-flight systems, they take these consequences into account. Because the effects of gravity are less in space, people and objects "float" in microgravity. Scientists had to create magnetic utensils that stay connected to food platters as well as straws with clamps to prevent liquids from accidently escaping. The "Vomit Comet," a KC-135 aircraft maintained by NASA in Houston, is used by researchers to test goods and prototypes in a microgravity environment (Nola Taylor Tillman 2017) [25]

2. Space food

Space food is a variety of food products specially formulated and processed for space flight use (Getsov P *et al* 2020) [14]. Due to the weightlessness of the atmosphere, astronauts consume space cuisine. Dietary nutrition is critical to astronauts' life assurance not only because nutritional status may be maintained by ingesting enough nutrients, additionally since good nutrition has an essential function in cognitive science during protracted space travel. Space meals should be small in shape, portable, easy to travel and consume, and resistant to the adverse effects of movement and radioactivity, as well as harsh climatic conditions such as low pressure.

2.1 Evolution of space food

As NASA began to launch humans into space, the quest for sustenance for the astronauts began. So far, the creation of space food has been subjected to several metrics and analyses in order to be classified as safe food. As shown in the table 1 Different missions were conducted in order to innovate space meals and drinks; nevertheless, the space food did not taste well owing to the decreasing environment, since taste buds' ability was weakened. From 1970 to 1980, the space station's gourmet offerings included more than 70 food items. Three varieties of space food were introduced during the Mercury experiment in the early 1960s.Tube foods, such as applesauce, were the first, and they were forced through into mouth like toothpaste (Jiahui Jiang *et al*. 2020) [18] (Lachance, Michel, and Nanz 1967) [21]

Cubed meals, which were compressed foods in 0.5-inch cubes that could be eaten in one bite, were the second version of meal (Jiahui Jiang *et al*.2020) [18] (Heidelbaugh 1966) [15].

The alternative was to ingest lyophilized powder after rehydrating.

The food supply for the Apollo spacecraft (1968-1972) was enhanced throughout the design phase, principally by optimizing food containers and increasing meal diversity. Retort sachets and canisters were added to the menu because they allowed heat-resistant meals to be kept at room temperature for an extended length of time (Jiahui Jiang *et al*. 2020) [18]. (Perchonok and Bourland 2002) [30]. The Apollo voyage was additionally the initial to utilise warm fluid, which made it simpler to reconstitute the dry food (Perchonok and Bourland 2002) [30].

Numerous reasons have led to the growth of the space framework, such as research into corporal functions in weightless environments, the acquisition of machinery, and crew contentment (Perchonok and Bourland 2002) [30]. Throughout the 1960s, studies on astronauts' medical ailments centred on ingesting and digesting in spacecraft, that was ultimately revealed to only be linked to esophagus activation (Paula 2018) [28]. Other astronauts, meanwhile, remarked that their appetite decreased in space, however this was due to the food fragrance being scattered in microgravity, turning the meal bland (Jim 2009) [19]. Once microgravity was proved to cause bone loss in 2000, researchers turned their attention to the impact of sodium on osteoclasts (NASA 2013) [24]. Therefore as result, calx and calciferol-rich meals are then provided at sufficient quantities.

Table 1: Types of space food till now (Jiang, J *et al*. 2020).

Technology	Process	Earliest application	Pros	Cons	Shelf-life	References
Previous advance food technology (AFT)	Freeze-drying	Mercury (1961-1963)	Food's aroma, color, and flavor are often natural and light in bulk.	High price, around four times that of traditional dehydration	1.5-2.5 years	(Perchonok and Bourland 2002) [30]. (Jiang, J *et al.* 2020) [18].
	Thermostabilizing	Apollo (1968-1972)	Easy to consume, tasty, and leaves minimal residue	The package's extra weight is considerable.	2-3 years	(Maya, Grace, and Michele 2015) [23]. (Jiang, J *et al*. 2020) [18].
	Irradiation	Apollo (1968-1972)	Ionizing radiation at a specific dose to render food's microbiological structure unusable	The package's extra weight is considerable.	2-3 years	; (Jiang, J *et al*. 2020) [18].
Emerging joint thermal technology	Pressure assisted thermal sterilization (PATS), Microwave assisted thermal sterilization (MATS)	Still in the development stage	Thiamin, folic acid, and vitamins A and C sustain less harm.	Meat color may be negatively impacted, and certain metabolic processes that indirectly destroy nutrients may be accelerated. electromagnetic field's irregular distribution; potential for edge overheating	5 years is the desired shelf life.	(Jiang, J *et al*. 2020) [18] (Maya, Grace, and Michele 2015; [23].
On-orbit food preparation technology	3D printing	International Space Station (2000-2020)	can be modified to meet the dietary requirements of various people	In-depth development of printable materials is required, as is addressing the issue of creating lightweight, intelligent machines.	The product doesn't need to have an extended shelf life.	Liu, Min, Bhandari, and Yang 2017 [22].
On-orbit food preparation technology	Space agriculture	2020-present	Simple horticulture and food processing necessities; strong stress tolerance and capacity to continue developing normally when in space	On the International Space Station, only green leafy crops like lettuce and mustard are currently produced for nourishment.	21-28 Days at 0 °C	Wheeler, (2006) [42]; Tibbetts, (2019) [41]

2.2 Classification of space food

Despite the fact that many different kinds of meals and drink containers were utilized on NASA spacecrafts, the inventory model has remained mostly consistent. In addition to Skylab, no US spacecraft has carried a refrigerator or freezer especially designed for food preservation. As a result, the meal may be stored at room temperature and is shelf- stable. The food is ground, and the bacteria are inactivated to maintain stability. Although corporate sanitation promotes a healthy food production, it can compromise quality attributes, including nutritive benefits and social acceptance.

Food is delivered in space in a number of methods, including the following:

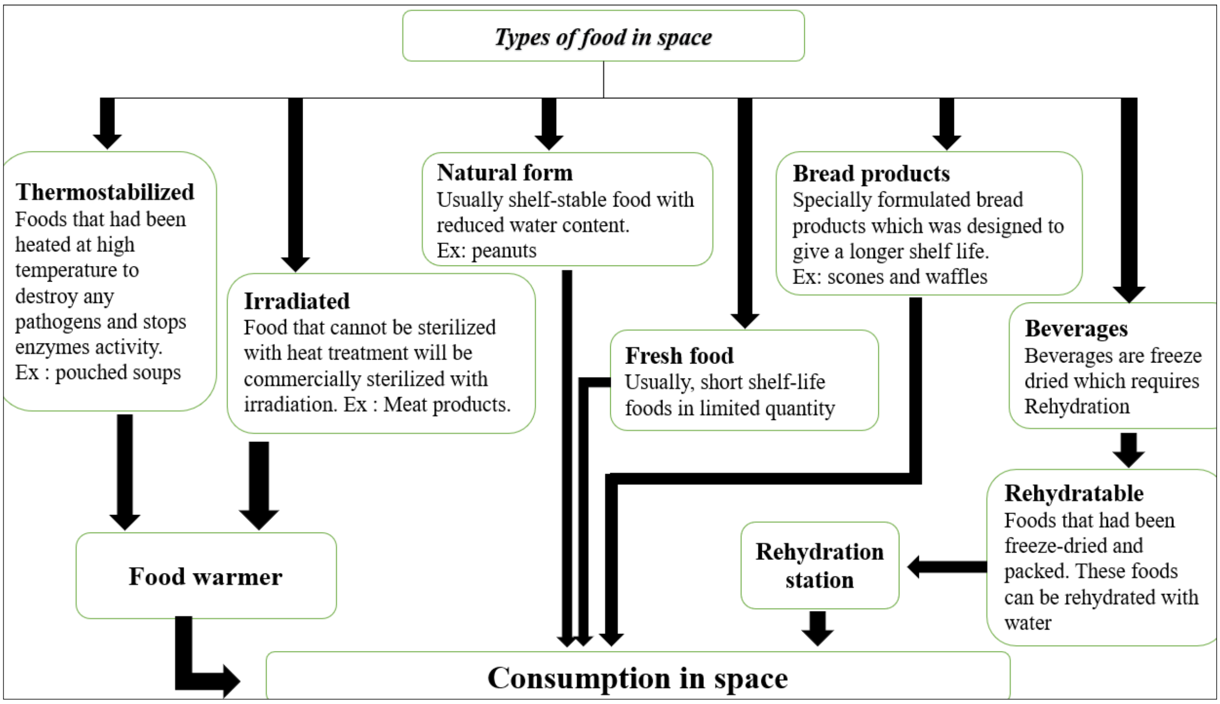

Fig 1: Food varieties in space taken from (Cooper *et al*., 2011)

2.2.1 Rehydratable Food

Due to the usage of both oxygen and hydrogen power generation, which create liquid as a byproduct, about half of the interstellar rations are dried. (1993, Bourland). Rehydrated staple meals and drinks are placed in individual packs including one intake valve sacks for rehydration. Dessert, shrimp cocktail, chicken and vegetables, and butterscotch pudding were available with the introduction of freeze drying.

The benefits of rehydrating freeze-dried foods include fast rehydration, minimal nutritional loss, light weight, and ease of storage. The method of freezedrying is frequently employed in the preparation of fresh vegetables and fruits. It may successfully protect the natural vitamin C while concentrating the scent of fruits and vegetables. In space, astronauts may also enjoy a variety of rehydration liquids. Rehydratable foods are dried to make storage simpler. As shown in fig 2 NASA food rations include both commercial and internally made freeze-dried meals, which are then rehydrated using the trip's drinking water supply. Rehydratable meals are frequently side dishes like hot green beans and cornbread dressing or cereals & beverages like milkshakes & chocolate shakes.

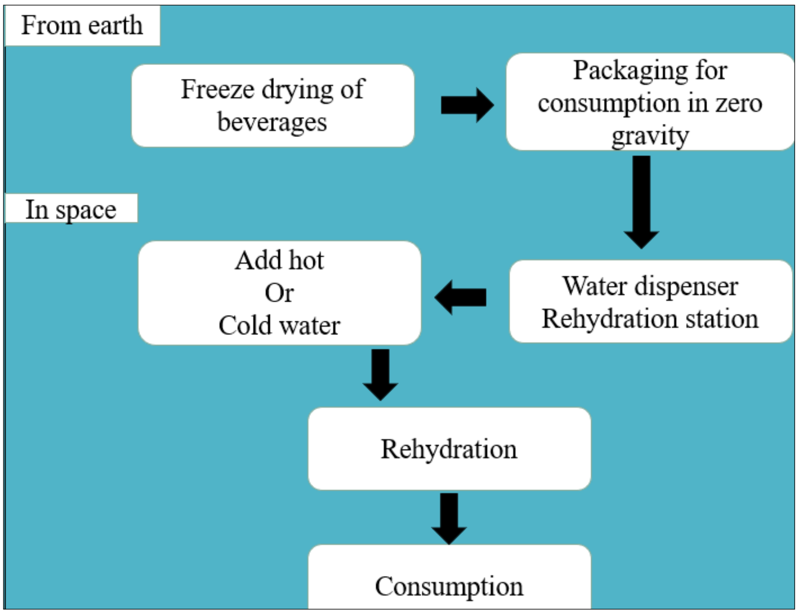

Fig 2: process for rehydration of space food.

2.2.1.1 Astronauts rehydrate their food in space

NASA's beverage packaging is a foil laminated version of a Capri Sun box. The NASA package is longer than the commercially available version. NASA follows the following processes for packaging drinks for spaceflight:

The packet contains dry beverage powder. The package is nitrogen flushed three times. After inserting the septum, the beverage package is sealed.

2.2.1.2 Role of water dispenser

The ISS contains a water dispenser with a needle that pierces the septum of a one-way valve and introduces water. The septum closes again after the needle is withdrawn. The personnel will wait for the food to complete hydrating before opening the container - a drink may take five minutes, while a food item may require fifteen minutes. (NASA, 2012)

2.2.2 Thermostabilized Food

Thermostabilized foods make up a significant section of the space food menu. NASA thermostabilized goods include pouched soups, pasta, sweets, and many entrees (Maya *et al*., 2015) [24]. These are canned items that have been cooked and sterilized and are packaged in elastic or metal packaging (Su, 2012).

This approach, also called as the retort technique, heats food to destroy pathogens, spoilage germs, and enzyme activity. NASA thermostabilized foods include pouched soups, appetizers, sweets, desserts, and meals. Thermostabilized foodstuffs have been heat treated and may be stored at room temperature. In cans, most fruits and fish (particularly tuna fish) are thermostabilized. The cans are opened using simple pull tabs, like fruit cups seen at your local grocery store. Plastic cups are used to package puddings.

2.2.3 Irradiated Food

Irradiated foods are sterilised using ionising radiation-generated highly energetic rays such as X-rays, c-rays, or high-speed electron beams (Zhang *et al*. 2007) [45]. In 1981, the FAO/IAEA/WHO validated food irradiation. Doses of up to 10 KG are conceivable (Khan *et al*. 2016) [17]. Irradiation is not routinely used to disinfect commercial goods. It has a little impact on food quality and can retain the unique taste of meals to the fullest extent feasible. Another advantage of irradiation is that the item may be packed before being irradiated, eliminating the possibility of contamination of a packing material and the packaging process. NASA has been granted special authority by the Food and Drug Administration (FDA) to create nine irradiation beef products for industrial sterility (FDA 2009). At the time, only one food that have been irradiated are steak and smoky turkey. These goods are manufactured and packaged in flexible foil pouches before being sterilized with ionizing radiation and kept at room temperature. Additional radioactive products for the International Space Station are being developed. The Apollo crew was the first to utilize irradiated food in space (Bourland 1999) [46]. From Apollo 12 through 17, all missions brought irradiated good bread, and on Apollo 17, a ham sandwich made of irradiated bread and irradiated sterilized ham debuted in collaboration with the Natick laboratory (Hartung *et al*. 1973) [47]. Irradiation sterilization technology is now widely used in combination with lyophilized technique.

2.2.4 Natural Form Food

Fresh fruits and vegetables, nuts, cookies, granola bars, and other natural foods are examples. Despite their short lifespans, fruits and vegetables give important mental health support to crews (Maya, Grace, and Michele 2015).

Natural form foods are widely available and shelf stability. The moisture content of the items ranges from low (almonds and peanuts) to medium (brownies and dried fruit), but they all have low water activity, which inhibits bacterial development. These items flesh out the menu by giving easily recognized menu items, more diversity, and foods that don't require any preparation time. These meals are ready to eat and come in flexible pouches. Nuts, granola bars, and cookies are some options. A fruit bars, which was designed to be ingested inside of the astronauts' suits without the use of their hands, was used by Apollo. This fruit bar was made of compact fruit leather and was coated in a starch film that was edible (Perchonok and Bourland 2002) [30]. Natural foods provide the energy, vitamins, and moisture that the human body need, as well as keeping the crews' psychological health in check. Natural food mass, on the other hand, might be substantial and cannot be kept for a lengthy period of time.

2.2.5 Frozen Food

To avoid the formation of huge ice crystals, these meals are quickly frozen. This retains the food's original texture and keeps it taste fresh. casseroles, chicken pot pie and Quiches, are a few examples.

2.2.6 Fresh Food

Foods with a short shelf life, such as fresh fruits and vegetables, are offered on a restricted basis, more for psychological support than to satisfy nutritional needs. To assure the safety of the food, they are cleaned with a 200 parts per million (ppm) chlorine rinse. The packs contain vegetables like carrots and celery. These foods haven't been treated or preserved in any way (Getsov, P *et al*. 2020) [14].

2.2.7 Beverages

Nowadays, either lyophilized beverage mixtures (including such tea or coffee) or flavoured liquids are used aboard the International Space Station (ISS) and the Spaceship. After being weighed, the drink combinations are vacuum packed into a beverage pouch. In the case of tea or coffee, add sugar or powder cream to the bag before closing it. Water can also be purchased in empty beverage pouches (Getsov, P *et al*. 2020) [14].

2.3 Technological challenges for space food

The difficulties are substantial, but not impossible, particularly when the key requirements are broken down individually. The following five components address the primary technology and scientific demands for a sustained space food system able to sustain long exploratory missions:

1. Foods that are nutritional, shelf-stable, and have an improved positive appeal.
2. shelf-stable items on the menu with a five-year minimum shelf life; and
3. partial gravity cooking processes that limit microbiological risk.
4. Nutrient distribution over time in shelf-stable foodstuffs.
5. a container that meets the requirements for high barrier, low weight, and processing adaptability.

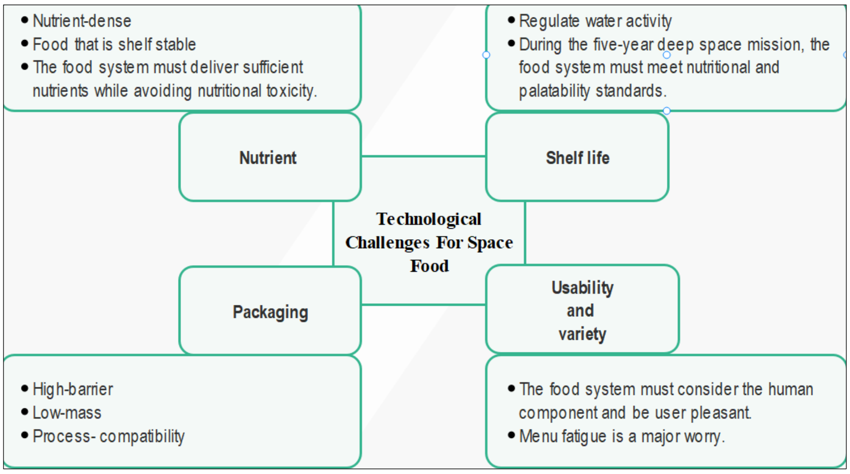

Fig 3: technological challenges for space food.

2.4 Innovations in space food

Innovations in space food are aiming to improve astronauts' health by focusing on their nutritional and health needs. To prevent the devastation of the environment, innovation is using environmentally friendly packaging materials. Due to the lack of a refrigeration system aboard the space station, innovations in storage are crucial since microbial attacks can occur quickly. NASA has accepted the duty of conducting space gardening experiments in the upcoming years because scientists are eager to provide the astronauts with fresh produce (Wheeler and Raymond M 2017) [36]. According to NASA, maintaining the climate in space requires the growth of plants, which will also be helpful for the astronauts' life in the coming years. In order to improve space drinks through the booze industries and produce new products, NASA is also conducting research on the study of crop functioning.

3. Drying

Drying is the oldest method of food preservation. Since history, the sun, wind, and a smoky fire have all been used to remove water from fruits, meats, grains, and plants. Food dehydration is the process of removing water from food by pumping warm air through all of it, hence preventing the creation of enzymes and bacteria. Dried foods are delicious, healthful, lightweight, easy to prepare, store, and use. The amount of energy necessary is less than that required to freeze or can, and the amount of space needed for storage is less than that needed for canning containers and freezing containers. The nutritious composition of food is only little affected by drying. While vitamin A is preserved after drying, it is light sensitive and should be maintained in a dark area. Yellow as well as bright green vegetables, such as capsicum, carrots, winter squash, and root crops, are high in vitamin A. Since heat degrades vitamin C, pre-treating foods with lemon, orange, or pineapple juice improves vitamin C level. Dried fruits and vegetables are healthful foods because they are full of fiber, carbohydrates, & low in fat.

3.1 Types of drying techniques

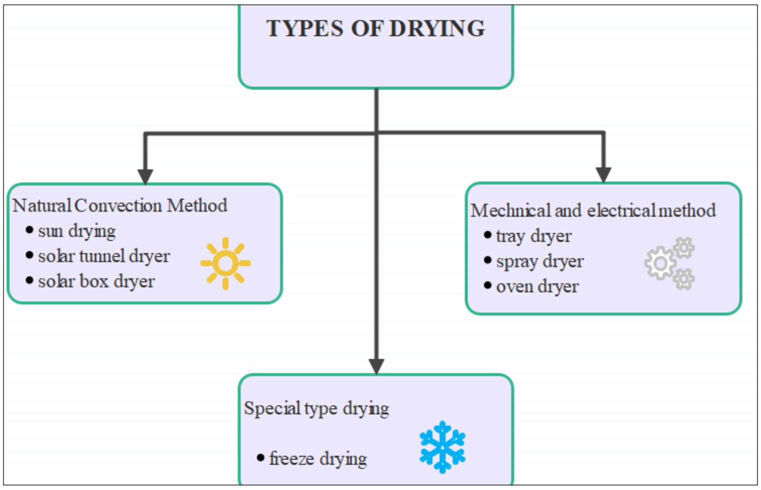

Fig 4: Types of drying techniques

3.2 Freeze drier

During WWII, freeze drying was widely employed to transport blood, serum, and penicillin. With the development of these contemporary freeze-drying techniques, lyophilization technology has improved and is currently used for a broad spectrum of uses in a variety of industries. Laboratory freeze dryers are commonly used in biological and environmental research, as well as the manufacture of many modern medications. In the household, lyophilizes were mostly commonly used to freeze dry products. This form of preservation not only extends the shelf-life of commodities, it has also been shown to lock in necessary nutrients and improve the flavor of foods like fruits, veggies, livestock, or even coffee.

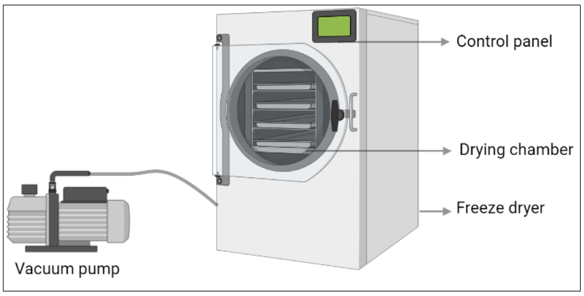

Fig 5: Schematic diagram of the freeze dryer

3.2.1 Freeze drying technology

Cryodesiccation, sometimes referred to as freeze drying and lyophilization. Pre-freezing of capillary permeability, vacuum sublimation of frozen fluids, and ablation of leftover adsorbed water from the polymeric matrix are all steps in this low-temperature drying process. (Zhang *et al*. 2017) [48]. Freeze-drying technology, which was first used in the food business in Western European countries, has now spread to the United States, England, France, and Japan, among many other places. It is among the most important dehydration method used in the food industry, and its rapid development in the twenty-first century has aided in the rapid expansion of the sector. Food has been commonly freeze-dried for use in outdoor activities including exploration, climbing, and the military. This process converts food's water directly from a solid to a gas in a vacuum by first freezing it at low temperatures. Freeze-drying provides many benefits over conventional dehydration techniques in the food business. It is especially ideal for heat-sensitive commodities because it safeguards the composition and prevents nutritional component loss while retaining the natural colour, smell, flavour, colour, and taste of fresh food to the greatest extent feasible (Cheng-Hai *et al*. 2008) [55]. The freeze-dried meal can be reheated and rehydrated in a matter of minutes. Food that has been frozen and dried is perfect for feasts, travel, gatherings, and amusement since it keeps a low moisture level. The freeze-dried meal can be reheated and rehydrated in a matter of minutes (Cheng-Hai *et al*. 2008) [55]. Food that has been frozen and dried is perfect for feasts, travel, gatherings, and amusement since it keeps a low moisture level (Tse-Chao Hua and Zhang 2010) [56]. Prior to sublimation drying, the raw components for processed foods are quickly frozen from unbound water into a solid state. During vacuum drying, it can reduce heat denaturation and prevent foaming (Zhang 2005a) [57]. Food is more naturally preserved and healthier thanks to the freeze-drying technology, which also preserves the food's essential nutrients, texture, flavor, and aroma. Furthermore, the cellular structure of food stays essentially unaltered, therefore Rehydrated food shares a physical structure with defrost frozen meals (NASA 1995). First cassata under a NASA contract, Whirlpool Inc. produced the first that had been freeze-dried for usage in space, but the product quickly fractured, making it difficult to consume.

3.2.2 The principle of freeze-drying technology

The three-state transition of water serves as the foundation for the freeze-drying principle (Han-Shan *et al*. 2008) [58]. The thermodynamic phase equilibrium theory states that the triple point of water is 0.0098 C and 4.579 mmHg of pressure. When the pressure is lower than the triple point, where vapor, liquid, and solid coexist in thermodynamic equilibrium, solid ice can sublimate straight to gaseous water vapor (Guo-Yan *et al*. 2010; Zhang 2005a) [59, 57]. Following desorption drying, the goods should be packed and stored in an inert gas or vacuum to maintain a constant moisture content and prevent oxidation denaturation. Except for a few products that need to be stored between 4 and 20 degrees Celsius, most freeze-dried goods are kept at room temperature (Tse-Chao Hua and Zhang 2010) [60].

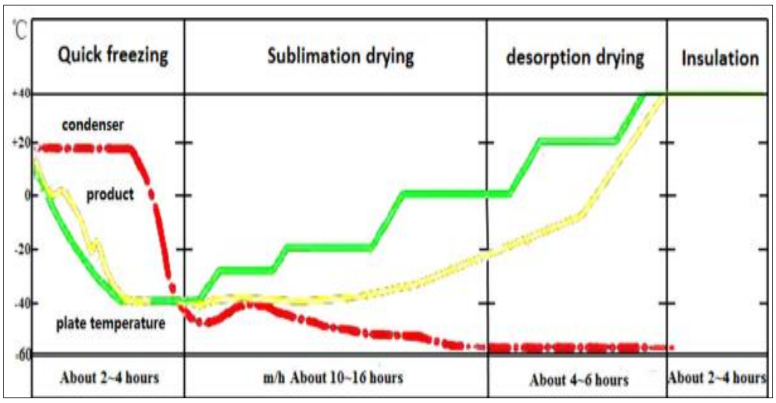

Fig 6: Freeze drying curves (Yang Liu *et al*.)

3.3 Water activity

The ratio of a food's vapour pressure in complete equilibrium with the air medium to the vapour pressure of distilled water in the same circumstances is known as a food's water activity (aw). The vapour pressure is 80% that of pure water at a water activity of 0.80. Water activity rises in response to temperature. Both the equilibria relative humidity (ERH) in percentage and the water activity in decimal form can be used to express a product's moisture status. The majority of foods have a water activity above 0.95, which provides enough moisture for bacteria, yeasts, and mould to grow. It is possible to reduce the moisture that is available to the point where the growth of the organisms is slowed. Water activity (a_w) is vital in the growth of microorganisms that cause food deterioration and loss of functional qualities owing to molecular mobility (Junqueira *et al*. 2017) [49]. From a mechanical and safety standpoint it is also crucial to have a_w value. Water activity in the range of 0.35-0.50 might cause undesirable organoleptic alterations from a mechanical standpoint. Because the quantity of free water accessible for biochemical reactions is limited, values below 0.6 can be regarded microbiologically or chemically stable from a safety standpoint (Dantas *et al*. 2018) [51].

Table 2: Minimum water activity values of spoilage microorganisms (Dilbaghi, Neeraj. (2023) [29].

Microbial group	Minimum aw	Examples
Halophilic bacteria	0.75	Wallemia sebi
Most molds	0.80	Aspergillus flavus
Most bacteria	0.91	Salmonella spp., Clostridium botulinum
Osmophilic yeasts	0.60	Saccharomyces bisporus
Most yeasts	0.88	Torulopsis spp

3.4 Pretreatment

Before freeze drying, several physical and chemical pretreatments, including as categorization, washing, slicing, blanching, and concentration, must be conducted on food items. The processes may differ depending on the type of food. In milkshake, we treat the sample fruit from which the milkshake is made, as well as dry the milk by freezing and sublimation: This freeze-drying process, which appears to have been created in 1945, involves freezing the product and providing heat such that moisture is eliminated by sublimation while maintaining a vacuum in the vaporizing chamber.

4. Packaging

Packaging is a key necessity for all products. Without packaging, the product cannot be preserved or transferred from one location to another. The packaging gives the product personality. As a result, packaging refers to the procedure of giving a product a practical, educational covering that safeguards the item during management, preservation, and transportation while simultaneously giving all parties involved important information about the package's contents. Packaging is necessary to protect a product during management, preservation, and transportation as well as to inform all parties involved of what is within the box. Packaging is the act of providing a protective and informative covering to a product. Modified atmosphere (MAP) and controlled atmosphere packaging (CAP) systems are being used more frequently due to the centralization of the production of retail meat slices and the transportation of goods over ever-greater distances. Due to these characteristics, packaged meat must have a longer shelf life than that afforded by overwrapping and must offer benefits other than those provided by vacuum packaging.

4.1 Types of packaging based on atmosphere

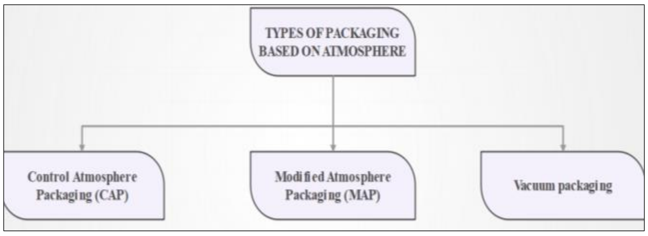

Fig 7: classification of packaging based on atmosphere.

4.1.1 Map
Modified Atmosphere Packaging, sometimes known as MAP, is a technique for altering the climate within containers containing perishable items (for example, beef, pork, chicken, and fish). The process's goal is to increase the product's stored product's shelf life. MAP extends the freshness and shelf life of numerous foods. Examples of perishable goods include cheese, meats, shellfish, and others. These meals usually contain a lot of oxygen, which MAP removes. Modified atmosphere packaging (MAP) is a sort of packaging in which the gaseous atmosphere encompassing a food product inside a pack is altered, and storage containers and layouts with an adequate point of gas barrier are used to maintain the altered atmosphere at a level suitable for food preservation. (A. Embleni 2013) [10].

MAP is a dynamically active or passive method that modifies a package's gaseous composition. With no further control over the initial gas composition, it is reliant on the interaction in between produce's oxygen consumption and the transfer of gases through the packing medium (Caleb *et al*. 2013) [4]. To quickly replenish or displace a gas, or to utilise gas scavengers or absorbers to generate an intended gas mixture inside a packaging, use the MAP technique (Caleb *et al*. 2012) [52]. By reducing the rate of respiration and delaying the enzymatic breakdown of complex substrates, modified atmospheric packaging (MAP) is poised to lengthen the shelf life of fresh goods (Kader 1986) [54]. Cost-effective The design of MAP is influenced by a wide range of additional factors, such as product weight, temperature, and the characteristics of the packaging material (such as film thickness, permeability, perforation density, and surface area) (Charles *et al*. 2003; Sandhya 2010; Caleb *et al*. 2012) [53] [52]. In the literature, the application of MAP in fresh and freshly cut produce has been extensively discussed (Farber *et al*. 2003; Sandhya 2010) [11, 32].

4.1.2 Cap
Controlled atmosphere packaging, abbreviated "CAP," refers to an active packaging system that continually maintains the proper environment within the package during the product's shelf life. A CAP agent binds or "scavenges" oxygen penetrating the package, or a sachet emits a gas. After air evacuation, the package's environment is implied by CAP. is purposefully maintained at roughly the same level. same over the course of the package. Another phrase that is occasionally used is packaging that is "intelligent," which might entail keeping an eye on depending on this information, maybe modifying the package. These package modifications may address ethylene, moisture and gas permeability, oxygen scavenging or control, and temperature regulation, odour elimination, and scent emission microbiological growth, product freshness or deterioration, plastics, as well as packaging integrity (Kropf *et al*. 2014) [8]. A layer that is totally impermeable to gases is necessary to fulfill these extremely strict criteria. be used. CAP supporters urge the usage of

- A film that has a layer of non-plastic substance, like metal;
- the package edges are heat sealed; and
- Complete air evacuation because even trace amounts of oxygen in the packaging have a negative impact on product colour. To extend shelf life, antioxidants and antimicrobials can also be added to films.

4.1.3 Vacuum packaging
As a technique for food preservation, suction wrapping precedes the use of gases by removing air from a pack before sealing. Its main purpose is to bring the containers into close proximity to the goods in order to remove oxygen from it. Vacuum packing involves sucking the air out of the product bag and hermetically sealing it. This extends storage or shelf life by preventing microbial growth and enhances hygiene by minimizing the risk of cross contamination. In addition to preventing taste loss and weight loss, vacuum packaging also prevents dehydration. products that can breathe in their packaging, like sliced veggies and fruits. The product is enclosed by regular air at a reduced pressure and is stored in an airtight rigid container or pouch (around one- third of normal atmospheric pressure). This prevents the product's metabolism as well as the development of bacteria that cause spoilage (A. Embleni 2013) [10].

Advantages

1. Retention of natural taste: Food's original nutritional content is preserved for a long period in vacuum cartons. It preserves the natural flavor, texture, and taste of food. Additionally, it prevents food from drying out while preserving its natural odour.

2. Saves wealth: What could be better than buying inexpensive bulk foods all at once and storing them for use in the future? Well, utilizing vacuum bags, it is essentially achievable. As there is no spoilage or damage, purchasing food results in significant financial savings.

3. Better product presentation: Using it and other sealers, the food seems clean and fresh. Additionally, it follows HACCP guidelines. Customers that use transparent vacuum sealers may inspect the food's conditions and hygiene before making a purchase.

4. Extended shelf life: Compared to plastic packets, vacuum sealing extend the food's overall shelf life by three to five times. Depending on the pantry, freezer, and refrigerator, you should store your product beneath the vacuum sealer for different lengths of time.

5. Neither any chemical preservatives needed: Other food storage methods rely on preservatives to keep food intact, safe, and fresh. Vacuum package sealers enable you to do away with the requirement for chemical preservatives.

6. Simple and Better packaging: Because containers take up so much room, it can be difficult to keep other food. Packaging food in vacuum bags is easy and efficient because it takes up the least amount of room and allows for easy stacking of full meals.

7. Flavorful meat: Vacuum bags assist marinate the meat while enhancing the flavor of your food with various spices. The seal contains all the delectable flavors, making it safe to eat for weeks.

8. Airtight barrier from external Components: Improper or insufficient sealing causes dust particles to penetrate your food. However, the product is protected from dangerous exterior elements like insects, moisture, dust, etc. when it is closed using vacuum bags. You avoid getting food poisoning, stomachaches, and acne-related issues.

5. Future aspects of space food technology

5.1 Nanotechnology

Because of their capacity to make food packaging with features like as high strength, strong barrier, light weight, and multi-function, nanomaterials offer a wide range of potential uses in the aerospace sector. Nanotechnology offers potential solutions to many problems using emerging nano techniques. Depending on the strong inter disciplinary character of nanotechnology there are many research fields and several potential applications that involves nanotechnology (Debnath Bhattacharyya *et al*. 2009) [50]. The nanoparticles in composite packaging can fulfil the requirements of space food packaging materials. Nanomaterials can increase the shelf life of food by up to 3-5 years due to their strong barrier, high flame retardant, and high thermal stability. The key study subjects for polymer nanocomposites were polyethylene, polystyrene, polystyrene, poly (Caprolactone), poly (ethylene terephthalate) (PET), polycarbonate, PAS, vinyl alcohol (EVOH), and polypropylene (PP). Polymer nanocomposites offer good physical qualities in addition to better gas resistance, the ability to minimize oxygen, water vapor dispersion, and volatile food fragrance (Jiang, J *et al*. 2020) [18].

5.2 Hurdle technology

Food packaging may benefit from hurdle technology as well. Many food preservation techniques, such as freezing, chilling, nutrient restriction, water activity reduction, acidification, pasteurization, fermentation and chemical/biological antimicrobials have been used to control microbial growth in foods (Imran Khan *et al* 2016) [17]. It will be easier to regulate food quality and nutrition when diverse storage processing, composition, ingredient source, temperature, packing, and configuration parameters are integrated with the hurdle method. NASA evaluated 16 average meals from the ISS every one, three, and five years for a period of 7 years, if necessary. Color change, texture, nutrition, sensory quality, and water replenishment rate were among the analysed factors. The mechanical integrity and barrier performance of the packaging film will be assessed both before and after processing and storage. Formulation, processing, and storage are all possible if verified barriers are sufficient. Combinations for processed food matrices will be identified individually to reach a five-year shelf life (Jiang, J *et al*. 2020) [18].

5.3 Inert gas flushed packaging

As addition to using packing materials, food can have its shelf life prolonged by using packaging that has been flushed with inert gas. NASA developed a technique that entailed washing the box with 70 percent ethyl alcohol, rinsing the bread and container with nitrogen three times, and then meticulously packaging each piece of bread in a sterile atmosphere. Bread samples can be kept mold-free for up to fourteen weeks (Jiang, J *et al*. 2020) [18].

5.4 On-orbit food preparation system

Because of the industry's rapid growth, aircraft food is progressively moving into increased production volume and variety diversity. The packaged and processed food system currently dominates the food supply technique. This model is restricted not just by the spacecraft's uplink load capability, but also by the crew's taste and diversity of possibilities. It is impossible to have a satisfying eating experience comparable to what one enjoys on a regular basis. The quality and nutrition of space food would decline to unacceptable levels in two to three years if present food stabilization practices are followed. Future exploration expeditions will necessitate a food supply chain that can be kept secure, attractive, and healthy for five years. In terms of Mars exploration, the Russia and United States are world leaders (Jiang, J *et al*. 2020) [18]. The US Mars exploration spacecraft landed successfully on Mars, while Russia just completed the MARS five hundred human Mars simulation project. The Mars age of space exploration has begun gradually. Long-duration manned spaceflight missions, which may involve stays on the natural satellite (moon) or other planetary land, can last up to two and a half years. Food may be transported to Mars before the team of scientist arrives, therefore the mission's food will have a five-year shelf life. According to NASA, just 7 of the 65 thermostabilized meals already offered on menus are expected to be tasty after 5 years (Jiang, J *et al*. 2020) [18].

With the advent of 3D printing, a new way of food preparation for on-orbit space missions is now conceivable. The basic purpose of 3D printing food is to preserve it for long periods of time by using edible raw materials when humans dwell in space, rather than just to make it palatable. The use of 3D printing in space may lessen the demand for a variety of materials. A 3D printer might improve the shape, texture, and flavour. NASA is now undertaking early research on the technology for digesting food while in orbit and has developed a prototype based on the concept (Jiang, J *et al*. 2020).

5.5 Life support system

Life support systems will be an important area of research for aerospace companies in prospective projects. NASA developed the ECLSS, which stands for life support system and environmental control. The use of edible vegetables for salad preparation on spacecraft has been proposed as the initial stage in regulating an ecological life support system in a confined space. Various countries have released plans of crewed deep-space exploration such as lunar research stations and landing on Mars. To travel out of the Earth, go into deep space and achieve long-term survival, a Bioregenerative Life Support System (BLSS) must be built to minimize the need of supplies from the Earth by *in situ* circulating oxygen, water and food for astronauts, and to prevent pollutions to extraterrestrial bodies by recycling waste. BLSS is an artificial closed ecosystem composed of humans, plants, animals and microorganisms based on ecological principles, and also a combination of technologies including biotechnology and engineering control technology. BLSS has the same structure of producer (plants), consumer (humans/animals) and decomposer (microorganisms) as the ecosystem on the Earth's surface, which is able to recycle and regenerate oxygen, water, food and other essential substances needed by human survival, and provide humans with comfortable environments similar to that of the Earth's ecosystem (Hong Liu *et al*. 2021) [16]. Space agencies are now investigating the feasibility of growing vegetables onboard the International Space Station. NASA first investigated red rose lettuce, zinnia, tomatoes, and cabbage. Green vegetation is essential for life's survival. Green plants can help crew members meet their vitamin and fiber demands by increasing their nutritional variety. On the one hand, photosynthesis in green plants may absorb carbon dioxide and create oxygen, so supporting the air circulation system. Eating antioxidant-rich veggies also reduces the crew's exposure to space radiation. In addition to their nutritional value, vegetables are seen as a desirable option for enhancing living standards on ship and offering psychological advantages to the crew. LADA, a tiny salad maker deployed on the International Space Station, will provide a temporary supply of vegetable food as well as entertainment. Numerous scholars are working to improve onboard salad-making capacities (Jiang, J *et al*. 2020) [18].

5.6 Animal breeding in space

The authors propose that the astronauts ingest enough animal proteins to guarantee their health, and that the metabolism involved in gaining animal proteins can be integrated with material circulation in the closed system. As a result, several countries have done extensive experiments on animal reproduction in space. Because of their short life cycles, fish and amphibians make great space food. Carp, rainbow trout, tilapia, swordtail fish, and more species are now being studied (CNR 2018). In Europe and Japan, sea urchins, snails, and salamanders have all been studied. However, space feeding or eating in space is still in the experimental stage since these species are sensitive to their feeding circumstances, notably the presence of live water (Jiang, J *et al*. 2020) [18].

Chinese researchers are employing a different strategy, proposing insects as possible candidates for life support systems. Past study has shown that large animals such as cows and sheep are not ideal. When lonely experimenters build feelings in the animals they feed every day in the small and tiny location, and if they end up consuming their companion animals who follow and feed every other day after day for living, extreme psychological changes will occur (CNR 2018).

6. Conclusion

It only makes sense to collaborate in space; after all, all space people, technology, gear, and spacecraft end up in - or are aiming for - the same destination. Many of our basic demands are the same, such as providing crew with access to fresh, safe, and nutritional meals during long-duration operations. the need of discovering and enhancing technologies for drying and packing space food to keep its nutritional content and palatability. The study discusses different procedures, like as freeze-drying and vacuum packing, that have been proved to efficiently preserve the quality of space food. Furthermore, rehydration procedures such as adding water or other liquids might enhance the texture and flavour of the dish. More study is needed, however, to optimize existing approaches and discover new ways to increase the shelf life and quality of space food. Overall, the creation of dependable and healthy space food is critical for long-term space mission success.

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