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Use of Hurdle Technology in Enhancing Shelf Life of Traditional Dairy Product

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Introduction

For time immemorial, food preservation has been necessary to supply food between harvest peaks and in times of need. Several preservation methods, such as heating, chilling, freezing, drying, salting, sugar addition, acidification, fermentation, removal of oxygen, and addition of preservatives have emerged over the centuries from empirical observations. However, only in the last century have the principles behind these traditional food preservation methods been elucidated. Moreover, a quantitative approach has been introduced that expresses heating in F values, chilling in t values, drying in aw values, acidity in pH values, removal of oxygen in Eh values, etc. The traditional food preservation methods, and therefore the underlying preservative factors, are often applied in combination. Microbial stability and safety, as well as the sensory and nutritional quality of most preserved foods, are based on a combination of several empirically applied preservative factors (hurdles), and more recently on knowingly employed hurdle technology.

Deliberate and intelligent application of hurdle technology allows a gentle, efficient preservation of foods, which is advancing worldwide. Various expressions for the same concept in different languages are now used: Hürden-Technologie in German, hurdle technology in English, technologie des barrières in French, barjernaja technologija in Russian, technologia degli ostacoli in Italian, technologia de obstaculos in Spanish, shogai gijutsu in Japanese, and zanglangishu in Chinese. Therefore, hurdle technology is a contribution to global sustainable development. Knowledge of the basic aspects related to hurdle technology (i.e., homeostasis, metabolic exhaustion, and stress reactions of micro-organisms) has also advanced in recent years. This has paved the way for the application of multitarget preservation of foods, which is the ambitious goal of the future in food preservation. In this contribution, the principles of hurdle technology, basic aspects, and advanced applications of hurdle technology in industrialized and developing countries are discussed, including food design based on hurdle

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technology. The conclusions section will summarize the state-of-the-art and will point out the perspectives of food preservation by hurdle technology.

Principles of Hurdle Technology

The most important hurdles commonly used in food preservation are temperature (high or low), water activity (aw) (see Colligative Properties), acidity (pH), redox potential (Eh), preservatives (nitrite, sorbate, sulfite, etc.), and competitive micro-organisms (e.g., lactic acid bacteria). More than 60 potential hurdles for foods of animal or plant origin, which improve the microbial stability and/or the sensory quality of these products, have been already described, and the list of possible hurdles for food preservation is by no means complete. At present, physical, non-thermal processes (high hydrostatic pressure, oscillating magnetic fields, pulsed electric fields, light pulses, etc.) receive considerable attention (see Nonthermal Processing), since in combination with other conventional hurdles they are of potential use for the microbial stabilization of fresh-like food products, with little degeneration of nutritional and sensory properties. Another group of hurdles, of special interest in industrialized and developing countries at present, would be 'natural preservatives' (spices and their extracts, lysozyme, chitosan, pectine hydrolysate, etc.). In most countries, these 'green preservatives' are preferred because they are not synthetic chemicals, but in some developing countries, they are given preference, since spices are readily available and cheaper than imported chemicals. The critical values of many preservative factors for the death, survival, or growth of micro-organisms in foods have been determined in recent decades and are now the basis of food preservation. However, the critical value of a particular parameter changes if additional preservative factors are present in the food. For instance, it is well known that the heat resistance of bacteria increases at low aw and decreases at low pH or in the presence of preservatives, whereas low Eh increases the inhibition of micro-organisms due to reduced aw. The simultaneous effect of different preservative factors (hurdles) could be additive or even synergistic. In food preservation, the combined effect of preservative factors must be taken into account, which is illustrated by the hurdle effect.

Principal hurdles used for food preservation

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
Bio preservatives		Competitive flora such as microbial fermentation
Other preservatives		Sorbates, sulfites, nitrites

Types of hurdles used for food preservation

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
Physico-chemical	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

Hurdle Effect

For every microbiologically stable and safe food, a certain set of hurdles is inherent, which differs in quality and intensity, depending on the particular product. In any case, the hurdles must keep the 'normal' population of micro-organisms in the food under control. The micro-organisms present ('at the start') in a food should not be able to overcome (i.e., 'leap over') the hurdles inherent in this food. This is illustrated by the so-called hurdle effect, which is of fundamental importance for the preservation of foods, since the hurdles in a stable product control microbial spoilage and food poisoning as well as desired fermentation processes.

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Some examples will facilitate the understanding of the hurdle effect, presented in Figure 1. Example 1 represents a food containing six hurdles: high temperature during processing (F value), low temperature during storage (t value), water activity (aw), acidity (pH), redox potential (Eh), and preservatives (pres.). The micro-organisms present cannot overcome these hurdles, and thus the food is microbiologically stable and safe. However, example 1 is only a theoretical case, because all of the hurdles are of the same height (i.e., intensity), and this rarely occurs. A more likely situation is presented in example 2, since the microbial stability of this product is based on hurdles of different intensity. In this particular product, the main hurdles are aw and preservatives, whereas other less important hurdles are storage temperature, pH, and redox potential. These five hurdles are sufficient to inhibit the usual types and numbers of micro-organisms associated with such a product. If only a few micro-organisms are present ('at the start'), a few or low number of hurdles will be sufficient for the stability of the product (example 3).

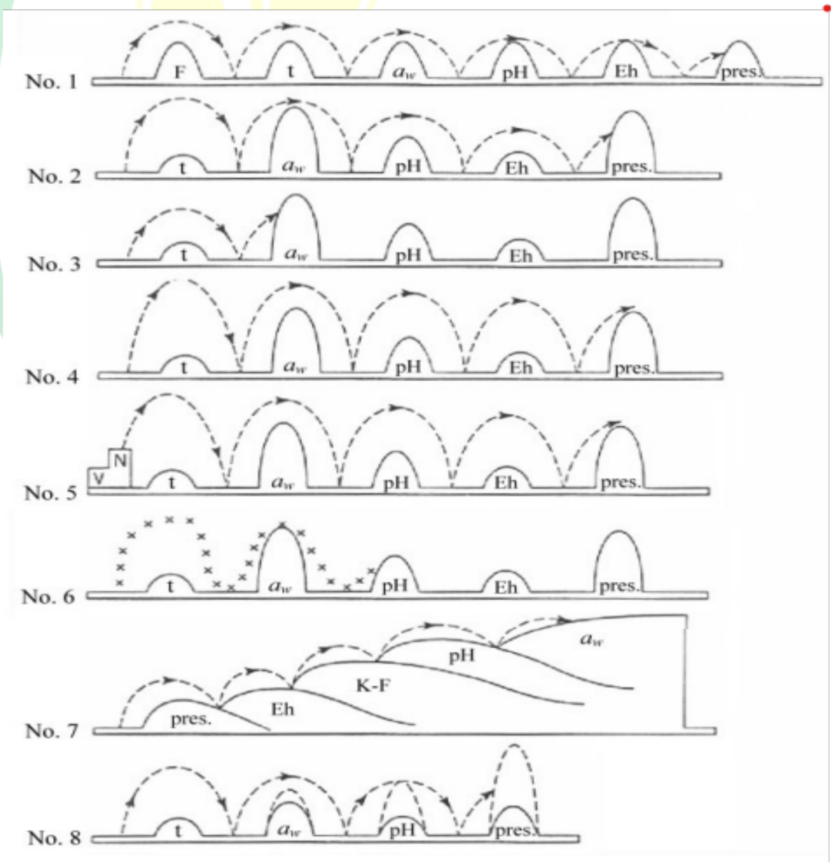

Figure 1. Eight examples of the hurdle effect that facilitate understanding of the application of hurdle technology in food preservation. See text for details. Symbols have the

following meaning: F, heating; t, chilling; aw, water activity; pH, acidification; Eh, redox potential; pres., preservatives; K-F, competitive flora; V, vitamins; N, nutrients. [Source: Leistner L. (1992). The super clean or aseptic packaging of perishable foods is based on this principle. On the other hand, as in example 4, if due to bad hygienic conditions, too many undesirable micro-organisms are initially present, even the usual hurdles inherent to a product may be unable to prevent spoilage or food poisoning. Example 5 is a food rich in nutrients and vitamins, which could foster the growth of micro-organisms (called the booster or trampoline effect), and thus the hurdles in such a product must be enhanced, or otherwise be overcome. Food preservation by combined methods. Food Research International 25, 151-158.] Example 6 illustrates the behaviour of sub-lethally damaged organisms in food. For instance, if the bacterial spores in a food are damaged sub-lethally by heat, the vegetative cells derived from such spores will lack vitality; therefore, they will be inhibited by fewer or lower hurdles. In some foods, stability is achieved during processing by a sequence of hurdles, which are important in different stages of a fermentation or ripening process and lead to a stable final product.

A sequence of hurdles operates in fermented sausages (example 7), and probably in ripened cheeses or fermented vegetables. Finally, example 8 illustrates the possible synergistic effect of hurdles, which likely relates to a multitarget disturbance of the homeostasis of micro-organisms in foods.

Use of hurdle technology in enhancing shelf life of traditional dairy product

Paneer is a highly perishable product. It was reported that the freshness of paneer remains intact only for 3 days at refrigeration temperature (Bhattacharya et al., 1971) at room temperature paneer does not keep good for more than one day. In order to increase the shelf life of paneer, additives, modification in paneer manufacturing process, surface treatments and packaging materials have been recommended by various workers. Several hurdle techniques have been used by researchers for increasing shelf life of paneer. One of the hurdle technologies involved mild heat treatment, minor reduction in water activity (0.95) and acidification (pH 5.0) to extend their shelf life of paneer to 14 days at 30°C. Use of 1% each of sodium chloride, sucrose and glycerol to decrease the water activity of paneer led to shelf-life extension of paneer (Rao and Patil, 1992). In another study, the shelf life of paneer curry was extended using hurdle technology. The product was formulated to have a water activity of 0.95, pH of 5.0 and potassium sorbate content of 0.1%. The product kept well for about 1 month and had a better quality than the heat-sterilized product stored under similar conditions (30°C) (Rao and Patil, 1999). Dipping of paneer in 5% brine, acidified brine (5% NaCl, pH 5.5) and hydrogen peroxide solution (0.2%, v/v) with or without delvocid (0.5%, w/v) extended the shelf life of paneer cubes of small size (1.0 × 0.25 × 0.5 inches) to 22, 20, 32 and 22 days respectively compared to 10 days for control at 8–10°C. It was observed that smaller paneer size helped in better diffusion of the solution and thus longer shelf life (Sachdeva and Singh, 1990).

Brown peda, a traditional Indian heat desiccated milk (khoa)-based confection characterized by caramelized colour and highly cooked flavour, is expected to have good shelf life in comparison with other khoa-based sweets due to low moisture content, higher amount of sugar and severe heat treatment applied during its preparation. However, brown peda is also very much susceptible to microbial spoilage due to unhygienic conditions adopted during its manufacture and handling and its poor packaging. Hence, with a view to improve the shelf life of brown peda by packaging interventions. Panjagari studied the effect of conventional cardboard boxes, modified atmosphere and vacuum packaging techniques on the sensory, physico-chemical, textural, biochemical and microbiological quality of brown peda during storage for 40 days at 30°C. They reported that the rate of loss of most quality attributes was rapid in control and modified atmosphere packaged samples compared to vacuum packaged samples. Based on the results obtained the authors concluded that brown peda could be best preserved up to 40 days at room temperature (30±1°C) without appreciable quality loss (Panjagari et al., 2007). Gasasase (poppy seeds) payasum is product prepared from poppy seeds and rice and by application of retort processing (f0 value 6 at steam pressure of 1.04 bar) to this product, there was a marginal change in its pH, acidity and HMF content and viscosity take place during storage which led to extension of its shelf-life to 6 weeks at 37°C temperature (Geetha, 2005). Curd rice is another traditional dairy product popular in South India. Normally shelf-life of curd rice is 24 h at 30°C, but attempts were made to increase self-life of curd rice by incorporating fresh ginger along with other spices (for seasoning) in milk and boiled for 2-3 min and it is then used for curd preparation of rice as per standard method and it was found that ginger added curd rice has shelf-life of 7 days at 37°C storage and 12 days at refrigerated storage (4 to 6°C). The acidity and water activity of fresh curd rice were 0.54 % and 0.994 respectively. The culture pH and natural preservative like ginger has been identified as probable hurdle for improved shelf-life of curd rice (Balasubramanyam et al., 2004). Dudhchurpi, a product of Himalaya region (Bhutan, Sikkim and Dargeeling) made from milk of yak or cow and is self-stable for several months without refrigeration. Most important for dudhchurpi is its texture (elasticity), since people living at high altitude chew it as 'energy tablets'. Sensory analysis and microbial stability of dudhchurpi was optimized by Hossain using combined several hurdles like heating, acid coagulation, addition of sugar and sorbate, smoking, drying and packaging in a closed container (Hossain, 1994).

Conclusion

Today public concern is toward minimal damage to food product with maximum protection of food to microorganism. So, any one preservation technique led to damage to nutritional value or sensory damage. So, hurdle technology is the best way by which we can improve both of these characteristics. In dairy industry we can use this technique and improve quality as well as it is possible to make some value-added product by this technique.