FOOD PRESERVATION AND STORAGE

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Abstract

Food preservation and storage is crucial to our world as concerns over food security and sustainability intensifies. Food spoilage is a widespread concern impacting food safety and sustainability worldwide. According to recent studies, one third of the food produced in the world is wasted every year. Major cause of the food wastage is the improper management of the food. However, controlled physiological conditions using advanced technologies can decrease the spoilage of the food to an extent. With the advancement in technologies, the food industry has been successful in overcoming almost all the challenges of food preservation and storage. Advancement in packaging of food has also helped in reducing the food wastage by increasing its shelf life, nutritional value and quality. In this chapter we will be discussing the physiological factors behind food preservation, conventional and non-conventional food preservation techniques, sophisticated packaging techniques, and regulatory bodies in the food industry.

I. Introduction

THe basic requirement of a man is food. A man consumes food as a source of energy and nutrients for his body. Man needs food in his daily life to feel satisfied. Apart from the nutrients, energy and satisfaction the food gives, the storing of enough food to meet requirements will also give the man a sense of security. Population and population growth directly influence food requirements in the world.The Food and Agriculture Organization (FAO) reported that 1/3rd of the world's food production is wasted every year. This points out that even though sufficient food is produced in the world it is not reaching everyone. This leads to hunger in the world. Sometimes, the food reaches the needy but it does not have any nutritional quality and this leads to undernourishment in people. So, it is vital to retain the nutritional quality of the food at the same time equip it with a long shelf life. Improper preservation techniques during processing, transportation, and storage are the main culprits of this food spoilage. Physiological challenges like improper temperature control, exposure to air and moisture, and inadequate sanitation also lead to spoilage and microbial growth in food products.The deterioration in the food quality makes it inconsumable and dangerous to the human body and nature. Presence and activity of microorganisms like bacteria, yeast, molds, etc., spoil food. These organisms break down the nutrients leading to changes in the sensory characteristics like appearance, texture, taste, and smell. Some microorganisms are common to many types of spoiled food but some are specific to some food. If not stored properly under suitable physiological conditions, these microorganisms will spoil the food. The need for food preservation arises from the desire to extend the shelf life of perishable foods and prevent spoilage, thus reducing food waste and ensuring a continuous supply of safe and nutritious food. Preservation methods aim to inhibit the growth of microorganisms, enzymes, and other factors responsible for food deterioration. Food preservation has a long history dating back to ancient times when early civilizations used methods like drying, salting, and fermentation to preserve food. Over the centuries, advancements in technology and scientific understanding have led to the development of various preservation techniques, such as canning, refrigeration, freezing, and modified atmosphere packaging (MAP).

A. Principle of food storage and preservation

Longer shelf life and maintaining the quality and safety of the food is the primary objective of food preservation techniques. The basic principles behind food preservation are inhibiting the activity of microorganisms, chemicals reactions that reduce the quality of the food, and endogenous enzymes. Food spoilage causes will be different in different types of food. But the physiological conditions that lead to the spoilage of food are almost the same. Some of the physiological factors that can be manipulated to preserve the food are temperature, water content, etc. At lower temperature, the cellular activity of the microorganisms are slowed down thus reducing the enzymatic activity of the organisms that lead to the food spoilage.

Removing the moisture content from the food will inhibit the growth of bacteria, molds and yeasts. Drying and salting are the techniques used to remove moisture from the food. By storing the food in air tight conditions can also prevent the spoliage of the food. In conclusion, food spoilage is a significant challenge, but effective food preservation techniques and storage practices play a crucial role in combating this issue. By understanding the principles of food preservation, the characteristics of food products, and the history of preservation methods, we can develop strategies to reduce food waste, improve food safety, and enhance global food availability.

TABLE I
FOOD FORMS AND DESCRIPTIONS

Food Forms	**Description**
Fruits	Fresh and whole fruits like apples, bananas, oranges, etc.
Vegetables	Crisp and nutritious vegetables like lettuce, carrots, etc.
Seafood	Fish and shellfish in dishes like sushi and ceviche
Meat and Poultry	Dishes featuring meat or poultry, like steak tartare
Dairy Products	Unpasteurized milk, cheese, and yogurt
Nuts and Seeds	Nutrient-dense nuts and seeds consumed as snacks
Grains and Legumes	Sprouted grains and legumes in salads and sandwiches
Herbs and Spices	Fresh herbs and spices for added flavor
Fermented Foods	Foods like kimchi and sauerkraut
Juices and Smoothies	Freshly squeezed fruit and vegetable juices or smoothies
Honey and Syrups	Natural sweeteners like honey and maple syrup

B. Factors affecting food.

Various factors significantly impact the quality, safety, and characteristics of food products across the food supply chain. Environmental conditions such as climate, temperature, and humidity influence the growth of crops and livestock, affecting the availability and quality of raw materials. Agricultural practices, including the use of pesticides and fertilizers, can impact the safety and nutritional content of crops. Different processing techniques, such as heating, freezing, drying, and canning, alter the nutritional composition and sensory attributes of food. The type of packaging materials and storage conditions affect the shelf life and quality of products. Transportation and handling during distribution can impact freshness and safety. Contamination during production, processing, or handling can lead to foodborne illnesses. Food additives, such as preservatives and colorants, influence taste and appearance. Globalization and international trade introduce new foods and processing methods, influencing dietary habits and food safety standards. Additionally, evolving consumer preferences for healthier, organic, and sustainably produced food drive innovation in the industry. Understanding and managing these factors are crucial for ensuring food safety, quality, and meeting diverse consumer demands. Stringent regulations, quality control measures, and ongoing research are essential for continually improving the food supply. Some physiological factors are discussed below :

1) microbial growth: - Microbial organisms, including bacteria, yeasts, and molds, can contaminate food at various stages of production, processing, or storage. - In meat and poultry production, ensuring hygienic practices and proper temperature control is essential to prevent bacterial contamination and foodborne illnesses. - Dairy products are susceptible to spoilage by different bacteria and yeasts, highlighting the significance of pasteurization and appropriate storage conditions. - In fruits and vegetable processing, measures like blanching and canning are employed to slow down microbial growth and enhance shelf life.

TABLE II
MICROBES THAT SPOIL FOOD: SUBSTRATES AND CHARACTERISTICS

Microbe Name	**Substrates**	**Characteristics**
Bacteria	Various food types, including meat, dairy, vegetables, and fruits.	Rapid growth, production of enzymes, causing spoilage and off-flavors.
Yeasts	Sugars in fruits, vegetables, and bakery products.	Fermentation, leading to alcohol and gas production, causing swelling and off-flavors.
Molds	Bread, fruits, dairy, and other processed foods.	Growth of visible mycelium, production of mycotoxins, causing surface spoilage.
Lactic Acid Bacteria	Fermented dairy, pickles, sauerkraut, etc.	Lactic acid production, resulting in acidic and tangy flavors, aiding preservation.
Pseudomonas spp.	Meat, fish, and dairy products.	Psychrotrophic bacteria, leading to spoilage at low temperatures.
Saccharomyces cerevisiae	Various fruits and bakery products.	Fermentation, producing ethanol and carbon dioxide, causing leavening and off-flavors.
Aspergillus spp.	Grains, nuts, and dried fruits.	Production of aflatoxins, leading to potential health risks and spoilage.
Clostridium spp.	Canned foods and vacuum-packed products.	Anaerobic spore-forming bacteria, causing spoilage and food-borne illnesses.
Rhizopus spp.	Soft fruits and vegetables.	Rapid growth and spread, leading to soft rot and mold growth.

2) enzymatic reactions: - Natural enzymes present in foods can lead to changes in color, flavor, and texture during processing and storage. - To address enzymatic reactions in fruits and vegetables, techniques like blanching or freezing are used to preserve quality. - The ripening of fruits is influenced by enzymatic reactions, necessitating careful handling during harvesting and storage. Sure! Here's a table summarizing how enzymatic reactions spoil food, including the enzymatic pathways involved and the chemical reactions that take place:

TABLE III
ENZYMATIC REACTIONS AND FOOD SPOILAGE

Enzymatic Reactions	**Food Type**	**Chemical Reaction**
Polyphenol Oxidase	Fruits	Polyphenols → Quinones
Lipase	Dairy Products	Triglycerides → Free Fatty Acids
Protease	Meat and Fish	Proteins → Peptides and Amino Acids
Amylase	Starch-based Foods	Starch → Maltose
Pectinase	Fruits and Vegetables	Pectin → Pectic Acid
Cellulase	Cellulosic Foods	Cellulose → Glucose
Phytase	Grains, Nuts, and Seeds	Phytate → Inorganic Phosphate

3) oxygen exposure : - Oxygen exposure can trigger oxidative rancidity in fats and oils, impacting the overall quality of food products. - Adequate packaging solutions play a crucial role in reducing oxygen exposure, especially in products containing fats and oils, such as snack foods and nuts.

TABLE IV
FOOD TYPE AND MOISTURE CONTENT

Food Type	**Moisture Content (%)**
Fresh Fruits	80 - 95
Fresh Vegetables	80 - 95
Meat and Poultry	60 - 75
Fish and Seafood	60 - 80
Dairy Products	35 - 85
Grains and Cereals	10 - 14
Dried Fruits	10 - 20
Dried Nuts	2 - 5
Dried Seeds	4 - 10
Frozen Foods	0 - 2
Refrigerated Foods	Varies

4) moisture: - Moisture content significantly affects microbial growth and enzymatic activity in various food items. - Proper drying and storage are essential in grain production to prevent mold growth and mycotoxin formation. - Moisture control is critical in baked goods to prevent mold growth and maintain freshness.

TABLE V
FOOD TYPE AND MOISTURE CONTENT

Food Forms	**Moisture content**
Fresh Fruits	80 - 95
Fresh Vegetables	80 - 95
Meat and Poultry	60 - 75
Fish and Seafood	60 - 80
Dairy Products	35 - 85
Grains and Cereals	10 - 14
Dried Fruits	10 - 20
Dried Nuts	2 - 5
Dried Seeds	4 - 10
Frozen Foods	0 - 2
Refrigerated Foods	Varies

5) temperature abuse: - Maintaining proper temperature control is essential to avoid rapid microbial growth and enzymatic reactions in perishable foods. - In meat processing, maintaining appropriate temperatures is crucial to prevent the growth of pathogenic bacteria.

TABLE VI
FOOD TYPE AND RECOMMENDED STORAGE TEMPERATURE

Food Forms	Description
Fresh Fruits	32°F to 50°F (0°C to 10°C)
Fresh Vegetables	32°F to 50°F (0°C to 10°C)
Meat and Poultry	32°F to 40°F (0°C to 4°C)
Fish and Seafood	32°F to 40°F (0°C to 4°C)
Dairy Products	Varies - Milk: 32°F to 40°F (0°C to 4°C) ,Cheese: 35°F to 45°F (2°C to 7°C) ,Yogurt: 32°F to 40°F (0°C to 4°C)
Grains and Cereals	Room temperature (cool, dry place)
Dried Fruits	Room temperature (cool, dry place)
Dried Nuts	Room temperature (cool, dry place)
Dried Seeds	Room temperature (cool, dry place)
Frozen Foods	0°F to -10°F (-18°C to -23°C)
Refrigerated Foods	32°F to 40°F (0°C to 4°C)

6) contamination: - Food can be contaminated at different stages of production, from agricultural practices to processing facilities. - Stringent adherence to food safety practices and sanitation measures is vital to prevent contamination.

TABLE VII
CONTAMINANTS IN FOOD PRODUCTS AND THEIR IMPACT

Contaminant	Food Product	Impact on Food
Salmonella	Poultry, Eggs, Meat	Causes foodborne illnesses.
E. coli	Raw Vegetables, Dairy	Causes severe food poisoning.
Mycotoxins	Grains, Nuts, Spices	Can cause liver and kidney damage.
Pesticides	Fruits, Vegetables	Can lead to acute and chronic health effects.
Heavy Metals	Fish, Seafood	Can cause neurological and developmental issues.
Melamine	Dairy Products	Can cause kidney stones and renal failure.
Ciguatera Toxin	Reef Fish	Causes ciguatera fish poisoning.
Histamine	Tuna, Mackerel	Can cause scombroid poisoning with allergic reactions.
Norovirus	Ready-to-eat Foods	Causes gastroenteritis and food poisoning outbreaks.

7) inadequate packaging: - Inadequate packaging can expose food to moisture, air, and contaminants, leading to spoilage. - Ensuring the use of proper packaging materials and techniques is essential to preserve the quality of products like snacks, cereals, and processed meats.

8) time and age of food: - Food quality can deteriorate over time due to microbial growth and enzymatic activity. - Regular inventory control and rotation of perishable goods are essential practices in retail and foodservice settings.

9) pest infestation: - Pest infestation can contaminate food products during storage and transportation. - Implementing effective pest control measures is crucial in grain storage facilities and warehouses.

10) chemical reactions: - Chemical reactions between food components or with packaging materials can impact taste and quality. - Selecting appropriate packaging materials to prevent negative interactions with food is crucial.

TABLE VIII
CHEMICAL PATHWAYS AND REACTIONS IN FOOD SPOILAGE

Chemical Pathway/Reaction	Food Components	Spoilage Effect
Oxidation	Fats and Oils	Rancidity, off-flavors, and odors due to the breakdown of unsaturated fatty acids.
Enzymatic Browning	Phenols in Fruits and Vegetables	Browning of tissues and development of off-flavors and colors.
Hydrolysis	Proteins and Lipids	Breakdown of proteins and fats into smaller compounds, causing spoilage.
Fermentation	Carbohydrates	Production of acids, alcohols, and gases leading to souring and gas formation.
Lipolysis	Triglycerides	Formation of free fatty acids, leading to rancidity in fats and oils.
Lipid Oxidation	Fats and Oils	Oxygen reacts with lipids, producing off-flavors and damaging nutrients.
Maillard Reaction	Amino Acids and Sugars	Browning, off-flavors, and reduction in nutritional value.
Hydrolytic Rancidity	Fats and Oils	Hydrolysis of triglycerides into glycerol and free fatty acids, causing rancidity.
Fungal Mycotoxin Production	Grains, Nuts, Spices	Production of toxic compounds by molds and fungi.

11) improper processing: - Inadequate processing can leave surviving microorganisms that cause spoilage. - Ensuring proper heat treatment, such as pasteurization and canning, is vital to prevent foodborne illnesses.

II. Food Preservation

CHEMICAL METHODS

Chemical methods play a significant role in food preservation by preventing microbial growth and preserving food quality. Preservatives such as sodium benzoate, sorbic acid, and potassium sorbate are added to food products to inhibit the growth of bacteria, yeasts, and molds, thus extending their shelf life. Antioxidants like ascorbic acid, BHA, and BHT are utilized to prevent the rancidity of fats and oils in processed foods. Nitrates and nitrites act as curing agents in cured meats, effectively inhibiting harmful bacteria while preserving the characteristic color. Chelating agents, like EDTA, are employed to bind metal ions in food, preventing metal-catalyzed oxidation. Additionally, acidulants like citric acid create an acidic environment that hinders microbial growth. It is crucial to use these chemicals within regulated limits to ensure food safety and quality. Furthermore, ongoing research is focused on exploring natural alternatives to align with consumer preferences for more natural food preservation methods. Chemicals : Sodium Benzoate (E211): A widely used preservative in acidic food products like fruit juices and pickles. Sorbic Acid (E200):Frequently used in cheeses, beverages, and bakery products. Nitrates (E251) and Nitrites (E250):Found in cured meats like bacon, ham, and sausages to preserve color and inhibit bacterial growth. Sulfites (Sulfur Dioxide - E220):Used to prevent discoloration and inhibit microbial growth in dried fruits, wines, and processed potatoes. Ascorbic Acid (Vitamin C - E300):An antioxidant utilized in canned fruits and vegetables to maintain color and nutrient content. BHA (Butylated Hydroxyanisole - E320) and BHT (Butylated Hydroxytoluene - E321):Synthetic antioxidants used to prevent rancidity in fats and oils, commonly found in cereals, snack foods, and processed meats. Potassium Sorbate (E202): Effective mold inhibitor used in cheeses, wines, and baked goods. Calcium Propionate (E282): Used to prevent mold growth in bread and other baked goods. Ethylene Diamine Tetraacetic Acid (EDTA - E385): A chelating agent used in canned seafood and beverages to prevent metal-catalyzed oxidation. Propionic Acid (E280): Used in bread, cheese, and bakery products to inhibit mold and bacteria growth.

1) Affects of chemicals on food:

- - Inhibits Microbial Growth: Chemical preservatives, such as sodium benzoate and sorbic acid, effectively inhibit the growth of bacteria, yeasts, and molds, leading to an extended shelf life for food products.
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- Prevents Oxidation: Antioxidants like ascorbic acid, BHA, and BHT play a vital role in preventing oxidative reactions, thereby protecting fats and oils from becoming rancid and maintaining the quality of the food. - Retains Color: Nitrates and nitrites act as curing agents in cured meats, preserving the characteristic pink color while also preventing the growth of harmful bacteria. -
- Chelating Agent: EDTA serves as a chelating agent that binds metal ions in food, effectively preventing metal-catalyzed oxidation and preserving the quality of canned foods. -
- Adjusts Acidity: Acidulants like citric acid are used to create an acidic environment that inhibits microbial growth, particularly in products like beverages and sauces. -
- Inhibits Mold Growth: Potassium sorbate is known for its ability to inhibit mold growth in various food products, such as cheeses, wines, and baked goods. -
- Preserves Texture: Chemicals like calcium propionate are employed to maintain the texture of baked goods by inhibiting mold and bacterial growth. -
- Enhances Shelf Life: Proper use of chemicals significantly extends the shelf life of food products, contributing to a reduction in food waste. -
- Ensures Food Safety: Chemical preservation plays a crucial role in preventing foodborne illnesses by controlling the growth of pathogenic microorganisms in food products. -
- Facilitates Global Distribution: Chemical preservation enables the safe transportation of food products over long distances without spoilage, thereby supporting international trade and ensuring food security.

PHYSICAL METHODS

A. Conventional Methods

Traditional methods of food preservation and storage are ancient techniques utilized to extend the shelf life of food and safeguard it from spoilage. These practices have been refined by various cultures over centuries and passed down through generations. While there might be some common ground between the terms ”conventional” and ”traditional,” they generally address different aspects of food preservation.

1. **Drying/Dehydration**: Drying is one of the oldest methods of food preservation. It involves removing moisture from food through natural processes such as sun drying, air drying, or using smoke. Dehydration inhibits microbial growth by reducing the water activity in the food, making it less conducive to bacterial and fungal growth. Various fruits, vegetables, grains, and meat can be preserved through drying.

2. **Salting**: Salting is a traditional preservation technique that involves the addition of salt to food items. Salt draws out moisture from the food, creating an environment with lower water activity, which inhibits the growth of bacteria and other microorganisms. Salted fish and vegetables are common examples of this preservation method.

3. **Fermentation**: Fermentation is a natural preservation process where beneficial microorganisms, such as lactic acid bacteria, convert sugars and starches in food into acids and alcohols. These acids and alcohols lower the pH of the food, creating an acidic environment that prevents the growth of spoilage and pathogenic bacteria. Fermented foods like sauerkraut, kimchi, and yogurt have been consumed for their enhanced shelf life and probiotic benefits.

4. **Smoking**: Smoking is a preservation technique commonly used for meat, fish, and cheese. The smoke from burning wood contains antimicrobial compounds that help preserve the food and enhance its flavor. The process of smoking also involves drying the food, further reducing its moisture content and inhibiting bacterial growth.

5. **Canning**: Canning is a preservation method that involves placing food in airtight containers and subjecting it to heat to destroy microorganisms, particularly Clostridium botulinum spores. The heat treatment, known as canning, ensures a sealed environment, preventing recontamination. Canned foods have a long shelf life and can be stored without refrigeration.

6. **Use of Herbs and Spices:** Various herbs and spices have been used for centuries to preserve food due to their natural antimicrobial properties. For example, garlic, ginger, cinnamon, and cloves have shown antimicrobial activity against a range of bacteria and fungi. Incorporating these herbs and spices into food preparation provides both preservation and flavor-enhancing benefits.

B. Non-Conventional Methods

- **Modern Techniques for Food Preservation**

Food preservation holds paramount importance within the food industry, safeguarding perishable food items to maintain their safety, nutrition, and availability for consumption over extended periods. Time-honored techniques like canning, drying, salting, and fermentation have served for centuries, but with the advent of modern technology, various machines have emerged, significantly enhancing the efficiency and effectiveness of food preservation processes. These revolutionary machines have ushered in a new era for the food preservation industry, enabling superior quality control, heightened productivity, and prolonged shelf life for an array of food products. Let's delve into some common food preservation methods that machines have facilitated:

1) Refrigeration: Both in commercial and household settings, refrigerators and freezers are indispensable appliances. They rely on a refrigeration cycle to cool and maintain perishable food items at temperatures that impede microbial growth. Fruits, vegetables, meats, dairy products, and other perishables benefit from this method, ensuring their freshness for an extended duration.
2) Freezing: Commercial freezing machines, like blast freezers and tunnel freezers, have been specifically designed to rapidly freeze food items. The quick freezing process forms smaller ice crystals, preventing damage to the cellular structure of the food, thus retaining its quality and nutrients. Frozen foods boast an extended shelf life and offer convenient storage and distribution
3) Vacuum Packaging: The use of vacuum sealers, machines that eliminate air from food packaging, creates a vacuum inside. This method thwarts the growth of spoilage-causing bacteria that require oxygen to thrive. By removing oxygen, vacuum packaging extends the shelf life of products such as meat, fish, vegetables, and grains.
4) Dehydration: Food dehydrators or drying machines extract moisture from food items, thereby inhibiting the growth of microorganisms that spoil food. Reduced moisture content also makes the food lighter and more compact for storage. Dried fruits, jerky, and various herbs exemplify foods preserved using this method.
5) Canning: Automatic canning machines have simplified the process of preserving food in airtight containers. Canning involves heating food to destroy bacteria and other microorganisms, subsequently sealing it in cans or jars to prevent further contamination. Canned goods, including fruits, vegetables, soups, and sauces, possess extended shelf lives and necessitate no refrigeration until opened.
6) Pasteurization: Pasteurization machines are widely employed in the dairy industry to heat milk and other dairy products to a specific temperature, effectively eliminating harmful bacteria while preserving taste and nutritional value. This process significantly extends the shelf life of perishable dairy products.

The integration of technology with traditional food preservation methods has brought significant improvements to the preservation and storage of food. Time-tested techniques have been enhanced by modern advancements, resulting in more efficient and safer practices. Advanced equipment, quality control measures, and standardized processes have made traditional methods more reliable and commercially viable. Additionally, packaging innovations, improved storage facilities, and efficient transportation have extended the shelf life of preserved foods. Technology has also facilitated the sharing of traditional knowledge globally, preserving cultural heritage while meeting modern demands. Striking a balance between technology and tradition ensures the authenticity and nutritional value of preserved foods in today's food industry.

- **Advanced Technologies of Food Preservation**

Advanced food preservation techniques, such as High-Pressure Processing (HPP), Pulsed Electric Field (PEF), Ultrasound Technology, Vacuum Packaging, Nanotechnology, Cold Plasma Technology, Electron Beam Irradiation, Ozone Treatment, Edible Coatings, Smart Packaging, and Biopreservation, have gained worldwide prominence for various reasons. These methods play a pivotal role in ensuring improved food safety by inactivating pathogens and spoilage microorganisms, resulting in safer food consumption. Moreover, advanced preservation techniques significantly extend the shelf life of perishable foods, thereby reducing food waste. They also preserve the nutritional content and enhance the overall quality, taste, texture, and appearance of food products, leading to higher consumer satisfaction. Additionally, these methods allow for efficient global trade and distribution, enabling food to reach diverse markets and consumers. By meeting the demands for safe, long-lasting, and high-quality food products, advanced techniques have become integral to the food industry. Moreover, they help minimize the reliance on chemical additives and address climate-related challenges, contributing to sustainable food preservation practices. Through continuous research and innovation, these technologies continue to revolutionize the preservation landscape, ensuring food security and safety on a global scale.

1) High Pressure Processing (HPP) High Pressure Processing uses high hydrostatic pressure to remove microorganisms like bacteria, molds, etc., enzymes, and pathogens that reduce the quality and of the food products. It will help to increase the shelf life of the food while retaining the nutritional value and organoleptic attributes of the food. Unlike most of the food preservation techniques HPP uses water instead of heat or other chemicals. It is known as the "clean label" technology as it does not use any chemicals for the food preservation. Water is introduced at a high uniform pressure usually at 600MPa or 87,000Psi. The food products are packaged in flexible packages like plastic containers or pouches and then introduced into the pressure water chamber. Pressure applied on the products should be uniform and simultaneous from all directions. HPP is effective to inactivate food spoilage organisms like bacteria, fungi, viruses, parasites, etc. This non-thermal technique will not lead to any undesirable changes in the taste or texture of the food products and helps to retain the vitamins, enzymes and antioxidants of the food product.
2) Pulsed Electric Field Technology Pulsed Electric Field(PEF) technology uses short intense burts sof electric energy to disrupt the cellular structures in the food. The food is placed in between two electrodes of high electric voltage, usually in the range of 20-80kV/cm. The food is subjected to electric pulses that are of short duration, ranging from microseconds to milliseconds. These pulses create pores or holes in the cell membranes of microorganisms and plant tissues present in the food. The microbial enzymatic activities will be inactivated due to the disruption of cellular structures extending the shelf life of the food products.PEF requires less energy compared to thermal processing, making it a potentially more environmentally friendly technology. PEF is used to enhance the extraction of juice from fruits and vegetables while maintaining the product's nutritional quality and taste. PEF treatment of milk has been shown to improve milk quality, extend shelf life, and inactivate pathogens without compromising the nutritional content. PEF can be applied to fruits and vegetables to extend their shelf life, reduce spoilage, and retain their fresh-like characteristics. PEF treatment of meat has shown potential in tenderization, pathogen reduction, and shelf life extension.
3) Vacuum Cooling Vacuum cooling is one of the best evaporative cooling methods to increase the shelf life of the food. It is mainly used to preserve horticultural products like fruits and vegetables by reducing post-harvesting thermal deterioration. Under atmospheric pressure, water boils at 100°C. But if the imposed pressure is reduced to 611 Pa water can boil at 0°C producing a cooling effect. The water inside the porous and moisture foods when subjected to vacuum pressure can boil to achieve this cooling effect. The vacuum cooling technique is performed by placing the fresh produce in a vacuum chamber. The air from the vacuum chamber is then removed to create a low pressure environment. As the pressure inside the chamber decreases, the boiling point the moisture inside the food also decreases lowering the product temperature. Vacuum cooling is commonly used for cooling vegetables, leafy greens, fruits, mushrooms, and other delicate products. However, it is essential to note that not all food items are suitable for vacuum cooling, and certain precautions need to be taken. Some items might experience physical damage or collapse due to the rapid pressure change.
4) Cooling tunnels Products can efficiently cool down in a controlled atmosphere provided by cooling tunnels, lowering the risk of contamination and extending shelf life. Food products are cooled using a combination of airflow and refrigeration in cooling tunnels. Typically, the tunnels are conveyor systems, in which food items are loaded onto a conveyor belt and moved through the tunnel. Cooled air flows over and around the products as they pass through the tunnel, removing heat and lowering their temperature. Automated systems are frequently used to control the cooling process. By keeping an eye on the temperature and airflow, these systems make sure that the food products cool to the proper temperature in the allotted time. The texture, flavor, and appearance of the food products are preserved thanks to this controlled chilling. Cooling tunnels help prevent the formation of harmful microorganisms, which is crucial for perishable food products. The risk of bacterial contamination is reduced by rapidly lowering the temperature, improving food safety. Rapid chilling serves in reducing the rate of food products' deterioration, hence extending their shelf life. This is particularly advantageous for perishable fresh and refrigerated commodities. Large ice crystals in frozen foods are prevented by controlled cooling since they can harm cells and have a poor effect on texture and flavor. The quality of frozen food items is maintained through cooling tunnels, which encourage the production of smaller ice crystals. Advanced refrigeration systems and airflow optimization are used in the design of cooling tunnels to maximize energy efficiency.
5) Freeze Drying Using a vacuum to sublimate the frozen water from ice to vapor, freeze-drying, sometimes referred to as lyophilization, is a sophisticated method of food preservation. It entails freezing the food product to remove the water from it. A stable, dry food with intact flavor, color, texture, and nutritional content is the result of this method. The freezing, primary drying (sublimation), and secondary drying (desorption) phases of the freeze-drying process are the three key steps. The food product is quickly frozen at extremely low temperatures during the freezing step, often below

-40°C (-40°F). Ice crystals are created inside the food structure during the freezing process. In the sublimation or primary drying stage the water is directly turned into vapor without passing through the liquid phase by reducing pressure in a controlled environment. Freeze drying machines use vacuum pumps to reduce the pressure. The formed water vapor is then collected and eliminated from the system. In the secondary drying or desorption phase, the temperature is slightly increased to get rid of any remaining moisture after the sublimation. This step is crucial to reduce the microbial growth and activity. Freeze-drying is the best preservation technique to preserve the nutritional quality of the food. It helps to retain the original color, texture and flavor of the food products. Free-dried food also has an extended shelf life and is rehydratable. Since freeze-dried foods have most of their water removed, they become significantly lighter and take up less space, making them ideal for transportation and storage.

TABLE IX
COMPARISON BETWEEN MODERN AND TRADITIONAL METHODS OF FOOD PRESERVATION AND STORAGE

Aspect	Modern Methods	Traditional Methods
Technological Advancements	Incorporate advanced technologies like refrigeration, freezing, pasteurization, and vacuum packaging to extend shelf life efficiently.	Rely on natural methods like sun-drying, salting, smoking, and fermentation passed down through generations.
Preservation Time	Can extend the shelf life of food for much longer periods, ranging from weeks to years.	Typically suitable for short-term preservation, usually up to a few months.
Nutritional Value	Retains better nutritional value due to controlled temperature and minimal exposure to contaminants.	May lead to some nutrient loss due to prolonged exposure to environmental factors.
Scaling	Suitable for large-scale industrial production and global distribution.	Often limited to small-scale and local use.
Convenience	Offers convenient and readily available preserved food products.	Requires more effort in preparation and may have limited availability.
Cost	Generally higher costs due to technology and infrastructure investments.	Often more cost-effective as it relies on traditional practices and local resources.
Chemical Additives	May use some preservatives and additives for extended shelf life.	Usually no or minimal use of chemical additives.
Environmental Impact	Some modern methods can generate waste and have a higher carbon footprint.	Generally more eco-friendly and sustainable.
Examples	Canning, Freeze-drying, Vacuum Packing.	Sun-drying, Salting, Fermentation.

- *C. Modern Packaging Techniques*

The advancements in material science, concerns about sustainability and consumer demands for higher quality food has helped in the evolution of packaging techniques in food industry. Unlike the early times, now packaging is not just about storing the food safely, it's about interacting with the food and improving their quality and being transparency about the quality of the product to the customer s. Some of the advanced mode of food packaging techniques currently used are Active packaging techniques. Active packaging interacts with the packaged food improving the quality and increasing the shelf life of the food. It maintains the freshness of the food while addressing different sustainability and environmental challenges.

1) Oxygen scavengers are the main type of active packaging used currently. A certain level of oxygen in the packaging will reduce the nutritional value of the food thus reducing its shelf life. Vacuum sealing can remove around 90-95
2) Ethylene scavengers are the type of active packaging materials used to pack fruits and vegetables. Ethylene is a phytohormone that is responsible for the ripening, degradation of chlorophylls and deterioration of fruits and vegetables. The main component in ethylene scavengers are potassium permanganate. The potassium permanganate in the packaging will oxidize the ethylene into carbon dioxide and water thus slowing down the ripening and degradation fruits and vegetables inside the package.
3) Carbon dioxide generating system is another innovative method to increase the shelf life of food products. High CO2 levels inhibit the microbial growth on the surfaces of food products. So, impregnation of a package with CO2 is practiced increasing the shelf life of food products. This type of packaging is used for fish, meat, poultry, cheese, etc.
4) Intelligent packaging is one of the most creative and successful active packaging. It is found that the composition of headspace of food packages are changed over times. Intelligent packaging is equipped to identify and report these changes in the food package, the temperature change and microbiological quality of the food products. Time-temperature indicators are of two types: visual and radio frequency identification (RFID) tag. The visual indicators change colour when the temperature is changed. In case of RFID tag, the radio waves emitted from the tag is converted to data and this data is then passed to a host computer for further analysis. The seal and leak indicators helps to find any leak in the packaging. The gas composition of the package headspace is monitored continuously for any variation. The visual indicator changes color when the oxygen concentration of package headspace exceed the required limit.

D. Regulatory Bodies in Food Industry

Regulatory authorities in the food industry play a vital role in safeguarding the safety, quality, and authenticity of the food supply chain. Their main responsibility involves setting and enforcing standards, guidelines, and regulations that govern various aspects of food production, processing, labeling, and distribution. Their primary focus is to safeguard consumers from potential health hazards and deceptive practices while promoting fairness and transparency in the food sector. Here are some key regulatory bodies involved in overseeing the food industry:

1) Food and Drug Administration (FDA): The FDA serves as the primary regulatory body in the United States, ensuring the safety and accurate labeling of food products, both for humans and animals. They oversee a broad spectrum of food items, ranging from fresh produce to processed foods, dietary supplements, and food additives. Additionally, the FDA plays a significant role in preventing, investigating, and responding to foodborne illnesses.
2) European Food Safety Authority (EFSA): Within the European Union, EFSA operates as an independent agency providing scientific advice on food safety matters. They evaluate and communicate potential risks associated with the food chain, including genetically modified organisms (GMOs), novel foods, food additives, and pesticides. EFSA's assessments are critical in establishing EU-wide food safety regulations.
3) Food Standards Australia New Zealand (FSANZ): FSANZ is the regulatory body responsible for developing food standards and regulations for Australia and New Zealand. They establish guidelines for food composition, labeling, contaminants, and hygiene throughout the food supply chain, ensuring the safety and consistency of food products in these countries.
4) Codex Alimentarius Commission: Established by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), the Codex Alimentarius Commission formulates international food standards, guidelines, and codes of practice to promote fair trade and protect consumers. It serves as a reference for many countries' food regulatory frameworks.
5) US Department of Agriculture (USDA): The USDA plays a crucial role in regulating certain aspects of the food industry, particularly those related to meat, poultry, and specific egg products. They oversee food safety during production and processing, ensuring compliance with mandatory inspection processes and standards.
6) European Commission Directorate-General for Health and Food Safety (DG SANTE): This department of the European Commission is responsible for health and food safety policies within the European Union. They develop and enforce regulations related to food safety, animal health, and plant health.
7) World Health Organization (WHO): While not directly focused on food regulation, the WHO provides guidance and establishes global standards for food safety, nutrition, and public health. They collaborate with other regulatory bodies to promote best practices and combat food-related health challenges worldwide.

These regulatory bodies collaborate with governments, food industries, and various stakeholders to ensure compliance with regulations, investigate food safety incidents, and conduct research to enhance food safety practices. Their collective efforts contribute to maintaining consumer confidence in the food supply chain, safeguarding public health, and fostering fair and ethical practices within the food industry.

III. Conclusion

In conclusion, food preservation and storage are essential for ensuring that there will constantly be access to healthy, savory food for both the present and the future. Humans have used a variety of methods throughout history to improve the shelf life of food and avoid deterioration, from ancient methods like drying and fermentation to contemporary inventions like refrigeration and freezing. With the growing global population and shifting patterns of food consumption, the significance of food preservation and storage has only increased. We can lessen food waste, fight food scarcity, and lessen the environmental impact of food production and distribution by implementing effective preservation techniques. The nutritional value and flavor of food can also be preserved for longer periods of time thanks to breakthroughs in technology and research in food preservation technologies. To ensure food safety and sustainability, it is crucial to find a balance between innovation and established methods. To limit the danger of foodborne illnesses and waste, people and communities must be educated on the safe handling and storage of food. In addition to promoting sustainable food preservation practices, governments and organizations must also fund research to create more effective preservation techniques. In conclusion, food preservation and storage are indispensable elements of our modern food systems, and by embracing responsible practices, we can contribute to a healthier, more food-secure, and environmentally sustainable world.

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