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Advanced techniques for food preservation: a Review

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ABSTRACT

Food processing industry has global importance because of providing approach to prevention of food spoilage. This review focuses on protection of food materials. Non thermal preservation methods which can provide high quality food were considered. The modern and advanced techniques are: 1.High Pressure Food Preservation; HPP involves subjecting food to 300-700 MPa to produce high quality food, 2.Modified Atmosphere; Gases are used to change the atmosphere that inhibit microbial growth, 3.Non thermal Plasma; Ionized gas inhibits microbial growth and deactivates enzymes, 4.Bio Preservation; Bacteriocins produced by bacteria are added to reduce pathogen growth, 5.Hurdle Technology; Different hurdles in food preservation are regulated, 6.Pulsed Electric Field; PEF uses short electric burst for microbial inactivation and 7.Nanotechnology; Nanoparticles detoxify the effect of microbes. These advanced techniques are contributing in saving the great economic loss of food stuff both in fields and storage houses.

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1. Introduction

Food manufacturers always find manners to prolong the shelf life and save the economic aspects of food without disturbing the physiochemical conditions of food. Therefore, the advanced techniques for food preservation provide high quality food without any unnatural ingredients. Food technology means to select, process, preserve, package and deliver food in natural nutritive conditions (1). Advanced techniques for food preservation mean to treat and handle the food in such a way as to stop the reproduction of spoilage bacteria and decrease the wastage of food because of providing rancorous environment to microbes. These are achieved by high pressure, modification of atmosphere, microbial agents, hurdles or plasma action (2).

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2. High Pressure Food Preservation (HPP)

High/Ultra pressure food preservation is also known as Pascalization or Bridgemanization which emphases on food sterilization through inactivation of metabolism of microorganisms and certain enzymes of food by using high pressure (3).

2.1. Basic Principles of HPP

The basic principle of this technology is to change the molecular configuration. It is enhanced by decreasing in volume and increasing in temperature under high pressure. This causes the inactivation of microbes but the nutrition and physical fitness of food are remained. This technique affects only on the non-covalent bonds of food which results in saving of nutrition of food (effect of covalent bonds of food results in change in nutrition). HPP makes permeable the microbe's cell membrane and inhibition of enzymes important for life and makes food safe from microbial infestation (4).

According to Kadam et al., (4), the change in volume due to pressure causes increase in temperature (3°C temperature increases/100MPa pressure). But according to Yordanov and Angelova (5), the inactivation of spores takes place by increasing temperature within the pressure because spore inactivation is difficult as compared to the vegetative cells, (690MPa and 80°c temperature for 20 min). This technology aims to provide unaffected (with no damage in shape) food. Water is present around the food articles so pressure is not directly applied on the food causes the inactivation of microbial activity but the food nutrition remains safe and shelf life of food increases. Saving of food shape is by the uniform pressure in all directions on water present around the food instead of food itself.

3. Processing Technology

This food processing technology aims to prepare high quality food with required nutrition, physical and chemical characteristics (6). Foodstuffs are exposed to high pressure above 350 MPa (7) 300-800MPa (8) 100-800 MPa (4) or 300-600 MPa (5) for a few seconds to several minutes, the reduction volume is 12% and temperature rises about 3-4°C. This causes to deactivation of microbes and certain enzymes without significant molecular constituents such as vitamins, important proteins, color and flavor. The extent of deactivation is affected by the intrinsic properties such as pH, water availability, fat contents, minerals and sugar contents, bacterial growth phase and pressure, temperature and time combinations that are applied (7). When pressure is applied, the membrane of microbes is damaged easily in exponential phase of growth and their membranes would not be repaired while in stationary phase of growth, the membrane of microbes resists for some time before disruption and also is able to restore (9). When spores are formed then heat within the pressure is applied to destroy the microbial spores which results in increaseing the shelf life of food materials (8).

4. Modified Atmosphere

A modified atmosphere means to amend the atmosphere for increasing the shelf life of food. It means to change the atmosphere of a package containing food for getting rid of microbial spoilage. This process tries to lower the oxygen and higher the carbon dioxide contents in the package which inhibits the growth of microbes and lower the pH (10, 11). The packaging is of two types:

1) Modified atmosphere packaging (MAP): This technique emphasizes on the renewal of air inside the package by a specific gas or mixture of gases which is different from our atmosphere. This inhibits the growth of microbes in the package and saves the economic and nutritional aspects of food (10). In MAP, low permeable and high permeable packages are formed for the meat and fruits, vegetables etc (12). According to Sandhya (13) for protection and keep the quality the oxygen percentage in a modified atmosphere for fruits and vegetables descends between 1-5% (13).

2) Vacuum Packaging: Here the product is placed inside a package presenting low permeability to oxygen. In this modified atmosphere 10-20% increase in carbon dioxide is produced by the microbial activity. This carbon dioxide may inhibit the growth of undesirable microbes (10).

4.1. Role of Gases in Modified Atmosphere

Carbon dioxide: It performs an essential part in the protection of food in term of modified atmosphere. Because carbon dioxide is water and lipid soluble, it contains bacteriostatic and fungistatic features. The effects on microbes are the prolong lag phase and dwindle the growth rate in log phase. This causes the long term inhibition of microbial growth. But in log phase the inhibitory effects are decreased.

Aerobic bacteria such as psychotropic bacteria do not grow while some anaerobic bacteria i.e., *Clostridium perfringens* grow normally. In another case, Yeasts produce some carbon dioxide during its growth which helps in its growth. To avoid these problems, scientists apply a mixture of gases which are shown in the table 1. Temperature must be kept low because solubility of food tissues is increased with the increase in temperature (11).

Carbon dioxide effects on microbes in several ways:

- The physiochemical features of proteins are altered.
- Inhibition of enzymes.
- Amend the functions of microbe's cell membranes. and
- Intracellular pH alterations due to the breakdown of bacterial membrane (14).

Table 1. Combinations of gases in modification of atmosphere (11)

	Name of Combination	Combination of gases
1	Inert Blanketing	Nitrogen
2	Semi Reactive Blanketing	Carbon dioxide/Nitrogen Or Oxygen/carbon dioxide/nitrogen
3	Fully Reactive Blanketing	Carbon dioxide Or Carbon dioxide/oxygen

4.2. Nitrogen gas

In case of nitrogen gas, there is no antimicrobial activity. It helps in prevention of blast of packages that can take place within the carbon dioxide. So nitrogen is used within the carbon dioxide (11).

4.3. Important facts in process of Packaging

- The package material allows permeability of oxygen, carbon dioxide and water vapors.
- Through the seal and defective structural areas, there is a transferring of oxygen, carbon dioxide and water vapors.
- Thickness, surface area and temperature (cause of small changes) of package are the important taking care factors during the packaging of different types of food materials (15).

5. Non Thermal Plasma

Non thermal plasma for the inhibition of spoilage microbes and deactivation of enzymes had been generated by the use of electric field in 1960. It was used for saving fruit juices, soups, beaten eggs and skim milk. Plasma is a fourth state of matter. A gas, when it is present in ionized form is advanced as plasma. It is a mixture of electrons, protons, neutrons, ions, molecules and atoms. It is generated by the coupling of energy within the gas which dissociates it. Plasma is divided into two states, Equilibrium state or thermal Plasma and Non equilibrium state or non-thermal plasma. In equilibrium state of plasma, the temperature or local thermodynamics of all the components of plasma is almost same so this state is known as thermal state of plasma while in non-equilibrium state of plasma the temperature of its components is different and is called as non-thermal plasma which is used for the preservation of food materials. Non-thermal plasma is generated at low atmospheric pressure and low temperature (30-60°C), while thermal plasma is generated at high pressure and temperature (16).

Non-thermal Plasma Action: Inhibition of certain enzyme and microbial growth by non-thermal plasma is not the old technique. First it was used in the mid of 20th century. Different gases in ionized form were used but considerable results were obtained by oxidation effect. Now it is considered that oxygen and nitrogen are the best gases for increasing the shelf life and saving the economic importance of food materials. Plasma acts on the double bond of fatty acids of microbial membranes which disturbs the transport system. It also damages the nucleic acid and enzymes, the nucleic acid is mutated and wrong proteins are formed which results in the death of microbes (17). Non-thermal plasma is efficient in the deactivation of most vegetative bacteria and fungi while it does not inactivate the bacterial spores and some enzymes completely. The effects on food by non-thermal plasma are not considerable while thermal plasma disturbs the quality and appearance. The aspect of nutritional effects is not well known in respect of non-thermal plasma (17, 18).

6. Bio Preservation

It is the preservation of food items from pathogens by using the natural or controlled microorganisms or their antimicrobial compounds or fermentation products (19). Those microbes are chosen which affects positively on the physical, chemical and biological composition of food and provides good flavor (20). The microbes which are harmless to humans, compete with spoilage and pathogenic bacteria, generate good odor, contribute in production of nice flavor, produce acids, antimicrobial substances and have fermentation capacity are used rather than those which have only fermentation property (19). The microbes produce antimicrobial substances which may be organic acids, hydrogen peroxide or bacteriocins which decline the pH of local environment and create a selective barrier against the pathogens (21).

6.1. Lactic Acid Bacteria

LAB are non-motile, gram-positive bacteria and belong to genera Lactococcus, Streptococcus, Lactobacillus, Pediococcus, Leuconostoc, Enterococcus, Carnobacterium, Aerococcus, Oenococcus, Tetragenococcus, Vagococcus, and Weisella. They can ferment by producing lactic acid. They compete for nutrients and produce inhibitor agents such as acids, hydrogen peroxide and bacteriocins (22). LAB are either homofermenters or heterofermenters which produce lactic acid or produce acetic acid, ethanol, formic acid and carhon dioxide with the lactic acid respectively (23). Homofermenters change sugars into lactic acid. Glycolysis results in Pyruvate and then it is converted into lactic acid to ferment the food and heterofermenters use pentose phosphate cycle in which glucose in changed into ribose 5-phosphate and NADPH is produced which is the reducing power of the cell (24). LAB has large ecological range, present as contaminants or added for the fermentation process. Research on genetics and physiology gives information about different biochemical pathways use in the preservation of food materials (23). According to Khalid (24), LAB have not ability to make ATP because they grow in aerobic environment so they ferment and get ATP. They also survive in aerobic environment because they have ability to produce products such as hydrogen peroxide for the protection from oxygen in aerobic environment.

6.2. Bacteriocins

These are the peptides or complex proteins manufactured by the Lactic Acid Bacteria. These are not called as the antibiotics because these are not digested easily. These have more capacity to survive and act for the biopreservation. These efficiently compete with the spoilage bacteria for the nutrition. Colicine, a first bacteriocin which was discovered by the Andre Grantia in 1925. Bacteriocins are non toxic to lab animals and eukaryotic cells. These are thermoresistant and have great antibacterial activity. LAB that produce Bacteriocins are used for biopreservation. The Bacteriocins which are purified or semi-purified in nature are engaged as protector for food items. Use of a product previously fermented with a bacteriocin producing strain can be as an ingredient in food processing (25). The requirements and ability of microbes are:

- To attach on the food the for decreasing the attachment of spoilage bacteria
- To linger there, divide and manufacture organic acids, hydrogen peroxide and bacteriocins. And
- It must be safe (20, 22).

7. Hurdle Technology

This technology consists several preservative factors (hurdles) collaboration which secures the food from the influence of pathogens or spoilage bacteria, therefore the nutrition, economic aspect, taste, texture and smell remain safe (26,27). The hurdles are temperature (low temperature and high temperature for the storage and processing prospects respectively), acidity (pH), low water activity, redox potential, preservatives (e.g., sulfite, nitrite, sorbate), and competitive microorganisms e.g; lactic acid bacteria (Fig.1). For example a food product is microbiologically secure because of six described hurdles. Microorganisms may overcome some hurdles but not tame all the preservative factors. Thus food is safe from the influence of microbes. This is only a theoretical view (28). In hurdle technique, the food spoilage microbes are put in the confrontational environment. The food is secured but microbes show some responses. The responses may be the stress reactions, metabolic exhaustions, homeostasis disturbance and several other responses by applying the multitarget preservations.

In this respect, the homeostasis of microbes is mainly disturbed, which causes prolong lag phase of microbial growth and inhibition of multiplication takes place. So the microbes are either inactive or even die. This technique also causes autosterilization (Metabolic Exhaustion). For example, first the food is heated at 95°C mildly and then stored at 37°C. . By these heat and cold hurdle, the microbes are metabolically exhausted. In the result, the microbes are either at rest or even die. Under the influence of hostile environment, the microbes may produce stress proteins for his survival. The microbes compete with the hurdles to survive rather than the multiplication process. When we use different hurdles, these must hit the different sites of microbes i.e; cell membrane, proteins, DNA, enzymes etc. At the same time and in the result the food is secured. It is now observed that the use of 6 hurdles for saving the economic aspect of food is somewhat old, so for increasing the shelf life of food some advanced

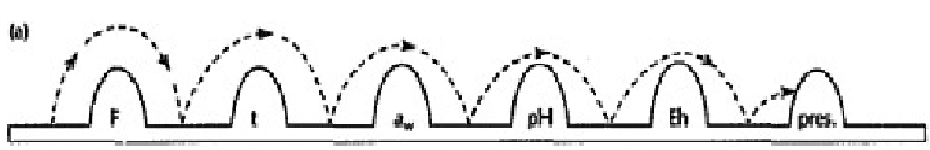

Figure 1: Schematic hurdle technology

hurdles e.g, food irradiation, ultra high pressure or pulsed technology should be used for best results. Food microbiologists could also learn from Pharmacologists because of use of Biocides. Twelve different classes of biocides are present for the saving of food. They act on different target sites of microorganisms (27).

By hurdle technology, three results are observed:

- Additive Consequence: The effectiveness of one substance is added.
- Synergistic Sequel: The concentration of combine action is lower than the individual.
- Antagonistic Outcome: The concentration of individual action is lower than the combine action.

In case of antagonistic effect, it is observed that a single hurdle in some cases is more efficient than the combination of hurdles (26).

7.1. Pulsed electric field (PEF)

It is an advance technology for protection of food from spoilage of microorganisms by applying pulses of electric field. It also aims to serrate the high nutrition, excellent quality and physically undamaged food to the consumers. This technique also presented the superiority than the heating processing and provide original texture, color, flavor and taste of food through deactivation of spoilage microbes (29). In this technique a potential electric field is applied for milliseconds which has more than 1V potential (according to Mohamed and Eissa (29), the PEF potential is about 1-80 kv/cm), this causes breakdown of microbe's membrane. In fact, there is 10mV resting potential of cell membrane of microbes, by applying the 1V pulses of electric field, the resting potential is drastically increased than the 10mV and cell membrane is ruptured (30). This is known as electrophoration, electric breakdown or cell membrane disruption. According to Schoenbach (31) lower temperature and increase in time causes more disruption. This technology is applied at room temperature. According to field intensity, the electrophoration is either reversible or irreversible which means cell membrane discharges or lyses respectively. It is also applied within other technique e.g; extension of raw skim milk by combining heat and pulsed electric field (29). DNA, RNA and intracellular organelles within the cell membrane are also disturbed except the spore and enzymes. Because the spores are highly resistant to high temperature and osmotic pressure, high and low pH and mechanical shocks. These are so small sized and are not dehydrated and mineralized. The activity of enzymes is altered but does not deactivated. It has high initial cost and only for liquids. If bubbles are formed during the process, it leads to non-uniform treatment and safety problems (32). This technique is applied to the beers, green pea soups, eggs, milk, orange and apple juices. The electric field may be applied as exponentially decaying, square waves, bipolar or oscillatory pulses at ambient, subambient and slightly above ambient temperature (29,30,32).

8. Nanotechnology

It is an advanced, expensive and emerging technology for the food preservation which is interpreted as the characterization of matter at atomic and molecular level to form a device for the controlling of spoilage microorganisms and increasing shelf life of food. The matter size is 1-100nm (33). In this respect, the nanoparticles are manipulated to form a device similarly like humans and other microorganisms are formed by the cell (basic structural and functional unit of life) and cell are formed with the cell membrane, cell wall and other micro structures (34). By the characterization of nanoparticles, different types of devices and systems are formed for the food preservation action. For example, nanosensors for the detection of chemical contaminants. These are also for the food borne pathogens identification by measurement of nucleic acid, proteins and other metabolic products of microbes (35). Nanosensors bind and color the microorganisms (36). Nanofilteration is another device for selecting of material on size and shape base. Similarly Heat and Mass transfer Nanofibrication device for increasing heat resistance (35). In the respect of food processing, the incorporation of nano-sized particles take place, mostly silver and occasionally zinc sulphide for the antimicrobial activity (36).

9. Conclusion

Food preservation is the processing of food for increasing the shelf life of food, inhibiting the microbial infestation and decreasing the wastage of food, presence of seasonal food through out the year which means to serrate the variety in food and developing new technologies and superb equipments for food preservation. The conventional heat treatment methods have been designed to save food but undesirable changes occur, leads to compromise the quality both nutritional and sensorial. To avoid these changes novel non thermal methods are being introduced, receiving more attention. Among these modern non thermal techniques HPP, Modified atmosphere, Non thermal plasma, biopreservation, hurdle technology, pulse electric field and nanotechnology can be safe and contribute in longer shelf life with high quality.

Conflict of interest

The authors have no conflict of interest.

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