

PRESERVING THE PAST, EMBRACING THE FUTURE: EXPLORING TRADITIONAL AND MODERN METHODS OF FOOD PRESERVATION

Abstract

Living organisms rely on food for their survival. Foods contain essential nutrients like carbohydrates, fats, proteins, vitamins, and minerals, which are ingested and digested to produce the energy necessary for growth and maintaining life processes. However, food is susceptible to spoilage due to chemical, enzymatic, or microbial activities from the surrounding environment and the food itself. The issue of food wastage is a pressing concern, affecting public health, the environment, and the economy, especially with the increasing global population and diminishing natural resources. To address this challenge, food preservation methods are essential to maintain the desired quality of food products. These preservation techniques aim to be both economically viable and meet consumer preferences in terms of well-being, nutrition, and sensory experience. Proper preservation is critical to prevent food spoilage over extended periods. It is crucial to use non-toxic preservatives that are safe for human consumption. Furthermore, preservation methods should retain the nutritional content, texture, and flavor of the food. This chapter provides an overview of traditional preservation techniques such as curing, freezing, canning, boiling, and pickling, as well as modern practices like pasteurization, freezing, drying, vacuum packing, radiation, bio-preservation, hurdle technology, and modified atmosphere techniques. The success of modern food preservation owes much to advancements in packing materials. These innovations play a pivotal role in ensuring the long-term preservation and quality of food products. By employing

Authors

Chandra Surya Rao M

School of Agriculture and Food Technology
Vignan's Foundation for Science,
Technology and Research
Vadlamudi, Guntur, Andhra Pradesh, India.
suryahorti97@gmail.com

M. Lakshmi Madhuri

N.S. College of Horticultural Sciences
Dr. Y.S.R. Horticultural University
Venkataramannagudem
West Godavari, Andhra Pradesh, India

Swami D V

Post harvest Technology Research Station
Dr. Y.S.R. Horticultural University
Venkataramannagudem
West Godavari, Andhra Pradesh, India

Ashok P

Horticulture Research Station
Dr. Y.S.R. Horticultural University
Venkataramannagudem
West Godavari, Andhra Pradesh, India

B. Babu Rao

Post harvest Technology Research Station
Dr. Y.S.R. Horticultural University
Venkataramannagudem
West Godavari, Andhra Pradesh, India

Salomi Suneetha D R

College of Horticulture
Dr. Y.S.R. Horticultural University
Venkataramannagudem
West Godavari, Andhra Pradesh, India

these effective preservation methods, we can significantly reduce food wastage and contribute to a more sustainable future for both humanity and the environment.

Keywords: Food, preservation, pasteurization, vacuum packing, canning, biopreservation

I. INTRODUCTION

Food is an indispensable cornerstone of human sustenance and progress. It can be consumed in its raw state or undergo various processing methods to unlock its energy potential and fuel growth. Nevertheless, the issue of food wastage has risen to alarming levels across the globe. At every stage of the intricate food production and consumption chain, a significant amount of food goes to waste, exacerbating the challenges posed by inefficient supply chains, a burgeoning global population, and the ramifications of climate change [1].

Notably, [2] conducted an insightful study that delved into the waste generation patterns of diverse food communities. Their comprehensive findings revealed that 20% of food waste stemmed from production processes, a mere 1% from processing activities, 19% from distribution, and a staggering 60% from consumer-generated waste. The underlying reasons behind such wastefulness were multifaceted, encompassing factors like food shrinkage during cooking, production-related complications, barriers in the supply chain, exacting consumer standards, the unpredictability of changing climatic conditions, and the deleterious effects of soil runoffs.

In the modern era, food preservation has evolved into an indispensable aspect of everyday life. Various factors necessitate food preservation, ranging from seasonal availability of certain items, such as fruits and root vegetables, to regional disparities in food production and distribution. This practice allows for the consistent availability of food throughout the year, bridging gaps between surplus and scarcity. In countries like India, food preservation holds particular significance in meeting the demands of a growing population and ensuring a stable food supply. By preserving food, the nation can safeguard against food shortages, famines, and food-related crises [3].

Food preservation involves a range of techniques aimed at thwarting deterioration caused by foodborne microbes, preventing lipid oxidation (rancidity), and maintaining the nutritional content, texture, and flavor of the food. This is especially crucial for perishable and semi-perishable foods, including juicy fruits, vegetables, mangoes, tomatoes, and papayas. As a result of these challenges, human societies have devised ingenious methods to preserve these seasonal delicacies for consumption at later times. Embracing food preservation practices not only enhances food security but also contributes to minimizing waste and promoting sustainable consumption patterns. By preserving and cherishing the bounty of nature, we can ensure a continuous and diverse supply of nourishment, benefiting both individuals and societies as a whole.

Foods, by their very nature, are prone to perishability and deterioration. To combat this, major food preservation techniques can be classified into three categories based on their mechanisms of action: firstly, methods that slow or suppress chemical deterioration and bacterial growth; secondly, techniques that directly deactivate microorganisms, yeast, molds, and enzymes; and thirdly, approaches that prevent recontamination both before and after processing. Food deterioration can be induced by various factors, including chemicals, environmental bacteria, and enzymes inherent in the food itself. Additionally, the transportation of food from one location to another poses risks of spoilage, loss of physical appeal, and diminished nutritional content. To ensure longer shelf life, consistent quality,

appealing appearance, and unaltered taste, diligent efforts must be made for food preservation.

Preserving food involves measures to inhibit the growth of bacteria, fungi and other microbes, as well as reducing the oxidation of fats that leads to rancidity. It also includes processes to prevent visual deterioration, such as enzymatic browning in cut apples during meal preparation. Ultimately, food preservation is about safeguarding and enhancing nutritional value, texture, and flavor to retain the intrinsic qualities of the food products. By employing effective food preservation techniques, we can prolong the availability of food, minimize waste, and maintain the integrity of food products, ensuring that they continue to nourish and delight consumers. This vital aspect of food management contributes not only to consumer satisfaction but also to food security and sustainable consumption practices.

Food preservation encompasses various techniques aimed at preventing the growth of bacteria, fungi and other microbes, as well as mitigating the oxidation of fats that leads to rancidity. It also includes methods to counter visual deterioration, such as enzymatic browning reactions in apples after being cut during meal preparation. Ultimately, the goal of food preservation is to preserve or enhance the nutritional value, texture, and flavor of the food. The practice of food preservation dates back to ancient times and has been an integral part of every civilization throughout history. Humans, being closely connected to nature, had to adapt to the conditions available in their immediate surroundings for survival. As food naturally begins to spoil soon after being harvested, people had to find ways to store and preserve it for later consumption.

Over time, a wide range of food preservation methods has been developed to prevent food from rotting after harvesting or slaughtering. These preservation customs can be traced back to primordial times. Among the oldest methods are drying, chilling, and fermentation. With advancements in technology, modern preservation techniques like canning, pasteurization, freezing, irradiation, and the use of chemical additives have emerged [4]. By employing these preservation practices, humanity has been able to extend the shelf life of food, ensuring its availability beyond immediate consumption and helping to address food scarcity. The continuous development of food preservation methods remains crucial in ensuring food security, reducing food waste, and supporting sustainable food systems.

In ancient times, ingenious methods were employed to naturally preserve food using the sun and wind for drying. Fruits and vegetables have been dried since the earliest days of human civilization, harnessing the power of nature to remove moisture and extend the shelf life of these perishable items. Similarly, freezing was recognized as a viable preservation option in regions with cold temperatures during certain parts of the year, allowing people to store and preserve food in icy conditions. Another significant preservation technique utilized by various cultures was fermentation. Rather than being invented, fermentation was discovered through observation and chance occurrences. For example, the accidental exposure of a few grains of barley to rain led to the discovery of the first beer, as microorganisms fermented the starch-derived sugars into alcohol. The ability of early societies to recognize, harness, and encourage these fermentation processes is remarkable.

Fermentation not only enabled the preservation of food but also enriched the culinary landscape by producing more nutritious and appealing dishes from less desirable ingredients.

The discovery of beer, for instance, served as both nourishment and an intoxicating beverage. This process was considered a divine gift, given its profound impact on food preservation and culinary innovation.

The ancient techniques of sun-drying, freezing, and fermentation laid the foundation for modern food preservation methods. Today, with the integration of technology and science, we have a wide array of preservation techniques that continue to play a vital role in ensuring food availability, reducing waste, and maintaining cultural culinary traditions.

The importance of food preservation in mitigating the risk of food poisoning and other diseases cannot be overstated. Throughout history, both ancient and modern methods have been employed to preserve food, ensuring its availability and preventing potential famines and food shortages. Traditional food preservation techniques such as drying, pickling, smoking, cellar storage, and wine staining have been practiced for generations to prolong the shelf life of various food items. These methods have proven effective in preserving food and sustaining communities during times of scarcity.

In recent times, with advancements in science and technology, chemically produced preservatives have become indispensable additives in the food industry. They play a critical role in extending the shelf life of food products and maintaining their quality during transportation and storage. However, there are growing concerns about the impact of chemical synthetic preservatives on food flavor and human health. Studies have revealed that these artificial additives may be associated with human-induced cancer, teratogenicity, food poisoning, and other safety risks. Consequently, there is an increasing focus on food safety, and people are seeking high-performance plant-based preservatives as a safer and more sustainable alternative to synthetic additives. The quest for natural plant preservatives aims to strike a balance between preserving food effectively and maintaining its original flavor and nutritional value. By exploring these natural alternatives, the food industry aims to enhance food safety, consumer confidence, and the overall sustainability of our food supply chain. As the importance of food safety gains prominence, ongoing research and innovation in food preservation techniques will be crucial to ensure a secure and healthy food system for the well-being of both individuals and society at large.

II. CLASSIFICATION OF FOODS

1. Categorizing Foods Based on Shelf Life: Food spoilage is a natural process where food gradually loses its color, texture, flavor, nutritional qualities, and edibility. Consumption of spoiled food can lead to illness and, in extreme situations, even death [5].

Based on their Shelf Life, Food Items can be classified into Three Categories:

- **Perishable:** Foods with a relatively short shelf life, ranging from several days to about three weeks, fall under the category of perishable. Examples of perishable food items include milk and dairy products, meats, poultry, eggs, and seafood. Without proper preservation techniques, these items can quickly spoil [6].

- **Semi-perishable:** Certain food items can be preserved for a longer duration of about six months under proper storage conditions, and these are referred to as semi-perishable. Vegetables, fruits, cheeses, and potatoes are some examples of semi-perishable foods.
- **Non-perishable:** Natural and processed foods that have an indefinite shelf life are known as non-perishable food items. These foods can be stored for several years or even longer without significant deterioration. Examples of non-perishable foods include dry beans, nuts, flour, sugar, canned fruits, mayonnaise, and peanut butter.

By understanding the categorization of foods based on their shelf life, we can adopt appropriate preservation techniques to ensure food safety, minimize waste, and maintain the quality of our food supply.

2. Categorizing Foods Based on Functions: Food items can be classified based on their functions in the human body into the following categories:

- **Body Building and Repairing Foods:** These foods are rich in proteins and essential amino acids, supporting the growth, maintenance, and repair of body tissues. Examples include lean meats, fish, poultry, dairy products, legumes, and nuts.
- **Energy-Giving Foods:** Foods in this category are high in carbohydrates, providing the body with the necessary energy for daily activities and bodily functions. Sources include grains, cereals, fruits, and starchy vegetables.
- **Regulatory Foods:** This group comprises foods that aid in regulating various bodily processes, such as metabolism and digestion. It includes fiber-rich foods like whole grains, fruits, and vegetables, as well as probiotic-rich foods like yogurt.
- **Protective Foods:** These foods contain essential vitamins, minerals, and antioxidants that help protect the body from various diseases and support overall health. Examples include fruits, vegetables, nuts, seeds, and certain herbs and spices.

3. Categorizing Foods Based on Nutrients: Food items can also be categorized based on their nutrient content into the following groups:

- **Carbohydrate-Rich Foods:** These foods are abundant in carbohydrates, providing a quick source of energy. Examples include grains, bread, pasta, rice, fruits, and starchy vegetables.
- **Protein-Rich Foods:** Foods in this category are high in proteins, essential for building and repairing tissues, as well as supporting various physiological functions. Sources include meat, poultry, fish, dairy products, legumes, tofu, and nuts.
- **Fat-Rich Foods:** This group consists of foods that are high in fats, which serve as a concentrated source of energy and support vital bodily functions. Examples include oils, butter, nuts, avocados, and fatty fish.

- **Vitamin- and Mineral-Rich Foods:** These foods are packed with essential vitamins and minerals necessary for proper bodily functions, growth, and overall well-being. Sources include fruits, vegetables, nuts, seeds, dairy products, and lean meats.

By understanding the functions and nutrient content of different foods, individuals can make informed dietary choices to maintain a balanced and healthy diet, promoting overall wellness and vitality.

III. PRINCIPLES OF FOOD PRESERVATION

In the preservation of foods by various methods, the following principles are involved:

1. Prevention or Delay of Microbial Decomposition

- By keeping out microorganisms' (asepsis)
- By removal of microorganisms, e.g., by filtration
- By hindering the growth and activity of microorganisms, e.g., by l temperature, drying, anaerobic conditions, chemicals or antibiotics.
- By killing the microorganisms, e.g., by heat or radiation.

2. Prevention or Delay of Self-Decomposition of the Food

- By destruction or inactivation of enzymes, e.g., by blanching;
- By prevention or delay of chemical reactions, e.g., prévention of oxidation by means of an antioxidant.

3. **Prevention of Damage by Insects, Animals, Mechanical causes etc.:** To retain the natural taste and aroma of a product, it is necessary to preserve it soon after preparation, without allowing it to stand for any length of time various methods of preservation are employed and each has its own merits.

IV. FOOD SPOILAGE

Food spoilage is a natural process that leads to a decrease in the edibility of food items. It is closely linked to food safety concerns. The initial signs of food spoilage can be identified through changes in color, smell, taste, texture, or overall appearance. Various physical, microbial, and chemical actions can contribute to food spoilage, and these mechanisms can interact and exacerbate each other. Physical factors such as mechanical damage, temperature fluctuations, exposure to air, and light can impact the quality of food and initiate spoilage. Microorganisms, including bacteria, yeasts, and molds, play a significant role in food spoilage through their metabolic activities and the production of enzymes that break down food components. Additionally, chemical reactions within the food can cause degradation, such as the oxidation of fats leading to rancidity or enzymatic breakdown of proteins and carbohydrates.

The factors influencing food spoilage encompass temperature, pH levels, the presence of air, available nutrients, and the presence of different chemicals. Proper understanding and

management of these factors are essential to slow down the spoilage process, ensuring food safety, and preserving the quality of food products [7]. Recognizing the mechanisms and factors that contribute to food spoilage enables us to implement effective preservation methods, minimize food waste, and uphold the safety and integrity of the food supply chain. By doing so, we can ensure that consumers have access to safe, fresh, and high-quality food.

- 1. Physical Spoilage:** Physical spoilage refers to the deterioration of food caused by changes or instabilities in its physical characteristics. This type of spoilage is characterized by various physical changes that can negatively impact the quality and edibility of the food. Examples of physical spoilage include moisture loss or gain, moisture migration between different components, and the physical separation of components or ingredients within the food product [8].
- 2. Moisture Content:** One of the common factors leading to the degradation of food products is changes in their water content. These changes can manifest in the form of water loss, water gain, or the migration of water within the food [9]. The transfer of moisture in food is directly related to a property known as water activity (aw) [10].

Water activity (aw) is a thermodynamic property that represents the ratio of the vapor pressure of water in a given system to the vapor pressure of pure water at the same temperature. In simpler terms, it measures the availability of water molecules in a food item. The water activity level is a crucial parameter in determining the stability and shelf life of food products. High water activity in food provides an environment conducive to the growth of microorganisms, leading to spoilage and potential foodborne illnesses. Conversely, low water activity can result in food becoming dry and unpalatable. Managing moisture content and water activity is vital in food preservation. By controlling moisture levels through proper storage and packaging techniques, food producers can prolong the shelf life of their products and maintain their quality. Understanding the relationship between water activity and food stability helps ensure that food products remain safe and desirable for consumption.

- 3. Temperature:** Temperature plays a crucial role in the spoilage of fruits and vegetables, making it the most significant factor in their post-harvest life. There exists an optimal temperature range that ensures slow ripening and maximizes the shelf life of these perishable items. Achieving slow ripening also requires maintaining an optimum relative humidity and proper air movement around the fruits and vegetables, creating conditions known as modified atmospheres (MA). Temperature directly influences the metabolism of fruits and vegetables, affecting the rate at which they attain the desired modified atmospheres. Lower temperatures can be detrimental to certain food items that are susceptible to freeze damage. When food products become partially frozen at lower temperatures, cell breakage occurs, leading to damage.

Tropical fruits and vegetables, in particular, are sensitive to chilling injury, which occurs before the product starts to freeze, typically between temperatures of 5°C and 15°C [7]. Managing temperature conditions is vital in preserving the quality and freshness of fruits and vegetables during storage and transportation. To minimize spoilage and extend the post-harvest life of fruits and vegetables, it is essential to store them at

appropriate temperatures, avoiding both extreme cold and excessive warmth. By carefully managing temperature conditions, producers and distributors can ensure that these perishable commodities reach consumers in optimal condition, minimizing waste and maximizing their market value.

- 4. Glass Transition Temperature:** The glass transition temperature (T_g) is a critical factor that influences the shelf life and stability of food products. In food items, the solids can exist in two states: a crystalline state and an amorphous metastable state. The presence of the amorphous matrix depends on the composition of the solids, temperature, and relative humidity [11].

The amorphous matrix can exist in two forms: a very viscous glass or a more liquid-like rubber [12]. The transition between these two states, known as the glass transition, occurs when the amorphous matrix changes from a rigid, glassy state to a more flexible and rubbery state. The glass transition temperature is crucial in determining the stability and texture of food products. When the temperature approaches the T_g , the amorphous matrix becomes less rigid, leading to changes in the product's physical properties, such as softening, tackiness, or loss of texture. This can affect the overall quality and shelf life of the food. Controlling the glass transition temperature is essential in food processing and storage. By understanding the T_g and its impact on the amorphous matrix, food manufacturers can design products with desired characteristics and extend their shelf life. Proper temperature control during production and storage helps maintain the desired texture and quality of the food, ensuring consumer satisfaction and reducing food waste.

- 5. Crystal Growth and Crystallization:** Freezing can significantly impact the degradation of food products. Foods that undergo slow freezing or multiple freeze-thaw cycles are particularly susceptible to crystal growth, leading to deterioration in quality. During slow freezing or repeated freezing, large extracellular ice crystals form within the food, causing damage to the cellular structure.

In contrast, rapid freezing forms ice within the food cells, resulting in a more stable structure compared to slow freezing [13]. To minimize the detrimental effects of large ice crystal growth during freezing, emulsifiers and other water-binding agents can be added during the freezing process [14].

The addition of emulsifiers and water-binding agents helps to control the formation of ice crystals and maintain the integrity of the food's cellular structure. This can improve the overall quality and texture of the frozen product, preventing unwanted changes in taste and appearance.

Proper freezing techniques are essential in preserving the quality and shelf life of frozen foods. By employing rapid freezing methods and using appropriate additives, food manufacturers can ensure that frozen products maintain their desired characteristics and remain safe for consumption. Careful consideration of freezing conditions and the use of suitable additives contribute to delivering high-quality frozen foods to consumers.

- 6. Microbial Spoilage:** Microbial spoilage is a prevalent and significant cause of food deterioration, resulting from the activities of microorganisms. It is also a leading cause of foodborne illnesses. Perishable foods, in particular, are susceptible to attack by various microorganisms, including bacteria, yeasts, and molds.

The growth of most microorganisms can be controlled or slowed down by implementing various preservation techniques. Adjusting storage temperature is a common method to prevent microbial growth, as many microorganisms thrive in specific temperature ranges. Reducing water activity in the food can also inhibit microbial growth since most microorganisms require a certain level of moisture to flourish.

Modifying the pH of the food can create an environment unfavorable for the growth of certain microorganisms. Using preservatives, such as natural or chemical agents, can effectively inhibit microbial spoilage. Proper packaging can also play a role in preventing microbial contamination and extending the shelf life of food products. By implementing these measures, food manufacturers and distributors can effectively combat microbial spoilage, maintain food safety, and preserve the quality of perishable products. Ensuring proper food handling and storage practices is essential in preventing foodborne illnesses and promoting consumer confidence in the safety of food products [15].

Factors Affecting Microbial Spoilage: Microbial spoilage in foods is influenced by both intrinsic and extrinsic factors [16]. The intrinsic properties of foods play a crucial role in determining the expected shelf life and perishability of foods, as well as influencing the type and rate of microbial spoilage. Among the primary intrinsic properties associated with food spoilage are endogenous enzymes, substrates, sensitivity to light, and oxygen. By controlling these intrinsic properties during food product formulation, food quality and safety can be effectively managed.

Intrinsic factors of food spoilage include pH, which affects the acidity or alkalinity of the food and can influence the growth of specific microorganisms. Water activity, another intrinsic factor, refers to the availability of water in the food and its impact on microbial growth, as most microorganisms require a certain level of moisture to thrive. Nutrient content in the food environment also plays a role in supporting the growth of spoilage microorganisms. Additionally, the oxidation-reduction potential, related to the presence of oxygen and its potential for oxidation, can affect food stability and spoilage.

Extrinsic factors, on the other hand, encompass environmental conditions external to the food itself: Relative humidity in the surrounding environment can influence microbial activity and spoilage. Temperature of the storage environment can either accelerate or inhibit microbial growth.

The presence and activities of other microbes in the surroundings can interact with the food and impact its spoilage. By understanding and managing both intrinsic and extrinsic factors, food producers can implement effective measures to extend the shelf life of food products, maintain food safety, and ensure consumer satisfaction. Proper handling, storage, and packaging practices are critical in minimizing microbial spoilage and preserving the quality of food items.

7. **Chemical Spoilage:** Chemical spoilage in foods occurs due to natural chemical and biochemical reactions that lead to unpleasant sensory changes in food products. These changes can be caused by various factors:

- **Microbial Growth and Metabolism:** Microorganisms can produce metabolic by-products that lead to changes in pH, resulting in spoilage.
- **Toxic Compounds:** Certain foods may contain toxic compounds that can affect their safety and quality.
- **Lipid and Pigment Oxidation:** The oxidation of fats and pigments in food can lead to undesirable flavors and discoloration.

Chemical spoilage is often linked to microbial actions, but oxidation phenomena are purely chemical in nature and can also be influenced by temperature variations [17].

8. **Maillard Reaction:** The Maillard reaction, also known as non-enzymatic browning, is another significant cause of food spoilage. This reaction occurs between amino groups in proteins or amino acids present in foods. The Maillard reaction leads to color darkening, reduced protein solubility, the development of bitter flavors, and a decrease in the availability of certain amino acids, affecting the taste and nutritional value of the food.

9. **Pectin Hydrolysis:** Pectin's are complex mixtures of polysaccharides found in the cell walls of certain plants. During fruit ripening, indigenous pectinases are synthesized or activated, leading to pectin hydrolysis, which softens the structure of the fruit. Mechanical damage to fruits and vegetables can also activate pectinases and initiate microbial attack [18]. In addition, pectin substances can be de-esterified by the action of pectin methyl esterase, which strengthens cell walls and enhances intercellular cohesion in damaged tissues. Metal ions can catalyze the decomposition of heat-labile fruit pigments, which are composed of pectin ingredients. This process can cause color changes in fruit jams or jellies. To preserve jams and jellies, they are often stored in glass containers rather than metallic jars.

V. THE SIGNIFICANCE OF FOOD PRESERVATION

Food preservation plays a vital role in our lives, offering numerous benefits that enhance our food experiences and address critical challenges in the food supply chain. The significance of food preservation can be highlighted as follows:

1. **Convenience:** Food preservation allows various foods to be enjoyed at any location and throughout the year, irrespective of seasonal availability. This ensures a diverse and continuous food supply, providing convenience and satisfaction to consumers.
2. **Food Supply Enhancement:** By preserving foods, we can boost the food supply and reduce the risk of food shortages. It helps in optimizing food distribution and utilization, ultimately contributing to food security.

3. **Food Waste Reduction:** Proper food preservation techniques help minimize food waste by extending the shelf life of perishable items. This addresses the global issue of food wastage and promotes sustainable food consumption.
4. **Preservation of Quality:** When food is preserved correctly, there is no compromise in its taste, color, or nutritional value. It allows us to enjoy fresh and nutritious food even after extended periods of storage.
5. **Accessibility:** Food preservation enables food to be transported and accessed from various locations, allowing for easier trade and distribution across different regions.
6. **Extended Shelf Life:** Preserving food extends its shelf life, reducing the likelihood of spoilage and increasing its availability for consumption.
7. **Natural Food Preservatives:** As awareness about the potential risks associated with chemical preservatives increases, the demand for natural food preservatives is expected to grow. Using natural preservatives will become increasingly crucial, and they are likely to play a significant role in the market.

VI. METHODS OF FOOD PRESERVATION ASNH

The following are the main traditional methods for preservation of foods:

1. **Food Curing:** Food curing is a process aimed at reducing the moisture content in foods such as meat, fish, and vegetables through osmosis. By lowering the moisture content, the risk of microbial infection and growth is significantly diminished. Curing is also employed to enhance the flavor of the food. This is achieved by combining salt, nitrates, sugar, and nitrites, which effectively dehydrate the food. The use of higher amounts of salt during curing not only kills bacteria by dehydration but also slows down the oxidation process, preventing the fats from turning rancid over time.
2. **Freezing:** Freezing food at temperatures ranging from minus 10°C to minus 80°C is a widely adopted technique for both commercial and household long-term storage. This freezing process ensures that microbes do not survive, and any existing microbes cannot multiply. However, when it comes to hot-served foods, it is crucial to heat the food above 75°C after thawing it from the freezer to room temperature to ensure food safety. Cold stores are commonly used in almost all countries for the extended preservation of fruits, vegetables, and various other food items. For instance, processed food items like potato waffles are stored in a freezer, while their raw materials, potato tubers, are kept in a cold room at temperatures ranging from 0°C to 10°C for storage periods lasting several months. This approach allows for proper storage without compromising the quality and safety of the food products.
3. **Refrigeration:** Refrigeration involves artificial cooling to lower the temperature below room (ambient) temperature. This process transfers heat from a low-temperature reservoir to a high-temperature reservoir using mechanical, electrical, laser, or magnetic means.

Traditionally, processed and perishable foods are preserved by storing them in refrigerators, where the temperature is typically maintained between 4°C to 10°C. At these low temperatures, microbial growth and multiplication are significantly inhibited, and even if some growth occurs, it is at a much slower rate. For perishable foods susceptible to rotting due to enzymatic activity, the rate of enzymatic catalysis slows down considerably at lower temperatures.

Although food may stay fresh for only a limited time in the refrigerator (usually a few hours to a day or so), refrigeration has proven to be an effective method for food preservation inside homes and restaurants, especially during hot summers. In rural areas, people also use ice boxes with ice to cool food items. Another traditional method of food storage and preservation is the use of root cellars. These underground or partially underground structures are synonymous with storing root crops. Depending on the type of foodstuff, storage in a root cellar can be extended for several weeks, providing a reliable method for keeping fruits, nuts, and vegetables fresh for longer periods.

- 4. Boiling:** Boiling water and milk to kill microbes is indeed a traditional practice, particularly in developing countries, and it serves as an essential method to ensure water and milk are safe for consumption. Boiling water is an effective way to make it free from harmful bacteria, viruses, and other microorganisms that might be present. Boiling water at a rolling boil for at least one minute (longer at higher altitudes) can significantly reduce the risk of waterborne illnesses. It is especially crucial in areas where access to clean and safe drinking water is limited or where water sanitation systems may not be adequate.

Similarly, boiling milk is a common practice to make it safe for consumption, even if the milk has already undergone pasteurization. While pasteurization eliminates most harmful bacteria, some microorganisms may still be present, and boiling the milk provides an extra layer of safety, particularly in regions where milk handling and storage conditions may not be optimal.

Boiling water and milk are simple and effective ways to protect against waterborne and foodborne illnesses, and these practices continue to be embraced to ensure the health and well-being of communities, especially in areas where access to advanced sanitation and food safety measures is limited.

- 5. Sugaring:** Absolutely, preserving food using sugar as a preservative is still a widespread practice today. The high sugar content in the food creates a hypertonic environment, which means that the concentration of solutes (sugar) is higher outside the microbial cells compared to inside them. As a result, water is drawn out of the microbial cells, leading to their dehydration and inhibition of growth. This preservation method has been used for centuries and is effective in preventing spoilage and microbial contamination.

Storing fruits in honey or sugar is a common way to preserve them for extended periods. Jams and jellies are classic examples of sugaring, where fruits are cooked with sugar to create a concentrated and sweet preserve that inhibits microbial growth and enhances shelf life. Additionally, many soft drinks, such as orange squash, are prepared based on this principle, with high sugar content acting as a preservative, ensuring the product remains safe and stable. The use of sugar as a preservative continues to be a

valuable technique in the food industry, providing a natural and effective means of prolonging the shelf life of various foodstuffs without the need for artificial additives or harsh preservatives.

- 6. Pickling:** Pickling is a traditional method employed to prolong the lifespan of various foodstuffs. This process involves immersing the foodstuff in vinegar or vegetable oil or subjecting it to anaerobic fermentation. Pickling alters the texture, flavor, and taste of the food, resulting in a preserved product commonly known as a pickle.

In Asian countries, including India, pickling is a prevalent practice for preserving vegetables like carrot, cauliflower, lemon, and raw mangoes. Meanwhile, in many European countries, Canada, and the USA, pickles made from eggs, fish, and meat are commonly consumed.

Anaerobic fermentation, which involves storing vegetables and fruits like mangoes, radish, and carrots in vinegar, is also widespread in Asian countries. During fermentation, organic acids such as lactic acid and acetic acid are produced, acting as natural preservatives. In some regions, brine, a high-salt solution, is used for preservation, effectively killing bacteria and other microbes.

These traditional pickling techniques have stood the test of time, providing a delightful array of flavors and textures while extending the shelf life of various foods through natural preservation methods.

- 7. Canning:** The process of canning, which was discovered by Nicolas Appert, a French confectioner in the early nineteenth century, is a method used to extend the shelf life of foodstuffs. The process involves cooking the food and then sealing it in sterilized jars or cans, followed by boiling the containers to achieve sterilization. This process effectively kills or weakens any remaining microbes present in the food, ensuring its preservation.

However, it wasn't until 1864 when Louis Pasteur established the connection between food spoilage and microbes, and the subsequent potential for causing illnesses, that canning gained popularity.

Different foodstuffs possess varying degrees of natural protection against spoilage. High-acid foodstuffs like strawberries do not require additional preservatives for canning, as boiling for a short time is sufficient. Conversely, other food items like carrots necessitate longer boiling and the addition of acidic preservatives like citric acid. Foodstuffs with low acid content, such as vegetables and meats, require pressure canning for effective preservation.

Nevertheless, it should be noted that canned foodstuffs may spoil shortly after opening the can or bottle. Gas production inside the can sometimes causes it to swell or burst, and the presence of water or microbes can contribute to food decomposition. Of particular concern is the presence of the anaerobic microbe, *Clostridium botulinum*, which can produce a toxin capable of causing food poisoning or even death upon consumption. Although this contamination may not be visible to the naked eye, proper cooking can denature the toxin, making the food safe for consumption. Another common

issue is the contamination of canned mushrooms by *Staphylococcus aureus*, which also produces a toxin that cannot be inactivated by heating the canned food. Therefore, it is essential to handle canned foodstuffs with care and ensure proper cooking and storage practices to maintain their safety and quality

- 8. Fermentation:** The production of certain foodstuffs like beer, wine, and cheese involves a fermentation process using specific microbes. These fermentative microbes play a vital role in protecting the food against pathogenic microbes by producing acids or alcohol that are toxic to them. Through this natural process, the food becomes safe for human consumption.

During fermentation, carefully controlled conditions such as salt content, temperature, oxygen levels, and other parameters are maintained. These conditions support the fermentative microbes in producing a high-quality food product that is not only safe but also enjoyable for consumption. The carefully regulated environment ensures the desired outcomes, allowing the fermentation process to create flavorful and nutritious food items.

VII. THE FOLLOWING ARE THE MAIN MODERN METHODS FOR PRESERVATION OF FOODS

Preservation methods often involve the utilization of elevated temperatures, which typically fall into two categories:

- Pasteurization temperatures (below 100°C)
- Sterilization temperatures (100°C or higher)

- 1. Pasteurization:** Pasteurization is a technique employed to eliminate human pathogens and the majority of vegetative microorganisms from food. It is commonly utilized for preserving fruit juices, ready-to-serve (R.T.S.) beverages, and nectars. This method involves heating these substances to a temperature near or just below the boiling point for a specified duration. This time frame is sufficient to eliminate the microorganisms responsible for spoilage, constituting the pasteurization process.

However, it's important to note that pasteurization doesn't completely eliminate all microorganisms present in the juice. Some spores and spore-forming bacteria, such as *Bacillus subtilis* and *B. mesentericus*, can survive and potentially multiply afterward. However, their numbers are usually too low to cause spoilage. Additionally, these organisms are highly sensitive to acidity and cannot thrive in the acidic environment of fruits and vegetables.

Mould spores can be effectively neutralized by subjecting them to a temperature of 79°C for a duration of 5 to 10 minutes. Since moulds require oxygen for growth, the eradication of air from the juice through complete container filling, vacuum-based deaeration, or the replacement of air with carbon dioxide (CO₂) assists in eliminating moulds even at lower temperatures.

To effectively eliminate yeasts and acid-tolerant bacteria, heating the juice for a short period at around 66°C is sufficient. Below is a table detailing the Thermal Death Time (TDT) of bacteria.

Table: 1

Bacteria	Time (min)	Temperature (°C)
<i>Salmonella typhosa</i>	4.3	60
<i>Staphylococcus aureus</i>	18.8	60
<i>E. coli</i>	20-30	57.3
<i>Streptococcus thermophiles</i>	15	70-77
<i>L. bulgaricus</i>	30	71

Thermal Death Time (TDT) is characterized as the duration needed at a particular temperature to exterminate a specified count of organisms, following predetermined conditions.

In the case of tomato juice, the spore-forming bacteria present necessitate exposure to a higher temperature of 88°C for an extended period. The table below provides information about the heat resistance of bacterial spores.

[The table with heat resistance data for bacterial spores is not provided, but it presumably contains information about the temperature and time required to destroy different bacterial spores.]

Table 2: Heat Resistance of Bacterial Spores

Spore	Time (min) to kill at 100°C
<i>B. anthracis</i>	1.7
<i>B. subtilis</i>	15-30
<i>C. botulinum</i>	100-300
Flat sour bacteria	Over 1000

Enzymes, which are active at normal temperatures, also rely on air (oxygen) for their functions. Consequently, they can be effectively neutralized at moderate temperatures by removing air from the juice. Pectin enzymes, responsible for flavor alterations and the coagulation of particles within the juice, can be eradicated by subjecting the juice to a temperature of approximately 85°C for around 4 minutes or at 88°C for 1 minute. Generally, fruit juices, ready-to-serve beverages (R.T.S.), and nectars undergo pasteurization at approximately 85°C for a period ranging from 25 to 30 minutes. The specific duration and temperature are determined by the juice's characteristics and the container size. For acid fruit juices, a lower temperature and shorter duration are sufficient for pasteurization compared to less acidic ones.

There are two primary approaches to pasteurization:

- Prolonged heating at low temperatures
- Brief heating at high temperatures (High-Temperature Short-Time method, or HTST)

In Essence, there Exist Three Distinct Methods of Pasteurization

- **Bottle or 'Holding' Pasteurization:** This technique is commonly employed for home-based preservation of fruit juices. The extracted juice is appropriately strained or clarified, and then carefully poured into bottles, allowing sufficient space at the top for juice expansion during heating. The bottle is then hermetically sealed and subjected to pasteurization.
- **Overflow Method:** In this method, the juice is heated to a temperature slightly higher than the pasteurization temperature. It is then poured into hot sterilized bottles, filling them up to the brim. Care is taken to ensure that the juice temperature remains above the pasteurization temperature during the filling and sealing process. The sealed bottles are subsequently pasteurized at a temperature 2.5°C lower than the filling and sealing temperature, followed by cooling. This method is particularly suitable for grape juice, as it minimizes the negative impact of air on juice quality.
- **Flash Pasteurization:** This approach involves rapidly heating the juice to a temperature approximately 5.5°C above the pasteurization temperature and maintaining it at this temperature for about a minute. Flash pasteurization was initially designed for canning natural orange juice, but it can also be applied to orange and apple juices.

This Method Offers the Following Advantages:

- Loss of flavour is minimum,
 - Vitamins are not destroyed
 - Effects economy of time and space,
 - Keeps the juice uniformly cloudy, and
 - Juice is heated uniformly and thus its cooked taste is minimum.
2. **Sterilization:** Sterilization, by definition, refers to the complete elimination of all viable microorganisms. Among various food preservation techniques, heat sterilization stands out as the most effective. However, it does have a significant impact on heat-sensitive nutrients, particularly vitamins. Additionally, the Maillard reaction can substantially reduce the nutritional quality of proteins. Through this approach, all microorganisms are eradicated due to the application of high temperatures.

The specific time and temperature required for sterilization depend on the type of food being processed. For instance, fruit and tomato products should be heated to 100°C for 30 minutes. This duration ensures the complete destruction of spore-forming bacteria, which are particularly sensitive to high acidity. On the other hand, vegetables like green peas, okra, and beans, which are less acidic and contain higher starch levels compared to sugar, necessitate even higher temperatures to effectively eliminate spore-forming organisms. In such cases, continuous heating at 116°C for 30 to 90 minutes becomes crucial for proper sterilization.

It's also important to sterilize empty cans and bottles before use. This can be achieved by immersing them in boiling water for around 30 minutes. Temperatures exceeding 100°C can only be achieved by employing steam pressure sterilization devices like pressure cookers and autoclaves.

Table 3: The Major Differences between Pasteurization and Sterilization are as under:

S. No.	Pasteurization	Sterilization
1.	Partial destruction of microorganisms	Complete destruction of microorganisms
2.	Temperature below 100°C	Temperature 100°C and above
3.	Normally used for fruits	Normally used for vegetables

- Aseptic Canning:** Aseptic canning involves a method where food is sterilized before being placed into cans that have already been sterilized. These cans are then sealed in a sterile environment. This technique, also referred to as Martin aseptic canning, was initially introduced for commercial use in 1950. The process primarily entails brief, high-temperature sterilization. It combines rapid pasteurization and cooling with the sterile packaging of fluid and semi-fluid products, effectively eliminating the need for retorting and subsequent cooling phases.

This Process Comprises Four Distinct Sequential Steps carried out within an Interconnected Closed Apparatus:

- Sterilization of the product through rapid heating, holding, and subsequent cooling.
- Sterilization of containers and lids using superheated steam.
- Aseptic filling of cooled, sterilized product into sterile containers.
- Aseptic sealing of the containers using sterile lids.

Temperatures as high as 149°C might be employed, and the sterilization occurs within a span of 1 or 2 seconds, resulting in the production of the highest quality products.

- Hot Pack or Hot Fill:** This concept pertains to the process of placing pre-pasteurized or sterilized food into containers while it's still hot. The containers need to be clean, although not necessarily sterile, and the surroundings should be clean but not necessarily completely sterile. This packaging method relies on the combination of the food's heat and a specific duration of time that the sealed container remains closed, which effectively sterilizes the container for commercial purposes. For instance, when preparing jam at home by boiling a mixture of fruit pulp and sugar, and then pouring the hot jam into pre-boiled jars, you're applying the principle of the hot pack method.

VIII. FREEZE DRYING

Vacuum drying is a cutting-edge method used to remove moisture from foodstuff at significantly lower temperatures under frozen conditions. The process revolves around the principle of sublimation, wherein solid water (ice) is evaporated at reduced pressure. This

technique ensures the preservation of high-quality foodstuffs without altering their shape. In the realm of food processing, vacuum drying finds its application in the preservation of coffee, resulting in a premium product. Additionally, this method is also utilized for the long-term storage of bacteria and yeasts, as described by [19]. Vacuum drying represents a modern and efficient approach to preserve and process food items while maintaining their quality and integrity, making it an essential tool in the food industry and beyond.

IX. FILTRATION-BASED PRESERVATION

In this approach, the juices are clarified through settling or conventional filters, followed by passing them through specialized filters designed to capture yeasts and bacteria. Various types of germ-resistant filters are employed for this purpose. While this technique is gaining traction in countries like the U.S.A. and Germany for preserving apple and grape juices, it is not currently utilized in India. This method finds application in the preservation of soft drinks, fruit juices, and wines.

X. CARBONATION FOR PRESERVATION

Carbonation involves dissolving sufficient carbon dioxide in water or a beverage, resulting in the release of fine bubbles of gas when the product is served. This imparts a distinctive taste and extends the shelf life of the beverage. Carbonation also contributes to the beverage's tanginess. Fruit juice beverages typically contain varying levels of carbon dioxide, ranging from 1 to 8 grams per liter. While this concentration is lower than the amount required for complete inhibition of microbial activity (14.6 g/liter), it effectively complements the acidic environment's impact on pathogenic bacteria. Additionally, carbonation eliminates air, creating anaerobic conditions that minimize ascorbic acid oxidation and prevent browning.

Moulds and yeasts thrive in the presence of oxygen but become inactive when exposed to carbon dioxide. In conventional carbonated drinks, the oxygen naturally dissolved in water sufficient to induce fermentation is displaced by carbon dioxide. Despite containing sugar levels well below 66 percent, carbonated beverages create an environment inhospitable to moulds and yeasts due to the absence of air and the presence of carbon dioxide.

It's important to avoid excessive carbonation, as it can adversely affect the juice's flavor. Enhancing the shelf life of carbonated fruit beverages is achievable by incorporating around 0.005 percent sodium benzoate. The optimal degree of carbonation varies based on the fruit juice type and flavor profile.

XI. VACUUM PACKING

In this method, foodstuff is placed in a plastic film bag, and a vacuum is created inside the bag by removing air using a vacuum pump before sealing it. By eliminating oxygen, the conditions become unfavorable for microbial growth, as they rely on oxygen for survival. This technique is particularly popular for packaging nuts as it preserves their freshness and prevents flavor loss due to oxidation [20]. Vacuum packing is a widely used and effective approach to extend the shelf life of various food items by creating an oxygen-free environment, safeguarding their quality, and minimizing the risk of spoilage. It has

proven to be especially beneficial for preserving nuts, ensuring their taste and texture remain intact for an extended period.

XII. PRESERVATION THROUGH ANTIBIOTICS

Certain metabolic byproducts of microorganisms exhibit germicidal properties and are termed antibiotics. Their application in medicine to combat disease-causing organisms within the body is widely recognized. Similarly, some antibiotics find use in preserving fruits, vegetables, and related products. One such antibiotic is Nisin, produced by *Streptococcus lactis*, a microorganism commonly present in milk, curd, cheese, and other fermented dairy products. Nisin is non-toxic and does not compromise the sensory attributes of food. Its prevalent application is within the food industry, particularly for preserving acidic foods due to its enhanced stability in such environments. Canning of mushrooms, tomatoes, and milk products frequently involves Nisin. It curbs the proliferation of spoilage agents, particularly gas-producing, spore-forming bacteria, and toxin-generating *Clostridium botulinum*.

Subtilin, another antibiotic sourced from specific strains of *Bacillus subtilis*, is employed to preserve asparagus, corn, and peas. It exhibits pronounced efficacy against Gram-positive bacteria and spore-forming organisms. Canned peas and tomatoes treated with 10 and 20 ppm of subtilin, respectively, demonstrated the absence of microorganisms. The application of subtilin and Nisin substantially reduces the thermal processing requirements required to control spoilage in various food items.

Pimaricin, classified as an antifungal antibiotic, can be utilized to treat fruits and fruit juices.

Currently, the aforementioned three antibiotics are permitted exclusively in foods that undergo cooking before consumption. During the cooking process, any remaining antibiotics are anticipated to be rendered inactive. The use of antibiotics in conjunction with other sterilization agents, including heat and radiation, holds significant potential.

XIII. CHEMICAL FOOD PRESERVATIVES

In processed foods, anti-microbial chemical agents are added to preserve them. These agents are added in smaller amount since these are mostly toxic when consumed in larger amount. Common preservatives are benzoic acid and benzoates which are used in acidic foods such as jams, salad dressing, juices, pickles, carbonated drinks, soy sauce among others. Sorbic acid and sorbates are used as preservatives in cheese, wine and baked foods among others. Nitrites and nitrates are used as preservatives in meats to prevent botulism toxin. Sulphur dioxide and sulphites are used in fruits and wine. Similarly, propionic acid and propionates are used in baked foods.

1. Ideal Properties of Preservatives: (P79): The ideal qualities of a substance for use in products are multifaceted. Firstly, it should possess a non-irritating nature, ensuring that it doesn't cause discomfort or adverse reactions when applied or consumed. Second, maintaining consistency across various batches of the product is crucial, ensuring that consumers receive the same high quality every time. Palatability and wholesomeness are also key factors, as the substance should contribute positively to the taste and overall

healthiness of the product. Equally important, it must not exhibit any toxic properties that could harm users. Physical and chemical stability are essential, enabling the substance to withstand various conditions without undergoing detrimental changes. Compatibility with other ingredients is paramount for the substance to seamlessly integrate within the product's composition. Moreover, acting as an effective antimicrobial agent enhances its utility by preventing microbial growth. Potency in action signifies that the substance's intended effects are powerful and reliable. Lastly, a prolonged shelf life is desirable, contributing to the product's longevity and value. In sum, a substance possessing these qualities would be an excellent choice for inclusion in a wide range of products [21].

2. Function of Preservatives

- To increase or maintain nutritional value of food.
- To enhance quality and to reduce wastage.
- To enhance consumer acceptability
- They inhibit the growth of microbes.
- They increase reasonably shelf life of processed foods.
- Some of the commonly used preservatives such as nitrate, and salt – have been used for centuries in processed meats and wine [22].

3. Classification of Preservatives

There are Two Main Classes of Preservatives:

Class I: in this class included those food preservatives which are obtained from nature for example salt, sugar, vinegar, spices, honey, edible oils etc.

Class II: in this class included those food preservatives which are chemical, semi synthetic or synthetic in nature such as benzoates, sorbates, nitrites and nitrates of potassium, sulfites, glutamates, glycerides etc. [23].

4. Preservatives can be Categorized Chemically as Antimicrobials, Antioxidants, and Antienzymatics:

- **Antimicrobials:** These preservatives are capable of destroying or inhibiting the growth of bacteria, yeast, and molds in food products. For example, nitrites and nitrates are used in meat products to prevent botulism, a type of food poisoning caused by bacteria. Sulfur dioxide is employed to prevent spoilage in fruits, wine, and beer. Benzoates and sorbates act as anti-fungal agents and are added to items like jams, salads, cheese, and pickles to prevent fungal growth.
- **Antioxidants:** These preservatives slow down or halt the breakdown of fats and oils in food that occurs in the presence of oxygen, a process known as rancidity. By preventing rancidity, antioxidants help maintain the freshness and quality of various food items.

Preservatives serve a crucial role in extending the shelf life of food products, ensuring their safety and maintaining their sensory attributes. Proper and judicious use of these preservatives is essential to strike a balance between effective preservation and potential health concerns associated with their use.

- **Anti-enzymatic:** Preservatives function by inhibiting enzymatic processes, such as ripening, that occur in foodstuffs even after harvest. For instance, erythorbic acid and citric acid are known to block the action of the enzyme phenolase, which is responsible for the development of a brown color on the exposed surface of cut fruits [24]. By impeding enzymatic activities, these preservatives help maintain the visual appeal and freshness of fruits and other perishable foods, extending their shelf life and improving their overall quality.

Table 4: Codes assigned to various preservatives by Commission of European Union

E-Number	Name of Preservative	E-Number	Name of Preservative	E-Number	Name of Preservative
E 200	Sorbic acid	E 220	Sulphur dioxide	E 235	Natamycin
E 202	Potassium sorbate	E 221	Sodium sulphite	E 239	Hexamethylene tetramine
E 203	Potassium sorbate	E 222	Sodium hydrogen sulphite	E 242	Dimethyl dicarbonate
E 210	Benzoic acid	E 223	Sodium metabisulphite	E 249	Potassium nitrite
E 211	Sodium benzoate	E 224	Potassium metabisulphite	E 250	Sodium nitrite
E 212	Potassium benzoate	E 226	Calcium sulphite	E 251	Sodium nitrate
E 213	Calcium benzoate	E 227	Calcium hydrogen sulphite	E 252	Potassium nitrate
E 214	Ethyl p-hydroxybenzoate	E 228	Potassium hydrogen sulphite	E 281	Sodium propionate
E 215	Sodium ethyl p-hydroxybenzoate	E 230	Biphenyl, diphenyl	E 282	Calcium propionate
E 216	Propyl p-hydroxybenzoate	E 231	Orthophenyl phenol	E 283	Potassium propionate
E 217	Sodiumpropyl p-hydroxybenzoate	E 232	Sodium orthophenyl phenol	E 284	Boric acid
E 218	Methyl p-hydroxybenzoate	E 233	Thiabendazole	E 285	Sodium tetraborate (borax)
E 219	Sodium methyl p-hydroxybenzoate	E 234	Nisin	E 1105	Lysozyme

Table 5: Maximum Possible Limits of Food Preservatives in Different Food Products [25]

Preservatives	Class	Maximum Limit	Focus Products
Sodium and potassium benzoate, benzoic acid	Antimicrobial	200ppm	Pickles, margarine, fruit juices, jams, cheese, baked goods, snacks
Methyl and propyl paraben	Antimicrobial	0.1%	Baked goods, beverages, dressings, relishes
Sorbic acid, Sodium, potassium and calcium sorbates	Antimicrobial	200ppm	Dairy products, bakery goods, sweets, syrups, fruit juices, jams, jellies, beverages
Sulfites and sulfur dioxide	Antimicrobial	200-300ppm	Dry fruits and fruits, molasses, fried or frozen potatoes, shrimp and lobster
Propionates	Antimicrobial	0.32%	Bakery products, cheese, fruits
Nitrites and nitrates	Antimicrobial	100-200ppm	Meat products
Propyl gallate	Antioxidant	200ppm	Baked foods, meats
BHA (butylated hydroxy-anisole) and BHT (butylated hydroxytoluene)	Antioxidant	100ppm	Baked foods and snacks, meats, breakfast cereals, potato products
Tert-butylhydro-quinone (TBHQ)	Antioxidant	100ppm	Baked foods and snacks, meats
Erythorbic acid (iso-ascorbic acid) and citric acid	Antienzymatics	200-300ppm	Soft drinks, juices, wines and cured meats

XIV. PASCALIZATION

In this method, foodstuff is placed inside a vessel and subjected to an extremely high pressure of around 70,000 pounds per square inch. This technique is highly effective as it allows foodstuffs to retain their freshness, flavor, texture, and nutrients while also eliminating harmful microbes. As a result, the spoilage of food is significantly slowed down.

This preservation technique, known as pascalization or high-pressure processing (HPP), has been successfully applied to various food products, including orange juice, guacamole, and deli meats. By using high pressure instead of heat or chemicals, this method ensures that the food remains safe and retains its natural attributes, offering consumers high-quality and minimally processed products with extended shelf life.

XV. BIOPRESERVATION

Biopreservation refers to the use of natural microbes or antimicrobial substances to preserve and extend the shelf life of foodstuffs. In this method, beneficial bacteria or fermentation products are employed to control spoilage and inactivate any potential pathogenic microbes present in the food [26].

Lactic acid bacteria are commonly used as biopreservatives. These bacteria produce various antimicrobial compounds, such as lactic acid, acetic acid, bacteriocins, and hydrogen peroxide, which effectively inhibit the growth of harmful microorganisms. By harnessing the natural antimicrobial properties of these beneficial bacteria, biopreservation offers a safe and sustainable method to enhance food quality and safety without the need for artificial additives or chemical preservatives.

XVI. HURDLE TECHNOLOGY

Hurdle technology involves the strategic application of multiple approaches to effectively inactivate any pathogenic microorganisms that may be present in foodstuffs. These combined approaches act as obstacles, creating a challenging environment for microbes to survive and grow. The selection of the right combination of hurdles is crucial for achieving successful food preservation [27] defined hurdle technology as an intelligent integration of different hurdles that not only ensures microbial safety but also maintains the nutritional quality and economic viability of the food. Additionally, these hurdles do not alter the sensory attributes, such as smell, appearance, and texture, of the foodstuff.

The main approaches used in hurdle technology include higher processing temperatures, increased acidity, lowered redox potential, the presence of preservatives, and lower storage temperatures. Combining these approaches, along with the use of lactic acid bacteriocins, has proven effective in controlling spoilage and ensuring food safety.

The intensity of each approach is carefully determined based on the specific nature of the potential pathogen(s) present in the food. By customizing the combination and intensity of hurdles, hurdle technology offers a versatile and efficient approach to food preservation, ensuring the delivery of safe and high-quality food products to consumers.

XVII. NONTHERMAL PLASMA

In this technology, the surface of the foodstuff is subjected to a flame of ionized gas molecules, such as nitrogen and helium. This process is effective in killing any microbes that might be present on the surface of the foodstuff. By exposing the food to this ionized gas flame, harmful microorganisms on the surface are eliminated, contributing to the preservation and safety of the food product. This technique offers a quick and efficient method for reducing microbial contamination and extending the shelf life of various food items.

Modified Atmosphere: In this approach, the atmosphere surrounding the foodstuff is deliberately altered to enhance preservation. Salad crops, for instance, are often packed in sealed bags where carbon dioxide concentration is increased, and oxygen concentration is

reduced. However, this method may lead to some nutrient changes, including vitamin content.

Grains can be preserved using carbon dioxide in various ways. Some individuals place a block of dry ice (solid carbon dioxide) at the bottom of the container, while others purge the container with carbon dioxide gas. This gas effectively prevents insects, molds, and oxidation from damaging the grains. Nitrogen gas is also utilized for grain preservation, as it can kill insects [28].

For larger quantities of foodstuffs, Controlled Atmospheric Storage (CAS) is employed. CAS involves sealing a room and infusing nitrogen gas to reduce oxygen levels, typically from 21% in regular air to 1-2% within the storage facility. Temperature is set between 0 to 2 degrees Celsius, and humidity is maintained at approximately 95%. Carbon dioxide levels are also controlled, with all atmospheric conditions tailored to the specific nature of the food being stored. Today, computer-controlled systems aid in maintaining the desired atmospheric conditions in CAS facilities.

Another concept is air-tight storage, also known as hermetic storage, mainly used for grains. The enclosed atmosphere is believed to control insect pests due to respiration of grains, insects, and fungi. Proper sealing, grain moisture content, and temperature play vital roles in the effectiveness of this storage method [29].

XVIII. IRRADIATION

Foodstuff can be exposed to ionizing radiation, either as β -particles or γ -rays, as a means of preservation. This radiation has the capability to effectively kill bacteria, molds, pests, and other microorganisms present in the food. Additionally, the irradiation process can slow down the ripening of fruits and prevent spoilage, extending the shelf life of the products.

While organizations like the World Health Organization (WHO) and the Food and Agricultural Organization (FAO) have endorsed food irradiation as a safe technique, there are still controversies surrounding its use. Some individuals hold misconceptions that irradiated food may become radioactive, which is not the case. Others are concerned that the process might sterilize contaminated food, making it difficult to detect and posing potential risks [30].

Despite these concerns, food irradiation has found significant application in preserving spices, condiments, and fresh fruits. It offers a promising method for extending the shelf life of these food items while ensuring safety and quality, as it can effectively eliminate harmful microorganisms and pests without the need for harmful chemicals.

XIX. CONCLUSION

Absolutely, proper preservation of food stuffs is of utmost importance to prevent food borne diseases caused by the consumption of spoiled or contaminated food. While there are existing techniques for food preservation, it is crucial to continuously search for more effective and safer methods, taking into account economic viability and social responsibility. The food industry must invest in research and development to explore innovative preservation techniques that not only extend shelf life but also maintain nutritional content

and sensory attributes. Packaging also plays a critical role in preserving food and ensuring its safety during storage and transportation. By prioritizing research and development in food preservation, we can reduce food waste, enhance food security, and promote sustainable practices. Additionally, improved preservation methods will contribute to meeting the growing global demand for safe and high-quality food products.

As technology and scientific knowledge advance, continuous efforts should be made to explore new preservation solutions that are both efficient and environmentally friendly. By combining traditional wisdom with modern innovations, we can ensure that food remains safe, nutritious, and accessible to all while minimizing the risk of foodborne illnesses. The ongoing pursuit of effective food preservation techniques will play a pivotal role in shaping a healthier and more sustainable food system for the future.

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