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Use of Hurdle Technology in Food Preservation

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ABSTRACT

In industrialized countries there is a rapidly increasing 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. Hurdle technology is an intelligent mix of hurdles which works synergistically and provides safe, healthy products of high quality. The present review focuses on hurdle technology: different types of hurdles used, how these hurdles work together (mechanism), its effect on the microorganism and ultimately it explains how it gives a quality food product. A literature search was carried out and a total of 11 food products and their effect after the application of hurdle technology were studied. It was found that the application of this technology will result in a safe product with optimal shelf life, improved microbial stability, sensory quality, nutritional & economic properties, convenient to use, incur in less transportation and storage costs. Thus, hurdle technology is a technology which aims to improve the total quality of foods by the application of an intelligent mix of hurdles.

Keywords-- Hurdle technology, hurdles, inactivation, quality, stability

I. INTRODUCTION

The present review focuses on hurdle technology, different types of hurdles used and how these hurdles work together (mechanism), its effect on the microorganism and ultimately how it affects the quality of the food. ***The Hurdle technology*** *is also called as combined preservation, combination technology; it was developed as a newer concept for safe, stable, nutritious, tasty and economical foods.*

Hurdle Technology: History

Origin of preservation

Since the beginning of time, man has searched for ways to preserve the life length of food materials. Before the concept of food processing preservation developed, humans were forced to travel from one place to another place in order to locate fresh foods. Food had to be eaten almost immediately after it was either killed in instances of animal meat or not long after harvesting for fruits and vegetables. Discovering a method to save food was vital to the expansion and development of mankind as it is today [1].

Origin of hurdle technology

For centuries, combined methods were applied empirically in food preservation. For example, combination treatment includes heat, reduced moisture content and antimicrobial chemicals deposited from the smoke onto the surface of the food. Some smoked foods may also be dipped or soaked in brine or rubbed with salt before smoking, to infuse the flesh with salt and thus add a further preservative mechanism. In jam and other fruit preserves, the combined factors are heat, high solids content (reduced water activity) and high acidity. In vegetable fermentation, the desired product quality and microbial stability are achieved by a combination of factors such as salt, acidification, and so forth [2].

After the factors (F, t, a_w, pH, Eh, competitive flora, etc.) governing the traditional methods of food preservation were better understood, their interaction was studied. The preservation factors were called hurdles and their interactions the hurdle effect. The logical next step was to modify and optimize the hurdles in foods. This approach was called intelligent hurdle technology [3].

II. HURDLE TECHNOLOGY: NEED AND SIGNIFICANCE

In industrialized countries there is a rapidly increasing 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 & simple, but reliable.

Therefore the application of this technology will result in a safe product with

- optimal shelf life, improved microbial stability and sensory quality
- Improved nutritional & economic properties
- convenient to use, incur in less transportation and storage costs

- 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 [3].

Methodology

A literature search on hurdle technology, different types of hurdles used and the mechanism involved was conducted. To find out the application of hurdle technology in particular food products, science direct database was used. A total of 11 food products and their effect after the application of hurdle technology were studied.

Hurdle Technology: Types

Table.1. Individual Hurdles grouped according to primary function [4]

Microbiocidal hurdles that reduce microbiological load	Bactofugation®, Competitive microflora, Microfiltration, Ripening (ageing), Thermization, High-pressure treatment, Ultrasonication, Electromagnetic Energy Treatment, Low Intensity Irradiation
Microbiostatic hurdles that limit and/or prevent growth by biochemical means	pH, Carbon dioxide (CO_2), Use of Preservatives, Modified atmosphere, Redox potential control, The Lactoperoxidase system, The hydrogen peroxide catalase method.
Microbiostatic hurdles that limit and/or Prevent growth by physical means	Refrigeration, Water activity control, Freezing, Time
Hurdles that prevent contamination	Light, Coatings, Packaging

Table.2. Principal hurdles used for food preservation [5, 6].

Parameter	Symbol	Application
High Temperature	**F**	Heating
Low Temperature	**T**	Chilling, Freezing
Water Activity	a_w	Drying, Curing (with added salt), Conserving, (With added sugars)
Acidity	**Ph**	Acid addition or formation
Redox Potential	E_h	Removal of oxygen (by Vacuum packaging and Nitrogen packaging) or addition of ascorbate
Biopreservatives		Competitive flora such as microbial fermentation
Preservatives		Sorbates, Sulfites, Nitrites

Table.3. Types of hurdles for food preservation [2, 5].

Type of hurdles	Examples
Physical	Aseptic packaging, electromagnetic energy such as microwave, radio frequency, pulsed magnetic fields and high electric fields), high temperatures (e.g.blanching,), ionizing radiation, low temperature (chilling, freezing), modified atmospheres, packaging films, Photodynamic inactivation, ultra-high pressures, ultrasonication and ultraviolet radiation
Physicochemical	Ethanol, Carbon dioxide, lactic acid, lactoperoxidase, low pH, low redox potential, low water activity, Maillard reaction products, organic acids, oxygen, ozone, phenols, phosphates, salt, smoking, sodium nitrite/nitrate, sodium or potassium sulphite, spices and herbs, surface treatment agents
Microbial	Antibiotics, bacteriocins, competitive flora, protective cultures

III. HURDLE TECHNOLOGY: MECHANISM

Food preservation implies putting microorganisms in a unfriendly environment, in order to inhibit their growth or to cause their death. The feasible responses of microorganisms to this hostile environment determine whether they may grow or die. The various responses of microorganisms are:

Homeostasis

Homeostasis is the tendency to uniformity and stability in the internal status of organisms. If the homeostasis of these microorganisms is disturbed by preservative factors in foods, they will not multiply, i.e. they remain in the lag-phase, before homeostasis is repaired (re-established). The repair of disturbed homeostasis demands much energy of microorganisms, and the restriction of energy supply inhibits the repair mechanisms of microbial cells. The energy restrictions for microorganisms can be caused by applying anaerobic conditions such as MAP or vacuum packaging. Therefore, food preservation can be achieved by disturbing the homeostasis of microorganisms in a food temporarily or permanently [7].

Table.4. Homeostatic responses to stress by microorganisms [6].

Stress factor	Homeostatic response
Low levels of nutrients	Nutrient scavenging; oligotrophy; 'stationary-phase response'; generation of 'viable non-culturable' Forms
Lowered Ph	Extrusion of protons across the cell membrane; maintenance of cytoplasmic pH; maintenance of transmembrane pH gradient
Lowered water activity	Osmoregulation; accumulation of 'compatible solutes'; avoidance of water loss; 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 changes
Raised levels of oxygen	Enzyme protection (catalase, peroxidase, superoxide dismutase) from H_2O_2 and oxygen-derived free Radicals
Presence of biocides	Phenotypic adaptation; reduction in cell wall/membrane permeability
Ionizing radiation	Repair of single-strand breaks in DNA
High hydrostatic pressure	Uncertain; possibly low spore water content
High voltage electric discharge	Low electrical conductivity of the spore protoplast
Competition from other microorganisms	Formation of interacting communities; aggregates of cells showing some degree of symbiosis; biofilms

Metabolic Exhaustion

The bacterial spores that survive after the heat treatment are able to germinate under less favorable conditions than those under which the vegetative bacteria are able to multiply. Therefore, when hurdles (less favorable conditions) are created, the vegetative microorganisms can be derived from the germination of bacterial spores. But the vegetative bacteria ca not grow or even die (due to prevailing of less favorable conditions).They will die more quickly if

a. The stability is close to the threshold for growth
b. Storage temperature is elevated.
c. Antimicrobial substances are present.
d. The organisms are sub-lethally injured (e.g. by heat).

The vegetative microorganisms will struggle for every possible repair mechanism to overcome this hostile environment by using their energy. After complete use up of their energy, the microorganisms 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.

e.g. for liver sausages treated at 95°C, & stored at 37°C, the clostridium spores that a survived during the heat treatment are vanished during storage. This is due to the fact that bacteria spores are able to germinate under less favorable conditions than where vegetative cells of bacilli & clostridiums are able to multiply. Therefore, during storage some of viable spores germinate, but the vegetative cells deriving from these spores die. Thus, the spore count actually goes down during storage [7].

Stress Reactions

Under stress, some bacteria become more resistant to heat & become more virulent, due to generation of stress shock proteins. These stress shock proteins help the organism to cope with stress situations. This is the main limitation to the process of hurdle technology & to avoid the synthesis of stress shock proteins, multi target preservation should be applied. The synthesis of these proteins is induced by heat, pH, a_w, ethanol & so on, as well as by starvation [7].

Multi-Target Preservation

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 [7].

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, aw, Eh) within the microbial cell & disturb the homeostasis of microorganisms present in several respects [7].

IV. HURDLE TECHNOLOGY: APPLICATION AND SAFETY

1. ***Apple Juice***

[8] investigated the influence of ultraviolet irradiation (UV) and pulsed electric fields (PEF) on microbial inactivation, selected quality attributes (colour, pH, Brix, non-enzymatic browning index (NEBI) and antioxidant capacity) and enzymatic activity (polyphenol oxidase (PPO) and peroxidase (POD)) of fresh apple juice. The two technologies were applied as stand-alone treatments (TUV or TPEF) or in combination (TUV+PEF or TPEF+UV). TUV was a batch process while TPEF was continuous and consisted of 100 square-wave pulses (1s, 15 Hz) at 40 kV/cm. Apple juice samples processed by a heat exchanger at 72°C (TH72) or 94°C (TH94) for 26 s were used as controls. TUV and TPEF resulted in a 2.2 and 5.4 log reduction respectively, while the respective reductions for TH72 and TH94 were 6.0 and 6.7 log cycles. TPEF+UV and TUV+PEF achieved similar reduction to TH94 (6.2 and 7.1 log cycles, respectively) on an incubated sample (48 h at 37°C), with TUV+PEF producing a greater microbial reduction than TPEF. Juice colour and level of phenolic compounds were less affected by the alternative treatments than by heat pasteurisation. Reduction of PPO and POD activity was greater ($P < 0.001$) in TPEF, TUV+PEF or TPEF+UV than in TH72. In their experiment showed the potential of a combination of UV irradiation and PEF to obtain satisfactory total microbial inactivation and improved product quality compared to heat pasteurization [8].

Safety:

1. Elimination of E. coli, *Saccharomyces cerevisiae* count.

2. ***Skim milk beverage***

[9] studied a possible synergistic effect of hurdle technology using a combination of Pulsed Electric Fields (PEF) technology and a natural ingredient, cinnamon, on inactivation of *Salmonella typhimurium* in skim milk (SM). Firstly, different cinnamon concentrations (1, 2.5 and 5% (w/v)) were added to inoculated SM (107 CFU/mL) for quantitative study of the effect of the natural ingredient on microbial growth behaviour (bactericidal/bacteriostatic) at different temperatures (8, 25, 36 °C). 5% (w/v) cinnamon supplementation of SM (SM-5% C) was bacteriostatic with regard to *S. typhimurium* growth according to μmax [0.016 ((CFU/mL)/h) (8 °C); 0.259 ((CFU/mL)/h) (25 °C); 0.603 ((CFU/mL)/h) (37 °C)] and λ [282.8 (h) (8 °C); 15.38 (h) (25 °C); 2.587 (h) (37 °C)] values. Secondly, PEF treatments of 10, 20 and 30 kV/cm were applied, at treatment times ranging between 60 and 3000 μs. All cinnamon supplementation levels (1, 2.5 and 5% (w/v)) had a synergistic effect within [0.171–0.989] log10 cycles (pb0.05) due to non-thermal combination processing. The maximum synergistic effect was achieved by 10 kV/cm–3000 μs PEF treatment with 5% (w/v) cinnamon SM supplementation. The maximum inactivation level (1.97 log10 cycles) due to hurdle combination was achieved at 30 kV/cm–700 μs in SM-5% C. The results of the present study could be applied to improve the safety of various dairy-based products that are subject to *S. typhimurium* contamination. Because of the flavour and taste value of cinnamon, its interest as a natural ingredient with antimicrobial capacity is increasing, specifically in dairy derivative products. This study indicates the applicability of PEF in combination with this natural ingredient to enhance the safety of beverages, revealing the synergistic effect of this combination of technologies which could increase *S. typhimurium* inactivation rates by about 1 log10 cycle. It contributes to obtaining knowledge for future possible applications of this hurdle technology, reducing the intensity of treatments required to achieve a lethal level and making efficient use of resources [9].

Safety:

1. Elimination of *Salmonella typhimurium*.
2. When injected may cause the gastrointestinal problems.

3. ***Pineapple slices***

[10], prepare a shelf stable, ready-to-eat and safe intermediate moisture pineapple slices using hurdle technology. They used a combination of hurdles including potassium metabisulfite dip, osmotic dehydration, infrared drying, polyethylene packaging and a radiation dose of 1 kGy. This combination was found to be effective in extending the shelf life of pineapple slices up to 40 days under ambient storage temperature, whereas the control non-treated slices spoiled within 6 days. The potassium metabisulfite dip was indispensable for browning inhibition. Osmotic dehydration and infrared drying

reduced aw, which prevented microbial growth. The radiation dose was found effective in eliminating the residual microbial load on these pineapple samples. Thus ensuring the RTE intermediate moisture pineapple slices as microbiologically safe with good texture, colour and sensorily accepted throughout storage [10].

Safety:

1. Pesticides are usually applied to plants to combat insects, plant diseases, and weed growth to assist in the growth of the fruit or vegetable so washing of fruits with water is important.
2. Concentration of KMS solution is should be in safe level for heath of people.
3. Radiation dose should be 1kGy.

4. ***Pickled fruits and vegetables***

[6], in his article covers an overall review of the microbial safety of fruits and vegetables, preservative method including major preservative factors used in pickling technology, concept and mechanism of hurdle technology. Fruits and vegetables can become contaminated with pathogenic microorganisms from different sources. Pickling or fermentation is one traditional method used to preserve fruits and vegetables. Acidified pickled food products may not be safe against some pathogens which have high resistance to acidic pH. *E. coli* O157:H7 could be a pathogen of greatest concern in pickled products because of its low infectious dose and high acid tolerance. In pickled products, acid, salt, and heating are major factors that contribute to food preservation and these factors are applied in combination. Current regulations and industrial practices regarding acidified pickled foods are possibly out of date because of the scarcity of information on pathogen control in these foods. Therefore, finding the combined effects of three major factors is necessary to formulating the correct application of preservation factors that can increase the microbial safety and total quality of pickled products [6].

Safety:

1. Use commercial vinegar with a minimum acidity of 5%.
2. Hard water reduces the acidity of pickling solutions and can affect the growth of bacteria. So only use soft drinking quality water or distilled water.
3. Wash produce carefully to remove dirt and bacteria.
4. Internal pasteurizing temperature should be 74°C for 15 min followed by prompt cooling.
5. Destruction of *Escherichia coli* O157:H7.

5. ***Shelf-stable meat products***

A number of ready-to-use shelf stable meat products have been developed by using a combination of hurdles (irradiation, reduced water activity, and vacuum packing). The effectiveness of these hurdles in preventing the growth of *Clostridium sporogenes*, *Staphylococcus aureus* and *Bacillus cereus* in these products was tested. Radiation sensitivity (D_{10} values) of *S. aureus, C. sporogenes* and *B. cereus* in intermediate moisture (IM) mutton kababs were found to be 0.36, 3.0 and 0.29 kGy respectively. Radiation treatment (2.5 kGy) resulted in complete elimination of inoculated 106 cfu of *S. aureus* and *B. cereus* but not of *C. sporogenes*. The water activity (aw) of 0.85 and vacuum packaging of products prevented the growth of all three organisms inoculated into these samples during 3 months of storage at room temperature. Irradiation usefully inactivated yeast and molds which otherwise grow in the kababs after 2 months of storage. Numbers of B. cereus decreased during storage. The studies demonstrated by [11], resulted through the combination of the above hurdles result in microbiologically safe and shelf-stable meat products [11].

6. ***Mango slice***

The fractional amount of sodium chloride, potassium sorbate and sodium bisulphite were evaluated by [12], in mango slices immersed in limited volumes of syrup at 25, 50 and 70°C. The syrup contained 250 g sucrose, 1.5 g sodium chloride, 0.5 g potassium sorbate and 0.25 g sodium bisulphate per kilogram of solution. Fick's second law was used to calculate effective diffusion coefficients and to predict solute content in the mango slices. Diffusion coefficients were affected by temperature and were correlated by the Arrhenius equation. The experimental data fit the proposed mathematical model well, allowing prediction of the system's behavior at different temperatures. The resultant diffusivities ranges were 2.63–3.54 $x10^{-9}$ m2/s for sodium chloride, $3.88x10^{-9}$–8.3 x 10^{-10} m^2/s for potassium sorbate and 1.83 x 10^{-7}–5.98 x $10^{-}8$ m^2/s for sodium bisulphite. Among the three experimented chemical barriers, sodium bisulphate was the one having the highest effective diffusivity coefficients and, consequently, reaching equilibrium in shortest time, followed by sodium chloride and potassium sorbate. Thus the product had better stability and antioxidant properties (due to HSO_3 or SO_2) [12].

7. ***Korean seasoned beef***

A Korean beef product seasoned in concentrated soy sauce was vacuum packaged in a gas barrier plastic pouch and pasteurised. The effect of addition of vinegar and/or sake to the product was examined by [13] as preservation hurdles to improve microbial stability, and sensory quality. A combination of vinegar and sake improved the microbial stability of the product at 8 and 20°C, while added vinegar and/or sake did not improve the sensory quality of the product. The sensory quality of the products with or without single use of vinegar or sake degraded significantly during 10 days of storage at 8°C, which made the treatment effect less pronounced. Thus, the combined addition of vinegar and sake may be considered as a possible alternative with minimal loss of organoleptic quality when longer storage is required like usual use conditions of sous vide packaging [13].

Safety:

1. Inactivation of *C. botulinum* and *Listeria monocytogenes.*

8. ***Kimchi***

[14], provided a basis for developing effective hurdle technologies using naturally occurring antimicrobial agents to extend shelf life of kimchi. Kimchi is a traditional Korean fermented food. Since it ferments continuously during distribution and storage, the extension of shelf life by preventing over-acidification is a major concern in the kimchi industry. One of the most frequently

attempted ways to delay fermentation is to add naturally occurring antimicrobial agents. The addition of naturally occurring antimicrobial agents may enhance the acceptability of kimchi to consumers over a longer period of time but may also have a disadvantage in that it may cause changes in sensory quality, especially if added in large amounts. To avoid undesirable sensory changes, application of hurdle technologies which involve using combinations of low amounts of various naturally occurring antimicrobial agents as ingredients should be explored with the goal of controlling fermentation. If synergistic or additive antimicrobial effects can be achieved using small amounts of a combination of natural agents, changes in sensory qualities will be minimized, thereby prolonging shelf life [14].

Safety:

1. Inactivation of Total aerobic bacteria and lactic acid bacteria.

9. ***Minimally processed French beans***

Citric acid treatment in combination with gamma radiation and modified atmosphere packaging was employed by [15], as hurdles for control of microorganisms and extending shelf life of minimally processed French beans. Response surface methodology was used to optimize citric acid treatment and γ-irradiation dose to obtain product with desired microbial and sensory quality. Optimum processing conditions (citric acid 8.4 g L^{-1}; irradiation dose 0.7 kGy; 10 °C) resulted in modified atmosphere of 18% O_2 and 4% CO_2 at end of storage period. Under these conditions shelf life of the product could be extended by one week with acceptable sensory and nutritional quality as evaluated by total antioxidant, phenolics, flavonoids and vitamin C content [15].

Safety:

1. Inactivation of *Listeria monocytogenes.*

10. ***Safe and Self Stable Casings***

Currently the natural casings are stored either highly salted or frozen and utilized as early as possible in order to avoid spoilage. Hurdle technology can improve the safety of natural casings without affecting their functional properties. The casing was prepared using a combination of hurdles viz. reduced water activity, packaging and gamma irradiation. Washed lamb intestines were treated with common salt to reduce water activity to 0.80 ± 0.02, packed in polyethylene bags and subjected to gamma-irradiation (5 and 10kGy). Control non-irradiated samples had high total viable counts (106CFU/g), aerobic spores (103CFU/g), spores of sulphite reducing clostridia (103CFU/g), potentially pathogenic bacteria such as staphylococci (104CFU/g) and coliforms (102CFU/g). Treatment with gamma radiation resulted in a dose dependent reduction in counts of these microbes. A dose of 5kGy was sufficient to reduce total viable counts by three log cycles; spore counts by two log cycles and completely eliminate *staphylococci* and *coliforms*. Samples subjected to a 10kGy dose were devoid of any viable microbes. The reduced water activity of the product prevented growth of the microbes in natural casings during storage at room temperature. Sausages prepared using hurdle processed natural casing were examined for sensory and textural properties. [16], observed that product acceptability and mechanical strength was not affected by radiation processing. Thus there is scope to develop safe and shelf-stable natural casing using a combination of hurdles including radiation [16].

Safety:

1. Inactivation of *staphylococci* and *coliforms.*

11. ***Caprine Keema***

[17], was envisaged to develop and extend the shelf life of the highly perishable Indian traditional meat product, chevon (capine) keema, through the application of hurdle technology. The hurdles used were water activity (aw) and pH as variable hurdles as well as vacuum packaging, preservatives and heat treatment as constant hurdles. The water activity of the product was adjusted to 2 levels viz., 0.90 and 0.88 by the addition of humectants. The product with 0.90 was preferred for sensory quality. The pH of the keema was adjusted with lactic acid to 3 desired levels viz. 5.50, 5.65 and 5.80. The product with pH 5.8 was the most acceptable and with pH 5.50 was the least acceptable. Standardised keema with aw 0.90 and pH 5.80 was stored at ambient temperature (36.2°C) and evaluated for physico-chemical, microbiological and sensory characteristics. There was a decrease in the growth rate of aerobic and anaerobic counts and complete inhibition of *Staphylococcus aureus*. Although sensory scores for hurdle treated keema declined upon storage, the product was well accepted up to the 3rd day and fairly accepted up to 5^{th} day whereas the keema prepared by the traditional method was acceptable only on the first day. Hurdle technology significantly improved the shelf life of keema [17].

Table.5. Tabulated summary of Hurdle Technology Application and Safety

Food	Hurdles	Advantage
Apple Juice [8]	• TUV = 254 nm, 30 min, 30 W + • TPEF = 40 kV/cm for 100 µs	• Total microbial inactivation • Improved product quality compared to heat pasteurization

Skim milk beverage [9]	• PEF = 30 kV/cm–700 µs • Cinnamon = 5% (w/v)	• Improve the safety of various dairy-based products that are subject to *Salmonella typhimurium* contamination (increase *S. typhimurium* inactivation rates by about 1 log10 cycle). • Cinnamon - increases the sensory quality (Flavour and taste) antimicrobial capacity
Pineapple Juice [10]	a) Potassium metabisulfite b) Osmotic dehydration c) Infrared drying d) Polyethylene packaging e) Radiation (1 kGy)	• Potassium metabisulfite = Inhibit browning reaction. • Osmotic dehydration and infrared drying reduced aw, which prevented microbial growth. • The radiation dose eliminated the residual microbial load. • Microbiologically safe with good texture, colour and sensory accepted throughout storage. Shelf life extended up to 40 days than the control non-treated slices spoiled within 6 days.
Pickled fruits and vegetables [6]	a) Acetic acid b) Salt c) Heating	• Acetic acid = Lowers Ph • Salt = Lowers a_w • Heating increase the microbial stability • Inactivation of *Escherichia coli* O157:H7
Shelf-stable meat products (Intermediate moisture (IM) mutton kababs**)** [11]	a) Irradiation (2.5 kGy) b) Reduced water activity (0.85) c) Vacuum packing	• Inactivated *S. aureus*, *C. sporogenes* and *B. cereus* during 3 months of storage at room temperature. • Irradiation inactivated yeast and molds which otherwise grow in the kababs after 2months of storage.
Mango slice **[12]**	a) Sucrose - 250 g b) Sodium chloride - 1.5 g c) Potassium sorbate - 0.5 g d) Sodium bisulphate - 0.25 g per kilogram of solution	• Improved self life with better antioxidant power
Korean seasoned beef [13]	a) Vinegar (6.5% Acidity) b) Sake (14% Alcohol) c) Sugar d) Salt e) Packaging (nylon/PE/ nylon/PE/nylon/LLDPE) f) Pasteurised	• Improves microbial stability(*C. botulinum* and *Listeria monocytogenes)* • Minimal loss of organoleptic quality when longer storage is required.
Kimchi [14]	a) Garlic chive (140 mg/100 g of kimchi) b) Mustard c) Control of kimchi fermentation using fruits or fruit seed extracts. d) Essential oil of persimmon leaves: e) Green tea leaf (*Camellia sinensis* L.) extract and green tea	• Shelf life of kimchi could be extended by 1.5 days by adding garlic chive extract at the early stage of fermentation. • kimchi containing >0.3% mustard extract showed significantly higher scores for most of the sensory attributes. • inhibition of growth of LAB in kimchi through the addition of fruit and fruit seed extracts • The fermentation period of kimchi can be extended by 5to 7 days by adding essential oil of persimmon leaves. • Use of green tea catechins as natural preservatives for kimchi.
Caprine Keema [17]	a) aw 0.90 (humectants - isolated soya protein), b) pH 5.80, c) Vacuum packaging, d) Preservatives, e) Heat treatment	• Decrease in the growth rate of aerobic and anaerobic counts • Complete inhibition of *Staphylococcus aureus.* Shelf life extended to 3-5 days than the traditional method in which keema was acceptable only on the first day.
Safe and Self Stable Casings	a) Water activity (Common salt = 0.80 ± 0.02)	• Control non-irradiated samples had - high total viable counts (106CFU/g),

[16]	b) Packaging (polyethylene bags) c) Gamma irradiation (5 and 10kGy).	- aerobic spores (103CFU/g), - spores of sulphite reducing clostridia (103CFU/g), - *Staphylococci* (104CFU/g). - *Coliforms* (102CFU/g). • 10kGy dose were devoid of any viable microbes. • The reduced water activity of the product prevented growth of the microbes in natural casings during storage at room temperature. • Product acceptability and mechanical strength was not affected by radiation processing. Increased the stability and safety

Hurdle Technology: Limitation

- High cost
- High level of humectants and preservatives are required
- Storage can be done maximum up to 3-6 months
- Restricted to meat sector
- High amount of antimicrobials additives(i.e. chemical over loading)

Hurdle Technology: Future Aspects

There has been increasing interest in the design and application of hurdle technology in food preservation over the past few years .It is expected that this development will proceed in the near future, especially national and international funds have now been establish that should allow for cogitative studies in this field**.**

- The stability and quality of foods is based on empirical and more recently on knowing Hurdle technology. To follow this successful route, further basic as well as applied research is needed.
- The basic research in this context should center around the ***interrelation of homeostasis and hurdle technology.*** Results could lead to a better understanding of stress reactions and metabolic exhaustion of microorganism, and finally to materialization of multi-target preservation of food, as a new concept.
- The hurdle technology should be applied to improve total quality of foods. The validation of suggested ***user guide to food design*** should include ***predictive microbiology*** as well as ***HACCP***. The coupling of hurdle technology with modern preservation methods like radiation, UH Pressure, Ultrasonic radiation should be strengthened.
- It may be expected that hurdle technology foods with a ***relatively high*** a_w will partially replace IMFs, because lower amounts of humectants and less drying are required, and this would be desirable from the sensory and nutritive product of view. However, deliberate hurdle technology should be applied without sacrificing the microbial stability and safety of foods, especially those which are stored without refrigeration.
- Therefore, if the hurdle technology foods are to become more sophisticated, they will require a thorough understanding of the principles involved as well as more back up by Good Manufacturing Practice (GMP) and possibly by the HACCP concept.

V. CONCLUSION

Researchers have explored a number of hurdles and still they are experimenting to find out new hurdles and their combinations for the effective inactivation of microbes and ensuring a better and safe food product. In this study, we have come across more than 30 hurdles for the preservation of foods and the number of useful hurdles is by no means complete. Even the most advanced food preservation methods (e.g., pulsed technologies) are more effective if applied in combination with traditional hurdles. Therefore, hurdle technology in the future will probably remain the cornerstone of food preservation.

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