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Effective Food Preservation by Hurdle Technology

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Abstract

A seed is a fully grown ovule that contains an embryo, or a tiny, immature plant, as well as food stores, all covered in a seed coat for protection. The bulk of human calories originate from seeds, particularly those found in cereals, legumes, and nuts. Many seeds are edible. The endosperm, or seed embryo, predominates and supplies the majority of the nutrition in many seeds. The pods of the drumstick tree, also known as the Moringa plant (Moringa Oleifera), which is endemic to Northern India, are used to make moringa seeds. Rich in vitamins, calcium, iron, and vital amino acids, moringa is a nutrient-dense plant. Numerous vital nutrients, including lignans, omega-3 fatty acids, dietary fiber, vitamins, and minerals, are found in flax seed. A soluble fiber, such as β-glucan, gums, and pectin. Soup is favored and liked by all. Tomato powder, flax seed, sunflower seed, drumstick seed, and dry vegetables along with spices and condiments were used to make this Magic Broth. Magic Broth from Drumstick Seed was well-received during the sensory assessment. Analysis was done on the nutritional value and storage capabilities. According to an organoleptic evaluation, Drumstick seed Magic Broth received the top rating for the panelists' assessments of the sensory qualities. A nutrient-rich product that helps with blood glucose management is magic broth. Its iron, fiber, and protein contents are very high. Magic Broth is the recommended treatment for diabetes mellitus. It is a widely consumed meal that appeals to people of all ages.

Keywords: Food Preservation; Hurdle Technology; Competitive Microorganisms

Introduction

The microbial safety and stability as well as the sensory and nutritional quality of most foods is based on an application of combined preservative factors called hurdles. Hurdles can be intelligently selected and intentionally applied to both traditional and novel foods for better preservation of the product [1]. Every food has some inherent preservation factors, such as the extent of heat treatment received (F), the water activity (aw), low-temperature storage (t), the redox potential (Eh) etc. These factors may be referred to as hurdles because microorganisms must jump these hurdles to develop and spoil the product.

The degree to which obstacles are present in a product determines its stability. The greater the intensity or quantity of these obstacles, the more challenges it will be for microbes to get past them. The severity of one or two obstacles is unusually elevated in the standard preservation approach, making it very challenging for microorganisms to get past that obstacle. Many foods cannot be preserved by a single hurdle alone without affecting their sensory and nutritional properties. Therefore, hurdle technology can be used to keep microbiological hazards and other microorganisms under control, with or without combinations with microbial steps, to obtain and retain end product safety or suitability by combining the selected hurdles.

Hurdle Effect

Microbial growth is dependent upon many conditions in the organism's environment such as ingredients, nutrients, water activity, pH, presence of preservatives, competitive microorganisms, gas atmosphere, redox potential, storage temperature, and time. Therefore, it is possible to restrict, delay, or prevent microbial growth by controlling these circumstances [2]. More than 60 potential barriers for foods of animal or plant origin that increase the microbiological stability and/or sensory quality of these goods have already been examined. Physical, nonthermal processes, such as high hydrostatic pressure, oscillating magnetic fields, pulsed electric fields, light pulses, etc, are currently receiving a lot of attention because, when combined with other conventional barriers, it can be used for the microbial stabilization of food products that resemble fresh foods with little loss of nutritional value and sensory quality.

History of Hurdle Technology

Leistner and colleagues introduced the term "Hurdle effect" in 1976, recognizing that it encapsulates the widely understood notion that the intricate interplay of factors such as temperature, water activity, pH, and redox potential plays a crucial role in determining the microbial stability of food products.

Leistner pioneered the application of barrier technology in 1994, transforming it into hurdle technology. In 1995, he further developed the concept of multi-target preservation of Food. In 1999, he coined the term "Invisible Technology" as a synonymous approach to hurdle technology.

Hurdle technology has been widely used by the food industry to assure the stability and safety of food Leistner L, et al. [3] and others have developed the idea of merging numerous components into the "hurdle effect" in recent years. Management of hurdle technology should align with the principles of HACCP. This requires systematic design and selection of an optimal combination of hurdles.

Several factors have led to the creation of hurdle technology, include:

- Consumer desires for healthier foods that maintain original nutritional qualities
- The shift to ready-to-eat and convenience foods, which require little processing by consumers
- Consumer preference for more "natural" food, which requires less processing and fewer chemical preservatives.

Principles of Hurdle Technology

Food is made safe and stable using traditional preservation techniques such as heating, chilling, freezing, freeze-drying, drying, curing, salting, sugar-adding, acidification, fermentation, smoking, or oxygen removal Leistner. Several processed foods, particularly those that are conventionally prepared, depend on the cumulative impacts of several barriers for their microbiological safety, stability, and sensory qualities [4]. At lower levels, several obstacles were cleverly integrated to create very effective preservation strategies that are very effective [3].

Hurdles apply obstacles (hurdles) to contaminating microorganisms concurrently, including heat, aw, irradiation, chemical, pH, competing flora, etc. [4]. These barriers work together to cause injuries that are worse than those caused by a single barrier. To get over each obstacle, the microbes have to make some specific efforts. When there are more obstacles, microbes must put up more effort to get through them Leistner L, et al. [3]. Choosing the ideal combination of hurdles that will result in injuries and death requires an understanding of the physiology of microbial cells as well as their growth requirements [5]. Food preservation methods are more concerned about the physiology and behavior of microorganisms in foods viz. stress response, homeostasis, and metabolic difficulties [4] Table 1.

Symbol	Parameter	Application
F	High temperature	Heating
T	Low temperature	Chilling, freezing
aw	Reduced water activity	Drying, curing, conserving
pH	Increased acidity	Acid addition or formation
Eh	Reduced redox potential	Removal of oxygen or addition of ascorbate
Pres.	Preservatives	Sorbate, sulfite, nitrite
c.f.	Competitive flora	Microbial fermentation

Table 1: Some of the most important hurdles used.

Need for Hurdle Technology

The rapid expansion of the economy and the rising number of working women, there has been a notable increase in income within the middle class, leading to a prevalent trend of dining out. Consequently, there has been a surge in demand for processed food. Furthermore, modern consumers increasingly seek fresh, natural, and minimally processed ready-to-eat food products. Key hurdles utilised include food preservatives (such as nitrite, sorbate, sulphite) and competitive microorganisms (like lactic acid bacteria) [6] Figure 1.

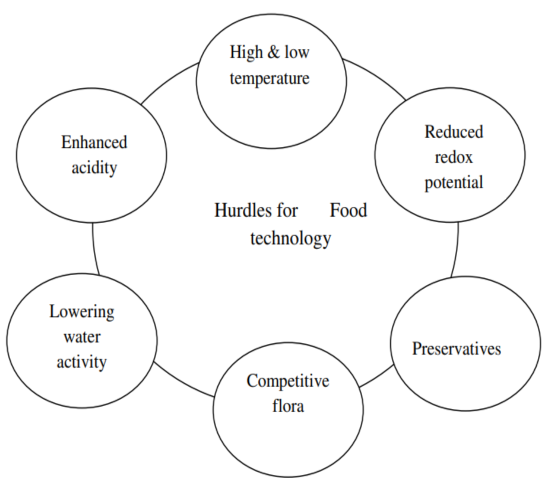

Figure 1: Some common hurdles used for preservation [7].

Significance of Hurdle Technology

- Enhances the quality of food and ensures microbial activity
- Food lasts longer while remaining stable and safe
- Due to hurdle effects, it has a great sensory and nutritional value
- It can be used in both big and small businesses
- Does not alter the consistency or quality of food products
- It satisfies the consumer's current need for meals that are fresh, natural, and barely processed
- It is economically advantageous for the Nation because it conserves resources like money, time, energy, and others [8].

Mechanism of Hurdle Technology

The hurdle technology affects the physiology and growth of microorganisms in food. There are mainly four main mechanisms by which hurdle technology affects the growth of microorganisms in foods, these are, homeostasis, metabolic exhaustion, stress reaction, and multi target preservation.

Homeostasis

Homeostasis, which translates as "same state", refers to the act of maintaining the internal environment of the body in a stable state when the external environment is altered. In the domains of pharmacology and medicine, a lot is already understood about homeostasis in higher animals at the molecular, subcellular, cellular, and systemic levels [9]. It is vital to apply this information to the bacteria responsible for food deterioration and poisoning. The homeostasis of microorganisms is an important phenomenon in food preservation, if it is disrupted by preservatives added to foods, these microorganisms will not multiply, remain in the lag phase, or even perish, before homeostasis is repaired. Therefore, food preservation is accomplished by temporarily or permanently disrupting the microbe's normal state of homeostasis in a food [10]. Obstacle technology affects the physiology and development of bacteria in food. Homeostasis, metabolic exhaustion, stress response, and multi-target preservation are the four main mechanisms that have an impact on the multiplication of bacteria in food.

Metabolic Exhaustion

Metabolic exhaustion, which results in the death of germinated spores and ensures the effectiveness of hurdle technology, can be used to automatically sterilize food products. Numerous varieties of bacteria, mold, and yeast can endure and survive high temperatures [11]. Metabolic exhaustion of bacteria, which could “auto sterilize” food, is another phenomenon of practical significance. This was originally noticed in research using liver sausage that had been gently cooked (95°C core temperature) and then seasoned with salt and fat to accommodate various water activities before being injected with Clostridium sporogenes and kept at 37°C. During storage, it was found that clostridia spores that had survived the heat treatment disappeared from the product. This unusual behavior could have a broad explanation, vegetative bacteria that are unable to grow will die, this happens more quickly when the storage temperature is elevated, antimicrobials are present, and the microorganisms are sub-lethally harmed. To survive the adverse environment, it appears that microorganisms in stable hurdle-technology meals exert all of their available repair mechanisms for their homeostasis. In doing so, they entirely exhaust their energy and eventually die if they reach metabolic exhaustion. This causes these foods to be automatically sterilized. Microbiologically stable are safer to store, especially at room temperature.

In fermented sausages, for instance, salmonellae that survive the ripening process will grow more rapidly if the items are held at room temperature, but they will likely survive longer and could cause a foodborne disease if the products are placed in the refrigerator. It is also generally known that salmonellae grow better in mayonnaise when it is chilled than when it is at room temperature [12].

The most plausible explanation is that these nutrients allow heat-sustained bacterial spores to germinate under less ideal conditions than those necessary for vegetative bacteria to grow. As a result, during product storage, particularly for foods that aren’t refrigerated, the spore counts in foods made with stable hurdle technology drops. The rate of metabolic exhaustion is accelerated when dietary items are subjected to various obstacles. The bacteria eventually need a lot of energy to maintain their homeostasis, which they are unable to do. As a result, it damages microbial cells and prevents further growth [13].

Stress Reactions

Under stressful circumstances, some bacteria become increasingly pathogenic due to the production of shock proteins. Proteins known as stress shock proteins are produced by cells in reaction to stressful situations such as those brought on by heat, pH, aw, ethanol, oxidative chemicals, cold, UV light, and famine. The simultaneous exposure of bacteria to various stresses will thus result in an increased need for energy, and more defensive stress shock proteins will be produced, which ultimately results in the death of the microorganisms [3]. The simultaneous induction of various stresses causes energy utilization and the creation of several stress shock proteins, which weakens the metabolism of the bacteria. Consequently, multitarget food preservation may be an effective strategy for reducing the development of stress shock proteins and in food preservation for the long term [4].

Multitarget Preservation

Leistener, et al. [3] first presented the idea of multitarget food preservation. If obstacles in a food simultaneously hit many targets inside microbial cells and disrupt the equilibrium of the microorganisms present in various ways, a synergistic impact might be attained. Therefore, using many barriers at once to preserve a certain meal should result in optimal microbial stability [3].

Types of Hurdles

Hurdles in food processing can be categorised into various types based on their nature and function. Some common types include:

Physical Hurdles

These are barriers or obstacles intentionally placed in food processing or packaging to inhibit the growth of microorganisms, enzymatic activity, or other undesirable changes. Physical hurdles include factors such as temperature, water activity, and physical barriers like membranes or coatings. This will create an environment that is hostile to pathogens or spoilage organisms, thereby extending the shelf life and ensuring the safety of the food product.

Physico-Chemical Hurdles

This refers to the use of chemical or biochemical factors to control microbial growth or enzymatic activity in food products. Physico-chemical hurdles involve manipulating factors such as pH, oxidation-reduction potential, salt concentration, preservatives, and antimicrobial agents. By adjusting these parameters, food producers can create conditions that inhibit the growth of harmful microorganisms or enzymes while maintaining the quality and safety of the product.

Microbially Derived Hurdles

These are hurdles derived from the natural activities of microorganisms, such as the production of organic acids, bacteriocins, or other antimicrobial compounds. Example, organic acids like lactic acid or acetic acid produced by certain bacteria during fermentation processes, which lower the pH of the food and create an environment unfavourable for pathogenic bacteria. Similarly, some microorganisms produce antimicrobial peptides or proteins (bacteriocins) that can inhibit the growth of competing microbes. By harnessing these microbially derived hurdles, the safety and stability of food products can be improved Table 2.

Type of hurdle	Examples
Physical hurdles	Aseptic packaging, electromagnetic energy (microwave, radio frequency, pulsed magnetic fields, high electric fields), high temperatures (blanching, pasteurization, sterilization, evaporation, extrusion, baking, frying), ionic radiation, low temperature (chilling freezing), modified atmospheres, packaging films (including active packaging, edible coatings), photodynamic inactivation, ultra-high pressures, ultra sonication, ultraviolet radiation
Physico-chemical hurdles	Carbon dioxide, ethanol, lactic acid, lacto peroxidase, 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
Microbially derived hurdles	Antibiotics, bacteriocins, competitive flora, protective cultures

Table 2: Examples of hurdles used to preserve foods.

Application of Hurdle Technology

Various research investigators have embraced hurdle technology concepts for processing a diverse range of food products, spanning dairy products, fresh fruits and vegetables, fruit-derived products, and animal products [14]. This technology finds extensive applications in the production of ready-to-eat foods and the creation of edible coatings. Combining chemical preservatives with other preservation methods proves beneficial as high concentrations of certain preservatives can pose chemical hazards. The appropriate utilization of combined methods ensures the stability of products, mitigates the undesired side effects of individual treatments, conserves energy, and reduces the necessary concentration of added preservatives [15].

Advantages of Hurdle Technology

The biggest benefit of hurdle technology is its propensity to defeat microorganisms that develop resistance to conventional preservation methods. In hurdle technology, various preservatives act synergistically by hitting various targets inside the cell of the spoilage microorganism [16]. When hurdles are used in lower concentrations, side effects can be avoided, production costs are reduced, and energy is conserved. A further benefit is the possibility of combining natural and synthetic preservatives, which lowers the risk of employing synthetic preservatives at high concentrations. The Possibility of improving shelf-stable food since food is preserved using mixed methods (hurdles) is excellent in sensory and nutritional content due to the gentle approach used and remains stable and safe even without refrigeration FAO.

Limitations of Hurdle Technology

- Depending on bacterial stress reactions, such as the creation of protective proteins, obstacles used in food preservation could produce a range of consequences
- Stress reactions may not occur when combining hurdles
- Depending on how intense it is, a hurdle could have a bad impact on food. For instance, chilling foods of plant origin to low temperatures might cause harm (chilling injury), whereas mild chilling will extend their shelf life. Another illustration would be the pH of fermented sausage, which needs to be low enough to suppress pathogenic bacteria without compromising flavor [4].

Challenges and Future Prospects

Changes in sensory characteristics are one of the variables that prevent obstacles from being used in food preservation, especially when chemical hurdles are also present. Unfavorable alterations can happen, and this can result in the food being completely rejected [17].

Even though this technology has been thoroughly studied since the late 1990s, there aren't any systematic studies on the quality and safety of food products. Future research, development, use, and commercialization of these technologies will be challenging. An ultrasound/other obstacle combination is necessary to shorten treatment time while retaining process effectiveness, product safety, and shelf life [18].

Understanding the target microorganisms stress response behavior is another significant difficulty; some of these organisms have defense mechanisms that they acquire when under stress, and they become more resistant when they recover. Although hurdle technology has been used in many food preservation applications, a fuller knowledge of how they work together will result in safer and high-quality goods. When there is a greater understanding of how individual and interaction elements eliminate microbes in foods, new techniques may be developed from core knowledge of hurdle technology [19].

The manufacturing of minimally processed foods will continue to use both conventional antimicrobials and cutting-edge preservation methods [20,22-30]. An infinite number of hurdle combinations specifically tailored for certain needs are anticipated, as research into hurdle and novel preservation approaches progresses [21,31-49] Tables 3 & 4.

Sl. No.	Hurdle combination	Preservation effects
1	Salt and glycerol at 13 and 180 g/kg flour + steaming	Eliminate Clostridium botulinum pores and increase the duration of steamed bread's shelf life from one to seven days [4].
2	Ultrasound (20 kH) + Heating (at 55 to 60 °C)	Destroy Saccharomyces cerevisiae cells [5].
3	Citric acid + gamma radiation + modified atmosphere packaging	Increase the duration of minimally processed French beans' shelf life [29].
4	UV+-heating (45 to 50 °C) + chemical additives (0.1 % sodium benzoate or potassium sorbate)	Acid-adapted *Escherichia coli* O157:H7 inactivation from orange and apple juices [27].
5	Slightly acid electrolyzed water dipping + exposure to ultrasound at 40 °C for 3 minutes	Prevents the growth of *Bacillus cereus* in potato [34].
6	Dipped into ascorbic acid/calcium chloride + pulse light treatments	Prevent fresh sliced apples from browning and softening [37].
7	Calcium oxide + Fumaric acid + slightly acidic electrolyzed water	Preserve the freshness of leafy greens to enhance their quality [38].
8	7-min UV-C treatment+ natural antimicrobial (vanillin and cinnamaldehyde) + storage at 5°C	After 30 days of storage, *Salmonella typhimurium* was not found in coconut water [23].
9	Sodium benzoate + potassium sorbate + blanching	Increase the tamarillo fruit sweet product's microbiological stability [41].
10	Bacteriocins-+ modified atmosphere storage	Increase the shelf life of fruits and vegetables [26].
11	Heating (70 °C for 10 min) + addition of 200 ppm potassium metabisulphite	Increase the duration of the white radish and sugarcane juice blend's shelf life by three months when kept in refrigerator.
12	Vacuum packaging (using nylon) + 10 % NaCl	Reduce the amount of moisture, water activity, aflatoxin, total viable count, and mold in Thai curry paste [40].
13	High-pressure processing + UV radiation	Helps in microbial inactivation with selective preservation of probiotic bacteria in fruit juices [42].
14	Sodium acetate at mildly acidic pH creates a hurdle effect	Control the growth of *Vibrio cholera* in plant extracts [47].
15	Low pH + mild heat treatment + cold storage	Controlled mesophiles, psychrotrophs, molds, and yeasts counts for the preservation of jabuticaba nectar.
16	Natural additives like lactic acid, sumac, fresh onion, oil, and salt + vacuum packaging + refrigeration	Increase the shelf life of fresh Za'atar (*Origanum syriacum*) [45].

Table 3: Application of hurdles in preservation of plant foods.

Sl. No.	Hurdle combination	Preservation effects
1	Isolated soy protein + lactic acid	Reduce both aerobic and anaerobic organism growth rates, and eradicate *Staphylococcus aureus* in standardized keema [32].
2	Osmotic dehydration using salt + polyethylene packaging + 10 kGy gamma-irradiation dose	Utilised to create a secure, shelf-stable casing for sausage production [24].
3	Microfiltration + pulse electric field (42 kV/cm for 612 µs) + heat (49 ºC)	Reduce the bacteria population by 7.1 log circles to guarantee "Cold" pasteurization in skimmed milk [48].
4	Textured soy protein + lactic acid	Increase the chicken sausage's shelf life to six days [44].
5	LAB bacteriocins + chitosan coating + super chilling	Enhance fish and other seafood stability and safety [49].
6	0.5 % marjoram essential oil + 2 % sodium tripolyphosphate	Minimise the growth of microorganisms, lipid oxidation, protein degradation, and sensory alterations in tilapia fillets kept at 4±1 °C under refrigeration [36].
7	1 % lemongrass oil + exposure to 200 uW UV per cm2 for 2 minutes	Reduce the *Escherichia coli* K-12 population below the level that can be detected in meat [25].
8	High-pressure processing (535-580 MPa) and 0.3 % InbacTM (organic acids and nisin formula).	Attempted to substitute salt with Artisalt™ in cooked harm and frankfurters by replacing the antibacterial qualities of sodium chloride [39].
9	Heating (50 °C) + pulse electric field (30 KV at 50 °C for 6 min),	Increase the milk's shelf life by 22 days [30].
10	Heating (50 °C) + pulse electric field (30 KV at 50 °C for 6 min)	Eliminate any *Escherichia coli* found in raw milk [31].
11	Chilling + modified atmosphere packaging + natural preservatives	Extended the shelf life of European eel fillets [28].

Table 4: Application of hurdles in preservation of animal foods.

Conclusion

Hurdle technology is a crucial strategy for enhancing quality standards during food processing and storage. Obstacles should be used wisely to enhance food's chemical, microbiological, and sensory properties. There are more than 60 barriers reported that can be used in a variety of foods in various combinations and concentrations. Due to its versatility, the technique can be applied to both contemporary and local food processing. When applied effectively, hurdle technology serves as a valuable tool for producing safe and delicious high-quality food products. This approach is not only relevant to modern preservation methods but has also been employed in traditional food production since ancient times. Whether applied in modern food processing or traditional methods, hurdle technology plays a crucial role in safeguarding food security, combating malnutrition, and addressing global hunger challenges. As we continue to innovate and refine this approach, it promises to remain a cornerstone of food preservation, contributing to the availability of safe and nutritious food for all.

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