IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 10, Issue 5 Ver. I (May. 2016), PP 09-13
www.iosrjournals.org

Hurdle Technology in Food Preservation

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Abstract: *Hurdle technology is used in industrialized as well as in developing countries for the gentle but effective preservation of foods. Previously hurdle technology, i.e., a combination of preservation methods, was used empirically without much knowledge of the governing principles. Since about 20 years the intelligent application of hurdle technology became more prevalent, because the principles of major preservative factors for foods (e.g., temperature, pH, a_w, Eh, competitive flora), wand their interactions, became better known. Recently, the influence of food preservation methods on the physiology and behavior of microorganisms in foods, i.e. their homeostasis, metabolic exhaustion, stress reactions, are taken into account, and the novel concept of multitarget food preservation emerged. In the present contribution a brief introduction is given on the potential hurdles for foods, the hurdle effect, and the hurdle technology. However, emphasis is placed on the homeostasis, metabolic exhaustion, and stress reactions of microorganisms related to hurdle technology, and the prospects of the future goal of a multi target preservation of foods.*

I. Introduction

Hurdle technology is a method of ensuring that pathogens in food products can be eliminated or controlled. This means the food products will be safe for consumption, and their shelf life will be extended. Hurdle technology usually works by combining more than one approach. These approaches can be thought of as "hurdles" the pathogen has to overcome if it is to remain active in the food. The right combination of hurdles can ensure all pathogens are eliminated or rendered harmless in the final product. Hurdle technology has been defined by Leistner (2000) as an intelligent combination of hurdles which secures the microbial safety and stability as well as the organoleptic and nutritional quality and the economic viability of food products.[2] The organoleptic quality of the food refers to its sensory properties, which are its look, taste, smell and texture. Examples of hurdles in a food system are high temperature during processing, low temperature during storage, increasing the acidity, lowering the water activity or redox potential, or the presence of preservatives. According to the type of pathogens and how risky they are, the intensity of the hurdles can be adjusted individually to meet consumer preferences in an economical way, without compromising the safety of the product.

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Hurdles

Each hurdle aims to eliminate, inactivate or at least inhibit unwanted microorganisms. Common salt or organic acids can be used as hurdles to control microbial in food. Many natural antimicrobials such as nisin,natamycin and other bacteriocins, and essential oils derived from rosemary or thyme, also work well.

Principal hurdles used for food preservation (after Leistner, 1995)

Parameter	Symbol	Application
High temperature	F	Heating
Low temperature	T	Chilling, freezing
Reduced water activity	a_w	Drying, curing, conserving
Increased acidity	pH	Acid addition or formation

Reduced redox potential	E_h	Removal of oxygen or addition of ascorbate
Biopreservatives		Competitive flora such as microbial fermentation
Other preservatives		Sorbates, sulfites, nitrites

"Traditionally, fermented seafood products common in Japan, provide a typical example of hurdle technology. Fermentation of sushi employs hurdles that favour growth of desirable bacteria but inhibit the growth of pathogens. The important hurdles in the early stages of fermentation are salt and vinegar. Raw fish is cured in salt (20–30%, w/w) for one month before being desalted and pickled in vinegar. The main target of these hurdles is C.botulinum. Growth of lactic acid bacteria during fermentation results in acid production from metabolism of added sugars and rice. The result is a pH hurdle important in controlling growth of *C. botulinum*." (Lee S ,2004)

Types of hurdles used for food preservation (from Ohlsson and Bengtsson, 2002)

Type of hurdle	Examples	
Physical	Aseptic packaging, electromagnetic energy (microwave, radio frequency, pulsed magnetic fields, high electric fields), high temperatures (blanching, pasteurization, sterilization, evaporation, extrusion,baking, frying), ionizing radiation, low temperature (chilling, freezing), modified atmospheres, packaging films (including active packaging, edible coatings), photodynamic inactivation, ultra high pressures, ultrasonication, ultraviolet radiation	
Physicochemical	Carbon dioxide, ethanol, 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	

Synergistic effects

There can be significant synergistic effects between hurdles. For example, Gram-positive bacteria include some of the more important spoilage bacteria, such as Clostridium, Bacillus and Listeria. A synergistic enhancement occurs if nisin is used against these bacteria in combination with antioxidants, organic acids or other antimicrobials. Combining antimicrobial hurdles in an intelligent way means other hurdles can be reduced, yet the resulting food can have superior sensory qualities. (Malik et al.,2014)

II. Other Applications

The hurdle effect and the hurdle technology are now applied widely in industrialized countries, especially for the development of stable and safe food products (food design), not only for meats, but also for a variety of foods, for instance, in mild technologies for fruit processing or in the shelf-life extension of fish In less developed countries too, the significance of hurdle technology for efficient food preservation has been recognized, e.g. in South Africa Iberoamerica and in the People's Republic of China. In Iberoamerica, traditional foods storable without refrigeration were studied in 11 countries, and 246 foods based on fruits, vegetables, milk, fish, cereals and meat were approved as stable. Most of these foods were IMF; however, the stability and safety of many products were due to empirically applied hurdle technology undoubtedly, hurdle technology is applicable not only for the preservation of meat, but also for other foods of animal and plant origin. At present, in the production of many foods, hurdle technology is empirically used without knowledge of the principles involved. However, it is foreseeable that in the future hurdles will be intelligently applied in food design. This has been illustrated by the successful stabilization of Paneer and Lup Cheong, two foods of developing countries. Paneer is a cottage cheese type product mixed with tomato sauce, onions and spices, which is frequently consumed in the northern part of India, because of its nutritive value and characteristic taste. However, Paneer spoils within 2 days under the environmental conditions of India (temperatures up to 35"(Z) and this is a severe drawback. In our laboratories we developed mildly heated Paneer in cans, with the desirable sensory characteristics, which is storable for several weeks without refrigeration. Lup Cheong is a raw but not fermented sausage of China, storable for several weeks without refrigeration. However, the Taiwanese variety of Lup Cheong, because of its desired soft texture (a, around 0.94), acquires a sour taste as a result of spoilage by lactic acid bacteria, and may be poisoned because of the growth of ***Staphylococcus aweus*** . In cooperation with a visiting scientist from Taiwan we stabilized Taiwanese Lup Cheong by the addition of 3.5% sodium lactate and 0.1% sodium acetate. The modified product remains tasty and is stable and safe even when stored for several weeks without refrigeration (Paula Luisina Gómez et al, 2011)

Hurdle Technology for Army Provisions

In less developed countries, foods storable without refrigeration are in demand, because energy is expensive, and electricity is not continuously available. However, for industrialized countries foods stable and safe without chilling have advantages too, because temperature abuse might occur during storage (especially in the home), and under some circumstances refrigeration is absent. The latter is true during military exercises. Therefore, our laboratories received a grant from the medical corps of the German Army for the selection of meat products storable for at least 6 days at 30°C. However, these meats should not be of the conventional army type, because soldiers prefer fresh foods rather than canned rations. As the execution of this army project is a good example of the possible accomplishments of hurdle technology, it will be described here in more detail. During the initial phase of the project a survey of potentially suitable meat products already on the market was carried out. We asked German meat processors to name for us their meat products which taste like those bought in delicatessen shops, but need no refrigeration, Twenty-four manufacturers named 100 of their products with 'fresh product characteristics,' which they considered stable. However, after incubation we could confirm the stability of only 75 products. From the results obtained, eight categories of products were distinguishable (Table I), because they had a stability and safety based on different principles of hurdle technology. We then manufactured the promising products under pilot plant conditions, challenged them with spoilage and food-poisoning bacteria, and investigated their stability, safety and quality during and after storage. If necessary, the recipes and technologies were modified and optimized. Finally, we produced the approved products in a medium sized meat factory, because they should perform well under practical conditions too. As large and small enterprises must be able to manufacture these rations, the processes had to be described for each product in detail, and therefore 15-20 critical control points for the process of each product group were defined. In this way, for the first time a linkage between hurdle technology (used for food design) and the hazard analysis critical control points (HACCP) concept (employed for process control) was achieved. If the recommended meat products are manufactured according to the outlined HACCP concepts, they are stable, safe and of high sensory quality, and thus could be used as attractive rations for soldiers during military exercises. In the processing of the meats recommended in this study, no microbiological tests are necessary; however, other parameters have to be strictly controlled: time, temperature, pH and aw. By following the suggested HACCP concepts, these controls should be done on-line. Hitherto, to measure the water activity of meats reliably within a few minutes was a problem. Now a new instrument is available which is based on freezing point detestation and allows exacta, measurement of meats within lo-20 min. This instrument was developed in our laboratories by it is manufactured by NAGY, D-70794 Filderstadt, Germany, and has been named a,-Cryometer (Fig. 1). Besides aw, also the temperature, pH and redox potential of foods, could also be measured with this instrument, by employing appropriate sensors, and this should be helpful in the monitoring of foods.

III. Additional Hurdles

Several related concepts for quality assurance of foods are currently under investigation within several FLAIR projects of the European Community: hurdle technology (used for food design),

the HACCP concept (used for process control), and predictive microbiology (used for process refinement). By considering these different approaches, an overall strategy for securing tasty, stable and safe foods should now be accomplished. The linkage between hurdle technology and HACCP has been achieved recently, as mentioned above. Predictive microbiology is a promising concept for computer-based and quantitative safety evaluation of foods, and is already advanced for predicting the growth, death and survival of pathogenic and spoilage bacteria in certain food products. Predictive modelling for the food industry, concerning the most common food-poisoning bacteria in a variety of foods, has been available in the UK since October 1992 under the designation Food Micromodel. However, the models available for predictive microbiology can manage only relatively few parameters (hurdles), i.e. temperature, pH, *a*,, aerobic or anaerobic conditions, and some preservatives (e.g. nitrite, lactic acid or carbon dioxide). These are important hurdles, and thus the available models give a good estimate of the behavior of food poisoning bacteria in foods. However, there are numerous additional hurdles

(Table 2), which are important for the stability and safety of foods. Thus, predictive microbiology cannot be considered to be a quantitative approach to hurdle technology, but only allows reliable predictions of the behaviour of microorganisms in relatively simple food systems, comprising not more than four factors (hurdles). Because several hurdles are not taken into account, the predicted results are fortunately often on the safe side, i.e. the limits indicated for growth of pathogens in foods by the models available are often more prudent ('failsafe') than the limits in the real food. Hurdle technology is applicable not only to safety, but also to quality aspects of foods, although this area of knowledge has been much less explored than the safety aspect. Some hurdles (e.g. Maillard reaction products) influence the safety as well as the quality of foods and this applies to many other hurdles. The possible quality\ hurdles in foods might influence the sensory, nutritive, technological and economic properties of a product, and the hurdles present might be negative as well as positive for securing the desired total quality of a food. Moreover, the same hurdle could have a positive or a negative effect on food quality, depending on its intensity. For instance, chilling too quickly to a low temperature may cause chill injury in fruits, which could be avoided by cold acclimation. To secure the desired total quality of a food, the safety and quality hurdles should be kept within the optimal range. (Panjagari et al., 2007)

IV. Basic Aspects

Even for Advents aspects of food preservation, such as the biological membrane deterioration and associated quality losses during the storage of food tissues, hurdle technology could provide a comprehensible illustration. suggested that the oxidation of plant and animal membrane lipids is influenced by a number of positive and negative extrinsic and intrinsic factors. Positive hurdles, which keep the membrane lipids in apparently unchanged physiological condition and thus prolong the shelf-life of foods, are: relatively low temperature, appropriate relative hurdles, absence of light and slight anoxia. Stanley concluded that the hurdle technology approach would seem to be applicable to a wider concept of food preservation than just microbial stability, but that, in order for it to work, a precise knowledge of the effectiveness of each hurdle for a given commodity is required. Hurdles that can be utilized to preserve plant tissue and thus food quality include antioxidants, controlled-atmosphere storage, low temperature, reduced ethylene levels, and effective packaging. Another fundamental aspect of food preservation by hurdle technology is the synergistic effect of combined processes. In practical terms, this could mean, for instance, that it is more effective to use different preservatives in small amounts in a food than only one preservative in larger amounts, because different preservatives might have different targets in the bacterial cells (e.g. disturbance of cell membrane, DNA, enzyme systems, pH or a,) and thus act synergistically.

V. Integer Foods

Finally, another challenging aspect of hurdle technology should be mentioned - the use of coatings for integer food pieces.. An example of a traditional food for which an edible surface coating is used to inhibit mould growth on the surface and to inactivate salmonellae inside of food is Pastirma, a raw beef product common in Moslem countries. The applied surface paste (3-5 mm thick) contains a binder, several spices and 35% fresh garlic. On the other hand, Torres (1987) studied the surface microbial stability of model foods by using coatings which maintain preservatives and the desired low pH, and he demonstrated that a low pH in the surface layer greatly improved the effectiveness of sorbic acid in this coating. Guilbert (1988) used superficial edible layers for the protection of easily perishable tropical fruits, and considered this as an application of hurdle technology without affecting the integrity of food pieces. Moreover, the so-called osmotic dehydration, a dewatering and impregnation process which consists of soaking foods {fruits, vegetables, meat, cheese and fish) in highly concentrated solutions of sucrose, sodium chloride or other humectants, could generally be employed for solute transfer from a solution into the product (Lerici et aZ., 1988). It is thus possible to insert not only water activity lowering agents, but also preservatives and nutrients, as well as substances which control the pH, texture and flavour of a food, and thus build up positive hurdles which improve the stability as well as the quality of food products (Raoult Wack et al., 1992). Here again, another mode of application of hurdle technology to foods with promising perspectives has been introduced.

The preservatives were spices, plant resins and other aromatic plant substances. Thus, hurdle technology is by no means a novel process, but still one which has a great potential for further research and application.

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