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Hurdle technology: A review

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Abstract
In industrialized as well as in developing countries, hurdle technology is used for the gentle but effective preservation of foods and was developed several years ago as a new concept for the production of safe, stable, nutritious, tasty, and economical foods. Previously hurdle technology, i.e., a combination of preservation methods *viz* physical, chemical and biological, was used empirically without much knowledge of the governing principles. The application of various preservation methods (hurdle technology) has become more prevalent now, because the principles of major preservative factors for foods (e.g., temperature, pH, a_w, competitive flora), and their interactions, became better known. However, recently, the influence of food preservation methods on the physiology and behavior of micro-organisms in foods, i.e. their homeostasis, metabolic exhaustion, stress reactions, are taken into account, and the novel concept of multi-target food preservation emerged. The main objective of hurdle technology is food preservation, but in addition, many hurdles were reported to improve sensory attributes. Hurdles application in food depends on the nature and chemistry of the food, as well as the processing and storage conditions. Many findings revealed that combination of preservatives at lower concentrations discourage microbial activities more than single preservative at higher concentration.

Keywords: Hurdle techniques, antimicrobials, homeostatic, preservation, water-activity

Introduction
Several preservation techniques are used to control the microbial growth. Some of the factors used in food preservation are temperature, water activity (aw), pH, oxidation–reduction potential (Eh), and preservatives and so on. Every factor has an optimum to minimum level influencing the microorganisms. When a single factor is used for food preservation, the condition beyond the required level is generally used. Such processes can reduce nutritional quality of foods. However, the consumers prefer fresh, natural, and healthy foods. Hurdle technology involves the use of combination of a number of milder preservation factors *viz* physical, chemical and biological to achieve an enhanced level of product quality, safety, and stability as shown in Table 1. Hurdles will reduce or stop growth of microorganisms (Erkmen and Bozoglu, 2016) [6]. Thus, hurdle technology can be defined as a process of rendering food to be free from spoilage and pathogenic micro-organisms by the combination of one or more preservation methods. The spoilage and pathogenic micro-organisms have to pass through these individual approaches called "hurdles" for maintaining their activity in food products (Subha, 2013) [16]. Hurdle application of different treatments offers synergistic advantage compared to separate using of the individual treatment (Bazhal *et al*., 2003) [3]. More recently out of the comprehension of the hurdle technology new concepts for food safety have emerged. The microbial stability and safety of most foods is based on a combination of several factors (hurdles), which should not be overcome by the micro-organisms present. Hurdles ensure microbial safety in food and maintained its nutritional and organoleptic parameters for consumer preference. Current research trends in food microbiology and food technology focus on mild, physical preservation techniques and the use of natural antimicrobial compounds examples include; combining traditional inactivation, survival and growth-limiting factors at sub inhibitory levels with emerging novel non-thermal intervention food preservation techniques using bacteriolytic enzymes (lysozyme), lactic cultures and culture products (e.g., bacteriocins), ionizing radiation, high hydrostatic pressure, or pulsed electric field (PEF) (Juneja, 2003) [10]. Combining inhibitory factors can result in a significant improvement in securing microbial safety and stability as well as the sensory and nutritional quality of foods. These include manipulation of factors such as temperature, water activity and acidity, as well as processes such as gas packaging and high pressure processing.

The aim is to interfere with several different mechanisms within micro-organisms simultaneously. This multi- targeted approach allows effective use of mild techniques. Combination treatments are applied because it is expected that the use of combined preservative factors will have greater effectiveness at inactivating micro-organisms than the use of any single factor. However, recent studies show that the combination of preservation factors can have unexpected antimicrobial activity. The combined use of several preservation methods, possibly physical and chemical, or a combination of different preservatives is an age-old practice. It has been commonly applied by the food industry to achieve product quality while maintaining food safety and stability (Lee, 2004) [12].

Table 1: Types of hurdles used in food preservation.

Types of hurdles	Examples
Physical	Aseptic packaging, microwave, pulsed electric field, blanching, chilling, freezing, ionizing radiations, ultrasonication, ultra-high pressures, modified atmospheres, ultraviolet radiation and so on.
Chemical	Ethanol, carbon dioxide, lactic acid, low pH, phenols, phosphates, sodium nitrite/nitrate, spices, herbs, surface treatment agents, etc.
Biological	Antibiotics, bacteriocins, competitive flora, protective cultures

Principles of hurdle technology

Preservative factors or hurdles disturb the homeostasis of micro-organisms. Homeostasis is the tendency to uniformity and stability in the internal status of organisms (Leistner, 2000) [14]. Micro-organisms should not be able to “jump over” all the hurdles present in the food product, otherwise result in food spoilage or food poisoning. Each of the preservative factors prevent multiplication of microbes and hence cause them to remain inactive or even die. The hurdle concept illustrates that complex interactions of temperature, water activity, pH etc are significant to the microbial stability as shown in Table 2 (Nura *et al*., 2016) [17].

Table 2: Principle hurdles used for food preservation

Parameter	Application
High temperature	Heating
Low temperature	Chilling, freezing
Water activity	Drying, curing (with salt), conserving (with sugar)
Acidity	Acid addition or formation
Redox potential	Removal of oxygen (by vacuum packaging and nitrogen packaging) or addition of ascorbate
Preservatives	Sorbates, sulfites, nitrites

Antimicrobial effects of hurdles: Mechanism

Preservation of food solely depends on unfavorable environmental conditions to limit or prevent microbial growth, shorten their survival, or cause death. The basis (physiological) for the growth, survival, and death of food-borne microorganisms must be known to understand behavior of microorganisms against hurdles in the food preservation. Application of hurdle technology in the food preservation efficiently mainly depends on the homeostasis, metabolic exhaustion, stress reactions, and multitarget preservation with hurdle conditions.

Homeostasis

It is the process that maintains the stability and uniformity of the living cells internal environment in response to the changes in external environment. Hurdles can disturb one or more of the homeostatic mechanisms. Some of the examples of homeostasis in the body are regulation of temperature and balance between acidity and alkalinity (pH). These factors are prerequisite feature of living cells and this applies to higher organisms as well as micro-organisms. The concept behind homeostasis is already known in higher organisms but this knowledge should be incorporated in micro-organisms important for the poisoning and spoilage of foods. Disturbing the homeostasis of the micro-organisms by various hurdles eventually results in the death of the spoilage causing microbes thereby protecting the food product from microbial spoilage (Sharma and Garima, 2016) [20]. Thus, preservation of the food is mainly brought about by disturbing the homeostasis of microbes in food and the best way to disturb the homeostasis is the application of multiple hurdles as shown in Table 3.

Table 3: Homeostasis responses to stress by microorganisms.

Stress factor	Homeostatic response
Lower levels of nutrients	Nutrient scavenging, oligotrophy, stationary-phase response, generation of viable non- culturable forms
Lowered pH	Extrusion of protons across the cell membrane
Lowered water activity	Osmoregulation, accumulation of compatible solutes, maintenance of membrane turgor
Lowered temperature for growth	Cold shock response changes in membrane lipids to maintain satisfactory fluidity
Raised temperature for growth	Heat shock response, membrane lipid change
Ionizing radiations	Repair of single strand breaks in DNA
Competition from other microorganisms	Formation of interacting communities, aggregates of cells, showing some degree of symbiosis, biofilms

Metabolic exhaustion

Metabolic exhaustion deals with auto sterilization of food. This was firstly observed in the experiment carried out on liver sausages inoculated with Clostridium sporogens and stored at 37 ^{o}C. The bacterial spores that survive after the heat treatment are able to germinate under less favourable conditions than those under which the vegetative bacteria are able to multiply. Therefore, when hurdles (less favourable conditions) are created, the vegetative micro-organisms can be derived from the germination of bacterial spores (Erkmen and Bozoglu, 2016) [6]. But the vegetative bacteria ca not grow or even die (due to prevailing of less favourable conditions).They will die more quickly if: 1) The stability is close to the threshold for growth, 2) Storage temperature is elevated, 3) Antimicrobial substances are present, 4) The organisms are sub-lethally injured (e.g. by heat).

This aspect of hurdle technology is accelerated if several hurdles are present, and this might increase energy demands to maintain internal homeostasis under stress conditions. The vegetative micro-organisms will struggle for every possible repair mechanism to overcome this hostile environment by using their energy. After complete use up of their energy, the micro-organisms are metabolically exhausted & they will die automatically due to deficiency of energy. This process is called auto sterilization. Therefore, during storage without refrigeration, some of viable spores germinate, but the vegetative cells deriving from these spores die. Thus, the spore count actually goes on decreasing during storage, & the product becomes even safe during storage especially at ambient temperature (Leistner. 2000) [14].

Stress reactions

Some microbes acquire tolerance or may become more virulent under stress conditions as they synthesize stress shock proteins. The synthesis of stress shock protein is affected by several factors like pH, water activity, ethanol, heat, oxidative compounds, starvation of nutrients etc. The different responses of microbes under stress conditions might hamper the food preservation. Exposure to multiple stresses simultaneously activates the energy utilizing synthesis of several stress shock proteins, in turn making the microbes metabolically weak. Therefore, multi-target preservation of foods could be an efficient approach towards reducing the synthesis of stress shock proteins in food (Leistner. 2000) [14].

Multi-target preservation

This aspect of hurdle technology is most effective method. The switch on of genes for synthesis of stress shock proteins will become more difficult if various stresses are achieved at the same time. This is because countering with different stresses simultaneously will demand energy, which the microorganisms cannot deliver since they become metabolically exhausted. A synergistic effect could become true if the hurdles in a food hit, at the same time, different targets (e.g. Cell membrane, DNA, enzyme system, pH, a_w, Eh) within the microbial cell & disturb the homeostasis of microorganisms present in several respects (Leistner. 2000) [14]. This antimicrobial action of preservative factors (hurdles) is called as “multitarget preservation.” Themultitarget actions of different hurdles increase the antimicrobial effect of each hurdle. Hurdle technology allows the use of individuall hurdles at lower intensity for improving product quality. Infact, food preservation is achieved by disturbing the normal cellular activities of microorganisms in foods, either temporarily or permanently. Different hurdles in a food will not just have an additive effect on stability, but might act synergistically (Neeha and Subhash, 2014) [16].

Hurdle technology: Need

In developed countries there is a rapidly growing demand from the consumer for fresh-like, minimally processed food products and in developing countries, food storable without refrigeration are of special interest, because refrigeration is costly and not continuously available. Furthermore, in less developed countries food preservation procedures should be inexpensive &and simple, but reliable. Consumers demand for healthier foods that retain their original nutritional properties. The shift to ready-to-eat and convenience foods which require little further processing by consumers. Consumer’s preference for more natural food that requires less of processing and fewer chemical preservatives (Neeha and Subhash, 2014) [16]. Hurdle technology provides a framework for combining a number of milder preservation techniques to achieve an enhanced level of product safety and stability. Improved nutritional & economic properties convenient to use, incur in less transportation and storage costs.

Therefore the application of this technology will result in a safe product with 1) optimal shelf life, 2) improved microbial stability and sensory qualitImproved nutritional & economic properties, 3) convenient to use, incur in less transportation and storage costs, 4) shelf stable at ambient temperature. Thus, hurdle technology is a technology which aims to improve the total quality of foods by the application of an intelligent mix of hurdles (Leistner. 1985) [13].

Applications of hurdle technology in different products:

Hurdle technology can be applied to wide categories of food which include; dairy products, fresh fruits and vegetables, fruits derived products, animal products (Aditya and Nida, 2015) [1]. Hurdle Technology is a novel concept which has several applications in the preservation of various food products such as:

Dairy products

Hurdle technology has been applied in many dairy products to enhance their shelf life. Shelf stable paneer can be prepared by applying various hurdles such as pH, aw, preservatives and Modified Atmosphere Packaging (MAP). The quality and shelf life of hurdle treated paneer extended from one to twelvedays at ambient temperature and six to twenty days at refrigeration temperature without affecting its physicochemical and sensory properties (Thippeswamy *et al*., 2011) [26]. Hurdle treated brown peda could be best preserved up to forty days at room temperature (30±1 ºC) without any quality loss (Panjagari *et al.*, 2007) [18].

Fruits & vegetables

Several hurdles are considered to be important in the preservation of various vegetables and fruits like carrot, pineapple, coconut & papaya to enhance their stability and shelf life. Shelf-stable grated carrot products are developed using hurdle technology. (Vibhakara *et al*., 2006) [28] used several hurdles such as antimicrobials, partial dehydration and packaging in polymeric bags to develop grated carrots that can remain fresh and microbiologically safe for more than six months at ambient temperature. Hurdle technology can also be applied to develop shelf stable RTE (Ready-To-Eat) intermediate moisture pineapple with increased shelf life. Osmotic dehydration, infrared drying and gamma radiation can successfully reduce the microbial load in pineapple slices increasing its shelf life up to 40 days (Saxena *et al*., 2009) [20].

Meat & meat products

Several hurdles such as marination, cooking and glycerol have been applied in the production of shelf stable chicken lollipop (Singh *et al*., 2014) [23]. Implementation of Hurdle technology to sausages helped to store them for longer duration (Thomas *et al.*, 2010) [27]

Hurdles in food preservation: Physical hurdles

Pasteurization

Refers to treatment of food (usually below 100 ºC) to destroy micro-organisms of public health significance. Pasteurization processes used in the industry do not kill all micro-organisms in foods; they only target pertinent pathogens and reduce spoilage organisms that may grow during storage and distribution (Silva and Gibbs, 2010) [22]. Foods are heat-processed to kill pathogenic bacteria. Foods can also be

pasteurized using gamma irradiation. Such treatments do not make the foods radioactive. The pasteurization process is based on the use of one of following time and temperature relationships.
High-Temperature-Short-Time Treatment (HTST) - this process uses higher heat for less time to kill pathogenic bacteria. For example, milk is pasteurized at 161°F (72 °C) for 15 seconds. Low-Temperature-Long-Time Treatment (LTLT) - this process uses lower heat for a longer time to kill pathogenic bacteria. For example, milk is pasteurized at 145°F (63 °C) for 30 minutes.

Sterilisation
In sterilisation with moist heat, temperatures generally range from 110 to 120 °C with sterilisation times being from 20 - 40 minutes. For example, canned foods are sterilised in an autoclave at about 121˚C for 20 min. Higher temperatures and shorter times may have similar effects (e.g., 134 ˚C for 3 min.). However, if conditions do not allow the germination of spores, lower temperatures and shorter times can also be applied (Leistner. 2000) [14]. For example, with acid fruit juices, jam, or desserts, heating to 80 – 100 ˚C for 10 min is normally sufficient. For killing bacterial endospores by dry heat, longer exposure times (e.g. up to 2 hours) and higher temperatures (e.g. 160 – 180 ˚C) are required than with moist heat.

Blanching
Blanching is a form of thermal processing applied mainly to vegetables and some fruit by exposing them to heated or boiling water or even culinary steam for a short period of time. Blanching is carried out at up to (70 to 100 ºC) using hot water. Combined with other hurdles like freezing, refrigeration, and packaging). Inactivate enzymes in plant tissues. Drive off inter- and intracellular oxygen and other gases from plant tissues. Eg: lipoxygenase, polyphenoloxidase.

Refrigeration
Ideally 0 ºC to 4 ºC for most foods, short term preservation (days to weeks), slows down microbial growth, respiration, enzyme/chemical reactions. Low temperature can lower the rate of chemical reactions and the action of enzymes. Generally, freezing can prevent the growth of most food-borne micro-organisms and the usual temperature for cold storage is 4.5-7 ℃. Refrigeration temperature lowers the growth rate of micro-organisms and chilling can slow down the enzymatic and microbial changes in food (Vibhakara *et al*., 2006) [28].

Freezing
For freezing, the ideal temperature is -18 ºC. Quality of the product depends on product, time, and temperature. Freezing is a long-term preservation (months to years) method which slow down chemical reactions, stops microbial growth and respiration. For frozen food, it should be stored at or below -18 ℃ where the enzymatic and microbial changes may be stopped or extremely slowed.

Water Activity
Water activity (a_w) is a measure of the amount of freely available water within a food. The aw of a food can be expressed as the ratio of the water vapour pressure of the food to the water vapour pressure of pure water at the same temperature. Water is required for microbial growth therefore foods with low water activities cannot support the growth of micro-organisms. Pathogenic and spoilage bacteria do not grow in food with a water activity of less than 0.85. Many yeasts and moulds however are capable of growth at much lower water activities than this; some can even grow at a_w 0.60. The water activity of a food can be altered from the value typical for a food type in order to prevent microbial growth via the addition of solutes or ions or by freezing or drying (Subha, 2013) [24]. It is as a result of water activity that dry foods such as crackers or dried pasta can have a shelf life of many months and not be spoilt by micro-organisms. Foods such as jams and parmesan cheese (a_w 0.60 - 0.85) will show signs of mould growth over time but no bacterial growth, and foods such as meat and milk (a_w 0.98 - 0.99) are associated with food poisoning causing bacteria.

Redox Potential
Also known as the oxidation-reduction potential or Eh, the redox potential of a food has an impact on microbial growth. Aerobic organisms require a food to have a positive redox potential (an oxidised state) whereas anaerobes require a negative potential (a reduced state) for growth. It should be noted that the presence of oxygen is not an absolute requirement for oxidation-reduction reactions as other compounds can accept electrons. Different foods have distinct redox potentials and these influence the type of microbial growth typically seen in that food. Foods of plant origin typically have a redox potential of +300 to 400 mV thereby favouring the growth of aerobic bacteria and moulds. Solid meat typically has a redox value of -200 mV and therefore anaerobic organisms are associated with this food type (Leistner. 2000) [14].

pH
The control of intracellular pH is required in order to prevent the denaturation of intracellular proteins. Each organism has a specific requirement and pH tolerance range; some are capable of growth in more acid conditions than others. Most micro-organisms grow best at neutral pH (7.0). Yeasts and moulds are typically tolerant of more acidic conditions than bacteria but several species of bacteria will grow down to pH 3.0. Bacterial pathogens are usually unable to grow below pH 4.0.

Modified atmosphere packaging (MAP): The practice of modifying the composition of the internal atmosphere of a package (commonly food packages, drugs, etc.) in order to improve the shelf life. The need for this technology for food arises from the short shelf life of food products such as meat, fish, poultry, and dairy in the presence of oxygen. From a microbiological aspect, oxygen encourages the growth of aerobic spoilage micro-organisms. Therefore, the reduction of oxygen and its replacement with other gases can reduce or delay oxidation reactions and microbiological spoilage**.** The modification process generally lowers the amount of oxygen (O_2) in the headspace of the package (Aditya and Nida, 2015) [1]. Oxygen can be replaced with nitrogen (N_2), a comparatively inert gas, or carbon dioxide (CO_2). Low O_2 and high CO_2 concentrations in packages are effective in limiting the growth of Gram negative bacteria, molds and aerobic micro-organisms, such as *Pseudomonas* spp. Use of additional hurdles such as temperature control (maintain temperature below 3 ºC), lowering water activity (less than 0.92), reducing pH (below 4.5) or addition or preservatives such as nitrite to delay metabolic activity and growth of pathogens.

High pressure processing

HPP is a non-thermal processing which has useful impact on item quality and has ability to inactivate micro-organisms in different food patterns. As an elective to traditional thermal handling, HPP has potential to prepare fantastic food with 'fresh like' qualities and enhanced functionalities (Akhmazillah *et. al.*, 2013) [2]

Principle

During HPP of food, food are introduced to ultra high hydrostatic pressure (UHHP or UHP), normally in the reach of 100-1000 Mpa. The preparing temperature throughout pressure processing might be balanced from beneath 0°c to above 100°c with introduction times extending from a couple of seconds to over 20 minutes (Yaldagard *et.al.*, 2008) [29]. The food items are condensed by even pressure from each angle and after that came back to their unique shape when the pressure is discharged. The items are condensed freely of the item size and geometry in light of the fact that transmission of pressure to the center is most certainly not mass and time dependant therefore the procedure is minimized.

Uses:

Inactivation of enzymes, harm to DNA, RNA, and ribosomes, and the downfall of membranes and cell wall. High pressure might be use to hinder microbial development in food. Other harming effect involves broad solute failure throughout pressurization, protein denaturation,

Ultra sound

Ultrasound is defined as sound waves having frequency that exceeds the hearing limit of the human ear (20 kHz). Ultrasound is one of the emerging technologies that were developed to minimize processing, maximize quality and ensure the safety of food products. Ultrasound is applied to impart positive effects in food processing such as improvement in mass transfer, food preservation, assistance of thermal treatments and manipulation of texture and food analysis (Knorr *et al.*, 2011) [11].

Principle

Ultrasonic waves (energy generated by sound waves of 20,000 Hz or more) generate gas bubbles in liquid media, that produce a high temperature-and pressure increase when they immediately burst.

Uses

The bactericidal effect of ultrasound is attributed to intracellular cavitation, that is, micro-mechanical shocks that disrupt cellular structural and functional components up to the point of cell lysis. Although ultrasound technology has a wide range of current and future applications in the food industry, including inactivation of micro-organisms and enzymes, presently, most developments for food applications are non-microbial.

Physio chemical hurdles

Salt (NaCl)

Reducing water content through salt curing. Mixing the salt with raw vegetables, fish and fruits it build osmotic pressure and water started draining from the cells (movement of low concentration liquid to high concentration). Salt in high concentration (15-20%) can prevent the water from being available for bacterial growth. It can slow down the growth rate of bacteria and thus the food is preserved. Salt can be used in brine (salt water) or applied to food directly.

Nitrate and nitrite

Curing meat and other perishable produce. Added to meat to keep it red and give flavour. Leafy vegetables have higher nitrate levels. (Celery, spinach, lettuce and potatoes contain the highest levels). Nitrite is mainly used in sausages, ham, bacon and pickled meat to inhibit the growth of *Clostridium botulinum*.

Acetic acid

One of the oldest chemicals known to human, the acetic acid bacteria (AAB), one of which is Acetobacterium, commonly found in foodstuffs, water, and soil. Acetic acid is one of the main products of AAB metabolism (Gonzalez *et al.*, 2005) [9]. The acid has GRAS status and is approved worldwide for use as a food additive and preservative. It is known to give a strong flavor profile and also increases the effectiveness of other flavour additives and substances present in food, particularly in bread

Ascorbic acid

Ascorbic acid and its salts have, for many decades, been leading antioxidants used on fruits and vegetables in fruit juices. This application method is effective in preventing browning and other oxidative reactions. Ascorbic acid also acts as an oxygen scavenger by removing molecular oxygen in polyphenol oxidase reactions. L-ascorbic acid and its various derivatives have GRAS status and are common preservatives in the production of canned foods.

Benzoic acid

Benzoic acid is one of the oldest and most commonly and widely used chemical preservatives. However, the use of sodium benzoate as a food preservative has been optimal in products that are acidic in nature, specifically suitable for foods and beverages with pH < 4.5. Benzoic acid is also often used in combination with sorbic acid in many types of products. This combination is particularly popular in confectionery (Suhr and Nielsen, 2004) [25]. It has been detected as a natural constituent of cranberries, raspberries, plums, prunes, cinnamon, and cloves.

Citric acid

Popular acidulant and, due to its flexibility, its use is standard in virtually every preserved food (Marz, 2002) [15]. Together with its salts, citric acid is, in fact, one of the most commonly used organic acids in the food as well as pharmaceutical industries.

Lactic acid

An organic acid with a wide range of industrial applications, classified as GRAS by the FDA and very often used in foods as an acidulant, flavoring agent, pH buffering agent, and of course as a preservative. Lactic acid is not naturally present in foods, but is produced during fermentation of foods by lactic acid bacteria. These foods include sauerkraut, pickles, olives, and some meats and cheeses (Barbosa-Cánovas *et al.*, 2003). Lactic acid is used in foodstuffs for acidification, to increase flavor and aroma, and is a potent microbial inhibitor. Lactic acid is applied to a diverse range of foodstuffs, including meats, fish, vegetables, cereals, and cake products. In fermented drinks it is used to contribute specifically to aroma and preservation (De la *et al.*, 2005).

Sorbic acid

The weak organic acid most extensively used in food preservation is sorbic acid. It has GRAS status and it is used together with the organic acids, benzoic acid and acetic acid, sorbic acids (or trans- trans-2,4-hexadienoic acids) are the most commonly used chemical preservatives of food and are GRAS, broad-spectrum, antimicrobial agents (Plumridge *et al.*, 2004) [19]. Sorbic acid is also often used in combination with benzoic acid for various types of products and confectionery. Sorbic acid and its salts have several advantages as food preservatives. They are highly active against fungi as well as a wide range of bacteria, in particular the catalase-positive organisms, their effective concentrations normally do not alter the taste or odor of a food product, and they are also considered harmless.

Sodium benzoate

As a food preservative, sodium benzoate is generally limited to products that are naturally acidic and is more effective in food systems where the pH $\leq$ 4. It is mainly used as an antimycotic agent and most yeasts and molds are inhibited by a concentration of 0.05–0.1%). Benzoates and para-benzoates are used primarily in fruit juices, chocolate syrup, candied fruit peel, pie fillings, pickled vegetables, relishes, horseradish, and cheese.

Ozone

Ozone is an effective, chlorine alternative, sanitizer with superior antimicrobial properties. It is capable of inactivating bacterial spores, molds, yeasts, protozoan cysts and viruses at relatively low concentration and in short exposure time when applied to pure cell suspensions. Ozone has been tested on nearly every type of food during storage and processing to improve the safety and to extend the shelf-life of these products. The ability of ozone to inactivate contaminant micro flora on food is variable; in some instances, however, ozone decreased food micro flora more than 5 log unit.

Compeitive micro- organism

Bacteriocins

Antimicrobial peptides (also referred to as bacteriocins), are more important substances produced by lactic acid bacteria. Bacteriocins are currently commercially applied in various industrial food systems for the control of pathogens. These substances are also known for their attractive characteristics that make them suitable for food preservation (Galvez *et al.*, 2007) [8]. They are nontoxic for eukaryotic cells, they have little influence on the gut micro-flora, have a broad antimicrobial spectrum, have a bactericidal mode of action, and are pH and heat tolerant. Bacteriocins are often used in combination with other antimicrobial agents such as organic acids. Nisin is an important commercially available bacteriocin and is produced by strains of *Lactococcus lactis* subsp. Lactis. Nisin is GRAS and the only bacteriocin that is permitted in food. It has been successfully applied in various foods, such as dairy products and salad dressings.

Lactic acid bacteria

LAB are employed in food industry for making yoghurt, cheese, sourdough bread, sauerkraut, pickles, beer, wine and other fermented foods. Besides prolonging the shelf life, lactic acid enhances the gustatory and nutritional value, imparts appetizing flavor and texture to the food. Some LAB produce proteinaceous antimicrobial compounds called bacteriocins which inhibit the growth of Gram-positive pathogenic and spoilage bacteria and used as food additives. Examples include, *Lactobacillus, Leuconostoc, Pediococcus, Lactococcus and Streptococcus.*

Antimicrobials

Certain foods naturally contain antimicrobial substances that will exhibit an inhibitory action on the growth of micro-organisms. Examples are essential oils contained within cloves, garlic, mustard and thyme, lactoferrin in cows' milk and lysozyme in eggs.

Advantages of hurdle technology over other preservation methods

- The greatest advantage of hurdle technology is tendency to conquer the ability of micro-organisms in developing resistance to conventional preservation methods because in combine technology different preservative acts synergistically by hitting different targets within the cell of the spoilage micro-organism.
- Hurdles are use at lower concentrations this prevent the undesired side effects, lower production cost and save energy.
- Another advantage is the opportunity of using natural preservatives in combination with synthetic preservatives, this also lower the risk associated with using synthetic preservatives at high concentration.
- Possibility of increasing shelf-stable foods; because food preserved by combined methods (hurdles) remains stable and safe even without refrigeration, and is high in sensory and nutritive value due to the gentle process applied. (FOA, 2006).

Apart from the advantages, hurdle technology have certain disadvantages like high cost, high level of preservatives required, and high amount of antimicrobials additives.

Conclusion

Novel techniques suitable for processing of food provide promising solutions to deliver safe food products with enhanced quality and shelf life. However, there are significant challenges in achieving the desired microbial safety while maintaining product quality with heat or nonthermal treatments alone. Issues related to the negative effects of heat treatments on product quality can be overcome by the use of natural additives or by employing nonthermal treatments. Various studies have shown that the combination of technological interventions are capable of improving shelf life and sensorial quality of food products while ensuring the microbial safety. Thus, hurdle technology is an intelligent mix of hurdles which works synergistically and provides safe, healthy products of high quality. The application of this technology will result in a safe product with optimal shelf life, improved microbial stability, sensory quality, nutritional and economic properties, convenient to use, incur in less transportation and storage costs. Therefore, hurdle technology is a technology which aims to improve the total quality of foods by the application of an intelligent mix of hurdles.

References

1. Aditya P, Nida M. Hurdle Technology-An Approach towards Food Preservation. International Journal Current Microbiology Applied Sciences. 2015; 4(7):802- 809.
2. Akhmazillah M, Farid MM, Silva M. High pressure processing (HPP) of honey for the improvement of

nutritional value. Innovative Food Science & Emerging Technologies. 2013; 20(0):59-63.
3. Bazhal MI, Ngadi MO, Raghavan GS. Minimal processing of foods using hurdle technologies. Food and Biological System, 2003, 342.
4. Barbosa GV, Fernández JJ, Alzamora SM, Tapia MS, López-Malo A, Chanes JW. General considerations for preservation of fruits and vegetables. Food and Argriculture Organization of the United Nations, 2003; 12(2):62-66.
5. De la RP, Cordoba G, Martin A, Jordano R, Medina LM. Influence of a test preservative on sponge cakes under different storage conditions. Journal of Food Protection. 2005; 68:2465-2469.
6. Erkmen O, Bozoglu TF. Food Preservation by Combination of Techniques (Hurdle Technology). Food Microbiology: Principles into Practice, 2016, 166-179.
7. Food and Agricultural Organization Technical Manual. Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas. FOA Agricultural Service Bulletin. 2006, 1-46.
8. Galvez A, Abriouel H, Lopez RL, Ben ON. Bacteriocin-based strategies for food bio-preservation. International Journal of Food Microbiology. 2007; 120:51-70.
9. Gonzalez A, Hierro N, Poblet M, Mas A, Guillamon JM. Application of molecular methods to demonstrate species and strain evolution of acetic acid bacteria population during wine production. International Journal of Food Microbiology. 2005; 102:295-304.
10. Juneja VK. Combining traditional and new preservation techniques to control pathogens: the case of *E. coli.* in food preservation techniques. 2003, 205-206.
11. Knorr D, Froehling A, Jaeger H, Reineke K, Schlueter O, Schoessler K. Emerging technologies in food processing. Annual Review of Food Science and Technology, 2011; 2:203-235.
12. Lee SY. Microbial Safety of Pickled Fruits and Vegetables and Hurdle Technology. Internet Journal of Food Safety. 2004; 4:21-32.
13. Leistner L. Food Engineering Vol III book, 1985.
14. Leistner L. Use of combined preservative factors in foods of developing countries. The Microbiological Safety and Quality of Food, I. 2000, 294-314.
15. Marz U. World markets for citric, ascorbic, isoascorbic acids. 2002; 68:4676-4678.
16. Neeha VS, Subhash BK. Use of Hurdle Technology in Food Preservation. International Journal of Engineering and Management Research. 2014; 4:204-212.
17. Nura A, Chukwuma AC, Oneh AJ. Critical review on principles and applications of hurdle technology in food preservation. Annals. Food Science and Technology, 2016. https://doi.org/10.1016/B0-12-464970-X/00173-2.
18. Panjagari NR, Londhe GK, Pal D. Effect of packaging techniques on self-life of brown peda, a milk based confection. J Food Sci and Technology. 2007; 47:117-125.
19. Plumridge A, Hesse SJ, Watson AJ, Lowe KC, Stratford M, Archer DB. The weak acid preservative sorbic acid inhibits conidial germination and mycelia growth of *Aspergillus niger* through intracellular acidification. Applied and Environmental Microbiology. 2004; 70:3506-3511.
20. Saxena BB, Mishra R, Chander, Sharma A. Shelf stable intermediate moisture pineapple (*Ananas comosus*) slices using hurdle technology. Food Science and Technology. 2009; 42:1681-1687.
21. Sharma S, Garima. Use of Hurdle Technology in Food Preservation. Current Research and Information on Biotechnology. 2016; 1(1):28-35
22. Silva F, Gibbs PA. Non-proteolytic Clostridium Botulinum spores in low-acid cold distributed foods and design of pasteurization processes. Trends Food Science and Technology. 2010; 21:95-105.
23. Singh VP, Pathak V, Nayak NK, Goswami M. Application of hurdle concept in development and shelf life enhancement of chicken lollipop: International Journal of Current Microbiology and Applied Sciences, 2014; 3(1):355-361.
24. Subha G. Biologically viable methods for food preservation: A Review. Research Journal of Chemical and Environmental Sciences. 2013; 1(2):1- 2.
25. Suhr K, Nielsen PV. Effect of weak acid preservatives on growth of bakery product spoilage fungi at different water activities and pH values. International Journal of Food Microbiology. 2004; 95:67-78.
26. Thippeswamy L, Venkateshaiah B, Patil S. Effect of modified atmospheric packaging on the shelf stability of paneer prepared by adopting hurdle technology. Journal of Food Science Technology. 2011; 48:230
27. Thomas R, Anjaneyulu ASR, Kondaiah N. Quality of Hurdle Treated Pork Sausages during refrigerated storage. Journal of Food Science and Technology. 2010; 47:266-272. doi: 10.1007/S13197-010-0041-1
28. Vibhakara H, Gupta D, Jayaraman K, Mohan MS. Development of a high-moisture shelf-stable grated carrot product using hurdle technology. Journal of Food Processing. 2006; 30:134-144.
29. Yaldagard M, Mortazavi S, Tabatabaie F. The principles of ultra high pressure technology and its application in food processing/preservation: A review of microbiological and quality aspects. African Journal of biotechnology. 2008; 7(16):2739-2767.