Int.J.Curr.Res.Aca.Rev.2022; 10(12): 60-92

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 10 Number 12 (December-2022)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2022.1012.007

Food Preservation by Controlling Biological, Chemical and Physical Methods

Kebede Dida Ariti* and Asres Yenesew Mossie

Ethiopian Institute of Agricultural Research, Melkassa Agriculture Research Center, P.O. Box 436, Adama, Ethiopia

**Corresponding author*

Abstract

In order to retain food quality at the optimal level, which will yield the greatest advantages and nutritional benefits, various food processing procedures are involved in food preservation. Foods can be grown, harvested, processed, packaged, and distributed using various food preservation techniques. Inappropriate food handling is one of the main goals of food preservation planning in agriculture, to create value-added goods, and to offer dietary variety A vast variety of chemical and biological interactions have the potential to degrade food. Food preservation methods like drying, cooling, freezing, and pasteurization have been promoted in order to prevent the chemical and microbiological deterioration of food. The methods used to prevent these spoilages have evolved in recent years, becoming increasingly sophisticated and becoming a highly interdisciplinary discipline. Food goods are preserved using highly sophisticated technologies like irradiation, high-pressure technology, and hurdle technology. The mechanics, conditions of use, benefits, and drawbacks of several food preservation methods are presented and discussed in this review article. Also, this article lists many food types and clarifies the various physical, chemical, and microbiological elements that contribute to food rotting. In addition, this article has examined the market economy of processed and preserved foods.

Article Info

Received: 10 November 2022
Accepted: 12 December 2022
Available Online: 20 December 2022

Keywords

Biological, Food, preservation, Microorganism, chemical, Temperature, Physical, water activity, Antimicrobial.

Introduction

Foods are organic compounds that are eaten to provide nutrition. Foods come from either plants or animals and are composed of moisture, protein, lipids, carbohydrates, minerals, and other organic compounds. Foods can get spoiled through microbiological, chemical, or physical processes. Foods' nutritional content, appearance, texture, and palatability are all subject to spoiling (Rahman, 2007). As a result, foods must be preserved if they are to maintain their quality over an extended length of time. The procedures or methods used to maintain both internal and exterior elements that could lead to food decomposition are referred to as food preservation.

The main goal of food preservation is to prolong its shelf life while preserving its original nutritional composition, color, texture, and flavor. The practice of "food preservation" has a long history, going back to the prehistoric era when a tribe of primitive people realized they needed to store food after killing a large animal that they couldn't all consume at once. Understanding how to preserve food was the first and most crucial step in creating civilization. Various societies have employed nearly identical fundamental methods to preserve food throughout time and space (Nummer, 2002). All across the world, conventional food preservation methods like pasteurization, drying, freezing, chilling, and chemical preservation are widely utilized. Irradiation, high pressure technology, and hurdle technology are three examples of how scientific research and developments are influencing the development of new and evolving technologies (Blum, 2012; Freedman, 2011; Rahman, 2014). Since it involves processes relating to food growth, harvesting, processing, packaging, and distribution, food preservation processing has evolved into a highly interdisciplinary field. Hence, to preserve food during the food production and processing stages, an integrated approach would be helpful. Around $7 trillion worth of processed food is sold globally today, and this market is steadily expanding over time (WFMOMV, 2013).

The development of the food processing industries in many nations is largely due to rapid industrialization and globalization. Food processing is an advantageous part of the manufacturing sector in developing nations, according to an examination of the UNIDO Industrial Statistics Database (2005), and its contribution to national GDP rises with national income (Wilkinson and Rocha, 2008; Kar, 2014). This review paper examines several physical, chemical, and biological elements that contribute to food rotting while also classifying various food items. In this article, the fundamentals and developments of many simple and cutting-edge food preservation methods which are said to prevent food spoiling and produce longer shelf lives as well as their workings, conditions for application, benefits, and drawbacks are covered. The article also discusses the processed and preserved food market trend around the world. Researchers, technicians, and industry management can gain a complete understanding from this review that could be very helpful in developing efficient and integrated food preservation technologies and ensuring food safety.

Food preservation and characteristics of microorganisms

Food classification: Foods can be grouped in general according to their processing methods, nutritional content, and shelf life. Shelf-life-based food categories of food gradually loses its color, texture, flavor, nutritional value, and edibility as a result of food rotting, which is a natural process. Consuming rotten food can cause disease and, in the worst-case scenario, death (Steele, 2004). Food items can be divided into three categories based on how quickly they spoil: perishable, semi-perishable, and non-perishable (Doyle, 2009). Perishable foods are those with a short shelf life, typically between a few days and three weeks. Foods that spoil quickly include meats, poultry, eggs, dairy products, and shellfish**.** If specific preservation strategies are not understood, food products may spoil immediately (Doyle, 2009).

Semi-perishable

Under ideal storage circumstances, certain food items can be stored for a long time (about six months). They are classified as semi-perishable foods. A few examples of semi-perishable food items are fruits, vegetables, cheeses, and potatoes.

On-perishable

Non-perishable food items are both natural and processed foods with an endless shelf life. Some foods have an extended shelf life of several years or more. Nonperishable foods include things like dry beans, almonds, flour, sugar, canned fruits, mayonnaise, and peanut butter.

Using nutrients and functions to classify foods. Foods can be grouped into the following categories based on how they help the body function: (a) foods that build and repair the body; (b) foods that provide energy; (c) foods that are regulatory; and (d) foods that are protective. Foods can be divided into four categories based on their nutritional value: (a) foods high in carbohydrates; (b) foods high in protein; (c) foods high in fat; and (d) foods high in vitamins and minerals.

Food categories based on extent and purpose of processing

A range of food processing techniques are used by the food industries to transform fresh ingredients into food products. Foods can be categorized into three main groups based on how much and how they are processed. Unprocessed or minimally processed foods, processed ingredients utilized in the food industry or in the culinary arts, and ultra-processed food products are all discussed by Carlos *et al.,* (2010).

Food spoilage: mechanism

Food edibility declines as a result of food deterioration. Food rotting and food safety are related (Steele, 2004). Color, smell, flavor, texture, or the food itself can be used to identify the early stages of food deterioration. Food deterioration can result from a variety of physical, microbiological, or chemical processes. Since the deterioration brought on by one mechanism might stimulate another, these mechanisms are not necessarily mutually incompatible. The main causes of food deterioration are temperature, pH, air, nutrition, and the presence of different compounds (Steele, 2004).

Physical spoilage

Physical food deterioration is described as food that has undergone physical alteration or instability. Examples of physical deterioration include moisture gain or loss, moisture movement between distinct components, and physical separation of ingredients or components (Steele, 2004; Roos and Karel, 1991; Rahman, 1995). Physical deterioration is primarily influenced by moisture content, temperature, glass transient temperature, crystallization, and growth.

Moisture content

The alteration in the water content of food products is a common reason for their deterioration. It could take the shape of water gain, water loss, or water movement (Fabunmi *et al.*, 2015). The water activity (aw) of a food item directly influences moisture transfer in food (Steele, 2004; Balasubramanian *et al.*, 2010). The ratio of the vapor pressure of water in a system to the vapor pressure of pure water at the same temperature is used to express the thermodynamic attribute known as water activity (aw) (Rahman, 1995; Barnwal *et al.*, 2010). It is also possible to substitute equilibrium relative humidity at the same temperature for pure water vapor pressure. With increasing temperature, water activity in food products 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 *et al.*, 2005; Kader, *et al.*, 1989; Fennema, 1996).

Temperatures

The most contributing element to the rotting of fruits and vegetables is temperature. The right temperature range can promote post-harvest vitality and slow ripening. Moreover, 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. The metabolism of the goods is typically hampered by temperature, which also affects the rate of achieving the required (Kader, *et al.*, 1989). Foods that are prone to freeze damage may suffer unfavorable effects as a result of low temperatures. Food goods become damaged when their cells break when partially frozen at lower temperatures. The majority of tropical fruits and vegetables 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

This temperature has an impact on how long food goods can be stored. Food products' solid constituents might be either crystalline or amorphous in nature. The composition of materials, temperature, and relative humidity all affect this occurrence (White *et al.*, 1966). The amorphous matrix can take the form of a rubber that is more liquid-like or a very viscous glass (Karmas *et al.*, 1992).The transition 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 substantially influences the glass transition temperature (Levine and Slade, 1981). Due to the glass transition phenomenon, dry food products change state when stored in extremely humid environments (Steele, 2004).

Crystal growth and crystallization

Food deterioration can also be a result of freezing. Foods that are slowly frozen or frozen repeatedly suffer greatly as a result of crystal development. They have significant extracellular ice accumulation. These foods are more stable than processed foods with gradual freezing because rapid freezing creates ice inside food cells (Reid, 1990). Emulsifiers and other water binding agents can be applied during freezing cycles to reduce the formation of big ice crystals (Levine and Slade, 1981). Foods having a high sugar content can crystallize sugar as a result of moisture buildup or temperature rise. The result is a gray or white look as sugar rises to the surface from within. Sugar crystallization causes sugar cookies to stolon, sweets to become grainy, and ice cream to become grainy (Steele, 2004). Fructose or starch can be added to sugar solutions to prevent crystallization. Moreover, time is vital in the process of food products' sugar crystallizing above the relevant glass transition temperature (Roos and Karel, 1991).

Microbial spoilage

Food rotting that result from the action of microorganisms is known as microbial spoilage.

Moreover, it is the main source of foodborne illnesses. Different microbes frequently damage perishable foods. Adjusting storage temperature, lowering water activity, lowering pH, adding preservatives, and using the right packaging can all slow or stop the growth of most microbes (Tianli *et al.*, 2014).

Microorganisms involved in food spoilage

Molds, yeasts, and bacteria are the three main kinds of microorganisms that cause food to spoil.

Factors affecting microbial spoilage

There are both internal and external factors that can influence microbial food deterioration (Jay, 2000). The projected shelf life or perishability of foods is determined by their intrinsic qualities, which also have an impact on the kind and rate of microbial deterioration. The main intrinsic factors that contribute to food spoiling include endogenous enzymes, substrates, light sensitivity, and oxygen (In'tveld, 1996). These characteristics can be managed during the food product formulation process to regulate food quality and safety (Doyle, 2009). The pH, water activity, nutrient content, and oxidation-reduction potential are intrinsic food rotting factors (Steele, 2004; Doyle, 2009; Jay, 2000). Relative humidity, temperature, the presence of other bacteria, and their activities are extrinsic causes of food degradation (Steele, 2004; Jay, 2000).

Chemical spoilage

Food items are the consequence of natural, chemical and biological interactions that produce unpleasant sensory outcomes. Fresh foods may have minor quality alterations as a result of: (a) microbial development and metabolism. which (a) causes pH changes, (b) produces poisonous substances, and/or (c) causes oxidation of lipids and pigments in fat, which produces unfavorable tastes and colors (In't Veld, 1996; Van Boekel, 2008). Microbial activities and chemical deterioration are connected. The oxidation process, however, is essentially chemical in nature and is influenced by changes in temperature (In't Veld, 1996).

Oxidation

Ammonia and organic acid are produced when amino acids interact with oxygen. The basic spoiling reaction for fresh meat and fish stored in the refrigerator is shown below (Jay, 2000).

Amino acid + O2deaminase NH3 + Organic acid

The process of lipid oxidation, in which unsaturated fats (lipids) react with oxygen, is referred to as "rancidification" (Enfors, 2008). The results in food products include color change, off-flavor development, and poisonous chemical creation. Metal oxides can act as a catalyst for rancidification, and light exposure speeds up the process. Following this reaction, carbonyl molecules are created that give food its rancid flavor (Enfors, 2008).

Proteolysis

A protein's peptide and iso-peptide linkages are hydrolyzed in a limited and highly specific manner during proteolysis, a common and irreversible post translational alteration. Several protease enzymes are necessary for the overall phenomenon (Rogers and Overall, 2013). In numerous regulatory processes, various specialist proteases are crucial. Furthermore, both normal and pathological situations are linked to very specialized proteolytic events (Igarashi *et al.,* 2006). This reaction occurs commonly with foods that include nitrogen molecules. Proteolysis is the process by which proteins are broken down into smaller amino acids. The strong taste of several of these peptides can be either bitter or sweet (Enfors S-O, 2008).

Putrefaction

Through a series of anaerobic processes known as putrefaction, amino acids divert to amines, organic acids, and pungent sulfur compounds like mercaptans and hydrogen sulfide. 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 and Herbal, 2003). The majority of these compounds have unpleasant smells. At temperatures higher than 15 °C, putrefaction is quite common in meats and other protein-rich meals. The increased warmth makes microbial activity easier (Enfors, 2008; Panda and Herbal, 2003).

Maillard reaction

The Maillard reaction, a non-enzymatic browning process, is another major reason why food spoils. The amino group of proteins or the amino acids found in food experience this process. The typical effects of the Maillard reaction include color darkening, decreased protein solubility, the development of bitter tastes, and decreased nutritional availability of specific amino acids. This reaction happens when dry milk, dry whole eggs, and breakfast cereals are stored (Desrosier and Singh, 2014).

Pectin hydrolysis

Dicotyledonous and some monocotyledonous plants' cell walls are almost one-third made up of pectin's, which are complex combinations of polysaccharides (Hoff and Castro, 1969; Walter and Taylor, 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. In weakened tissues, firm fruits, and vegetables, this esterification process is started in situ by enhancing intercellular cohesion and fortifying cell walls through a mechanism involving calcium. Fruit pigments that are heat-labile and made of pectin components are broken down by metal ions as a catalyzing agent. This procedure is what changes the color of fruit jams or jellies (Walter and Taylor, 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 taste or smell rotten (Steele, 2004). Because the liberated volatile fatty acids have a strong malodor and taste, hydrolytic rancidity in fats like butter is very obvious (Rodriguez and Mesler, 1984). A variety of food preservation techniques, including as pasteurization, boiling, refrigeration, freezing, vacuum treatment, and the addition of antimicrobial agents, are used to extend the shelf life of foods and slow down the rotting process. Generally speaking, the majority of techniques involve eliminating or controlling elements that influence bacterial growth, such as the use of low or high temperatures, moisture management, dehydration, and the use of specific chemicals as preservatives.

Low-Temperature

Many foods have their shelf life extended by microbes when stored at low temperatures for Food Preservation and Features of Psychotropics. Because low temperatures slow down many of the physical and chemical reactions that take place in food, they also lower the growth rates of microbes. Hence, employing low temperatures can stop the growth of the majority of foodborne pathogens and bacteria that cause food spoiling. While foodborne bacteria' activities can be hindered at temperatures above freezing and can usually be stopped at subfreezing temperatures, foods are preserved by keeping them at low temperatures. organisms with a maximum growth range of 10-15^{0}C and a temperature range from below zero to 200C. For creatures that can thrive at 5°C or lower, the term "psychrotroph" was proposed (Eddy and B.P, 1960). It seems sense that psychrotrophs would be the organisms responsible for the rotting of meats, poultry, and vegetables in the 0–50°C range. According to some research, psychrotrophs and non-psychrotrophs can be separated by the former's failure to grow on a nonselective medium at 43°C in 24 hours and the latter's capacity to do so (Mossel *et al.*, 1960). The range between ambient temperatures, which are typically between 10-150°C, and the typical refrigerator range (5-7°C), is known as the chilling range. Some fruits and vegetables, including limes, potatoes, and cucumbers, can be stored at these temperatures. 0°C to 70°C are considered refrigerator temperatures. -18°C or lower is considered the freezing point. Nonetheless, some microbes can and do grow inside the freezer range, albeit at a very sluggish rate. Under normal conditions, all microorganisms are incapable of growing at freezing temperatures. The distribution of bacterial species and strains that can thrive at or below 7°C is more evenly distributed among gram-negative genera than it is among gram-positive genera.

High-Temperature

Food Preservation and Thermophilic Foods' Attributes High temperatures are used to preserve food because of how they harm germs. Any temperatures above ambient are referred to as high temperatures. There are two temperature categories that are frequently used in relation to food preservation: pasteurization and sterilization.

Heat-based pasteurization involves either the elimination of all disease-causing organisms (as in the case of pasteurizing milk) or the elimination or reduction of the number of organisms that cause food to spoil, as in the case of pasteurizing vinegar. Milk is heated as follows to pasteurize it: Low temperature, long time (LTLT) at 145°F (63°C) and high temperature, short time (HTST) at 1610°F (72°C) for 15 seconds each. 191°F (89°C) for 1 second, 194°F (900°C) for 0.5 second, 201°F (94°C) for 0.1 second, and 212°F (1000°C) for 0.01 second Sterilization is the process of eliminating all living things that may be detected using a suitable plating or counting technique.

Physical method of food preservation

Physical food preservation techniques use physical treatments to prevent, eliminate, or get rid of unwanted bacteria without using antimicrobial chemicals or byproducts of microbial metabolism as preservatives. Physical dehydration techniques (drying, freeze-drying, and freeze concentration), chilly storage, or freezing storage can all impede microbial growth. Microorganisms can be eliminated by well-established physical microbicide treatments like heating (including microwave heat treatment), UV or ionizing radiation, as well as newer non-thermal treatments like the application of high hydrostatic pressure, pulsed electric fields, oscillating magnetic fields, photodynamic effects, and a combination of physical processes like heat irradiation, dehydro irradiation, and mano thermosonication.

Physical processing

Drying

Drying or dehydration is the process of removing water from a solid or liquid food by means of evaporation. The purpose of drying is to obtain a solid product with sufficiently low water content. It is one of the oldest methods of food preservation (Berk, 2013). Water is the prerequisite for the microorganisms and enzymes to activate food spoilage mechanisms. In this method, the moisture content is lowered to the point where the activities of these microorganisms are inhibited (Pitt and Hocking, 2009; Rayaguru and Routray, 2010).

The majority of microbes can grow when the water activity is above 0.95. At water activity levels below 0.9, bacteria are not active. At water activity levels below 0.88, the majority of bacteria cannot grow (Leniger and Beverloo, 1975; Syamaladevi *et al.*, 2016).

There are a lot of benefits to drying. Food is stored, packaged, and transported more easily, its weight and volume are reduced, and various flavors and odors are added. Drying appears to be the least expensive technique of food preservation, despite all these advantages (Agrahar *et al.*, 2010). The drawbacks of this method are however there. After drying, there has occasionally been a noticeable loss of flavor and scent. Also lost as a result of drying are several useful substances like vitamin C, thiamin, protein, and fat (Jangam *et al.*, 2010; Salvato *et al.*, 2003).

Classification of drying

The three main types of drying are convective, conductive, and radiative. The most often used technique for getting foods that are over 90% dried is convective drying. Dryers can be divided into batch and continuous categories based on their mode of operation. Batch dryers are preferred for operations on a smaller scale and brief residence durations. Continuous drying is preferred when long periodic activities are necessary and drying costs need to be reduced (Baker, 1997).

Drying of different foods

Food items are processed through drying, including fruits, vegetables, meats, and fish. Spray drying or freeze-drying are also used to create instant coffee and tea (Bhat, 2012; Sagar *et al.*, 2010).

Pasteurization

A physical preservation method called pasteurization involves heating food to a specified temperature in order to kill the enzymes and microorganisms that cause deterioration (Baker *et al.*, 1997; Shenga *et al.*, 2010). This technique eliminates almost all of the pathogenic bacteria, yeasts, and molds. Food has a longer shelf life as a result (Laudan, 2009; Padilla *et al.*, 2016). After French scientist Louis Pasteur (1822–1895), who tested this method in 1862, it was given its name. He used this method to wine and beer (Brown, 2007). Pasteurization serves two purposes: to improve food safety for consumers by eliminating disease-causing pathogenic microorganisms that may be present in milk; and to improve food quality by eliminating rotting microorganisms and inactivating enzymes that affect milk's poor quality and shelf life. In general, pasteurization is a heat-treatment method for milk and other liquids that preserves their nutritional value while also ensuring the thermal eradication of germs and microorganisms responsible for food degradation. One food product that is pasteurized everywhere is milk, however in other regions of the world, other foods are also typically pasteurized. Moreover, all yeasts, molds, gram-negative bacteria, and many gram-positive bacteria are destroyed by milk pasteurization temperatures that are high enough. Thermophiles and thermoduric are the two categories of organisms that are classified as having the best chance of surviving milk pasteurization. Thermoduric organisms are those that can endure relatively high temperatures but do not necessarily grow there. The genera Streptococcus and Lactobacillus, as well as occasionally additional genera, are home to the non-functioning organisms that survive pasteurization of milk. The term "thermophilic organisms" refers to those that not only can tolerate relatively high temperatures but also need high temperatures for metabolic and growth processes. The thermophiles that are most significant in food are found in the genera Bacillus and Clostridium. In the brewing industry, beers are typically pasteurized (to kill spoilage biota) for 8 to 15 minutes at 60^0C.

Pasteurization techniques

The temperature-time combination affects pasteurization effectiveness. The majority of this combination is based on research on the thermal mortality rates of heat-resistant bacteria (Kutz, 2008). Vat (batch), high temperature short time (HTST), and ultra-high temperature (UHT) pasteurization procedures can be classified according to temperature and heat exposure; HTST and UHT are continuous processes (Arcand and Boye, 2012). Small plants with a capacity of 100–500 gallons should use a vat pasteurizer (Salvato, 2003). To prevent overheating, holding, or burning during vat pasteurization Rahman, High-temperature short-time (HTST) pasteurization is a continuous process pasteurizer outfitted with a sophisticated control system, pump, flow diverters or valves, and heat exchanger equipment (Salvato, 2003). According to Farrall (1980), HTST pasteurization is also referred to as "flash pasteurization." Both vat and HTST pasteurization efficiently kill harmful bacteria. However, ultra-high temperature (UHT) pasteurization is more successful than VAT and HTST at inactivating thermo-resisting spores. Food items undergo minor physical, chemical, or biological changes when they are heated (Tamime, 2009). The products are aseptically packaged in sterile containers after heating is complete (Drake, 2008). Compared to other pasteurized items, UHT pasteurized goods have a longer shelf life.

Several vitamins, minerals, and helpful microbes may be harmed during pasteurization due to the high heat involved. Vitamin C is diminished by 20%, soluble calcium and phosphorus are diminished by 5%, thiamin and vitamin B12 are diminished by 10%, and soluble calcium and phosphorus are diminished by 5% at pasteurization temperature. Ascorbic acid, vitamin C, and beta-carotene levels in fruit juices are reduced by pasteurization. From a nutritional perspective, these losses, however, can be regarded as minimal (Fellows, 2009).

Sterilization

Thermal sterilization

A prolonged shelf life is achieved via thermal sterilization, a heat treatment procedure that totally eliminates all living microorganisms (yeast, mold, vegetative bacteria, and spore formers) (Walter and Taylor, 1991; Rahman, 2007). Two types of thermal sterilization are retorting and aseptic processing (Knechtges, 2012). Pasteurization differs from thermal sterilization. Two types of thermal sterilization are retorting and aseptic processing (Knechtges, 2012). It is described as the packaging of food in a container and then sterilizing (Knechtges, 2012). Foods with pH levels exceeding 4.5 require sterilizing temperatures greater than 100°C. It is possible to reach this temperature in batch or continuous retorts. Continuous systems are gradually replacing batch retorts (Kirk, 2007). The most often utilized continuous systems in the food industry are rotary cookers and hydrostatic retorts (Tucker, 2007). shows several batch and continuous retort criteria.

The type of microorganisms found on the food, the size of the container, the acidity or pH of the food, and the manner of heating all have an impact on the time and temperature needed to completely sterilize meals. The *C. botulinum* bacterium's spores are typically intended to be destroyed by the thermal methods used in canning (can easily grow under anaerobic conditions, producing the deadly toxin that causes botulism). However, *C. botulinum* is not viable in acidic foods (pH less than 4.6), therefore such goods can be appropriately treated by dipping in water at temperatures slightly below 100°C. The sterilizing procedure involves heating to temperatures more than 100°C. The sterilization process for low-acid foods (pH greater than 4.6) is typically carried out in steam vessels called retorts at temperatures ranging from 116° to 129°C.

The retorts are controlled by programmed devices, and thorough records are kept of the time and temperature treatments for each batch of processed cans. In order to prevent any surface rusting, the cans are dried after the heating cycle and cooled down to a temperature of roughly 38°C by water sprays or in water baths. All living things that can be counted using a suitable plating or enumerating technique are destroyed.

Aseptic packaging

Commercially-sanitized food is placed in a sterilized package and then sealed in an aseptic setting as part of aseptic packaging (Potter and Hotchkiss, 1999). Paper and plastic are used in traditional aseptic packaging. You can sterilize something with either heat treatment, chemical treatment, or a combination of the two (Potter and Hotchkiss, 1999). To preserve liquids, dairy goods, tomato paste, and fruit slices, aseptic packing is frequently employed (Kirk-Othmer, 2007). It can significantly enhance the shelf life of food products. For instance, the Characterization process can extend the shelf life of liquid milk from 19 to 90 days, while coupled UHT processing and aseptic packaging can extend shelf life to at least six months. Plastics with a relatively low melting point are utilized to make the packaging for aseptic processing. Moreover, aseptic filling can accept a variety of packing materials, such as (a) metal cans disinfected by superheated steam, (b) paper, foil, and plastic laminates sterilized by hot hydrogen peroxide, and (c) a variety of plastic and metal containers sanitized by high-pressure steam. Miller, (2006) Hence, aseptic packing skill is improved and cost is reduced by the wide variety of packages. Aseptic packing uses both steam infusion and steam injunction as its direct method. A plate heat exchanger, a scraped surface heat exchanger, and a tubular heat exchanger are all parts of the indirect approach to aseptic packing (Ohlsson and Bengtsson, 2002). One of the quickest heating techniques is steam injection, which frequently gets rid of volatile ingredients from specific food products. Instead, steam infusion reduces the possibility of scorching products and allows greater control over processing conditions than steam injection. Foods that are viscous can be treated using steam infusion (Ohlsson and Bengtsson, 2002). Higher pressures and flow rates require the use of tubular heat exchangers. Only low viscosity foods can be used with these exchangers because they aren't flexible enough to handle changes in manufacturing capacity. In contrast, plate exchangers solve these issues. However, due to the need for frequent cleaning and sterilization, this exchanger is now less used in the food industry (Ohlsson and Bengtsson, 2002).

Ultra-Heat Treatment (UHT)

High hydrostatic pressure, also known as ultra-high-pressure processing (HPP), uses pressures of up to 900 MPa to destroy bacteria in food. Also, this method prevents food from spoiling, postpones the start of chemical and enzymatic deteriorative processes, and preserves the vital physicochemical and physical properties of food. Without compromising the chemicals that give vitamins, tastes, and colors their color, HHP has the potential to be a significant preservation technique. HPP technology's unmatched advantages include enhanced flavor with great nutritional value (Bhat *et al.,* 2012). Since relatively little energy is used and there aren't many waste products to discharge, this procedure is also environmentally benign. The expensive initial investment is this technology's main flaw. Moreover, a lack of knowledge and skepticism regarding this technology prevent HPP methods from being widely used (Grandison *et al.,* 2011). The use of extremely high temperatures in the processing of milk and milk products is a more recent innovation (UHT). The main characteristics of the UHT treatment include its continuous nature, the fact that it occurs outside of the package necessitating aseptic handling and storage of the product downstream from the sterilizer, and the extremely high temperatures (in the range of 140–150°C) and correspondingly brief times (a few seconds) necessary to achieve commercial sterility (Jelen, 1982). Consumer acceptance of UHT-processed milks is higher than that of conventionally heated pasteurized goods, and because they are commercially sterile, they can be kept at room temperature for up to 8 weeks without losing flavor. Depending on the type of salt used, the concentration used, and other variables, salt can have a variety of effects on microorganisms' ability to withstand heat. It has been demonstrated that adding CaCb to the Bacillus megaterium spores' growing media results in more heat-resistant spores, but doing so also results in the addition of L-glutamate, L-proline, or more phosphate content (Levinson *et al.,* 1964). Microorganisms suspended in the suspending menstruum have more heat resistance since sugars are present in it. When conditions are ideal for their growth, which is often around pH 7.0, microorganisms are most resistant to heat.

This fact is used to advantage when heating high-acid meals, when much less heat is used to achieve sterilization than when heating foods that are at or near neutrality. According to Cunningham and Line in Cunningham *et al.,* (1965), if the pH is lowered to around 7.0, egg white can be pasteurized in the same way as whole eggs. A particular species' endospores are more heat resistant when produced at its maximum temperature than when cultivated at lower temperatures. The most popular UHT product is milk, but cream, soy milk, yogurt, wine, soups, and honey are also produced using this method.

Cooking

Instead, then enhancing food quality for storage, this strategy is typically employed to enhance palatability. The act of heating water until it reaches a temperature of roughly 100°C is known as boiling. With rice, beef, fish, and beans, precooking is typically employed. Precooking, which greatly slows drying, can prevent the formation of surface pellicle (case-hardening). According to Potter, when a plant or animal is murdered, its cells open up more to moisture. After blanching or cooking the tissue, the cells may continue to open up to moisture. As long as the cooking does not result in excessive toughening or shrinking, cooked vegetables, meat, or fish can be dried more readily than their fresh equivalents. Meat products' ability to retain water is further reduced by cooking. The active (vegetative) cells of bacteria and fungi (yeasts and moulds) are typically quickly destroyed at this temperature if maintained for a sufficiently long period of time, allowing the heat to completely penetrate the foods and kill the microbes. Although boiling foods in water cannot completely destroy all microbes. Due to their high heat resistance, bacterial spores like those of Clostridium perfringens and Clostridium botulinum, which are present in non-acid and semi-acid foods like peas, corn, green beans, meat, etc. and produce harmful toxins in food, are not killed at this temperature even though their growth is inhibited. Foods must be boiled for at least 10 minutes to inactivate the toxin botulin. Foods must also be heated under pressure to quickly destroy the bacteria's spores, as heat destruction is influenced by temperature and time variations. Certain Staphylococci-produced enterotoxins, though, are difficult to neutralize. When the environment is right, thermophilic microbes can quickly induce food spoiling by withstanding the impacts of boiling and badly handled prepared items.

Canning

One of the most common methods of food preservation, the food contents are treated (heated to an appropriate temperature for a specified time to destroy microorganisms, including Clostridium botulinum spores) and sealed in an airtight container. The canning process was developed by Nicolas Appert. In general, this method usually yields a shelf life of 1 to 5 years, but in certain circumstances freeze-dried canned products, such as canned dried lentils, can last up to 30 years in edible condition. There is a nature. During storage, food is carefully prepared and packed in sealed cans, glass or plastic containers, exposed to a defined high temperature (above 100 °C) for a reasonable period of time and then cooled. During heating, oxygen is removed and the vessel is further sealed to avoid post-processing contamination. Also, the food is cooked in the container to kill micro-organisms and the can is sealed (either before or while the food is in the cooking process). To limit this and prevent the introduction of new microorganisms. After heat treatment, the sealed container should be immediately cooled to a temperature of approximately 38°C to avoid unwanted adverse effects of heat on the texture, taste or color of the food. This sterilizes the food and gives it a long shelf life without the risk of spoilage by unwanted microorganisms.

Refrigeration

It is a contemporary method of food preservation based on the observation that at refrigeration temperatures (0–5 °C or lower), harmful foodborne illness germs do not develop (or grow very slowly). Because it will slow down but not entirely stop the growth of germs (food spoiling microbes: bacteria and fungi), refrigeration is typically regarded as a temporary food preservation method. Hence, refrigeration only retains food for days as opposed to freezing, which keeps food for months. Practically, storing food at temperatures below 4°C can extend the shelf life of many goods.

Food that has gone bad cannot be made better because refrigeration simply slows microbiological decomposition. Typical foods kept in refrigerators include fresh produce, eggs, seafood, dairy, meats, and other items. The damage caused by exposure to low temperatures prevents some goods, like bananas, from being refrigerated. Limitation: Dehydration of stored goods due to moisture condensation is a problem with current mechanical refrigeration, but it has been resolved with the use of humidity control systems inside the storage chamber and the use of the right packaging techniques.

Freezing

By creating ice from water below freezing temperature, freezing slows down physiochemical and metabolic reactions and prevents the growth of harmful and pathogenic germs in food (George, 2008; Velez-Ruiz and Rahman, 2006). It reduces water activity and the amount of liquid water in the food products. When a food item freezes, heat transport is complicated by a simultaneous phase transition and change in thermal characteristics (Ramaswamy and Tung, 1984; Brennan, 2006). Two fundamental sequential stages of freezing are nucleation and growth. Ice crystals develop through a process known as nucleation, and then grow over time, as indicated by the term "growth" (Bhat *et al.*, 2012). When compared to other techniques of food preservation, freezing is much better at keeping the nutritional value and the natural color, flavor, and texture of foods, such as fruits, meats, breads, and cakes. It is advised that fresh vegetables should be blanched first before freezing to halt enzymatic activity (that can cause alterations in their nutritional values). Vegetables were placed in a kettle of hot water to be blanched. After giving them 1-2 minutes, stop the cooking right away by withdrawing them from the boiling water and plunging them into an ice bath.

Freezing time

The amount of time needed to get a product's beginning temperature down to a specific temperature at its thermal core is known as the freezing time. Generally, when food tissues are frozen slowly, larger ice crystals form in the extracellular spaces, whereas when tissues are frozen quickly, little ice crystals are scattered throughout the tissue (Ramaswamy and Tung, 1984). According to the food items and freezing equipment, the International Institute of Refrigeration (1986) defines various freezing time factors. The most crucial elements among these are the product's dimensions and forms, initial and final temperatures, the temperature of the refrigerating medium, the product's surface heat transfer coefficient, and changes in enthalpy and thermal conductivity (Barbosa *et al.,* 2005).

Each person quickly freezing Individual quick freezing typically refers to the rapid freezing of solid meals like fish, green peas, bits of meat, beans that have been chopped up, cauliflower pieces, shrimp, and cauliflower. On the other side, fast freezing is the term used to describe the freezing of liquid, pulpy, or semiliquid items like fruit juices, mango pulps, and papaya pulps.

Quick freezing produces significantly smaller ice crystals, which are less damaging to the food's cell structure and texture. Salt diffusion is hindered and food breakdown is prevented during shorter freezing times.

Moreover, IQF enables commercial freezing units to operate at higher capacities at a lower cost. But, setting up a quick-freezing unit requires a larger expenditure (Pruthi, 1999). Food items are processed using a variety of quick-freezing methods, including cryogenic freezing, air-blast freezing, and contact plate freezing.

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 Kotsiopoulos, 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 (Indira and Sudheer, 2007). When cooling is done at 15 °C, the freezing process is frequently referred to as chilling in practice (Lund, 2005). In contemporary food sectors, partial freezing is used to increase the shelf life of fresh food products. This procedure, known as "ultra-chilling," lessens the production of ice in foods (Lund, 2005). A variety of equipment can be used to chill, including a cryogenic chamber, continuous air cooler, ice bank cooler, plate heat exchanger, jacketed heat exchanger, and ice implementation system (James, 2008). The key factors affecting cooling rate include thermal conductivity, food's beginning temperature, density, moisture content, the presence or absence of a lid on the food storage container, the use of plastic bags as food packing equipment, and the size and weight of food units (Light and Walker, 1990). Chilling storage has both benefits and drawbacks, but it is widely utilized for its short-term preservation abilities. In addition to stopping post-harvest metabolic activity in intact plant tissues and post-slaughter metabolic activities in animal tissues, cooling slows down the growth of bacteria. Moreover, it prevents chemical processes that lead to color loss, such as oxidative browning, lipid oxidation, and enzyme-catalyzed oxidative browning. Moreover, it slows down the autolysis of fish, reduces the nutritional content of food, and, ultimately, results in moisture loss (Lund, 2005). Since this procedure necessitates specialized equipment and building alterations, chilling is highly capital expensive. Some foods may become less crispy after cooling (Arora, 2007). Unwrapped food surfaces are also dehydrated during the chilling process, which is a significant drawback (Handbook of Food Science, 2005).

Water Activity

The stability of food cannot be accurately predicted by water concentration, according to many studies on food qualities and reactions. In instances where the processes are dominated by equilibrium considerations, water activity offers an exceptional, possibly unique stability factor. In the case of microbial development, this is especially true because, through a number of now fairly well-understood mechanisms, microbial growth is stopped when there is an osmotic pressure difference between the optimally hydrated microbial cell and the surrounding medium (food). Water activity is also a very useful aspect in evaluating mobility-controlled processes in meals since it regulates the water content in the various food components, which in turn regulates the water's dominating impact on mobility (owing to plasticizing action), dietary ingredients with hydrophilicity (Fennema, 1996). Where the water activity is less than 0.94, most bacteria are unable to grow on food or other media. In comparison to yeasts, which in turn require a higher aw than molds, bacteria have higher water activity requirements. As a result, any factor that decreases water activity prevents first bacteria, then yeasts, and then molds (Elliott and Michener, 1965). Each species, however, has its own limitations that are connected to other development variables.

Radiation preservation

Food is preserved by being subjected to highly energetic radiation in order to increase product safety and shelf life. It could take the place of heat treatment as well as chemical preservatives. 40 distinct food products are currently allowed in 35 countries worldwide for what is known as cold pasteurization of food (Thayer and D.W, 2005). One of the most significant peaceful applications of gamma irradiation is the treatment of dairy products. Irradiation up to 10 kilobars did not pose any risk because it could not result in cancer, genetic mutation, or tumors (Mehran *et al.*, 2005). In the context of food science, irradiation is the process of applying this energy to a particular substance, such as a food product, in order to decrease the number of bacteria, get rid of parasites or insects, or stop the action of certain enzymes. Since it generates electrically charged ions as it interacts with target molecules, the radiation used to preserve food is known as ionizing radiation. High-energy electrons, X-rays, or gamma rays are the ionizing radiation sources utilized to disinfect microorganisms (y-rays). These techniques include pasteurization, fermentation, freezing, drying, canning, pickling preparation, chilling, controlled atmosphere storage, and the use of preservatives. The radiation approach stands out among the new technologies. By eliminating bacteria, the technique—which is quite similar to pasteurization—makes food safer to consume. Radiation essentially interferes with the biological processes that cause decay and sprouting. Radiation can be used to pasteurize and sterilize food without affecting the freshness or texture of the food because it is a cold process. Also, radiation is more efficient and can be used to cure packaged goods, unlike chemical fumigants, which can leave dangerous residues in food. It is possible to efficiently get rid of bacteria and parasites that cause sickness by utilizing irradiation. According to reports, frozen cells are more radiation resistant than non-frozen cells (Grecz *et al.*, 1965) Ionizing radiation (IR) is applied to a substance during the physical process of irradiation (Arvanitoyannis, 2010). Both natural and artificial IR exist. High-energy ultraviolet (UV) radiation, X-rays, and gamma rays are examples of natural IR; produced secondary radiation and accelerated electrons are examples of artificial IR (Moniruzzaman *et al.*, 2016; Sommers, 2010). More than 60 distinct meals are prepared using it in 40 different nations (Arvanitoyannis, 2010).The effects of IR include: (a) disinfestation of grains, fruits, and vegetables; (b) improvement of fruit and vegetable shelf life by reducing sprouting or altering rate of maturation and senescence; (c) extension of food shelf life by killing off spoilage organisms; and (d) improvement of food safety by killing off foodborne pathogens (Heldman and Moraru, 2010; Kanatt *et al.*, 2006). Radiation exposure regulations Kilo grays represent the IR dose applied to food. The amount of ionizing energy that 1 kilogram of radioactive material receives is equal to 1 gray. Legislative bodies determine the boundaries of IR regulation. These restrictions may be stated as a minimum dose, maximum dose, or allowed dose range depending on the regulatory body (Sommers, 2010). Consequences of radiation Even at large doses, IR has no effect on the nutritional factors, such as lipids, carbs, proteins, minerals, and the majority of vitamins (Smith and Pillai, 2004). IR may result in the loss of several micronutrients at high doses, including vitamins A, B1, C, and 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).

High-pressure

High hydrostatic pressure, also known as ultra-high-pressure processing (HPP), uses pressures of up to 900 MPa to destroy bacteria in food. Also, this method prevents food from spoiling, postpones the start of chemical and enzymatic deteriorative processes, and preserves the vital physicochemical and physical properties of food. Without compromising the chemicals that give vitamins, tastes, and colors their color, HHP has the potential to be a significant preservation technique (Bhat *et al.*, 2012; Dunne, 2007; Koutchma *et al.*, 2016). The superior qualities of HPP technology include freshness, better flavor, and great nutritional value. This procedure is also environmentally friendly because it uses very little energy and produces very little waste that needs to be discharged (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 processes is constrained by a lack of knowledge and mistrust regarding this technology (Bhat *et al.,* 2012; Yeung and Huang, 2016). Mechanism and underlying idea The HP technique adheres to the isostatic and Le Chatelier principles. Bhat Le Chatelier's principle states that when biochemical and physicochemical events are in balance, a change in volume occurs along with it, which then influences pressure. The isostatic principle relies on instantaneous and uniform pressure transmission across food systems, regardless of the size, shape, or geometry of the products (Bhat *et al.,* 2012).

Any reaction or structural change involving a volume change is affected by HP processes. Microorganisms are killed or their proliferation is hampered by the combined effects of cell membrane permeabilization and breakdown. Vegetative cells are rendered inactive at 3000 bar pressure (about) at room temperature, whereas spore inactivation necessitates much higher pressure together with a rise in temperature to 60–70 °C. Given that there is little effect below 40% moisture content, moisture level is crucial in this context (Ohlsson and Bengtsson, 2002). Two techniques for food preservation under high pressure are container processing and bulk processing.

Biologically

A biological process called fermentation preserves food by using microorganisms. This process entails the breakdown of carbohydrates by the activity of bacteria and/or enzymes (Shivashankar, 2002). The most prevalent types of microorganisms that cause fermentation in a variety of foods, including dairy products, foods made from cereal, and meat products, include bacteria, yeasts, and molds (Battock and Azam-Ali, 1998; Katz, 2001). Foods that have undergone fermentation are more nutrient-dense, wholesome, and easily digestible. This is a safe replacement for many harmful chemical preservatives (Lewin, 2012). Fermentation classification can happen naturally or be forced. Several kinds of fermentation are employed in the processing of food. This is a quick discussion of the mechanisms behind several food fermentation techniques: Hexose, a type of simple sugar, is fermented into alcohol and carbon dioxide by yeast. Alcohol content affects the quality of items that have undergone fermentation. To prevent the activity of aerobic microbes such the acetobacter, air is kept out of the product during this process. The prolonged shelf life of the products is ensured by this technique.

The following equation demonstrates how hexose can be converted to alcohol during fermentation (Dagoon, 1993).$C6H12O6 + O2 = C2H5OH + CO2$Hexose + Oxygen= Ethanol + Carbon dioxide. Alcohol fermentation is followed by the fermentation of vinegar. Alcohol is converted to acetic acid by Acetobacter in the presence of too much oxygen (Battock and Azam-Ali, 1998). Using this technique, foods are preserved as pickles and relishes (Koutchma *et al.,* 2016). Alcohol oxidation during vinegar production produces acetic acid and water (Battock and Azam-Ali, 1998). $C2H5OH + O2 = CH3\ COOH + H2\ O$Ethanol + Oxygen= Acetic Acid + Water.

There are two types of bacteria that cause lactic acid fermentation: homofermenters and heterofermenters. Through the glycolytic process, homofermenters mostly create lactic acid (Embden–Meyerhof pathway). The 6-phosphor gluconate/phospho ketolase route is used by heterofermenters to create lactic acid as well as significant amounts of ethanol, acetate, and carbon dioxide (Battock and Azam-Ali, 1998). Food is preserved using the fermentation process, which involves microbes. With the help of microbes and/or enzymes, this technique involves the breakdown of carbohydrates (Shivashankar, 2002). The most frequent microorganisms engaged in the fermentation of a variety of foods, including dairy products, foods made of cereal, and meat products, are bacteria, yeasts, and molds (Katz, 2001). Foods with a fermented flavor are more nutrient-dense, wholesome, and easily digestible. The term "bio preservation" refers to a technique for preserving food that makes use of natural antimicrobials and microbiota to extend the food's storage life (Ananou *et al.,* 2004, 2007).

The importance of lactic acid bacteria in this context stems from their ability to operate as natural bio preservatives that are antagonistic to spoilage bacteria and pathogens. The metabolites of LAB include peptide-based bacteriocins and acidic substances including acetic acid, lactic acid, hydrogen peroxide, and others (Cintas *et al.,* 2001). These metabolite components plus the antibacterial compound nisin, which has the potential to be a useful food preservative, are produced by the LAB when it competes for nutrients. The formation, proliferation, and bioactivity of spoilage bacteria can be controlled and inhibited by using the bacteriocin-producing LAB in combination with other efficient preservation strategies. homosexual fermentation. The fermentation of 1 molof glucose yields two moles of lactic acid C6H12O6 (Glucose) 2CH3CHOHCOOH (Lactic Acid).

Heterolactic fermentation

The fermentation of 1 mol of glucose yields 1 mol each of lactic acid, ethanol, and carbon dioxide (Battock and Azam-Ali, 1998). C6H12O6 = CH3CHOHCOOH + C2H5OH + CO2Glucose= Lactic Acid + Ethanol + Carbon dioxide. Several types of microbes are utilized exclusively during the fermentation process to provide flavor in foods (Shivashankar, 2002).

Chemical (Artificial Preservatives) Processes

One of the age-old and conventional methods of food preservation is the use of chemical agents (Michael Davidson *et al.,* 2005). The concentration and selectivity of the chemical reagents, organisms that cause food to decay, and the physical and chemical properties of the food products all affect how effective this procedure is (Frank and Paine, 1993).

The use and consumption of food additives and preservatives are expanding globally. North America now dominates the market for food preservatives, followed by Asia-Pacific (according to data from 2012). By the end of 2018, it is anticipated that the market for food preservatives will reach a value of $2.7 billion (Rohan, 2014). Yet, due to health issues, employing chemical reagents as food additives and preservatives is a contentious topic (Mursalat *et al.,* 2013). Several ordinances, regulations, and governmental bodies oversee how chemical preservatives and food additives are used in various nations (Michael *et al.,* 2005; Islam *et al.,* 2016).

Chemical preservatives

Preservatives are compounds that can slow or stop the growth of germs or any other degradation brought on by their presence (Adams and Moses, 2008). Certain food products' shelf lives are extended by food preservatives. Preservatives prevent microorganism-caused degradation, preserving the food's color, texture, and flavor (Adams, 2008). There are two types of food preservatives: natural and artificial. Chemicals that have the ability to preserve foods are found in animals, plants, and microbes. They also serve as flavorings, antimicrobial agents, and antioxidants (Msagati, 2012). Industrial facilities create artificial preservatives. They fall into the categories of "antimicrobial," "antioxidant," and "ant enzymatic" (Sati, 2013). According to Jay (2000), one of the reasons why chemicals are employed to stop or postpone food spoiling is because they are so effective at treating illnesses in people, animals, and plants. A natural or synthetic chemical applied to food to prevent spoiling due to microbial growth or unfavorable chemical changes is known as a food preservative. Preservatives are compounds that can prevent, delay, or stop the growth of germs or any other degradation brought on by their presence (Adams and Moses, 2008). Antimicrobial substances stop active metabolism and impede the formation of reproduction-related macromolecules.

The shelf life of food is extended by preservatives, which are food additives that guard against the action of microorganisms (fungi and/or bacteria). Also employed as preservatives in low pH foods are organic acids such acetic acid, benzoic acid, propanoic acid, and sorbic acid.

Often used to prevent Clostridium botulinum growth in foods containing raw meat, such as salamis, ham, bacon, and sausage, nitrates and nitrites are used. Sulphur dioxide and sulphites are frequently added to dry fruits, juices, and wines to prevent the growth of microbes. Antibiotics like nisin and natamycin are used to prevent the growth of germs and fungi in a variety of foods.

Food additives

The major goals of using food additives are to preserve and improve nutritional value, improve quality, decrease waste, increase customer acceptability, make food more accessible, and make food processing easier (De Man, 1999). Food additives are purposely added during food processing, packaging, or storage to change specific food qualities in the way that is intended. They can be either natural or synthetic chemical substances. The two main categories of food additives are deliberate and inadvertent. Of these two, deliberate additions are subject to severe governmental regulation (De Man, 1999). The National Academy of Sciences (1973) states that additives are prohibited when used to cover up poor manufacturing practices, conceal damage, spoilage, or other flaws, or perhaps even to trick consumers. Also, if chemicals significantly reduce nutrition, then their purposes are also unrelated (De Man, 1999).

Table.1 Classification of foods based on functions and nutrients (Chopra, 2005).

	Sources
Functions	
Body building and repairing foods	Milk, meat, fish, pulses, vegetables, and nuts
Energy-giving foods	Oil, butter, sugar, cereals, dry fruits, and starch foods
Regulatory foods	Water, raw vegetables, citrus fruits, and beverages
Protective foods	Milk, whole grain cereals, meat, vegetables, and fruits
Nutrients	
Carbohydrate-rich foods	Rice, wheat, and starchy vegetables
Protein-rich foods	Milk, meat, fish, egg, and nuts
Fat-rich foods	Oils, butter, and egg yolk
Vitamin- and mineral-rich foods	Fruits and vegetables

Table.2 Food classification based on the extent and purpose of processing (Carlos *et al.*, 2010)

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

Table.3 Active conditions of different microorganisms and affected foods (Jay, 2000; Doyle, 2009; Pitt and Hocking, 2009).

Microorganisms	Active condition				Affected foods
	pH	Temperature	Water activity	Heat sensitivity	
Molds	3.0–8.0	Grow across a wide range of temperature	0.62–1.0	Heat sensitive	Bottled mineral water, fermented foods
Yeasts	Grow around a broad range of acidic pH	Grow across a wide range of temperature, but prefer natural ambient temperature	Above 0.9	Heat resistant and can survive under scorching sunlight	Fermented foods
Bacteria	Broad pH range	Prefer growth at high temperature (≥55 °C)	Above 0.9 for gram positive and above 0.98 for gram negative	Mostly thermophiles	Fresh meat, poultry, sea food, eggs, and heat-treated foods

Table.4 Taste of different amino acids (Solms, 1969).

Taste	Amino acids
No taste/barely perceptible taste	D-Alanine, D-arginine, L-arginine, D-aspartate, L-aspartate, D-glutamate, L-histidine, D-isoleucine, L-isoleucine, D-lysine, L-lysine, D-proline, L-proline, D-serine, L-serine, L-threonine, D-valine, L-valine
Sweet taste	D-Tryptophan, D-histidine, D-phenylalanine, D-tyrosine, D-leucine, L-alanine, glycine
Bitter taste	L-Tryptophan, L-phenylalanine, L-tyrosine, L-leucine
Sulfurous taste	D-Cysteine, L-cysteine, D-methionine, L-methionine
Unique taste	L-Glutamic acid

Table.5 Processing temperature and time for different food products

Foods to be dried	Processing temperature and time
Fruits	
Cherries	70 °C for 2–3 h; 55 °C until dry
Coconuts	45 °C until dry
Pineapples	70 °C for 1–2 h; 55 °C until dry
Persimmons	60 °C for 1–2 h; 55 °C until dry
Pears (Asian)	60 °C
Vegetables	
Asparagus	60 °C for 2–3 h; 55 °C until dry
Beans, green	60 °C for 2 h; 55 °C until dry
Mushrooms	25–30 °C for 2–3 h; increase to 50 °C until dry
Onions	70 °C for 1–2 h; 55 °C until dry
Parsley	30 °C to 50 °C; may be room dried
Fish	
Carp	4 °C under high pressure for 15–20 min
Prawn	70 °C for 30 min
Meat	
All	80 °C for 2 h

Source. (Sagar *et al.*, 2010; Kristensen *et al.*, 2001)

Table.6 Pasteurization of different foods

Food type	Main purpose	Sub-purpose	Typical temperature–time combination used
Fruit juice (pH < 4.5)	Inactivation of enzymes (pectinesterase, polygalacturonase)	Destruction of spoilage-causing microorganisms (*Salmonella enterica, Cryptosporidium parvum*)	65 °C for 30 min, 77 °C for 1 min, or 88 °C for 15 s
Beer (pH < 4.5)	Destruction of spoilage-causing microorganisms (wild yeasts, *Lactobacillus* species)	Destruction of spoilage-causing microorganisms	65 to 68 °C for 20 min (in bottle) or 72–74 °C for 1–4 min at 900–1000 kPa
Milk (pH > 4.5)	Destruction of pathogens (*Brucellaabortis, Mycobacterium tuberculosis*)	Destruction of spoilage-causing microorganisms (*Streptococcus laptis, Streptococcus cremoris*) and enzymes	63 °C for 30 min or 71.5 °C for 15 s
Liquid egg	Destruction of pathogens (*Salmonella seftenburg*)	Destruction of spoilage-causing microorganisms	64.4 °C for 2.5 min or 60 °C for 3.5 min

Source:(Rahman, 2007).

Table.7 Comparison between different pasteurization techniques

Criteria	VAT	HTST	UHT
Process type	Batch	Continuous	Continuous
Typical temperature–time combination	65 °C for 30 min	72 °C for 15–30 s	135–150 °C for a few seconds
Foods preserved	Butter milk and sour cream	Milk, eggnog, frozen dessert mixes, fruit juices, etc.	Milk
Shelf life increase (milk)	Several days when refrigerated	2–3 weeks when refrigerated	6–9 months when aseptically packaged
Type of microbes destroyed	Vegetative pathogens	Vegetative pathogens	All bacteria and spores

Source:(Rahman, 2007)

Table.8 Comparison between different pasteurization techniques

Criteria	VAT	HTST	UHT
Process type	Batch	Continuous	Continuous
Typical temperature–time combination	65 °C for 30 min	72 °C for 15–30 s	135–150 °C for a few seconds
Foods preserved	Butter milk and sour cream	Milk, eggnog, frozen dessert mixes, fruit juices, etc.	Milk
Shelf life increase (milk)	Several days when refrigerated	2–3 weeks when refrigerated	6–9 months when aseptically packaged
Type of microbes destroyed	Vegetative pathogens	Vegetative pathogens	All bacteria and spores

Source: (Arcand and Boye, 2012; Rahman, 2007)

Table.9 Comparison between pasteurization and sterilization

Criteria	Pasteurization	Sterilization
Temperature level	Mild heat treatment process. Temperature level 65–75 °C (exception: UHT)	Severe heat treatment process. 135–140 °C and up to 150 °C are applied
Status of heat-resisting microorganisms	Many heat-resisting microorganisms, viruses, and spores may remain alive	Bacteria species, spores, and thermophiles
Change in nutritional capacity and profile	Negligible	Fats, protein, and sugar may decompose; calcium, minerals, and vitamins may escape
Storage	Refrigerated conditions	Ambient temperature
Product parameter (pH)	3.5 < pH < 4.6	pH > 4.6
Shelf life extension	For few days to weeks	For months

Source: (Heldman *et al.*, 2007; Kirk-Othmer, 2007)

Table.10 Comparison between batch and continuous retorts

Criteria	Batch retort	Continuous retort
Capital investment	Low capital investment and higher flexibility	Initial investment is high
Throughputs	Lower	Higher
Energy	Energy and labor intensive	Provides scope for energy saving
Time of heating to sterilization temperature	2–6 h	0.5–3 min
Sterilization time	20–60 min	15–90 s
Cooling time after sterilization	4–10 h	5–10 min
Food items	Useful in food processing operations which produce a mix of products in a number of package sizes	Baby foods in jar, pet foods, soup, canned meat, and beverages; acidic foods such as tomato products

Source: (Kirk-Othmer, 2007; Strumillo and Kudra, 1998; Grandison and Brennan, 2011)

Table.11 Different quick-freezing techniques (fishery products)

Criteria	Contact plate freezing	Air-blast freezing	Cryogenic freezing
Capital cost	Low capital investment	Economic to construct and operate	High capital costs
Operating cost	Low operating cost	Higher operating cost	Higher operating cost
Heat transfer	Controlled heat transfer	Efficient heat transfer	Efficient heat transfer
Product line	Generally bulk freezing	Flexible	Flexible
Required floor space	Large	Large	Small
Refrigeration plant	Required	Required	Not required
Maintenance cost	Low	Low	Minimum
Dehydration loss	High	High	Minimum
Product quality	Reasonably good product quality	Good product quality	Superior product quality

Source: (Venugopal, 2006).

Table.12 Chilling methods of solid and liquid foods

Solid foods	Batch air chillers	Warm food items are fed into large refrigerated room, widely used in industry
	Moving air	This cost-effective, hygienic, and widely used method incurs little damage to equipment. Surface dehydration of the food is the major disadvantage of this process
	Ice/ice water chilling	Food items are packed in boxes and then they are placed between layers of crushed ice. Melting ice assists to maintain the temperature at 0 °C. However, this method is not labor efficient and consumes much time comparing to other processes
	Cryogenic cooling	This method involves the use of liquid nitrogen to freeze the product. Thermal shock confrontation of food items makes this process vulnerable
	Immersion cooling/hydrocooling	A cost-effective cooling method is suitable for small products. This technique involves immersing or spraying the product in cool water at near 0 °C. Hydrocooling moisturizes food items which can be detrimental to some extents
Liquid Foods	Batch cooling of liquids	A jacketed stainless steel vessel of varying capacity with agitator inside is usually used for this type of chilling. The coolant may circulate through the jacket of the vessel or through a coil placed in the liquid food stuff, or both while the agitator incurs uniform heat transfer
	Continuous cooling of liquids	The continuous cooling of liquids can involve multi-plates and tubes, aeration, and double-pipe coolers. The most widespread piece of equipment is the multi-plate cooler, which has the best efficiency, high surface area for exchanging heat, easy cleaning opportunity, and less material requirement than others

Source: (Richardson, 2004).

Table.13 The water activity (a_w) limits for growth of principal foodborne disease organisms

Microorganism	Minimal a_w for growth
Salmonella	0.945
Clostridium botulinum	0.95
Clostridium perfringens	0.93
Staphylococcus aureus	0.86
Vibrio parahaemolyticus	0.94

Table.14 Regulatory limits for food irradiation applications

Type of dose	Benefits	Dose	Products
Low dose (up to 1 kGy)	Inhibition of sprouting	0.05–0.15	Potatoes, onions, garlic, root ginger, yam, etc.
	Insect disinfestation and parasite disinfection	0.15–0.5	Cereals and pulses, fresh and dried fruits, dried fish and meat, fresh pork, etc.
	Delay of physiological processes (e.g., ripening)	0.25–1.0	Fresh fruits and vegetables
Medium dose (1–10 kGy)	Extension of shelf life	1.0–3.0	Fresh fish, strawberries, mushrooms, etc.
	Elimination of spoilage and pathogenic microorganisms	1.0–7.0	Fresh and frozen seafood, raw or frozen poultry and meat, etc.
	Effect on food properties	2.0–7.0	Grapes (increasing juice yield), dehydrated vegetables (reduced cooking time), etc.
High dose (10–50 kGy)	Industrial sterilization (in combination with mild heat)	30–50	Meat, poultry, seafood, prepared foods, sterilized hospital diets
	Decontamination of certain food additives and ingredients	10–50	Spices, enzyme preparations, natural gum, etc.

Source:(Sommers., (2010)

Table.15 Food irradiation technologies

Factors	Electron beam	X-Ray	Gamma ray
Source	Accelerated electrons, typically 5–10 MeV	Induced by impingement of electron beam onto a metal plate. Conversion efficiency is 5–10%	Radioactive decay of Co-60 (2.5 MeV) or Cs-137 (0.51 MeV)
Processing time	Seconds	Seconds	Minutes
Penetration	6–8 cm, suitable for relatively thin or low-density products	30–40 cm, suitable for all products	30–40 cm, suitable for all products
Shielding for operator	>2 m concrete or 0.7 m steel/iron/lead	>2 m concrete or ~0.7 m steel/iron/lead	>5 m water or > 2 m concrete or 0.7 m steel/iron/lead

Source:(Sommers, 2010)

Table.16 Advantages and disadvantages of in-container processing and bulk processing

In-container processing		Bulk processing	
Advantages	**Limitations**	**Advantages**	**Limitations**
Applicable to all solid and liquid food	Complex materials handling	Simple materials handling	Only suitable for pumpable foods
Minimal risk of post-processing contamination	Little flexibility in choice of container	Greater flexibility in choice of container	Aseptic filling of containers required potential post-processing contamination
Major development needed for high-pressure processing	Greater dead time in use of pressure vessel	Maximum efficiency in use of high-pressure vessel volume	All pressure components in contact with food must have aseptic food design and be suitable for cleaning in place and sterilizing in place
Easier cleaning	–	Minimum vessel dead time (no opening/closing of vessel needed, faster loading/unload-ing)	–

Source: (Ohlsson and Bengtsson, 2002).

Table.17 Processing parameters of PEF-treated food products (Fellows, 2009; Maciej Oziembłowski, 2005).

Product	Processing conditions				
	Electric field strength (kV/cm)	**Number of pulses**	**Duration of pulses (μs)**	**Temperature of product (°C)**	**Log reduction (D)**
Orange juice	6.7	5	20	45–50	5
Milk	22	20	20	45–50	4.6
Skim milk	45	64	1.8–6	35	2
Yoghurt	23–28	20	100	63	2
Liquid egg	25.8	100	4	37	6
Pea soup	25–33	10–30	2	53–55	4.4
Fluid food	12–25	25	1–100	45–55	Shelf life extended from 3–7 days

Table.18 Microorganisms used in food processing and flavor compounds produced

Food items	Microorganisms	Flavor compounds produced
Buttermilk	*Streptococcus lactis* *Streptococcus cremoris* *Lactobacillus bulgaricus*	Lactic acid, diacetyl, small amounts of acetaldehyde
Yoghurt	*Streptococcus thermophiles* *Lactobacillus bulgaricus*	Acetaldehyde and diacetyl acetoin
Alcoholic fermented milk	*Saccharomyces sp.* *Lactobacillus sp.*	Ethanol acetoin and diacetyl
Sauerkraut	*Mixed cultures of* *Lactobacillus brevis* *Leuconostoc mesenteroides* *Lactobacillus plantarum*	Acetate and small amounts of short-chain fatty acids
Soybean milk	*Lactobacillus sp.* *Streptococcus thermophiles*	Aldehydes including pentanal
Soya sauce	*Aspergillus oryzae* *Lactobacillus sp.* *Saccharomyces rouxii*	Organic acids, alkyl phenols, and pyrazines
Tempeh	*Rhizopus sp.*	Fatty acid
Bread	*Saccharomyces cerevisiae*	Ethanol
Swiss cheese	*Propionibacterium shermanii*	Propionic acid
Cocoa	*Saccharomyces sp.* *Lactobacillus sp.* *Acetobacter sp.*	Fatty acids and aromatic acids

Source:(Shivashankar, 2002).

Table.19 Some types of natural preservatives: (Meyer, 2002)

Natural preservative	Example of food items	Functions
Salt	Salted fish	Salt and sugar draw the water out of microorganisms and retard the growth of microorganisms
Sugar	Jam	
Vinegar	Pickled mango	Vinegar provides an acidic condition which creates an unfavorable condition for microorganisms
Rosemary extract	Mayonnaise, margarine, oils and fats, etc.	Rosemary extracts work as antioxidant

Table.20 Classification of artificial preservatives (Garg *et al.*, 2010; Meyer, 2002; Rahman, 2007)

	Antimicrobial agents	Antioxidants agents	Antienzymatic agents
Definition	Inhibit the growth of undesirable microorganisms (fungi, bacteria, yeast)	Inhibit atmospheric oxidation. Mainly used for the products that contains unsaturated fatty acids, oils, and lipids	Prevent natural ripening process and oxidative deterioration of food by inhibiting the bacteria, parasite, fungi
Mechanism	Creates unfavorable environment for microorganisms by reducing moisture content and increasing acidity	Oxidation of unsaturated fats produces free radicals which can start chain reactions. In this reaction, aldehyde and ketones are produced which results in the rancid taste of foods. Antioxidants terminate these chain reactions by removing free radical intermediates and inhibit other oxidation reactions	Blocks enzymatic processes in the food that continue to metabolize after harvest. Metal chelating agents can remove the metal cofactors that many enzymes need
Applications	Sorbic acid (2,4-hexadienoic acid) and potassium sorbet for the preservation of cheese, bakery products, vegetable-based products, dried fruits, beverages, and other products as well as smoked fish, margarine, salad cream, and mayonnaises.	Butylated hydroxyl anisole, (BHA) for the preservation of butter, lard, meats, beer, baked goods, snacks, potato chips, nut products, dry mix for beverages	Citric acid for the preservation of foods, beverages, dairy products, and pharmaceuticals
	Benzoic acid and sodium benzoate for the preservation of mayonnaises, pickled vegetables, fruit preparation and fruit based drinks, dessert sauces and syrups	Butylated hydroxyl toluene (BHT) in fats and oils processing	EDTA (ethylenediamine tetra acetic acid) in food processing
	Lactic acid for the preservation of meats	Sulfites for the preservation of beer, wines, dried foods	Polyphosphates for the preservation of fresh peeled fruits and vegetables
	Parabens (esters of para-hydroxy benzoic acid) for the preservation of dried meat products, cereal and potato based snacks and confectionary	Vitamin E for the preservation off fruits and vegetables	Polyphosphates for the preservation of fresh peeled fruits and vegetables
	Nitrite (sodium nitrate) for the preservation of meat	Gallates in fats and oils processing	–
	Sulfur dioxide, sodium sulfite for the preservation of dried fruits, certain fruit juices, potatoes, and wines	Ascorbyl palmitate for the preservation of sausages and chicken broths	–

Table.21 Some types of food additives

Type of additive	Purpose	Example
Emulsifiers, stabilizers and thickeners	Impart a consistent texture to products; prevent separation of food	Algin, carrageenan
Anticaking agents	Enable products such as table salt to flow freely	Calcium silicate
Nutrients	Enrichment (replacement of nutrients lost during processing) and fortification (adding to the nutritional value of foods)	Folic acid, beta carotene, vitamin D, iron, iodine, etc.
Preservatives	Retard spoiling, prevent fats and oils from becoming rancid, prevent fresh food from turning brown	Nitrates, parabens, BHA, BHT, etc.
Leavening agents	Cause bread and baked goods to rise during baking	Sodium bicarbonate
Flavoring agents	Enhance flavor of foods	Monosodium glutamate (MSG)
Sweeteners	Add sweetness with or without extra calories	Sucrose
Coloring agents	Impart color to foods	Caramel
Fat replacers	Impart texture and creamy 'mouth feel' to food	Cellulose gel

Source: (Friis RH, 2012).

Table.22 Possible negative effects of food preservatives

Preservative	Where found	Possible negative effects
Sodium benzoate (E211)	Carbonated drinks, pickles, sauces, certain medicines (even some 'natural and homeopathic' medications for kids)	Aggravates asthma and suspected to be a neurotoxin and carcinogen, may cause fetal abnormalities. Worsens hyperactivity
Sulfur dioxide (E220)	Carbonated drinks, dried fruit juices, cordials, potato products	May induce gastric irritation, nausea, diarrhea, asthma attacks and skin rashes. Destroys vitamin B1. Causes fetal abnormalities and DNA damage in animals
Sodium meta-bisulfite	Preservative and antioxidant	May provoke life-threatening asthma
Potassium nitrate (E249)	Cured meats and canned meat products	May lower oxygen carrying capacity of blood; may combine with other substances to form nitrosamines that are carcinogens
P-hydroxy benzoic acid esters (parabens)	Preserved foods and pharmaceuticals	These compounds exert a weak estrogenic activity. Butyl paraben adversely affects the secretion of testosterone and the function of the male reproductive system
Lactic acid bacteria	Fermented foods	*Listeria monocytogenes* may grow in raw milk, meat, and vegetables during fermentation process. This pathogen is responsible for causing foodborne illness
Mono sodium glutamate (MSG)	All frozen foods, canned tuna and vegetables	Eating too much MSG can cause general weakness, flushing, heart palpitations, or numbness
Aspartame	Used as a low-calorie sweetener in gum, drinks, pudding, and yogurt	It may cause allergy and migraine headache
Sodium nitrite and sodium nitrate	Processed meats and fish to retain red color and avoid botulism	Consuming high amount of bacon, hot-dog, sausage containing nitrites or nitrates may cause type-1 diabetes. The risk is too prominent for pregnant women and children. These salts may also cause irritation to digestive system including mouth, esophagus, and stomach
Trans fat	Deep processed fast foods and certain processed foods	Increase cholesterol level and the risk of heart attack. Contribute to increased inflammation, diabetes, and obesity problems
Sodium sulfite (E221)	Used in wine making and other processed foods	Increase the risk of asthma and in extreme case may cause cardiac arrest
Potassium bromate	White flour, bread, and rolls	This salt is considered as carcinogenic and its presence in bread may cause harmful effects to human
Propyl gallate and tertiary butyl hydroquinone	Processed foods, vegetable oils and meat products	Low doses of propyl gallate can increase the risk of cancer, whereas tertiary butyl hydroquinone increases the incidence of tumors

Source: (Nogrady, 2013; Panday and Upadhyay, 2012; Kannall, 2017).

Fig.1 Summary of the review on method and modern aspects of food preservation and processing

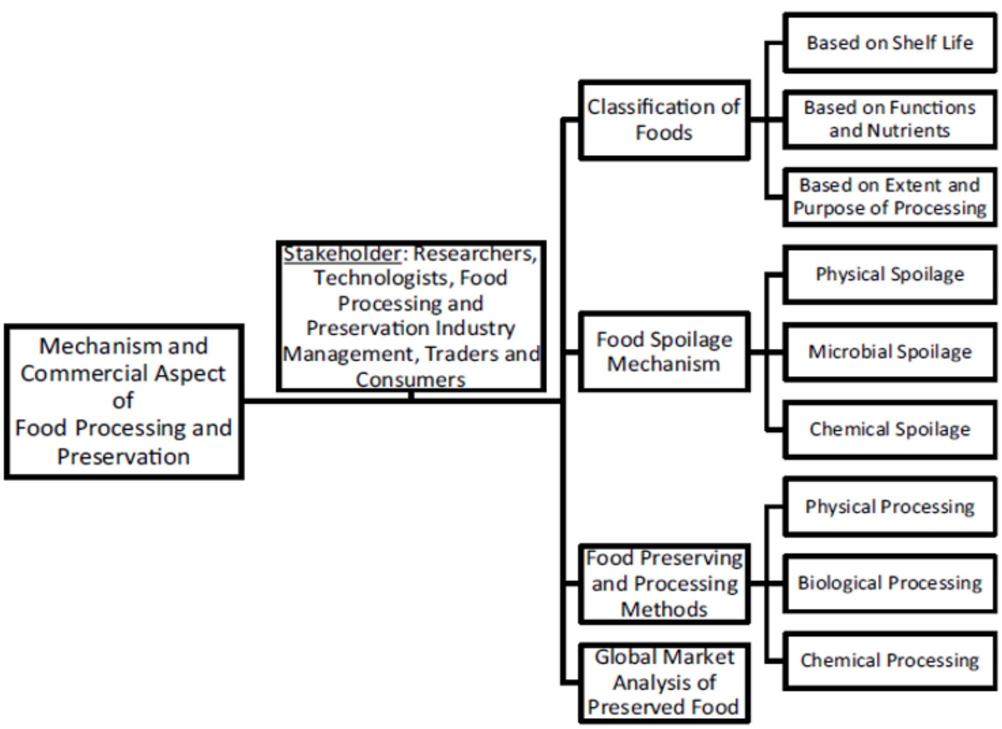


Table.23 Classification of artificial preservatives (Rahman, 2007)

	Antimicrobial agents	Antioxidants agents	Ant enzymatic agents
Definition	Impede the development of harmful microorganisms (fungi, bacteria, yeast)	Inhibit oxidation in the atmosphere. primarily applied to goods with unsaturated fatty acids, oils, and lipids	By limiting the growth of bacteria, parasites, and fungi, stop the natural ripening process and oxidative deterioration of food.
Mechanism	reduces moisture content and increases acidity to createan unfriendly environment for microbes.	Unsaturated fats undergo oxidation, which creates free radicals that might trigger a chain reaction. Aldehyde and ketones are formed in this process, giving food its rancid flavor. By eliminating the free radical intermediates, antioxidants stop these chain reactions and prevent subsequent oxidation processes.	Blocks the food's enzymatic reactions that carry on after harvest. Metal cofactors that many enzymes require can be removed by metal chelating agents.
Applications	For the preservation of cheese, bread goods, vegetable-based goods, dried fruits, beverages, and other goods as well as smoked salmon, margarine, salad cream, and mayonnaises. Sorbic acid (2,4-hexadienoic acid).	For the preservation of butter, lard, meats, beer, baked goods, snacks, potato chips, nut products, and dry mix for beverages, butylated hydroxyl anisole (BHA) is used.	Using citric acid to keep meals, drinks, dairy products, and medicines fresh
	Mayonnaise, pickled vegetables, fruit preparations, fruit-based drinks, dessert sauces, and syrups are all preserved using benzoic acid and sodium benzoate.	While processing fats and oils, butylated hydroxyl toluene (BHT) is used.	Processing food using ethylenediaminetetraacetic acid (EDTA)

Fig.2 Classification of food, recreated from references. **Source:**(Steele, 2004; Monteiro *et al.*, 2010).

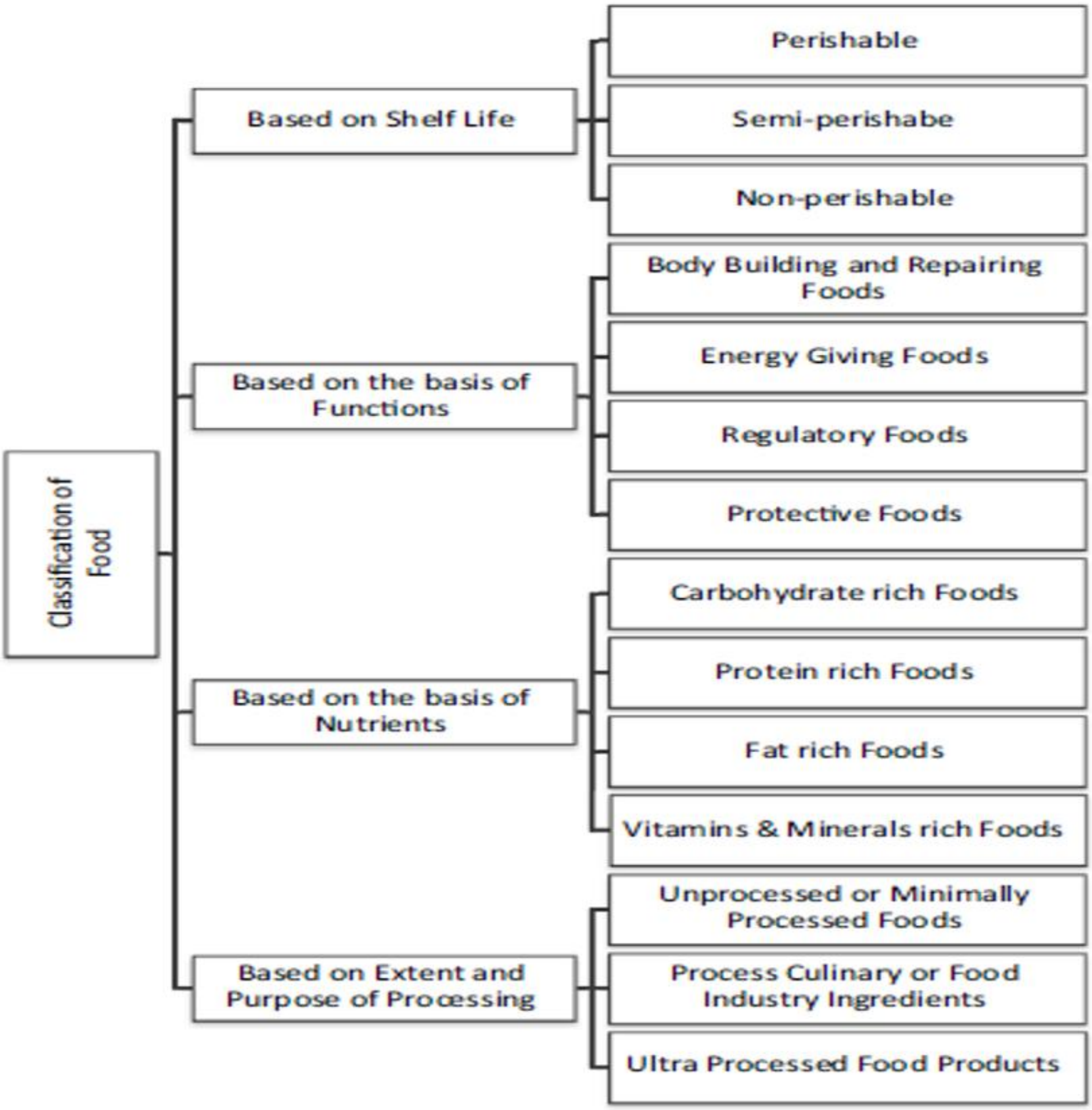


Fig.3 Key physical, microbial, and chemical factors affecting food spoilage (Steele, 2004).

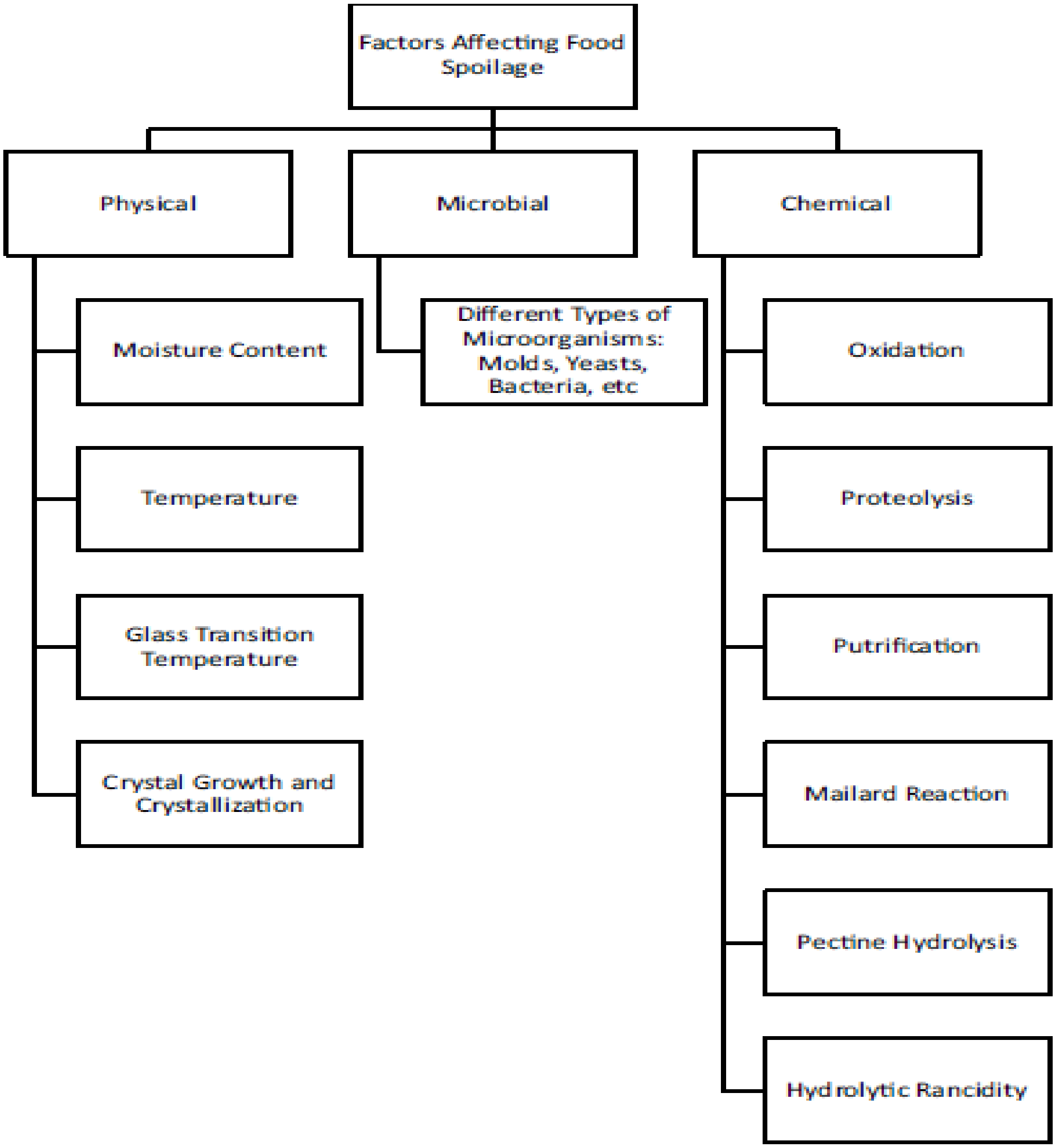
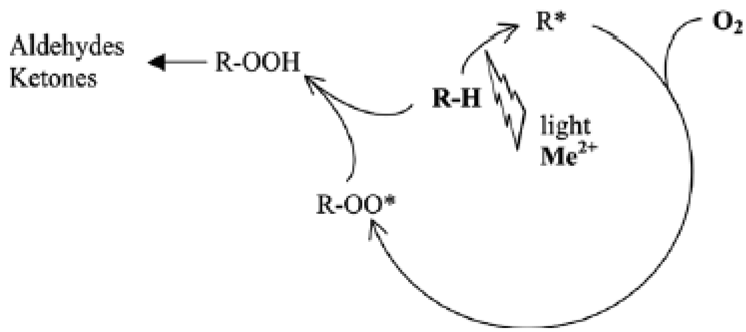


Fig.4 Auto-oxidation of fatty acids (Enfors, 2008).



$$\text{Proteins} \xrightarrow{\text{proteinase}} \text{Peptides} \xrightarrow{\text{peptidase}} \text{Amino Acids.}$$

Fig.5 Classification of food preservation and processing methods

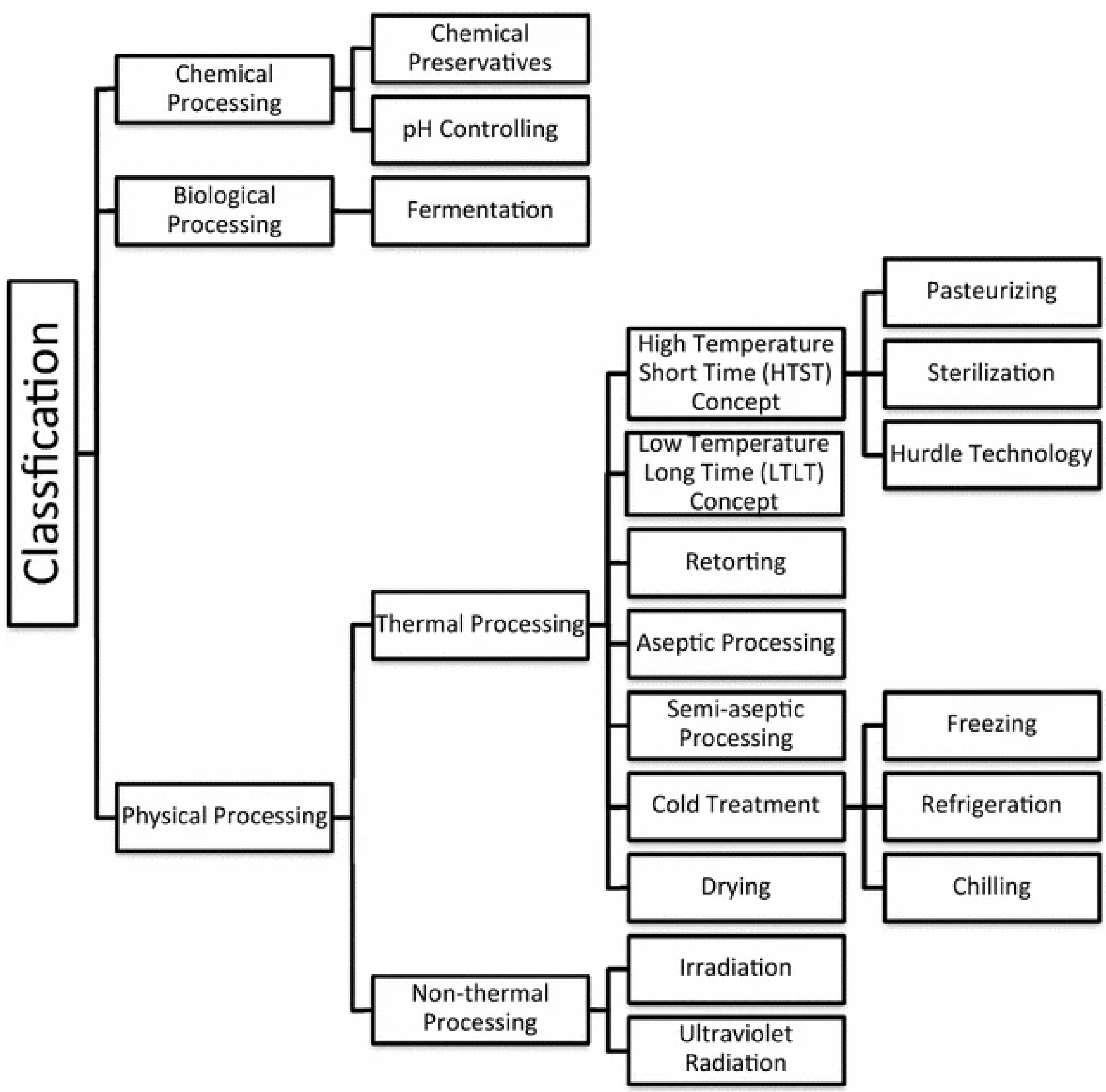


Fig.6 Structure of benzoic acid and sodium benzoate

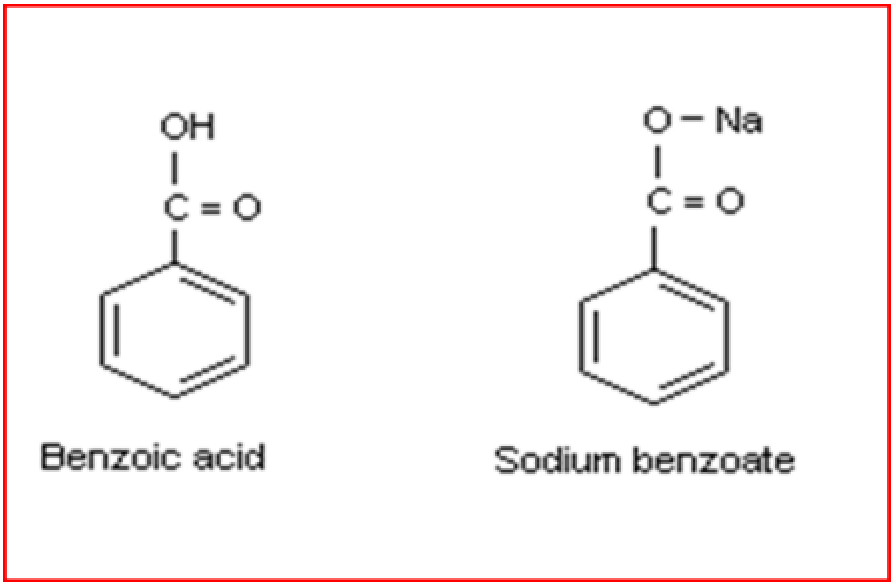
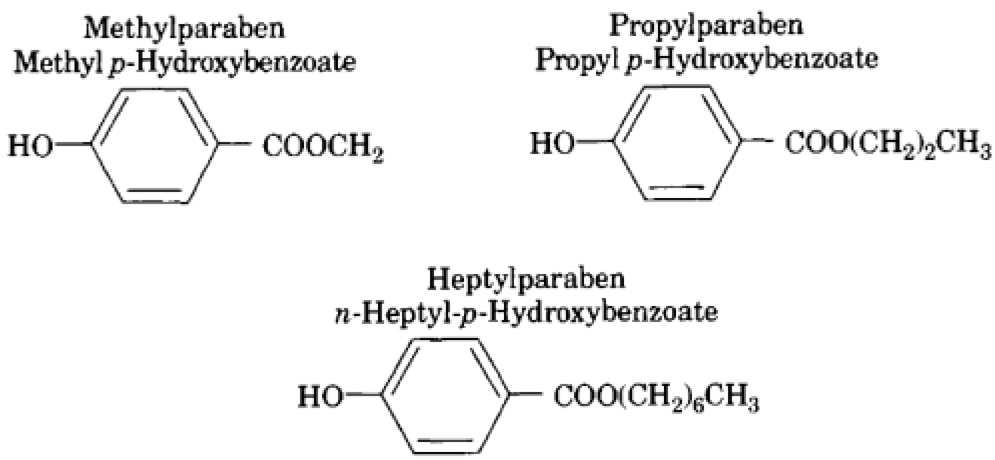


Fig.7 Structure of most commonly used derivatives of benzoic acid (parabens)



Possible health effects of food additives and preservatives

Although most chemical food additives and preservatives are regarded as harmless, some of them have unfavorable and even fatal adverse effects. For instance, when nitrates are consumed, they are transformed into nitrites, which can then combine with hemoglobin to form met-hemoglobin (also known as met-hemoglobin), which can result in unconsciousness and even death, especially in young children. Infants' behavior is negatively impacted by a variety of artificial food colorings, including tartrazine, Allura red, ponceau, and benzoate preservatives; these chemicals are blamed for the hyperactive behaviors of infants (Kent, 2015). Those with asthma may also be intolerant to preservatives. Sulfites, which are present in wine, beer, and dried fruits, are known to cause headaches in those who are susceptible to them and to create asthmatic symptoms.

They include sodium bisulfite, sodium meta-bisulfite, and potassium bisulfite. IARC's classification of sodium nitrate and sodium nitrite as "probable carcinogenic elements" for humans includes both substances (Nogrady, 2013). Pregnant women may have negative consequences from nitrates and benzoates. Pregnant women's hemoglobin and hematocrit readings decrease when they consume sodium nitrite. Benzoate and nitrite both cause a rise in serum urea and a decrease in serum bilirubin. As a result, the fetus's average weight and length decrease (Mowafy *et al.,* 2001). After intake, nitrates are transformed into nitrosamines, which could be dangerous for an unborn child (Food Preservatives, 2015).

Chemical antimicrobial

Antimicrobial preservatives are chemicals that are used to protect food and other organic materials from rotting or fermenting by stunting the growth of bacteria. Methyl, ethyl, propyl, and butyl Parabens and sorbic acid are two examples of antimicrobial preservatives. Propylene glycol (15–30%), Na, K, and Ca Sorbate, Benzoic acid, Na, K, and Ca Benzoate, Sodium metabisulfite substances containing BHT, BHA, Benzaldehyde, Essential Oils, Phenol, and Mercury.

One of the most widely used preservatives is paraben. They have a fair amount of activity against a variety of bacteria. Ethyl, propyl, and butyl esters are more active against yeast and mold, and the methyl ester is most efficient against bacteria and molds. Gram negative organisms are more resistant to parabens than gram positive ones. Many antimicrobial compounds, including lactoferrin, conglutinin, and the lacto peroxidase system, are found in cow's milk (Jay, 2000).

Sorbic acid (sorbates)

The linear chain acids' fungicidal effects have long been known. The effects of the unsaturated acids among them are better understood. When used at the recommended concentration (0.3%), sorbic acid (also known as 2,4-hexadienoic acid) is an unsaturated carboxylic acid that is frequently used as a food preservative since it has the benefit of having no taste or odor. Sorbic acid can be chemically produced or derived from rowan berries (*Sorbus aucuparia*). For sorbic acid and sorbates salts, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established recommended daily intake (ADI) limits of 25 mg/kg of body mass (Santini *et al.,* 2009).

Although research has revealed that the sorbates are also effective against a variety of bacteria, their main effectiveness is against molds and yeasts (Jay, 2000, Venturini *et al.,* 2002 and Santini *et al.,* 2009). In general, aerobes are more sensitive than anaerobes, and catalase-positive cocci are more sensitive than catalase-negative cocci.

Benzoic acid, benzoates

Benzoic acid has been utilized as an antioxidant and a preservative in the agricultural and food industries. Since many years ago, benzoic acid and its salt have been employed extensively in the food business as crucial food preservatives to prevent the growth of numerous bacteria, yeasts, and fungus in acidic environments. They are also found in other goods including cosmetics and medications. 638,000 tons of benzoic acid, one type of common chemical, are generated annually across the globe (Qi *et al.,* 2009). The citric acid cycle and oxidative phosphorylation enzymes are both inhibited by the activity of benzoic acid, which is also exerted on cell membranes. In 1908, the FDA approved sodium benzoate as the first chemical preservative that may be used in some foods, and it is still widely used in a variety of foods today. Due to benzoic acid's limited solubility in water, alkali metal salts of the acid, particularly sodium benzoate, potassium benzoate, and calcium benzoate, are frequently used as preservatives for fruit juice and soft beverages. Due to its considerable pH dependence, benzoic acid is frequently employed in conjunction with other preservatives, especially in acidic foods. Benzoates and benzoic acid are used to flavor soft drinks, non-alcoholic beer, pickled and canned fruit and vegetables, marmalade, jams, and jellies (with reduced sugar content)or no added sugar), candy, fish- and egg-based goods, fried shrimp, sauces, prepared salads, seasonings, and cooked beets.

As much as 0.1% of benzoic acid ($C6H5COOH$), benzoic acid's sodium salt ($C7H5NaO2$), and paraben esters are permitted in food. The structural formulae of the benzoic acid derivatives that have been given approval are as follows:

Sulphur dioxide and sulphites

As food preservatives, sulfur dioxide ($SO2$), sodium, potassium, and calcium sulfites prevent the growth of bacteria, yeast, and fungi. Prior to the fermentation of the wort, Sulphur dioxide and sulphites are typically employed in the wine-making process to stop the growth of potentially hazardous microbes. Additionally, these substances are frequently used in a wide variety of foods, including meat products with grains or vegetables, crustaceans and cephalopods, some species of salted and dried fish, fruits and dehydrated vegetables, crystallized, pulp, or in vinegar or brine, sweets, jams, jellies, pie fillings, glucose syrups, dry biscuits, starches, potatoes, juices and drinks containing fruit juice, some types of beer, wine, and other beverages, mustard, jelly, and a variety of vegetable-based proteins in place of meat, fish, or crustaceans. In place of sulfites, the addition 4-hexylresorcinol (C12H18O2) has been used to stop crustaceans, fresh shellfish, frozen, and deep-frozen food from browning.

Nitrites and nitrates

As food preservatives, potassium nitrite (KNO2), sodium nitrite (NaNO2), sodium nitrate (NaNO3), and potassium nitrate (KNO3) are all often employed. Nitrates and nitrites are used as preservatives to stop the growth of the germs Clostridium botulinum or as promoters of some food colors, according to Duijvenbooden *et al.*, (1989). In addition, fruits and vegetables have significant nitrate contents, ranging from 200 to 250 mg per kg. More than 85% of the usual amount of nitrate consumed by humans comes from vegetables, which are a significant source of nitrate (Gangolli, 1994).

Vegetables with high nitrate contents include lettuce, spinach, red beets, fennel, cabbage, parsley, carrots, celery, potatoes, cucumbers, radishes, and leeks (Pennington, 1998). Nitrite concentrations in fruits and vegetables are less than nitrate concentrations and are typically less than 10 ppm, seldom exceeding 100 mg per kg in foods that have been tainted, inadequately stored, or pickled (Iarc, 2010).

Acetic acid and acetates

As acetic acid is present, vinegar has long been known to have a preservation effect. As acetate is a white crystalline powder or granule, acetic acid is an inert liquid or crystalline solid. The majority of food goods, such as mustard, vinaigrette sauce, fruit and vegetable preserves, tinned fish, bread, mozzarella cheese and cream cheese, quick puddings, and infant food, use these chemicals as preservatives. Acetates or acetic acid have no negative effects.

Acquiring the knowledge to preserve meals was one of the key revolutionary inventions of human civilization since it was a requirement for man to settle down in one area and create a society. It is crucial and difficult to extend the shelf life of food products without affecting their original nutritional value. Food is an organic, perishable item that can spoil as a result of microbes, chemicals, or physical processes. In the past, many traditional methods for preserving food while preserving its nutritional content and texture included drying, chilling, freezing, and fermentation. Preservation methods have evolved and become more contemporary as time and demand have gone on.

The most recent developments in food preservation include pulsed electric field effect, high pressure food preservation, and irradiation. Moreover, other chemical agents have been developed as food additives and preservatives. Yet, due to potential health risks, there are growing worries about the use of chemical additives and preservatives in food products.

In general, it is still important and difficult to preserve food products without degrading the natural food qualities. Microorganisms that thrive in food and produce chemicals that alter its flavor, color, and texture. These microorganisms include bacteria and fungi. Food is an organic, perishable item that can spoil from a variety of microorganisms or microbiological, chemical, or physical processes. Preservation methods have evolved and become more contemporary over time in response to increasing needs.

The most recent advancements in food preservation technology include irradiation, high-pressure food preservation, and chemical or artificial effects. Understanding food deterioration mechanisms and food preservation procedures is crucial for ensuring food preservation and food safety over a lengthy shelf life. Learning how to store food was one of the most important revolutionary discoveries of human civilization since it enabled people to settle down and create societies. It is crucial and difficult to extend the shelf life of food products without affecting their original nutritional value.

Food is an organic, perishable product that can go bad owing to physical, chemical, or microbiological processes. In the past, many traditional methods for preserving food while preserving its nutritional content and texture included drying, chilling, freezing, and fermentation. Preservation methods have evolved and become more contemporary as time and demand have gone on.

The most recent developments in food preservation include pulsed electric field effect, high-pressure preservation, and irradiation. Moreover, other chemical agents have been developed as food additives and preservatives. Yet, due to potential health risks, there are growing worries about the use of chemical additives and preservatives in food products.

References

Adams M R, Moses, M O. Qi, P., Hong, H., Liang, X., & Liu, D. (2008). Assessment of benzoic acid levels in milk in China. Food Control, 20:414-418.Chemistry.; 98–99.

Agrahar-Murugkar D, Jha K. (2010). Effect of drying on nutritional and functional quality and electrophoretic pattern of soy flour from sprouted soybean (Glycine max). J Food Sci Technol.;47(5):482–7.

Ananou, S., Maqueda, M., Martínez-Bueno, M., and Valdivia, E. Bio preservation, an ecological approach to improve the safety and shelf-life of foods. In: Méndez-Vilas, A. ISBN 978-84-611-9423-0).2007; (4): 281-305.

Arcand Y, Boye J I (2012). Green technologies in food production and processing.1st ed. New York: Springer.

Arora,R K. (2007). Food service and catering management. New Delhi: APH Publishing Corporation;

Arvanitoyannis I S. (2010). Irradiation of food commodities: techniques, applications, detection, legislation, safety and consumer opinion. 1st ed. Burlington: Elsevier;

Azam-Ali, M. M. B. D. S., Fermented fruits and vegetables. A global perspective. Rome: Food and Agriculture Organization of the United Nations.

Baker C G J, Ranken M D, Kill R C. 1997. Food industries manual. 24th ed. New York: Springer.

Balasubramanian, S. Viswanathan, R. (2010). Influence of moisture content on physical properties of minor millets. J Food Sci Technol.;47(3):279–84.

Barbosa-Cánovas G V, Altunaker B, Mejía-Lorío D J,. (2005). Freezing of fruits and vegetables. Rome: Food and Agricultural Organization of United Nations;

Barnstorm, G.1968. Introduction. In: Mechanisms of Action of Food Preservation Procedures. Gould, G. W., Ed. Elsevier Applied Science, London.; 1–10.

Barnwal P, *et al.*, (2010). Effect of moisture content and residence time on dehulling of flaxseed. J Food Sci Technol.;47(6):662–7.

Battock M, Azam-Ali S. Fermented food and vegetables. FAO Agricultural services bulletin-134. Food and Agriculture Organization of theUnited Nations Rome; 1998.

Berk Z. Food process engineering and technology. Food Science and Technology, 2nd ed. Academic Press. 2013.

Bhat R, Alias A K, Paliyath G. 2012. Progress in food preservation. Hoboken: Wiley.

Blum D. (2012). Food that lasts forever, in TIME Magazine.

Borgstrom, G. Principles of Food Science. Macmillan, London. 1968.

Brennan J G. (2006). Food processing handbook. Weinheim: WILEY-VCH VerlagGmbH & Co. KGaA.

Brown A. (2007). Understanding food: principles and preparation. 3rd ed.Belmont: Wadsworth Publishing.

Carlos Augusto Monteiro R B L, Rafael Moreira Claro, Ines Rugani Ribeirode Castro, Geoffrey Cannon, (2010). A new classification of foods based on the extent and purpose of their processing. Cad SaudiPublic;6(11):2039–2049

Chopra P, (2005). Food and nutrition education. New Delhi: A P H PublishingCorporation.

Cintas, L. M., Casaus, M. P., Herranz, C., Nes, I. F. and Hernández, P. E. Review: Bacteriocins of Lactic Acid Bacteria. Food Science and Technology International. 2001.

Cunningham, F. E., and H. Line weaver. Stabilization of egg-white proteins to pasteurizing temperatures above 60°C. Food Technol. 1965; 19:1442-1447

Burkepile, D. E., J. D. Parker, C. B. Woodson, H. J. Mills, J. Kubanek, P. A. Sobecky and M. E. Hay. Ecol. 2006; 87: 2821–2831.

Dagoon J D. Applied nutrition and food technology, revised edn. RexPrinting Company Inc.; 1993

De Man J M, (1999). Principles of food chemistry. 3rd ed., New York: Springer

Desrosier N W, Singh R P. (2017). Food preservation. Encyclopedia BritannicaInc.; 2014. https://www.britannica.com/topic/food-preservation. Cited4 May .

Doyle M P. (2009). Compendium of the microbiological spoilage of foods andbeverages. Food microbiology and food safety. New York.

Drake M A, Drake S, Bodyfelt F W, Clark S, Costello M. The sensory evaluation of dairy products. 2nd ed. New York: Springer; 2008.

Duijvenbooden W V, Matthijsen A J C M, Speijers G J A, Went C F V, Apeldoorn M E V. Integrated Criteria Document Nitrate. *National Institute of Public Health and Environmental Protection Report.* 1989; (758473012)

Dunne C P. (2007). High pressure processing of foods. 1st ed. New York: BlackwellPublishing;.104.

Eddy, B. P. The use and meaning of the term "psychrophilic." J. Appl. Bacterial. 1960; 23: 189-190.

Enfors S-O, (2008). Food microbiology. Stockholm: KTH-Biotechnology;

Fabunmi O A, Osunde Z D, Alabadan B A, Jigam A A. (2015). Influence of moisture content and temperature interaction on mechanical properties of Novella pentadesma. J Adv Food Sci Technol.;2(2):81–5.

Farrell, J., and Rose, A. H., A. Rev. Microbiol., 21, 101-120. Farrell, J., and Campbell, L. I, Adv. microbial Physiol.1969; 3: 83-109.

Fellows P. 2009. Food processing technology: principles and practice, 3rd ed. Woodhead Publishing;

Fennema O R. (1996). Food Chemistry. 3rd ed. Marcel Dekker, Inc.

Fennema, O. & W. D. Powrie. 1964. Fundamentals oflow-temperature food preservation. Adv. Food Res.; 13:219-347.

Food Preservatives. (2015) Women's Nutritional Health Care.

Frank A, Paine H Y P. Ai handbook of food packaging. 2nd ed. New York: Springer; 1993.

Freedman D H. (2011). The bright, hi-tech future of food preservation, in discover magazine. Kalmbach Publishing Co.

Friis R H, (2012). Essentials of environmental health. 2nd ed. Burlington: Jones & Bartlett;

Gangolli S D, van den Brandt P A, Feron V J, Janzowsky C, Koeman J H, Speijers G J, *et al.*, Nitrate, nitrite and N-nitroso compounds. *Environ Toxicol Pharmacol*. 1994; 292 (1): 1 -38.

Garg N, Garg K L, Mukerji K G (2010). Laboratory manual of food microbiology.New Delhi: I.K. International Publishing House Pvt. Ltd;

George M. Food bio deterioration and preservation. In: Tucker G S, editor. Blackwell Publisher: Singapore. 2008.

Grandison A S, Brennan J G. 2011. Food processing handbook, vol. 1. 2nd ed. Weinheim: Wiley-VCH;

Grecz, N., O. P. Snyder, A. A. Walker, and A. Anellis. Effect of temperature of liquid nitrogen on radiation resistance of spores of *Clostridium botulinum*. Appl. Microbiol. 1965; 13:525736.

Handbook of Food Science, (2005). Technology and Engineering Vol. 03. Taylor & Francis group;

Hansen, N. H., and H. Riemann. Factors affecting the heat resistance of non sporing organisms. J. Appl. Bacteriol. 1963; 26:314-333.

Heldman D R, Lund D B, Sabliov C. (2007). Handbook of food engineering. 2nded. Boca Raton: CRC Press.

Heldman D R, Moraru C I (2010). Food encyclopedia of agricultural, food, andbiological engineering, 2nd ed. CRC Press; pp. 869–72.

Hock, T. D. Science, N. Y., 158, 1012-1019. Brock, T. D., and Brock, M. L., J. uppl. Buct. 1968; 31, 54-58.

Hoff J E, Castro M D, (1969). Chemical composition of potato cell wall. J AgricFood Chem.;17(6):1328–31.

Iarc Working Group on the Evaluation of Carcinogenic Risks to Humans. 2010. IARC monographs on the evaluation of carcinogenic risks to humans. Ingested nitrate and nitrite, and cyanobacterial peptide toxins.

Igarashi Y, Eroshkin A, Gramatikova S, Gramatik off K, Zhang Y, Smith J W, Osterman A L, Godzik A. Cut D B: (2006) a proteolytic event database. Oxford J.;35(1): D546–9

In't Veld J H H. (1996). Microbial and biochemical overview of foods: an overviewing J FoodMicrobiol.;33(1):1–18.

Indira V, Sudheer K P. (2007). Post-Harvest technology of horticultural crops. In: Peter KV, editor. Horticulture science. New Delhi: New India Publishing Agency

Islam M N, *et al., (2016).* A legislative aspect of artificial fruit ripening in a developingcountry like Bangladesh. Chem Eng Res Bull.;18(1):30–7.

Islam M N, Mursalat M, Khan M S. (20160. A review on the legislative aspect of artificial fruit ripening. AgricFoodSecur.;5(1):8.

James G. (1995). The therapeutic goods authority (TGA) perspective on functional foods. In: Foods of the Future Conference.

James S. (2008). Food biodeterioration and preservation. Singapore: Blackwell.

Jangam S V, Law C L, Mjumder A S 2. (2010). Drying of foods, vegetables and fruits,vol. 1, 1st ed. Singapore.

Jay J M. (2000). Modern food microbiology. 6th ed. Gaithersburg: Aspen Publishers;

Jelen, P. Experience with direct and indirect UHT processing of milk-A Canadian viewpoint. J. Food Protect. 1982; 45:878-883.

Kader A A, *et al.*, (1989). Modified atmosphere packaging of fruits and vegetables' Rev Food Sci Nutr.;28(1):1–30.

Kanatt S R, Chander R, Sharma A (2006). Effect of radiation processing of lambmeat on its lipids. Food Chem.;97(1):80–6.

Kannall E. (2017). The effects of food preservatives on the human body. Chron: The Hearst Newspaper, LLC.http://livehealthy.chron.com/effectsfood-preservatives-human-body-6876.

Kar B K. (2014). Multi-stakeholder partnership in nutrition: an experience fromBangladesh. Indian J Community Health.;26(1):15–21.

Karmas R, Pilar Buera M. Marcus K. (1992). Effect of glass transition on ratesof nonenzymic browning in food systems. J Agric Food Chem.; 40:873–9.

Katz F. (2001). Active cultures add function to yoghurt and other foods. FoodTechnol.; 55:46–9.

Kent L T,(2015). Food additive side effects. In LIVESTRONG.Com., leaf.

Kirk-Othmer. (2007). Food and feed technology, Vol. 1. New Jersey: Wiley-Interscience.

Kirk-Othmer. (2007). Food and feed technology, Vol. 1. New Jersey: Wiley-Interscience.

Knechtges P L. (2012). Food safety: theory and practice. 1st ed. Jones andBartlett: Burlington.

Koutchma T, Popovic V, Ros-Polski V, Popielarz A (2016). Effects of ultravioletlight and high-pressure processing on quality and health-relatedconstituents of fresh juice products. Compr Rev Food Sci Food Saf.;15(5):844–67.

Kristensen L, Pueslow P P. (2001).The effect of processing temperature and addition of mono- and di-valent salts on the heme- nonheme-iron ratioin meat. Food Chem.;73(4):433–9.

Kutz M. (2008). Handbook of farm, dairy, and food machinery. 1st ed. New York: William Andrew.

Laudan R. (2009). Food and nutrition: lifespan, human to pesticides. New York: MarshallCavendish.

Leniger H A, Beverloo W A, (1975). Food Process Engineering. Netherlands: Springer; 52.

Levine H, Slade L. A (1981). Polymer physico-chemical approach to the study of commercial starch hydrolysis products (SHPs). Carbohyd Polym.;6:213–44.

Levinson, H. S., and M. T. (1964). Hyatt. Effect of sporulation medium on heat resistance, chemical composition, and germination of *Bacillus megaterium* spores. J. Bacterial.; 87:87-886.

Lewin A. (2012). Real food fermentation: preserving whole fresh food with livecultures in your home kitchen, 4th ed. Quarry Books.

Light N, Walker A. (1990).Cook-chill catering: technology and management.New York: ElsevieScience Publishing co. Inc.;

Lund M K D B (2005). Physical principles of food preservation. 2nd ed. New York: Taylor & Francis;

Maciej Oziembłowski W K. (2005). Pulsed electric fields (PEF) as an unconventional method of food preservation. Polish J Food Nutr Sci.;14(55):31–5.

Mehran, N. T., Y. Tawfeak and M. Hewedy, (2005). Incidence of pathogens in kareash cheese. Egyptian Journal of Dairy Science.; 26(1): 295-300.

Meyer A S, Suhr K I, Nielsen P, Holm F. Natural food preservatives. In: Ohlsson T, Bengtsson N (Eds.) Minimal processing technologies in the food Industry, chap 6. Wood head Publishing; 2002. pp. 124–74

Michael Davidson P, Sofos J N, Larry Branen A (2005). Antimicrobials in Food,3rd ed. Food Science and Technology. CRC Press;

Miller G D, Jarvis J K, National Dairy Council, McBean L D. (2006). Hand book of dairy foods and nutrition. 3rd edn. Boca Raton: CRC Press.

Moniruzzaman M, Alam M K, Biswas S K, Pramanik M K, Islam M M, Uddin G S (2016). Irradiation to ensure safety and quality of fruit salads consumed in Bangladesh. J Food Nutr Res.;4(1):40–5.

Monteiro C A, Levy R B, Claro R M, Castro I R, Cannon G. A (2010). New classification of foods based on the extent and purpose of their processing. CadSaude Publica.;26(11):2039–49.

Mossel, D. A. A., and H. Zwart. (1960). The rapid tentative recognition of psychrotrophic types among Enterobacteriaceae isolated from foods. J.Appl. Bacterial.; 23:183-188.

Mowafy A R *et al.*, (2001). Effect of food preservatives on mother rats and survival of their offspring. J Egypt Public Health Assoc.;76(3–4):281–95.

Msagati T A M. (2012). The chemistry of food additives and preservatives. 1st ed. New York: Wiley-Blackwell.

Mursalat M, Rony A H, Rahman A H M S, Islam M N, Khan M S. (2013). A critical analysis of artificial fruit ripening: Scientific, legislative and socio-economic aspects. ChE Thoughts.;4(1):6–12.

Nielsen H B, Sonne A M, Grunert K G, Banati D, Pollák-Tóth A, Lakner Z, Olsen N V, Zontar T P, Peterman M. (2009). Consumer perception of the use ofhigh-pressure processing and pulsed electric field technologies in food production. Appetite.;52(1):115–26

Nogrady B, (2013). The hard facts of food additives. ABC Health and Wellbeing.

Nummer B A, (2002). Historical origins of food preservation. Http://nchfp.uga.edu//food_pres_hist.html

Ohlsson T, Bengtsson N (2002). Minimal processing technologies in food industry. Cambridge: Wood head Publication.

Padilla J A, González-Reynoso O, García H S, Aguilar-Uscanga B R, (2016). Effect of pasteurization, freeze-drying and spray drying on the fat globule and lipid profile of human milk. J Food Nutr Res.;4(5):296–302.

Panda H. Herbal. (2003). Foods and Its Medicinal Values. Delhi: National Institute of Industrial Research.

Panday R M, Upadhyay S K (2012). Food Additive. In: El-Samragy Y (Ed.) Food Additive, Chap 1. InTech, p. 1–30

Pennington J A T. (1998). Dietary exposure models for nitrates and nitrites. *Food Control*.; 9 (6): 385 -95.

Pitt J I, Hocking A D (2009). Fungi and food spoilage. New York: Springer Science+ Business Media.

Potter N N, Hotchkiss J H. (1999). Food science. 5th ed. New York: Springer

Pruthi J S. (1999). Quick freezing preservation of foods: foods of plant origin. Foods of plant origin. Vol. 2. Mumbai: Allied Publishers Limited;

Qi P., Hong, H., Liang, X., & Liu, D. (2009). Assessment of benzoic acid levels in milk in China. Food Control, 20:414-418.

Rahman M S (2007). Handbook of food preservation. 2nd ed. Boca Raton: Taylor and Francis.

Rahman M S (2007). Handbook of food preservation. 2nd ed. Food science and technology. Boca Raton: CRC Press.

Rahman M S. (1995). Food properties handbook. New York: CRC Press;

Rahman M S. (2007). Handbook of food preservation. 2nd ed. Boca Raton: Taylor and Francis.

Rahman S, Ahmed J. (2012). Handbook of food process design. 1st ed. NewJersy: Wiley-Blackwell.

Rahman, (2014). Food preservation. http://en.banglapedia.org/

Ramaswamy H S, Tung M A. (1984). A review on predicting freezing times of foods. J Food Process Eng.; 7(3):169–203.

Rayaguru K, Routray W.,(2010). Efect of drying conditions on drying kinetics and quality of aromatic *Pandanus amaryllifolius* leaves. J Food Sci Technol.;47(6):668–73

Reid D S. (1990). Optimizing the quality of frozen foods. Food Technol.;44(7):78–82.

Richardson P. (2004). Improving the thermal processing of foods. England Wood head Publishing in Food Science and Technology;

Rodriguez F, Mesler R. (1984). Some drops don’t splash. J Colloid Interface Sci.;106(2):347–52.

Rogers L D, Overall C M. (2013). Proteolytic post translational modification of proteins: proteomic tools and methodology. Mol Cell Proteomics.;12:3532–42.

Rohan M. (2014). Food preservative market worth $2.7 Billion by 2018.: Dallas.

Roos Y, Karel M (1991). Plasticizing effect of water on thermal behavior and crystallization of amorphous food models. J Food Sci.;56(1):38–43.

Sagar V R, Suresh P. Kumar. (2010). Recent advances in drying and dehydration of fruits and vegetables: a review. J Food Sci Technol.;47(1):15–26.

Salvato J A, Nemerow N L Agardy F J. (2003). Environmental Engineering. 5th ed.New York: Wiley.

Santini, A. O., Pezza, H. R., Filho, O. C., Sequinel, R., & Pezza, L. (2009). Potentiometric sensor for sorbic acid determination in food products. Food Chemistry, doi: 10.1016/j.foodchem.2009.02.012.

Saravacos G, Kotsiopoulos A E. (2002). Handbook of food processing equipment. Food engineering series. New York: Kluwer Academic/Plenum Publishers;

Sati S P, Sati N. (2013). Artificial preservatives and their harmful effects: Looking towards nature for safer alternatives. Int J Pharm Sci Res.;4(7):2496–501.

Shenga E, Singh R P, Yadav A S. (2010). Effect of pasteurization of shell egg on its quality characteristics under ambient storage. J Food Sci Technol.; 47(4):420–5.

Shivashankar B. (2002). Food processing and preservation. New Delhi: Prentice Hall of India Pvt Limited;

Silliker, J. H., Elliott, R. P., Baird-Parker, A. C., Bryan, F. L., Christian, J. H. B., Clark, D. S., Olson, J. C., Roberts, T. A., Eds. (1980). Microbial Ecology of Foods. Volume 1: Factors Affecting Life and Death of Microorganisms. Academic Press, New York.

Smith J S, Pillai S. (2004). Irradiation and food safety. Food Technology.;58(11):48–55

Solms J. (1969). Taste of amino acids, peptides, and proteins. J Agric FoodChem.;17(4):686–8.

Sommers B. A. N. A. C. H., (2010). Irradiation: food. encyclopedia of agricultural, food, and biological engineering. p. 864–8.

Steele R. (2004). Understanding and measuring the shelf-life of food, 1st ed.Wood head Publishing Limited.

Strumillo C, Kudra T. (1998). Thermal processing of bio-materials. Boca Raton: CRC Press.

Syamaladevi R M, Tang J, Villa-Rojas R, Sablani S, Carter B, Campbell G, (2016). Influence of water activity on thermal resistance of microorganisms in low-moisture foods: a review. ComprRev Food Sci Food Saf.;15(2):353–70.

Tamime A Y. (2009). Dairy fats and related products. 1st ed. West Sussex: Wiley-Blackwell.

Thayer, & D. W. (2005). Food irradiation: benefits and concerns. Journal of food quality.; 13(1): 147-169.

Tianli Y, Jiangbo Z, Yahong Y. (2014). Spoilage by alicyclobacillus bacteria injuice and beverage products: chemical, physical, and combined control methods. Compr Rev Food Sci Food Saf.;13(5):771–97.

Tucker G S. (2007). Food biodeterioration and preservation1st ed. New Jersy:Wiley-Blackwell.

Van Boekel M A (2008). Kinetic modeling of food quality: a critical review. Compr Rev Food Sci Food Saf.; 7:144–58.

Venturini, M. M., Blanco, D., & Oria, R. (2002). In vitro antifungal activity of several antimicrobial compounds against *penicillium expansum*. Journal of Food protection, 65(5):834-839.

Venugopal V. (2006). Seafood processing adding value through quick freezing, reportable packaging and cook chilling. Boca Raton: CRC Press, Taylor &Francis Group;

Walter R H, Taylor S. (1991). The Chemistry and Technology of Pectin. Food Science and Technology, 1st ed. Academic Press.

White G W, Cake bread S H 1. (966). The glassy state in certain sugar-containing food products. Int J Food Sci Technol.; 1:73–82.

Wilkinson J, Rocha R. (2008). Agri-processing and developing countries. Washington, DC: World Bank.

World Food Market Overview Marketing Essay. (2013). ttp://www.ukessays.com/essays/marketing/world-food-market-overview-marketing essay.

Yeung C K, 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):442–7.

How to cite this article:

Kebede Dida Ariti and Asres Yenesew Mossie. 2022. Food Preservation by Controlling Biological, Chemical and Physical Methods. *Int.J.Curr.Res.Aca.Rev.* 10(12), 60-92. doi: https://doi.org/10.20546/ijcrar.2022.1012.007