

A COMPREHENSIVE INFORMATION ON FOOD STORAGE AND PRESERVATION

Abstract

In order to keep food quality at the required level and maximise nutritional benefits, food preservation comprises a variety of food processing techniques. Growing, harvesting, processing, packaging, and distribution of food are all examples of food preservation techniques. The main goals of food preservation are to provide value-added goods, provide dietary variety, and combat improper agricultural planning. Numerous chemical and biological interactions could result in food deterioration. Drying, chilling, freezing, and pasteurisation are examples of traditional and archaic food preservation methods that have been promoted to prevent the chemical and microbiological deterioration of foods. The methods used to prevent these spoilages have evolved into a highly interdisciplinary discipline in recent years, becoming more sophisticated. Food items are preserved using cutting-edge technologies like irradiation, high pressure, and nanotechnology. The mechanisms, conditions of use, and a summary of the many food preservation methods are presented and discussed in this chapter. Additionally, this chapter lists various food categories and clarifies the various physical, chemical, and microbial factors that contribute to food spoilage. The experts and researchers working on food processing and food safety will find this article helpful in developing efficient and comprehensive methods to preserve foods.

Keywords: Food Preservation, Food storage, Food processing, Food spoilage, Preservatives, Microbes.

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I. INTRODUCTION

Lack of proper grain storage methods in developing nations causes losses of up to 20–30%, mainly as a result of postharvest pests. Smallholder farmers become trapped in poverty as a result of having to sell their grain shortly after harvest just to buy it back at a steep price a few months later. Farmers will not be able to reduce poverty and increase the security of their livelihoods if they are unable to store grains and sell excess output at profitable rates. In addition to contributing to environmental degradation and climate change, postharvest losses also require non-renewable resources like energy and fertiliser to produce, prepare, handle, and transport food that no one will ever eat. Pests in grain storage are associated to aflatoxin contamination and toxicity in addition to generating quantitative losses (Tefera and Abass, 2012).

The goal of agricultural intensification initiatives is to uncover best practises and creative solutions for raising agricultural output in ways that boost farm households' income and nutrition. However, a rise in land productivity without equivalent rises in the amount of food that is stored, processed, and prepared from the surplus crop might increase postharvest losses by a factor of more than 40%. Therefore, it is unclear whether agricultural intensification would make food insecurity and poverty worse or better for households who are unable to store extra produce; the majority of smallholder farmers fall into this group. Poverty may get worse due to increased intensification costs and decreased income from higher post-harvest losses. Therefore, enhancing smallholders' ability to process, store, and produce nutrient-dense meals for home use is a prerequisite for lowering poverty, hunger, and malnutrition in agricultural communities that are becoming more intensive (Tefera and Abass, 2012).

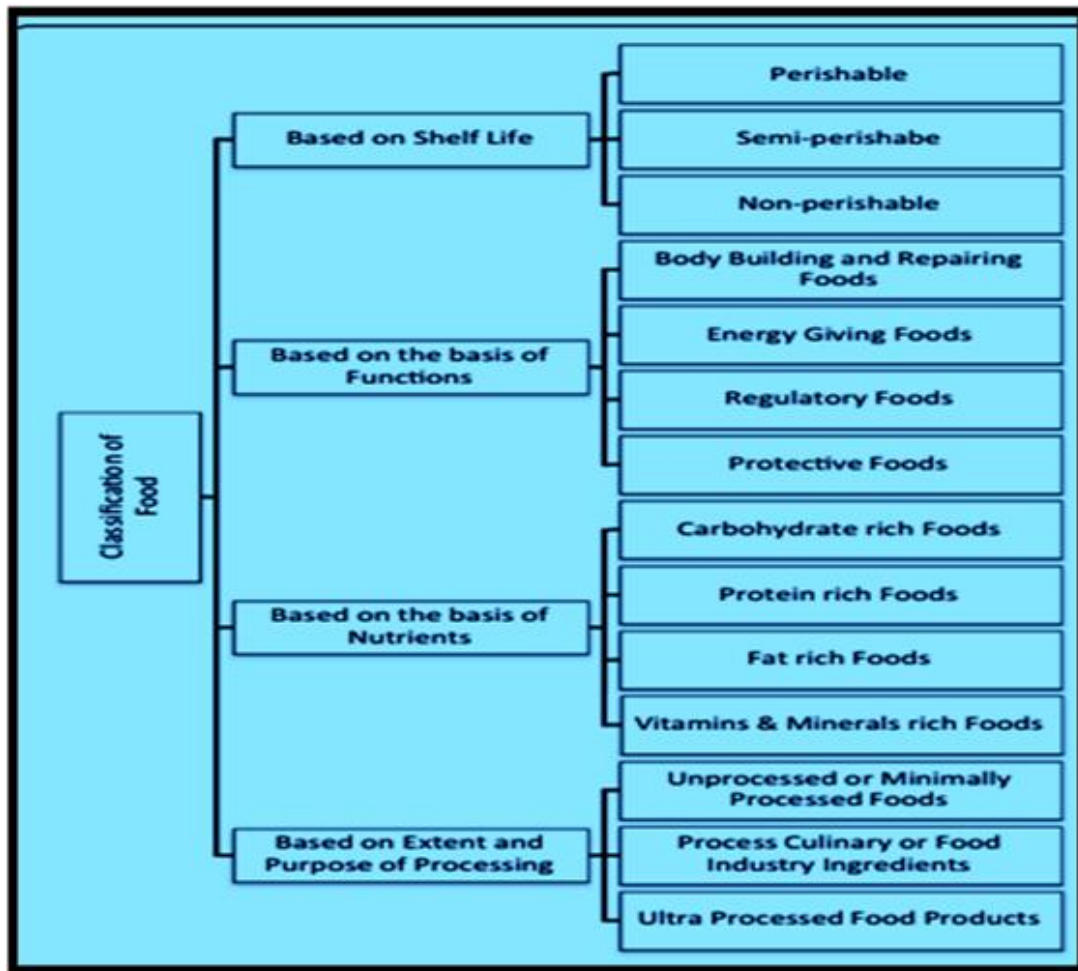
Food items will encourage the growth of bacteria since they are chemically composed of carbohydrates, protein, fat, water and minor amounts of organic and mineral substances, all of which serve as the microbes' main sources of energy for growth. To avoid this, several preservation techniques are suggested by Rahman, (2007). A preservative is a natural or synthetic substance that is added to a variety of goods, including food, medicine, paint, and wood, to stop microbial growth or unfavourable chemical changes from causing the goods to decompose. These preservatives are frequently included in a variety of foods and medicinal goods to lengthen their shelf lives (Shaikh et al. 2016).

To ensure the intake of food with a high nutritional content, which is essential for human health, food quality must be maintained. Therefore, the best way to preserve food quality and prevent it from deteriorating is to use preservation procedures. There are currently many different preservation procedures available to maintain the quality of food products for an extended period of time. Both conventional and cutting-edge preservation technologies can be used in conjunction with these procedures. Some of these preservation procedures also employ additional food preservatives, which may be further separated into artificial and natural preservatives. It is advisable to use artificial food and cosmetic additives sparingly since although while many of them are regarded to be safe, some of them have been related to cancer and are exceedingly hazardous. All synthetic chemical additives and preservatives should be avoided in general as many of them have not passed appropriate testing (Shaikh et al. 2016).

II. CLASSIFICATION OF FOODS

Foods may be widely categorised based on their shelf lives, uses, nutrient content, and processing methods (Table 1). The following sections provide a quick summary of several food groups.

Table 1: Classification of Food



(Source: Steele, 2004; Doyle, 2009)

1. Food categories based on shelf life: Food items can be divided into perishable, semi-perishable, and non-perishable categories based on their shelf life (Doyle, 2009).

- Perishable Foods that spoil quickly, with a shelf life of a few days to around three weeks. Perishable food items include meats, eggs, milk and dairy products, poultry, and shellfish. If unique preservation methods are not established, food products may deteriorate immediately (Doyle, 2009).
- Semi-perishable food items may be kept for a considerable length of time six months under ideal storage circumstances. Potatoes, vegetables, fruits, and cheeses are some examples of semi-perishable foods (Doyle, 2009).

- Non-perishable foods with an indefinite shelf life include both natural and processed foods. These foods have an extended shelf life of many years or more. Non-perishable foods include things like dry beans, almonds, sugar, canned fruit, mayonnaise, and peanut butter, to name a few (Doyle, 2009).

2. Food categories based on extent and purpose of processing: The food industries utilise a variety of food processing methods to transform fresh ingredients into food items. According to the extent and purpose of food processing, foods may be divided into three primary categories (Monteiro et al. 2010): (a) unprocessed or minimally processed foods, (b) processed culinary or food industry ingredients, and (c) ultra-processed food products. Table 2 categorises foods according to the extent and purpose for processing.

Table 2: Classification of Food Based on the Extent and Purpose of Processing

Food group	Extent and purpose of processing	Examples
Unprocessed or minimally processed foods	No processing or mostly physical processes used to make single whole foods more available, accessible, palatable, or safe	Fresh, chilled, frozen, vacuum-packed fruits, vegetables, cereals; fresh frozen and dried beans and other pulses; dried fruits, unsalted nuts, and seeds; fresh, dried, chilled, frozen meats, poultry, and fish; fresh and pasteurized milk, yoghurt, eggs, tea, and coffee
Processed culinary or food industry ingredients	Extraction and purification of components of foods, resulting in producing ingredients used in the preparation and cooking of dishes and meals, or in the formulation of ultra-processed foods	Vegetables, butter, milk cream, sweeteners, raw pastas, and noodles; food industry ingredients, such as high-fructose corn syrup, preservatives, and cosmetic additives
Ultra-processed food products	Processing of a mix of process culinary, or food industry ingredients and processed or minimally processed foodstuffs in order to produce accessible, convenient, palatable, ready-to-eat or to-heat food products with longer shelf life	Breads, biscuits, cakes, and pastries; ice-cream, chocolates, cereal bars, chips; sugared fruits, milk drinks, and other soft drinks; pre-prepared meat, poultry, fish, and vegetable; processed meat including chicken nuggets, hot dogs, sausages, burgers; salted, pickled, smoked, or cured meat and fish; vegetables bottled or canned in brine; fish canned in oil

(Source: Monteiro et al. 2010)

III. FOOD SPOILAGE

The natural process of food spoiling causes food to progressively lose its colour, texture, flavour, nutritional value, and edibility. Consuming spoiled food can result in disease and, in the worst case scenario, death (Steele, 2004). Food deterioration can result from a variety of physical, microbiological, or chemical processes. Since the deterioration brought on by one process might promote another, these mechanisms are not always mutually incompatible. The main causes of food deterioration include pH, temperature, air, nutrition and various chemicals present in the food (Steele, 2004). The following sections cover a variety of food spoilage-related topics:

1. **Physical spoilage:** Physical alterations or instability are the causes of physical food deterioration. Examples of physical deterioration include moisture gain or loss, moisture migration between distinct components, and physical separation of ingredients or components (Steele, 2004; Rahman, 2009). Moisture content, temperature, glass transition temperature, crystal development, and crystallisation are the main elements influencing physical deterioration.
 - **Moisture content:** The alteration in the water content of food items is a common reason for their deterioration. It might take the shape of water gain, water loss, or water migration (Fabunmi, et al. 2015). According to Steele, (2004) and Balasubramanian et al. (2010), the water activity (a_w) of a food item directly affects moisture transfer in food. According to Balasubramanian et al. (2010) and Barnwal et al. (2010), water activity (a_w) is a thermodynamic characteristic that is defined as the difference between the vapour pressure of water in a system and the vapour pressure of pure water at the same temperature. It is also possible to substitute equilibrium relative humidity at the same temperature for pure water vapour pressure. With increasing temperature, water activity in food items decreases. Generally speaking, foods have a water activity of 1 at room temperature, compared to 0.82 and 0.68 at 20 and 40 °C, respectively (Barbosa-Cánovas et al. 2005; Kader et al. 1989; Fennema, 1996).
 - **Temperature:** The most contributing element to the rotting of fruits and vegetables is temperature. The right temperature range can promote post-harvest vitality and delay ripening. Additionally, ideal relative humidity and ideal air flow around fruit and vegetables are needed for slow ripening. These ideal circumstances are sometimes referred to as modified atmospheres (MA). The metabolism of the commodities is often hampered by temperature, which also affects how quickly the target MA is attained (Kader et al. 1989). Foods that are prone to freeze damage may suffer unfavourable effects as a result of low temperatures. Food items become damaged when their cells break when partly frozen at lower temperatures. The majority of tropical vegetables and fruits are vulnerable to damage from chilling. This often happens between 5 and 15 °C prior to the food product starting to freeze (Steele, 2004).
 - **Glass transition temperature:** The glass transition temperature (T_g) affects how long food goods may be stored. Food products' solid constituents might be either crystalline or amorphous in nature. According to White and Cakebread, (1966), this phenomenon is influenced by the solids' composition, relative humidity and temperature. The amorphous matrix might exist as a rubber that is more liquid-like or as a highly viscous glass (Karmas et al. 1992). The shift from a glassy to a rubbery state takes place at the glass transition temperature. This process of second-order phase change occurs at a temperature that varies depending on the food. The glass transition temperature and food physical stability are connected. The concentration of water and other plasticizers has a significant impact on the glass transition temperature (T_g) (Levine et al. 1986). Due to the glass transition phenomenon, dry food products that are stored in extremely humid environments change in state (Steele, 2004).

- **Crystal growth and crystallization:** Food deterioration can also be a result of freezing. Foods that are slowly frozen or frozen several times suffer greatly as a result of crystal development. They have significant extracellular ice accumulation. These foods are more stable than processed meals that are frozen slowly because rapid freezing creates ice inside the food cells (Reid, 1990). Emulsifiers and other water binding agents can be introduced during freezing cycles to reduce the development of big ice crystals (Levine et al. 1988). Foods having a high sugar content can crystallise sugar as a result of moisture buildup or temperature rise. As a result, sugar rises to the surface from within and takes on a grey or white colour. Sugar crystallisation causes sugar cookies to stale, sweets to become grainy and ice cream to become grainy (Steele, 2004). Fructose or starch can be added to sugar solutions to prevent crystallisation. Additionally, time is a key factor in the sugar crystallisation process of food products above the corresponding glass transition temperature (Roos and Karel, 1991).
2. **Microbial spoilage:** Food spoilage that results from the action of microorganisms is known as microbial spoilage. Additionally, it is the main source of foodborne illnesses. Different microbes frequently damage perishable foods. By modifying storage temperature, lowering pH, lowering water activity, employing preservatives, and utilising suitable packing, the development of the majority of bacteria may be delayed or stopped (Tianli et al. 2014). Molds, yeasts, and bacteria are the three main kinds of microorganisms that cause food to deteriorate.
- **Factors affecting microbial spoilage:** Food microbiological deterioration can be influenced by both intrinsic and extrinsic variables (Jay, 2000). The projected shelf life or perishability of foods is determined by their inherent qualities, which also have an impact on the kind and pace of microbial deterioration. The main intrinsic factors that contribute to food spoiling include oxygen, endogenous enzymes, light sensitivity and substrates (in't Veld, 1996). These characteristics can be modified during the food product's formulation to regulate food quality and safety (Doyle, 2009). Water activity, pH, nutritional content, and oxidation-reduction potential are examples of intrinsic characteristics that cause food to degrade (Steele, 2004; Doyle, 2009; Jay, 2000). Food deterioration is caused by extrinsic variables such as temperature, relative humidity, the presence of other bacteria, and their activity (Steele, 2004; Jay, 2000).
3. **Chemical spoilage:** Foods inherently undergo chemical and biological processes, which provide unappealing sensory outcomes in food items. Fresh foods may experience minor changes in quality due to (a) microbial growth and metabolism, which results in pH changes, (b) toxic substances, and/or (c) the oxidation of lipids and pigments in fat, which produces unfavourable flavours and colours (in't Veld, 1996; Van Boekel, 2008). Microbial activities and chemical deterioration are interlinked. However, chemical processes such as oxidation are solely dependent on changes in temperature (in't Veld, 1996).
- **Oxidation:** Ammonia and organic acid are produced when amino acids interact with oxygen. This is the basic spoiling response for fresh meat and fish kept in the refrigerator (Jay, 2000). According to Enfors, (2008), the process of unsaturated fats

(lipids) reacting with oxygen is known as "rancidification," which is referred to as lipid oxidation. Color change, off-flavor development, and poisonous material creation are the effects on food products (Steele, 2004). The presence of metal oxides can catalyse rancidification, and light exposure accelerates the process. Carbonyl molecules, which are in charge of giving food its sour flavour, are created as a result of this reaction (Enfors, 2008).

- **Proteolysis:** The restricted and highly selective hydrolysis of peptide and iso-peptide bonds inside a protein constitutes proteolysis, a common and irreversible posttranslational alteration. Multiple protease enzymes are required for the overall phenomenon (Rogers, 2013). Numerous regulatory mechanisms use a variety of specialised proteases. Furthermore, both normal and pathological circumstances are linked to very specialised proteolytic events (Igarashi, 2007). Nitrogen-containing foods usually cause this response. Small-sized amino acids are ultimately formed from proteins after they have undergone proteolysis.
- **Putrefaction:** When amino acids divert to a combination of organic acids, amines and pungent-smelling sulphur compounds like hydrogen sulphide and mercaptans, it is referred to as putrefaction. The necessity of bacteria throughout the process makes this a biological phenomenon. Protein putrefaction also produces indole, phenols, and ammonia in addition to amino acids (Panda, 2003). The majority of these compounds have unpleasant smells. At temperatures higher than 15 °C, putrefaction is fairly prevalent in meats and other protein-rich meals. The increased warmth makes microbial activity easier (Enfors, 2008; Panda, 2003).
- **Maillard reaction:** Another major factor in food decomposition is non-enzymatic browning, sometimes referred to as the Maillard reaction. The proteins' amino group, or the amino acids found in food, undergoes this process. Common Maillard reaction effects include colour darkening, decreased protein solubility, bitter taste development, and decreased nutritional availability of certain amino acids. When dry whole eggs, breakfast cereals and dry milk are stored, this reaction takes place (Desrosier et al. 2014).
- **Pectin hydrolysis:** Dicotyledonous and certain monocotyledonous plants' cell walls are nearly one-third made up of pectin, which are complex combinations of polysaccharides (Hof and Castro, 1969; Walter, 1991). During fruit ripening, indigenous pectinases are produced or activated, causing pectin hydrolysis, which weakens the structure of food. Mechanically caused damage to fruits and vegetables can also trigger pectinases and start a microbial attack (Enfors, 2008). Pectin methyl esterase has the ability to de-esterify pectin compounds as well. By fortifying cell walls and boosting intercellular cohesion via a mechanism involving calcium, this esterification process is started in situ on injured tissues from fruits and vegetables. Fruit pigments that are heat-labile and made of pectin components are decomposed by metal ions. This procedure is what changes the colour of fruit jams or jellies (Walter, 1991). As a result, glass jars are used to store jams and jellies rather than metal ones.
- **Hydrolytic rancidity:** Lipids are degraded by lipolytic enzymes as a result of hydrolytic rancidity. In this process, water helps free fatty acids separate from

triglyceride molecules. These free fatty acids smell or taste rotten (Steele, 2004). Because the liberated volatile fatty acids have a strong malodour and flavour, hydrolytic rancidity in fats like butter is quite obvious (Rodriguez and Mesler, 1985).

IV. RECOMMENDED STORAGE FOR VARIOUS FOODS (USDA, 1997; HILLERS,1992)

- 1. Cereals, rice, breads and flour:** Bread should be consumed within 5 to 7 days and kept in its original packaging at room temperature. However, because mould development is prevented when bread is stored in the refrigerator, it will last longer and could even be firmer. To keep out moisture and insects, cereals can be kept at room temperature in firmly closed containers. To prevent the natural oils in whole wheat flour from going rancid, it may be kept in the freezer or refrigerator. Use within a year after storing uncooked white rice in airtight containers kept at room temperature. Due to the oil being rancid when stored at room temperature, brown and wild rice will have a reduced shelf life (6 months). Refrigeration can prolong the shelf life of raw white and brown rice.
- 2. Fresh vegetables:** Fresh vegetables may have a longer shelf life if the air (oxygen) in the package is removed, they are kept chilled at 40°F, and the humidity is kept between 95 and 100%. Most fresh vegetables may be kept in the refrigerator for up to five days. To maintain product moisture and avoid wilting, fresh green vegetables should always be wrapped or covered in moisture-proof bags. Root vegetables (onions, sweet potatoes, potatoes etc.), eggplant, rutabagas and squashes and should be kept between 50 °F and 60 °F in a cool, well-ventilated area. After being harvested, tomatoes continue to ripen, therefore they should be kept at room temperature. Before storing carrots, radishes, and beets in the refrigerator, remove the tops to prevent moisture loss and increase shelf life. Corn loses some of its flavour when being stored in the cold because of its high starch content. It is best to keep corn and peas in a vented container. Green leafy vegetables need to be well cleaned with cold running water, drained, sealed in plastic bags, and stored in the fridge. Fresh vegetables' freshness and nutritional worth will be maintained with proper storage.
- 3. Processed vegetables:** Canned vegetables can be kept for up to a year in a cold, dry place that is below 85°F (ideal, 50°F to 70°F). Canned vegetables can still be eaten a year later if they are in fine condition. Cans with severe dents, swelling, or rust should be thrown away. Vegetables may be kept frozen for eight months at 0°F in the freezer. Since dehydrated vegetables have a propensity to lose their flavour and colour, they should be kept in a cold, dry environment and utilised within six months. Before freezing home-prepared vegetables, they should be blanched.
- 4. Fresh fruit (split the content into paragraph):** Generally speaking, to increase shelf life, keep fresh fruit in the refrigerator or another cool environment. Using covered containers will help fresh fruit retain more moisture. Fresh fruit should always be kept in a separate compartment of the refrigerator since they can contaminate other items and absorb their flavours. Fresh produce should be rinsed under cold running water before eating to eliminate any potential pesticide residues, dirt, or germs. Fresh fruits and vegetables can be peeled and then thoroughly washed to remove contaminants.

Apples that are ready to eat should be kept in the refrigerator apart from other meals and consumed within a month. Apples kept at room temperature will quickly soften after a few days. Prior to placing apples in the refrigerator, remove those that have been damaged or have gone bad.

Pears and apricots that are still green should be allowed to mature at room temperature before being refrigerated to improve shelf life by up to 5 days. Unripe peaches can be allowed to mature at room temperature for two days before eating them. Ripe peaches should be kept in the refrigerator but eaten at room temperature.

Within five days following purchase, consume fresh grapes and plums that have been refrigerated. Grapes should be rinsed before eating and should be kept in the refrigerator away from other meals. Strawberries that are ripe can be kept in the refrigerator for about three days without contact with other meals. Before eating, strawberries should be cleaned and de-stemmed.

Lemons, limes, and ripe oranges, among other citrus fruits, may be kept in the refrigerator for two weeks. Honeydew melon, cantaloupe, and watermelon are just a few examples of melons that may mature at room temperature for 2, 3, and 7 days, respectively.

Bananas and avocados should ripen for 3 to 5 days at room temperature. Unripe bananas should never be kept in the refrigerator since the cold will cause the bananas to quickly become black.

5. **Processed fruit:** Fruit and fruit juices in cans can be kept for a year in a cool, dry environment below 85°F (best between 50°F and 70°F). Similar to canned vegetables, cans that are severely damaged, bulging, rusted, or leaking should be thrown away. Because the product has lost its moisture, dried fruits have a lengthy shelf life. Dried fruits that have not been opened can be kept at room temperature for six months.
6. **Dairy products:** Fluid milk has a shelf life of 8 to 20 days when kept in a refrigerator (40 °F), depending on the date of manufacturing and the storage conditions on the grocery store shelf. Milk is a very perishable food that is also incredibly nutrient-dense. Never leave milk out at room temperature, and always keep it covered or closed in the refrigerator. It is not advisable to freeze milk since thawed milk readily separates and can take on unpleasant odours. Dry milk may be kept for a year in sealed containers at cold temperatures (50°F to 60°F). Dry milk that has been opened, especially whole milk products, should be kept cool to minimise off tastes. Sweetened condensed milk and evaporated milk in cans can be kept at room temperature for 12 to 23 months.

Cheese, both natural and processed, should be refrigerated below 40°F and kept securely wrapped in moisture-resistant wrappers. On hard natural cheese, surface mould growth may be scraped off with a clean knife and thrown away. To avoid moisture loss, rewrap cheese. Mold development is a sign of food deterioration and should be removed from processed cheese, semi-soft cheese, and cottage cheese.

Preserve commercial ice cream cold, below zero degrees Fahrenheit. Commercial ice cream has a two-month shelf life before the quality starts to deteriorate. Return opened ice cream right away to the freezer to avoid moisture loss and the formation of ice crystals. To prevent ice crystal development, keep ice cream in a freezer at a consistent temperature.

- 7. Meats, poultry, fish, and eggs:** Due to their high levels of moisture and protein, animal products like poultry, egg, meat and fish are all very perishable and might be dangerous. Fresh slices of meat typically include spoilage bacteria on their surface that, after three days of refrigeration storage in oxygen-permeable packing film, will multiply, form slime, and cause deterioration.

Due to the production process and increased surface area of the product, ground beef products are more prone to spoiling. The bacteria in ground meats are widely dispersed and can multiply quickly in the presence of air. The lowest shelf of the refrigerator should be utilised to keep ground meats and they should be consumed within 24 hours after purchase. Although bacterial development is slowed by refrigerator storage, the product will nevertheless ultimately go bad. Ground beef should be stored in the refrigerator at a temperature between 33°F and 36°F.

Meats should be packaged in gas- and moisture-tight materials for maximum storage to avoid freezer burn. Bacon and other cured meats should be kept in the refrigerator in their original packaging. When exposed to air, cured meats often start to go bad. Therefore, after opening a box of cured meats, rewrap it. The typical shelf life of cured meats is one week. The shelf life of meats and meat products is extended by vacuum packing (absence of air) and modified atmospheric packaging (partial removal of air) (i.e. luncheon meats). Meats that have been gas-flushed and vacuum-packed have shelf lives of 14 days and 7 to 12 days, respectively.

After purchasing, poultry should be cooked right away or put in the freezer. For a year, poultry can be kept in the freezer (ideally, 0°F). You may defrost poultry in the microwave, refrigerator, or under cold running water. Cook poultry whole or in pieces until the internal temperature reaches 170°F or 180°F, accordingly. Reheating leftovers to 165°F before serving them should be done within 3 days of storing them in the refrigerator. The refrigerator should only be used to retain poultry broth and gravy for no more than two days. Before serving, reheat the food to a full boil (212°F).

Within one to two days, crab, shrimp and fresh fish kept in the refrigerator (just above 32°F) should be consumed. Fresh fish should never be kept in water to prevent the loss of nutrients, flavours, and colours. For three to six months at 0°F, frozen fresh, lean fish and seafood (but not shrimp) may be kept. At 0°F, shrimp may be kept for a year.

Eggs should be bought chilled and kept in their original carton in a refrigerator between 33°F and 37°F. Eggs kept in their original cartons are less likely to absorb flavours and odours from other items kept in the refrigerator. The "pack date" printed on the carton of eggs should be used within 3 to 5 weeks (1 to 365 representing pack date day within the year). Egg yolks and whites that are leftover can be kept in the refrigerator under cover for 2 and 4 days, respectively. Egg yolks are covered with water. While

pasteurised liquid eggs can be kept in the fridge for 10 days, hard-boiled eggs can only be kept there for a week. Pasteurized eggs and egg whites may both be kept for a year in the freezer. The freezer is not a place where shell eggs should be kept. For a year, dried eggs can be kept in the refrigerator in firmly covered containers.

- 8. Water:** Commercial bottled water undergoes rigorous water treatment (filter, demineralization, and ozonation) and strong environmental controls throughout manufacture and packaging, resulting in a shelf-life of one to two years. In the absence of sunlight, bottled water has to be kept in a cool, dry location. Due to the development of microorganisms during storage, household tap water only has a few days of shelf life. So, if consumers intend to keep water for an extended length of time, they should buy bottled water. Commercial bottled water is subject to FDA regulation since it is a food.

The fundamental goal of storage is to keep food fresh for a long time. Consequently, preservatives are crucial while keeping food. The following information is provided on various preservation methods and preservatives.

V. CLASSIFICATION OF PRESERVATIVES

There are two main classes of preservatives:

Class I: The food preservatives derived from nature, such as salt, sugar, vinegar, spices, honey, edible oils, etc., were included in this class.

Class II: Preservatives that are chemical, semi-synthetic, or synthetic in nature, such as benzoates, sorbates, potassium nitrites and nitrates, sulfites, glutamates, and glycerides, are included in this class (Anand and Sati, 2013).

Function of preservatives:

1. To retain or boost food's nutritional value.
2. To improve quality and lower waste.
3. To increase customer acceptance
4. They prevent microbial development.
5. They extend the shelf life of processed foods reasonably.
6. Vinegar and processed meats have been preserved for years with ingredients like salt and nitrate (Mirza et al. 2017).

1. Classification of preservatives based on functions

- **Antimicrobials:** Nitrites and nitrates, for example, prevent botulism (food poisoning caused by bacteria) in meat products. They can also kill or stop the growth of bacteria, yeast, and mould. Fruits, wine, and beer are protected from further deterioration by sulphur dioxide. In jams, salad dressings, cheese, and pickles, sorbates and benzoates are anti-fungal ingredients that stop the formation of mould.

- **Antioxidants:** These impede or inhibit the rancidity-causing breakdown of dietary fats and oils that takes place in the presence of air. Antioxidants come in three different varieties:
 - Since they prevent chain reactions by interacting with free radicals, true antioxidants like butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are frequently utilised in many food formulations as food preservatives.
 - Ascorbic acid is one example of a reducing agent with a lower redox potential than the medicine or excipients it is protecting.
 - The effects of other antioxidants are enhanced by antioxidant synergy, such as sodium edetate (Hugo and Russel, 2004).
- **Anti-enzymatic preservatives:** These inhibit the enzymatic mechanisms that cause foods to ripen long after harvest. For example, citric acid and erythorbic acid prevent the action of the enzyme phenolase, which causes the exposed surface of sliced fruits to become brown (Kulkarni et al. 2010).

2. Classification based on chemical

- **Acids:** Boric acids, Sorbic acids, Benzoic acid.
- **Esters:** Sodium benzoate, Propylparaben, Ethylparaben, Methylparaben, Butylparaben, Sodium propionate.
- **Alcohols:** Benzyl alcohol, Chlorobutanol, Phenyl ethyl alcohol.
- **Phenols:** Chlorocresol, Phenol, o-Phenyl phenol.
- **Mercurial compounds:** Nitromersol, Thiomersal, Phenylmercuric acetate, Phenylmercuric nitrate.
- **Quaternary ammonium compounds:** Cetyl pyridinium chloride, Benzalkonium chloride (Mirza et al. 2017).

3. Classification based on source

- **Natural preservatives:** These are derived from organic materials such as plants, minerals, animals, etc. Neem oil, sodium chloride, honey, sugar, spices, edible oils, etc. are a few examples.
- **Artificial preservatives:** These preservatives are manufactured by humans through chemical synthesis and are mildly active against a variety of bacteria. Examples include benzoates, sodium benzoate, sorbates, propionates, and nitrates (Seetaramaiah et al. 2011).

The Scientific Committee on Food (SCF), which is in-charge of assessing the safety of food additives, grants an E-number to an additive once it has received approval from the European Union Commission. E numbers are a universally recognised designation for compounds that have been given European Union and Swiss approval for usage. The class "Preservatives" has been given an E-number range of 200 to 299 (Inetianbor et al. 2015).

VI. DIFFERENT FOOD PRESERVATION METHODS

- 1. Drying:** Drying is one of the oldest ways of food preservation because it significantly lowers water activity, which delays or prevents bacterial development. Drying also helps to reduce weight.
- 2. Pickling:** By using anaerobic fermentation, pickling is a method of food preservation. Pickles are the name of the food that results. The process imparts a salty or sour flavour to the food. Vinegar, oil, alcohol, and brine are common pickling ingredients. A pH of less than 4.6, which is adequate to kill most bacteria, is another distinctive feature. Perishable foods can be preserved for months by pickling (Sharif et al. 2017).
- 3. Canning:** If done correctly, canning is a significant, secure technique of food preservation. Canning is the process of heating food, putting it in sterilised cans or jars, and then boiling the containers to sterilise or weaken any lingering microorganisms.
- 4. Freezing:** The two methods of food preservation that are most often used nowadays are refrigeration and freezing. When food is refrigerated, the purpose is to restrict bacterial growth to a crawl such that food spoilage takes significantly longer (perhaps a week or two instead of half a day) (Leistner, 2000; Wiley, 1994).
- 5. Chilling:** Foods are chilled at a constant temperature of between 1 and 8 °C. The cooling process lowers the products' starting temperatures and sustains their ending temperatures for an extended length of time (Saravacos and Kostaropoulos, 2002). It is used to slow down biochemical and microbial changes as well as to increase the shelf life of both fresh and processed foods (Sudheer and Indira, 2007).
- 6. Jellying:** Cooking in a substance that solidifies to produce a gel can preserve food. Gelatine, agar, maize flour, and arrowroot flour are a few examples of these materials.
- 7. Vacuum packing:** Food is often vacuum-packed in an airtight bag or bottle. The lack of oxygen in the vacuum atmosphere causes microorganisms to slowly deteriorate. Food can be harmed by air, which leads to rusting, the spread of bacteria, or lost property. This approach may preserve food for weeks or even months if it is refrigerated, making it ideal for goods that travel great distances (Leistner, 1992).
- 8. Water bath:** In this method, food is kept in a glass container filled with water that is firmly closed. The bottle is then put in a pot with just enough water to cover it, and the water is then turned off after 50 minutes. Before causing a rapid temperature rise that might cause the bottle to burst, leave the flask within the container until the water has totally cooled. The food may be preserved using this method for several months or even over a year (Lado and Yousef, 2002).

VII. RECENT ADVANCED PRESERVATION METHODS ARE AS FOLLOWS

- 1. Irradiation:** When a substance is exposed to a certain dose of ionising radiation (IR), the process is called irradiation (Arvanitoyannis, 2010). Natural and artificial IR are both possible. High-energy ultraviolet (UV) and X-rays are common components of natural

infrared (IR), while induced secondary radiation and accelerated electrons are the products of artificial infrared production (Sommers, 2010; Islam and Uddin, 2016). In more than 60 distinct foods across 40 different nations, IR is employed (Arvanitoyannis, 2010).

The effects of IR include: (a) disinfection of grains, fruits, and vegetables; (b) improvement of fruit and vegetable shelf life through inhibition of sprouting or by altering their rate of maturation and senescence; and (c) enhancement of food safety and shelf life through inactivation of foodborne pathogens (Heldman and Moraru, 2010; Kanatt et al. 2006).

Kilo greys represent the IR dosage provided to foods (kGy). A grey is equal to the amount of ionising radiation that 1 kilogramme of radioactive material has been exposed to. Legislative authorities determine the boundaries of IR regulation. These restrictions may be stated as a minimum dosage, maximum dose, or acceptable dose range depending on the regulatory body (Sommers, 2010). Even at large dosages, IR has no effect on the nutritional factors, such as lipids, carbs, proteins, minerals, and the majority of vitamins (Smith and Pillai, 2004). When IR is administered in large doses, several micronutrients, especially the vitamins A, B1, C and E, may be lost. FDA claims that the effects of IR on food's nutritional value are comparable to those of traditional food processing methods (Smith and Pillai, 2004).

- 2. High-pressure food preservation:** In order to destroy germs in food, high hydrostatic pressure or ultra-high pressure processing (HPP) technology applies pressure upwards of 900 MPa. Additionally, this procedure prevents food spoiling, postpones the start of chemical and enzymatic deteriorative processes, and preserves the vital physical and physiochemical properties of food. HHP has the potential to be a significant preservation technique that doesn't result in the degradation of vitamins, flavours, or colour components (Amit et al. 2017). The unparalleled benefits of HPP technology include better freshness and flavour as well as great nutritional content. This procedure is also environmentally beneficial since it uses very little energy and produces very little waste (Nielsen et al. 2009; Yeung and Huang, 2016). The high capital expense of this technology is a serious flaw. Additionally, the widespread use of HPP procedures is also constrained by a lack of knowledge and scepticism regarding this technology (Amit et al. 2017; Nielsen et al. 2009).

Le Chatelier's principle states that the combined effects of cell membrane permeabilization and breakdown result in the death or inhibition of microbial growth. While spore inactivation necessitates significantly higher pressure in conjunction with an increase in temperature to 60 to 70 °C, vegetative cells are rendered inactive at around 3000 bar pressure at ambient temperature. Since minimal influence is discernible below 40% moisture content, moisture level is crucial in this context (Amit et al. 2017).

- 3. Pulsed electric field:** Food is subjected to a pulsed high voltage field (20–40 kV/cm) while being sandwiched between two electrodes during pulsed electric field (PEF) food preparation. The PEF treatment time is often less than one second (Amit et al. 2017). This process's quick residence time and low processing temperature enable extremely successful microbial inactivation. Gram-negative bacteria are considerably easier to kill

with PEF processing than gram-positive bacteria. Compared to spores, vegetative cells are far more vulnerable to this process. Electroporation and disruption of cell membrane function are the causes of all cell death (Jay, 2000). PEF technology preserves the meals' flavour, colour, and taste.

Processes for non-thermal food preservation including PEF and HPP are thought to be more efficient than thermal processing (Ahmed and Rahman, 2012). The amount of pulses produced during processing and the electric field intensity (20–40 kV/cm) that are used to inactivate bacteria are the major factors in PEF. Most spoilage and harmful bacteria have been discovered to be susceptible to PEF. However, it should be emphasised that treating plant or animal cells requires a strong field and more energy, which raises the cost of processing. Additionally, the structure of solid food may be destroyed by this sort of field strength. PEF is therefore more suited to preserve liquid foods. Fruit or vegetable juices, milk, liquid eggs, and nutritional broth have all been successfully microbially inactivated with PEF (Sun, 2014).

- 4. Application of Nano technology in food preservation:** One of the most important measures in ensuring food safety is food packaging. No packaging material can penetrate natural chemicals, air gases, or water vapours (Robertson, 2006). In the case of packing fresh fruits and vegetables, which go through cellular respiration, completely limiting the movement and permeability of gases is not preferred. However, to avoid oxidation and decarbonation, the packaging of carbonated beverages should stop the passage of oxygen and carbon dioxide (CO₂) (Robertson, 2006). Depending on the food matrices and packing materials employed, different amounts of CO₂, oxygen, and water vapour pass through the system. In order to solve and get around these difficulties in food packaging, various nanocomposite materials, such as polymers, can be used (Abbaspour et al. 2015).

A nanoparticle with a diameter of less than 100 nm is a thousand times thinner than a book page that is around 100,000 nm thick or a hundred times thinner than a human hair that is about 10,000 nm thick. Recently, the capacity of food packaging to operate as a barrier against gases has improved thanks to the introduction of nanobiocomposites in food packaging (Ghanbarzadeh et al. 2014). The table below briefly outlines the uses of several nanoparticles in food packaging. The use of environmentally friendly biodegradable polymers supplemented with nanofillers is encouraged by current trends in food packaging (Abdollahi et al. 2012). The intake of these nano-compounds while consuming food, however, is a significant worry. Therefore, research into the toxic and immunogenic effects of these nanoparticles as well as their migration inside the human body is crucial (Azeredo et al. 2011). The biodegradability of these nanofilled, biodegradable polymers is a further issue (Klaine et al. 2012). Researchers throughout the globe who are looking for ecologically and human-friendly nanomaterials take these issues seriously (Klaine, 2009).

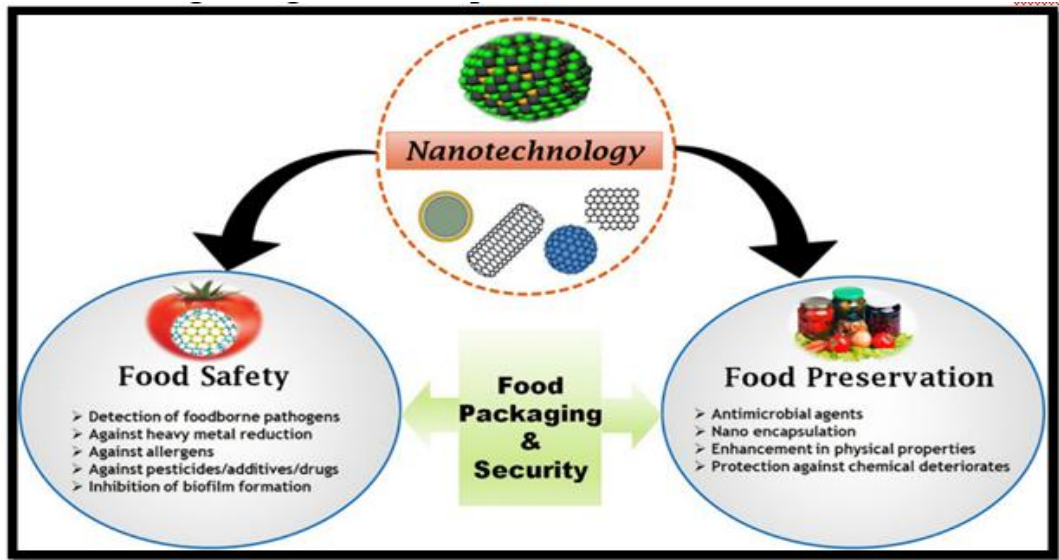


Figure 1: Application of Nano Technology Food Packing and Security
(Source: Bajpai et al. 2018)

Table 3: Nanoparticles for application in food packaging (Bajpai et al. 2018)

Types of nanoparticles	Matrix	Application
Silver	Asparagus, Orange juice, Poultry meat, Fresh-cut melon, Beef meat exudates	Retards the growth of aerobic psychrotrophics, yeasts and molds; antimicrobial effect against <i>Escherichia coli</i> and <i>Staphylococcus aureus</i>
Zinc oxide	Liquid egg albumen, Orange juice	Effectively reduces <i>Lactobacillus plantarum</i> , <i>Salmonella</i> , yeast and mold counts without changes in quality parameters
Titanium oxide	Strawberry	Reduces browning, slow-down ripening, senescence and decay
Silver oxide	Apple slice	Retards microbial spoilage

- 5. Fortification of edible films with bioactive agents for the application in food preservation:** For food coating and packaging applications, biodegradable films made from food components are being researched as environmentally benign and more sustainable substitutes for plastics and other synthetic film-forming materials. A particular emphasis is placed on the development of active packaging materials using natural components, particularly those derived from plants. Proteins, polysaccharides and lipids are common dietary ingredients that are used to make film matrixes. To improve these matrices' functional qualities, active substances like antioxidants and antimicrobials can be added. To have the necessary optical, mechanical, barrier, and preservation qualities needed for commercial applications, edible active films must be properly constructed (Chen et al. 2022).
- 6. Modified atmospheric packaging:** Modified Atmosphere Packaging, or MAP, is a natural way to extend the shelf life of food while preserving its quality and preserving the flavour, texture, and appearance of the original product. The best way to safeguard and

preserve food nowadays is using MAP. To preserve the original flavour, texture, and appearance of the food being packaged, MAP employs liquid nitrogen or a gas combination in modified atmospheric packaging. Nitrogen (N₂), carbon dioxide (CO₂), and other gases like nitrous oxide, argon, or hydrogen may also be present in MAP gas combinations. Each gas interacts with meals or liquids in a specific way that helps it maintain its original qualities. The gases can be mixed specifically for each type of product or used individually (<https://www.westairgases.com/blog/map-modified-atmosphere-packaging-gases-applications>).

In order to stop oxidation during packing, nitrogen, an inert gas, is typically utilised to force out ambient air. Nitrogen's poor solubility in water also contributes to its ability to maintain internal pressure and avoid package collapse, which eliminates the need for outside packaging and makes product transit and storage easier. N₂ vaporises fast and expands 700 times in volume. It uses far less nitrogen and is the most efficient approach to remove oxygen while achieving container stiffness. As carbon dioxide dissolves in food's liquid and fatty phases and lowers the pH level, it aids in the inhibition of microbial activity. By piercing biological membranes, it also alters permeability.

VIII. HEALTH HAZARDS CAUSED BY ARTIFICIAL PRESERVATIVES

Although artificial preservatives are generally regarded as harmless, some of them have harmful, carcinogenic, and life-threatening adverse effects. Sulphites, a popular preservative found in many fruits, can cause headaches, palpitations, allergic responses, asthma, cancer, and other negative effects.

1. **Nitrates and nitrites:** When sodium nitrite cooks at high temperatures or reacts with proteins to generate N-nitrosamines, it can cause cancer. The nitrate attaches to haemoglobin, which is the substance that delivers oxygen in blood to body tissues, and produces chemically changed haemoglobin (methaemoglobin), which reduces oxygen delivery to tissues and gives skin its blue colour.
2. Benzoates are known to cause brain damage and to cause allergies including skin rashes and asthma (Sharma, 2015).
3. Caffeine is a flavouring and colouring agent with stimulant and diuretic characteristics. Nervousness, palpitations, and possibly heart abnormalities are possible effects.
4. The skin, digestive system, and heart are all negatively impacted by the toxic and allergic responses caused by saccharin. Tumors and bladder cancer may also be brought on by it.
5. As an antibacterial preservative, sorbates and sorbic acid are added to foods. Although sorbate reactions are uncommon, urticaria and contact dermatitis have been reported.
6. Consuming foods containing monosodium glutamate might cause headaches, sweating, skin redness, nausea, and weakness (MSG).
7. The use of these dangerous preservatives during pregnancy may have a negative impact on the brain development of the foetus. Hydantoin, diazolidinyl urea, imidazolidinyl urea, and formaldehyde are all strong irritants that can irritate the skin, eyes, and lungs. Sperm DNA damage can result from exposure to these poisons at high doses (Vega-Mercado et al. 1997).
8. Because they typically manifest late or without any clear pattern, preservative-induced adverse effects are frequently exceedingly challenging to diagnose. Preservatives should thus not be used for an extended period of time (Baudouin et al. 2010).

IX. CONCLUSION

One of the most significant and revolutionary advancements in human civilization was the capacity to preserve food since it allowed individuals to establish themselves and create civilizations. But maintaining the nutritional content of foods while extending their shelf life is still crucial and challenging. Food is a perishable, organic product that can go bad due to physical, chemical, or microbial processes. Several conventional methods, including drying, chilling, freezing, fermenting, and other procedures, had evolved in the past to preserve food while maintaining its nutritional content and texture. As time and need have progressed, preservation techniques have changed and grown more modern. Pulsed electric field effect, high pressure food preservation, irradiation, and other recent advancements in food preservation include these. As food additives and preservatives, various chemical agents have also been produced. However, there are rising concerns regarding the use of chemical additives and preservatives in food items due to potential health dangers. To meet customer demand, the food processing and preservation sector has been growing quickly. To guarantee food safety and a long shelf life, it is crucial to understand food degradation mechanisms and food preservation techniques.

REFERENCES

- [1] Abbaspour, A., Norouz-Sarvestani, F., Noori, A. and Soltani, N., 2015. Aptamer-conjugated silver nanoparticles for electrochemical dual-aptamer-based sandwich detection of staphylococcus aureus. *Biosensors and Bioelectronics*, 68, pp.149-155.
- [2] Abdollahi, M., Rezaei, M. and Farzi, G., 2012. A novel active bionanocomposite film incorporating rosemary essential oil and nanoclay into chitosan. *Journal of Food Engineering*, 111(2), pp.343-350.
- [3] Ahmed, J. and Rahman, M.S. eds., 2012. *Handbook of food process design, 2 Volume Set*. John Wiley & Sons.
- [4] Amit, S.K., Uddin, M., Rahman, R., Islam, S.M. and Khan, M.S., 2017. A review on mechanisms and commercial aspects of food preservation and processing. *Agriculture & Food Security*, 6(1), pp.1-22.
- [5] Anand, S.P. and Sati, N., 2013. Artificial preservatives and their harmful effects: looking toward nature for safer alternatives. *International journal of pharmaceutical sciences and research*, 4(7), p.2496.
- [6] Arvanitoyannis, I.S., 2010. *Irradiation of food commodities: techniques, applications, detection, legislation, safety and consumer opinion*. Academic Press.
- [7] Bajpai, V.K., Kamle, M., Shukla, S., Mahato, D.K., Chandra, P., Hwang, S.K., Kumar, P., Huh, Y.S. and Han, Y.K., 2018. Prospects of using nanotechnology for food preservation, safety, and security. *Journal of food and drug analysis*, 26(4), pp.1201-1214.
- [8] Balasubramanian, S. and Viswanathan, R., 2010. Influence of moisture content on physical properties of minor millets. *Journal of food science and technology*, 47(3), pp.279-284.
- [9] Barbosa-Cánovas, G.V., Altunakar, B. and Mejía-Lorío, D.J., 2005. *Freezing of fruits and vegetables: An agribusiness alternative for rural and semi-rural areas* (Vol. 158). Food & Agriculture Org..
- [10] Barnwal, P., Singh, K.K., Mridula, D., Kumar, R. and Rehal, J., 2010. Effect of moisture content and residence time on dehulling of flaxseed. *Journal of food science and technology*, 47(6), pp.662-667.
- [11] Baudouin, C., Labbé, A., Liang, H., Pauly, A. and Brignole-Baudouin, F., 2010. Preservatives in eyedrops: the good, the bad and the ugly. *Progress in retinal and eye research*, 29(4), pp.312-334.

- [12] Chen, W., Ma, S., Wang, Q., McClements, D.J., Liu, X., Ngai, T. and Liu, F., 2022. Fortification of edible films with bioactive agents: A review of their formation, properties, and application in food preservation. *Critical Reviews in Food Science and Nutrition*, 62(18), pp.5029-5055.
- [13] de Azeredo, H.M.C., Mattoso, L.H.C. and McHugh, T.H., 2011. Nanocomposites in food packaging—a review. *Advances in diverse industrial applications of nanocomposites*, pp.57-78.
- [14] Desrosier., Norman Wilfred and Singh, R. Paul., 2018. "Food Preservation". *Encyclopedia Britannica*, 28 Sep.
- [15] Doyle, M.P., 2009. *Compendium of the microbiological spoilage of foods and beverages*. Springer Science & Business Media.
- [16] Fabunmi, O.A., Osunde, Z.D., Alabadan, B.A. and Jigam, A.A., 2015. Influence of moisture content and temperature interaction on mechanical properties of DESMA (Novella pentadesma) SEED. *Journal of Advanced Food Science and Technology*, 2(2), pp.81–5.
- [17] Fennema, O.R., 1996. *Food chemistry* (Vol. 76). CRC Press.
- [18] Ghanbarzadeh, B., Oleyaei, S.A. and Almasi, H., 2015. Nanostructured materials utilized in biopolymer-based plastics for food packaging applications. *Critical reviews in food science and nutrition*, 55(12), pp.1699-1723.
- [19] Heldman, D.R. and Moraru, C.I. eds., 2010. *Encyclopedia of agricultural, food, and biological engineering*. CRC press.
- [20] Hillers, V.N., 1992. Storing foods at home. *Extension bulletin-Washington State University, Cooperative Extension Service (USA)*.
- [21] Hoff, J.E. and Castro, M.D., 1969. Chemical composition of potato cell wall. *Journal of Agricultural and Food Chemistry*, 17(6), pp.1328-1331.
- [22] <https://www.westairgases.com/blog/map-modified-atmosphere-packaging-gases-applications>
- [23] Hugo, W. B. and Russell, A. D. 2004. *Pharmaceutical Microbiology*. Seventh Edition, pp.120-125, Blackwell Science.
- [24] Igarashi, Y., Eroshkin, A., Gramatikova, S., Gramatikoff, K., Zhang, Y., Smith, J.W., Osterman, A.L. and Godzik, A., 2007. CutDB: a proteolytic event database. *Nucleic acids research*, 35(suppl_1), pp.D546-D549.
- [25] Inetianbor, J.E., Yakubu, J.M. and Ezeonu, S.C., 2015. Effects of food additives and preservatives on man-a review. *Asian Journal of Science and Technology*, 6(2), pp.1118-1135.
- [26] in't Veld, J.H.H., 1996. Microbial and biochemical spoilage of foods: an overview. *International journal of food microbiology*, 33(1), pp.1-18.
- [27] Islam, M.M. and Uddin, G.S., 2016. Irradiation to Insure Safety and Quality of Fruit Salads Consumed in Bangladesh. *Journal of Food and Nutrition Research*, 4(1), pp.40-45.
- [28] Jay, J.M., 2000. *Modern food microbiology*. Maryland.
- [29] Kader, A.A., Zagory, D., Kerbel, E.L. and Wang, C.Y., 1989. Modified atmosphere packaging of fruits and vegetables. *Critical Reviews in Food Science & Nutrition*, 28(1), pp.1-30.
- [30] Kanatt, S.R., Chander, R. and Sharma, A., 2006. Effect of radiation processing of lamb meat on its lipids. *Food chemistry*, 97(1), pp.80-86.
- [31] Karmas, R., Pilar Buera, M. and Karel, M., 1992. Effect of glass transition on rates of nonenzymic browning in food systems. *Journal of Agricultural and Food Chemistry*, 40(5), pp.873-879.
- [32] Klaine SJ. Considerations for research on the environmental fate and effects of nanoparticles. *Environ Toxicol* 2009;28(9):1787e8
- [33] Klaine, S.J., Koelmans, A.A., Horne, N., Carley, S., Handy, R.D., Kapustka, L., Nowack, B. and von der Kammer, F., 2012. Paradigms to assess the environmental impact of manufactured nanomaterials. *Environmental Toxicology and Chemistry*, 31(1), pp.3-14.
- [34] Kulkarni, C., Deshpande, A. and More, S., 2010. Assessment of microbial contamination in commercial herbal oral medicinal liquids. *Int J Pharm Res Dev*, 2(9), pp.191-193.
- [35] Lado, B.H. and Yousef, A.E., 2002. Alternative food-preservation technologies: efficacy and mechanisms. *Microbes and infection*, 4(4), pp.433-440.

- [36] Leistner, L., 1992. Food preservation by combined methods. *Food research international*, 25(2), pp.151-158.
- [37] Leistner, L., 2000. Basic aspects of food preservation by hurdle technology. *International journal of food microbiology*, 55(1-3), pp.181-186.
- [38] Levine, H. and Slade, L., 1986. A polymer physico-chemical approach to the study of commercial starch hydrolysis products (SHPs). *Carbohydrate polymers*, 6(3), pp.213-244.
- [39] Levine, H. and Slade, L., 1988. Principles of "cryostabilization" technology from structure/property relationships of carbohydrate/water systems—a review. *Cryo-letters*, 9(1), pp.21-63.
- [40] Mirza, S.K., Asema, U.K. and Kasim, S.S., 2017. To study the harmful effects of food preservatives on human health. *J. Med. Chem. Drug Discovery*, 2, pp.610-616.
- [41] Monteiro, C.A., Levy, R.B., Claro, R.M., Castro, I.R.R.D. and Cannon, G., 2010. A new classification of foods based on the extent and purpose of their processing. *Cadernos de saude publica*, 26, pp.2039-2049.
- [42] Nielsen, H.B., Sonne, A.M., Grunert, K.G., Banati, D., Pollák-Tóth, A., Lakner, Z., Olsen, N.V., Žontar, T.P. and Peterman, M., 2009. Consumer perception of the use of high-pressure processing and pulsed electric field technologies in food production. *Appetite*, 52(1), pp.115-126.
- [43] Panda, H., 2003. *Herbal Foods and its medicinal values*. NIIR PROJECT CONSULTANCY SERVICES.
- [44] Rahman M. S., 2007. Food Preservation: Overview: Handbook of food preservation. 2nd Edition, pp. 3-7, London, CRC Press.
- [45] Rahman, M.S., 2009. *Food properties handbook*. CRC press.
- [46] Reid, D.S., 1990. Optimizing the quality of frozen foods. *Food Technol*, 7, pp.78-82.
- [47] Robertson, G.L., 2006. Modified atmosphere packaging. *Food packaging: principles and practice*, pp.313-329.
- [48] Rodriguez, F. and Mesler, R., 1985. Some drops don't splash. *Journal of colloid and interface science*, 106(2), pp.347-352.
- [49] Rogers, L.D. and Overall, C.M., 2013. Proteolytic post-translational modification of proteins: proteomic tools and methodology. *Molecular & Cellular Proteomics*, 12(12), pp.3532-3542.
- [50] Roos, Y. and Karel, M., 1991. Plasticizing effect of water on thermal behavior and crystallization of amorphous food models. *Journal of food science*, 56(1), pp.38-43.
- [51] Saravacos, G.D. and Kostaropoulos, A.E., 2002. *Handbook of food processing equipment* (Vol. 2012, pp. 331-381). Kluwer Academic/Plenum.
- [52] Seetaramaiah, K., Smith, A.A., Murali, R. and Manavalan, R., 2011. Preservatives in food products-review. *Int J Pharm Biol Arch*, 2(2), pp.583-99.
- [53] Shaikh, S.M., Doijad, R.C., Shete, A.S. and Sankpal, P.S., 2016. A Review on: Preservatives used in Pharmaceuticals and impacts on Health. *PharmaTutor*, 4(5), pp.25-34.
- [54] Sharif, Z.I.M., Mustapha, F.A., Jai, J., Yusof, N.M. and Zaki, N.A.M., 2017. Review on methods for preservation and natural preservatives for extending the food longevity. *Chemical Engineering Research Bulletin*, pp.145-153.
- [55] Sharma, S., 2015. Food preservatives and their harmful effects. *International journal of scientific and research publications*, 5(4), pp.1-2.
- [56] Smith, J.S. and Pillai, S., 2004. Irradiation and food safety. *Food technology (Chicago)*, 58(11), pp.48-55.
- [57] Sommers B.A.N.a.C.H., 2010. Irradiation: food. encyclopedia of agricultural, food, and biological engineering, p. 864–8.
- [58] Steele, R. ed., 2004. *Understanding and measuring the shelf-life of food*. Woodhead Publishing.
- [59] Sudheer, K.P. and Indira, V., 2007. *Post harvest technology of horticultural crops* (Vol. 7). New India Publishing.
- [60] Sun, D.W., 2014. Emerging technologies for food processing.
- [61] Sven-Olof Enfors., KTH – Biotechnology and Stockholm 2008. Food Microbiology.

- [62] Tefera, T. and Abass, A.B., 2012. Improved postharvest technologies for promoting food storage, processing, and household nutrition in Tanzania.
- [63] Tianli, Y., Jiangbo, Z. and Yahong, Y., 2014. Spoilage by Alicyclobacillus bacteria in juice and beverage products: chemical, physical, and combined control methods. *Comprehensive Reviews in Food Science and Food Safety*, 13(5), pp.771-797.
- [64] USDA. 1997. Basics for handling food safely. U.S. Department of Agriculture, Food Safety and Inspection Service, Washington, D.C.
- [65] Van Boekel, M.A., 2008. Kinetic modeling of food quality: a critical review. *Comprehensive Reviews in Food Science and Food Safety*, 7(1), pp.144-158.
- [66] Vega-Mercado, H., Martin-Belloso, O., Qin, B.L., Chang, F.J., Góngora-Nieto, M.M., Barbosa-Cánovas, G.V. and Swanson, B.G., 1997. Non-thermal food preservation: pulsed electric fields. *Trends in food science & technology*, 8(5), pp.151-157.
- [67] Walter, R.H., 1991. *Analytical and graphical methods for pectin* (pp. 189-225). Academic Press: San Diego, CA.
- [68] White, G.W. and Cakebread, S.H., 1966. The glassy state in certain sugar- containing food products. *International Journal of Food Science & Technology*, 1(1), pp.73-82.
- [69] Wiley, R.C., 1994. Preservation methods for minimally processed refrigerated fruits and vegetables. In *Minimally processed refrigerated fruits & vegetables* (pp. 66-134). Springer, Boston, MA.
- [70] Yeung, C.K. and Huang, S.C., 2016. Effects of high-pressure processing technique on the quality and shelf life of chinese style sausages. *J Food Nutr Res*, 4(7), pp.442-7.