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Preservation of Seafoods by Hurdle Technology

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Abstract

Fish and seafoods are a highly perishable product due to the biochemical composition and the high microbial load on the skin and gills of fish. The natural microflora that is more adapted to low temperatures results in lower thermal bacterial shock at the storage temperature. The development of new fish processing techniques is required because the demand for fish or seafood with minimum changes in sensory Biochemical and nutritional quality. This has led to the advent of hurdle technology in the field of seafood technology. Hurdle technology is the combined use of several preservation methods to make a product shelf-stable, to improve quality and to provide additional safety. This technology is used in many countries of the world, including India. The factors used for food preservation is called as hurdles. A combination of hurdle such as high temperature, refrigeration, irradiation, drying and smoking etc. are applied to eliminate the growth of microorganism. The application of several hurdle may reduce the rate of fish spoilage caused by spoilage microbe. The objective of this book chapters is focus on the preservative effect of hurdles technology on the quality and shelf-life fish and fishery products with recent, combined updated information.

Keywords: hurdle technology, seafood, quality, spoilage and microorganism

1. Introduction

Since the time immemorial, human society has been dependent on foods for their existence. We derive a variety of foods from plants and animals such as sea-foods, eggs, fishes etc. All these are consumed by man to satisfy their nutritional requirements, proper body growth and development, health and to increase their appetite value. But the food items of animal origin are perishable in nature as a result they get spoiled due to microbial activity. Hence to reduce this toxicity of food 'hurdle technology' was developed several years ago for the production of safe, stable, nutritious, tasty and economical foods. The hurdle technology, also called combined methods or combined processes, is an integrated approach of basic food preservation methods for making the food more safe, stable and nutritious [1]. It can also be defined as a method of achieving control or elimination of pathogens present in the foods for creating safe and shelf - stable food. The concept of hurdle technology is quite old but has been used by many countries across the globe including India for effective preservation of foods. It advocates the wise use of a combination of different preservation factors or techniques termed as hurdles in order to achieve multi-target,

mild but reliable preservation effects in foods. Hurdle technology developed with the concept to address the consumer demand to provide more natural and fresh food. According to Leistner [2] hurdle technology is the process of an intelligent combination of hurdles which safeguards the microbial safety and storage stability along with retains the sensory, nutritional quality and economic viability of food materials. It has come in response to several number of developments viz.,

- i. To fulfill consumers' demand for improved foods that retain their unique nutritional properties with freshness.
- ii. This technology shift food products ready-to-eat and makes it convenience foods with lesser processing requirements by consumers.
- iii. Basically, consumers prefer more 'natural food products' which requires less processing effort with use of minimum chemical preservatives.

It offers a framework for merging a number of milder preservation techniques to attain an improved level of product safety with longer stability (dimorianreview.com).

The hurdles technology can be applied in several fish and fishery products such as the salted fish, smoked, marinated products, pickles, canned fish products (high or low temperature), traditional Asian sauces (fermentative microorganisms) and more recently, in vacuum-packed products (redox potential). These preservative factors have been studied for several years ago. Hurdles technology have some pro (by inhibiting microorganisms) along with some cons (on other parameters such as nutritional properties or sensory quality), depending on their intensity. For example, salt content in food must be in such a limit to inhibit pathogens and spoilage microorganisms, but not too high to impair taste and act as pro-oxidants [3].

2. Significance of hurdle technology

1. Improves foodstuffs quality and ensures microbial activity.
2. Food remains safe and stable for a longer duration of time.
3. It is high in sensory and nutritive value due to hurdle effects.
4. It is applicable in both small- and large-scale industries.
5. Does not change the composition or integrity of food items.
6. It fulfills the current demands of the consumers for fresh, natural and minimally processed foodstuffs.
7. It is economically suitable for the nation as it saves money, time, energy and other resources.

3. History of hurdle technology

Food preservation techniques are an inseparable part of production of foodstuffs in order to overcome or counter the pathogen activities. Thus, the food

scientist applied combined use of several preservation methods including physical or chemical which is an age-old practice. This is generally used by the food industry to ensure food safety and stability. Seafood in terms of fresh fish which is a highly perishable product due to its chemical composition and high accumulation of microorganisms on its body surface. In 1976, Leistner introduced the term “Hurdle effect”. Leistner and co-workers acknowledged that the hurdle concept illustrates the well - known fact that the complex interactions of temperature, water activity, pH, redox potential, etc. are significant for the microbial stability of foods [4].

4. Principle of hurdle technology

Hurdle is defined as a factor, a condition, or a processing step that limits, or prevents the microbial growth and reduce microbial load. There are many preservation methods used for making foods stable and safe e.g., heating, chilling, freezing, freeze drying, drying, curing, salting, sugar addition, acidification, fermentation, smoking and oxygen removal. Currently, more than 50 hurdles are used in food processing industries throughout the world. Some of the principle hurdles used for seafood products are given in **Table 1**. The hurdle effect is the most fundamental importance for the preservation of foods, since the hurdles in a stable product, control the microbial spoilage, food poisoning and desired fermentation processes [5]. If the intensity of a particular hurdle in a food is too small, it should be strengthened, and in case, it is detrimental to the food quality.

4.1 The principle behind this hurdle technology can be summarized in the following ways

1. The preservative factors or hurdles disturbs the homeostatis of microorganisms.
2. Pathogens should not be allowed to cross or jump over all the hurdle effects present in the food items.
3. Preservative factors should not allow the microorganisms to proliferate and remain in an inactive stage or even kill them.
4. The hurdle effect shows that the complexity of interactions of temperature, water, pH, humidity are important factors to microbial stability.

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	Eh	Removal of oxygen or addition of ascorbate
Bio preservatives	—	Competitive flora such as microbial fermentation
Other preservatives	—	Sorbates, sulphites, nitrites

Table 1.
Principle hurdles used for food preservation.

5. Basic aspects of hurdle technology

The hurdle technology affects the physiology and growth of microorganisms in food. There are mainly 4 major mechanisms by which hurdle technology affects the growth of microorganisms in foods, these are -*Homeostasis*, *Metabolic exhaustion*, *stress reaction* and *Multi target preservation* (**Figure 1**).

5.1 Homeostasis

The literal meaning of “homeostasis” is “same state” and it refers to the process of keeping the internal body environment in a steady state, when the external environment is changed. In case of food preservation techniques, if somehow the homeostasis of the pathogens are disturbed, then they will not be able to proliferate themselves. They will remain in the lag phase or even die until their internal body temperature is maintained or recovered [7]. But microorganisms can acquire myriad routes to reach their homeostatic state. Thus, the most effective way to prevent their growth on food items is to go through combined methods of hurdle effect. Disturbing the homeostasis of the microorganisms by various hurdles eventually results in the death of the spoilage causing microbes thereby protecting the food product from microbial spoilage.

5.2 Metabolic exhaustion

Auto-sterilization of food products can be achieved by metabolic exhaustion, which leads to the death of the germinated spores and thus ensuring the success

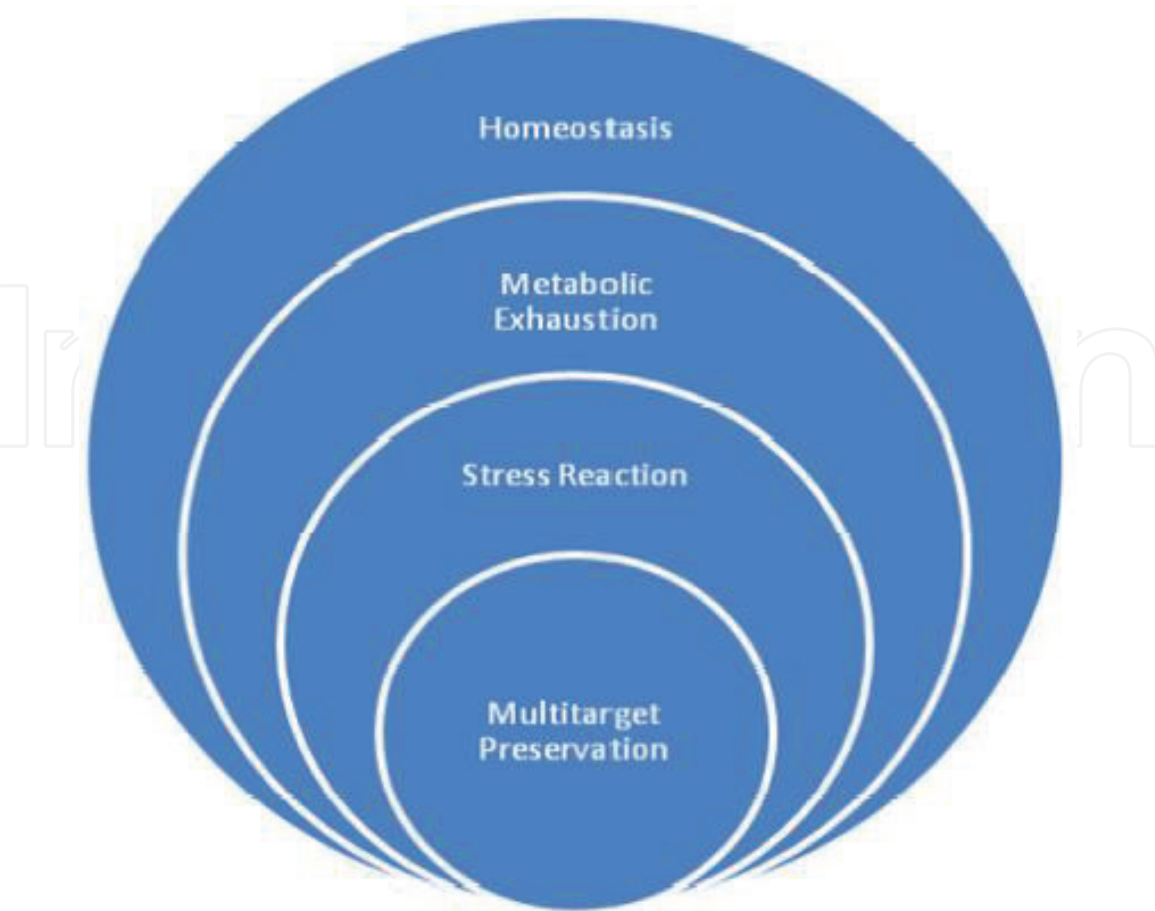


Figure 1.
Basic aspects of hurdle technology [6].

of hurdle technology. There are a number of different types of bacteria, mold and yeast which overcome and sustain the high temperature. Many bacterial spores which survive the thermal treatment are able to germinate in similar food products under unfavorable conditions than those under which vegetative bacteria are able to multiply [8]. Therefore, the microorganisms in the food products try every possible way to repair mechanisms for their homeostasis. By doing this, they completely use up their energy and die. This leads to auto-sterilization of foods. When multiple hurdles are applied in the food items, the rate of metabolic exhaustion is accelerated. In this due course, high energy is required by the microorganisms to maintain their homeostasis which is not achieved by them. Thus, it leads to microbial cell damage and inhibits their further growth [9].

5.3 Stress reactions

Due to generation of shock proteins, some bacteria become more and more virulent under stress conditions. The stress shock proteins are a family of proteins that are produced by the cells in response to exposure to stressful conditions, induced by heat, pH, a_w , ethanol, oxidative compounds, cold, UV light and starvation. Then, the simultaneous exposure to different stresses of bacteria will require high energy demand or at least much more protective stress shock proteins, which ultimately causes the death of the microorganisms [10]. Exposure to the multiple stresses simultaneously induces energy utilizing and synthesis of several stress shock proteins, in turn making the microbes metabolically weak. Hence, multitarget preservation of foods could be an efficient approach for minimizing the production of stress shock proteins and in food preservation for long term [2].

6. Multi target preservation of food

Leistner [11] has been developed the concept of “Multi-target preservation of food” which is a most significant aspect for efficient and effective preservation of targeted food products. Hurdles which are applied in the targeted food products might not just have effects on microbial stability but also it act synergistically [11]. The synergistic effect could be attained in the targeted food products, if the combined effects of different hurdles viz., pH, a_w , Eh, enzyme systems targets simultaneously within the microbial cell and thus disturb the homeostasis of the microbes. This phenomenon interpreting and difficult for the microbes to synthesize a number several stress shock proteins and to maintain their homeostasis [4]. Hence the application of multiple hurdles technique simultaneously would lead to an optimal microbial stability and effective food preservation.

7. Objectives hurdle technology

The main objective of this technology is food preservation, storage of food products and enhancement of their shelf life thereby giving us good quality products. There are several reasons for preserving the foods which are as follow (i) To ensure the safety of food from microbes (ii) To prevent the spoilage of food (iii) To enhance the keeping quality of food (iv) To control food borne infections and intoxications (v) To extend the shelf life of food (vi) To reduce economic losses [12].

8. Examples of the hurdle effect

Every stable and safe food and food products are having several sets of intrinsic hurdles which differs in quality and intensity based on a particular product, however, in any case the hurdles must keep the ‘normal’ population of microorganisms in this food under control. The microorganisms present at the begging stage of food

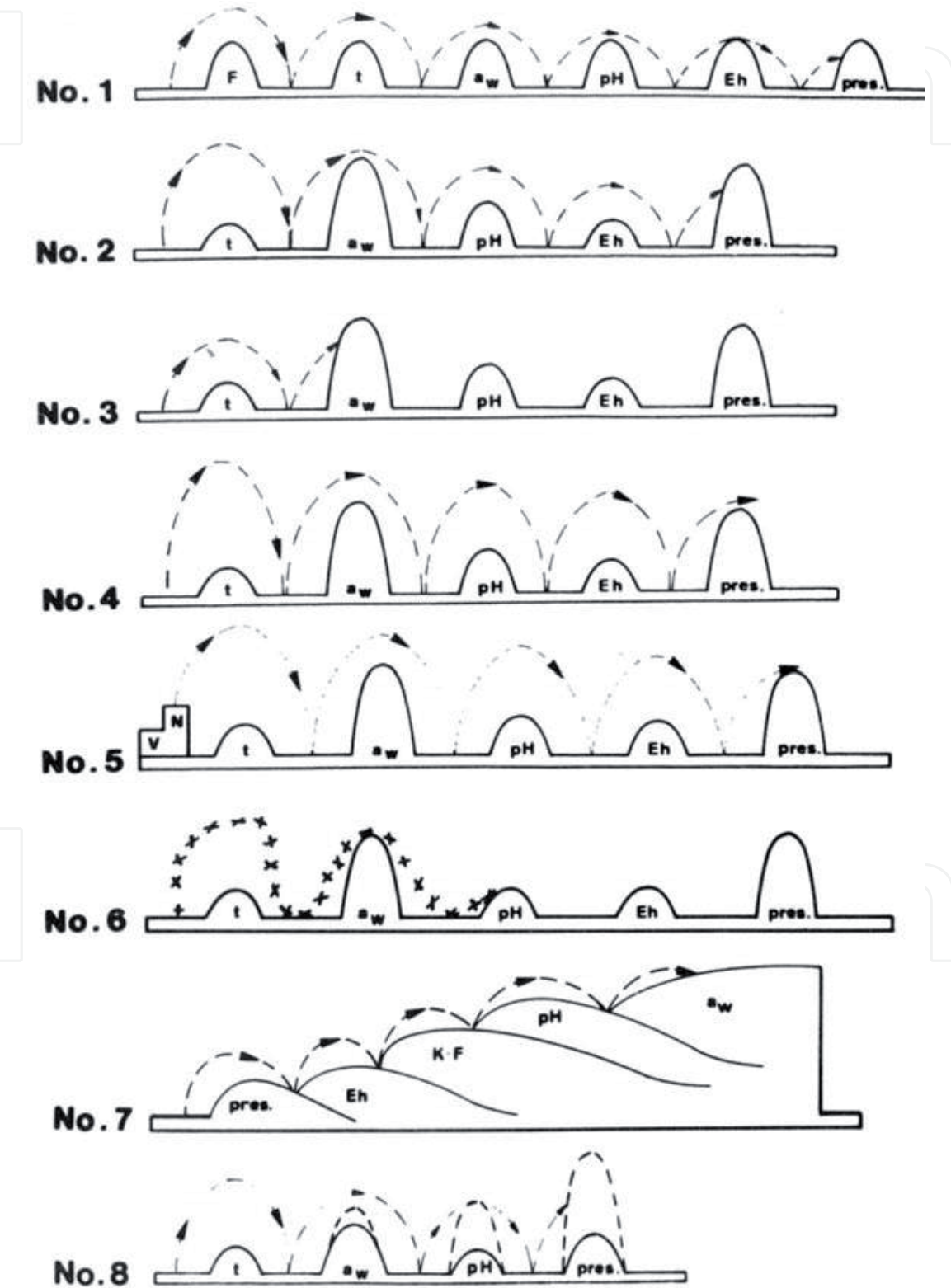


Figure 2. Illustration of the hurdle effect, using eight examples. Symbols have the following meaning: F, heating; t, chilling; a_w, water activity; pH, acidification; eh, redox potential; pres., preservatives; K-F, competitive flora; V, vitamins; N, nutrients [7, 11].

products, are incapable to jump over the next hurdles present in the food systems. Few examples of the hurdle effects depicted in **Figure 2**.

8.1 Fish and fishery products preserved by hurdle technology

While applying hurdle technology for particular food product the selected processing method (preservation and packaging) will affect the spoilage mechanism and leads to the major quality deterioration fish and fishery product. For example, the fish preserved by cold smoking process the combination of hurdles includes salt addition, mild thermal treatment and storage at low temperatures, in this case the quality deterioration is mainly attributed to microbial spoilage, resulting in sensory modifications and thus organoleptic rejection. However, when same food products stored at subzero temperatures then the quality deterioration is correlated with physical and chemical reactions, viz., dehydration and lipid oxidation. These are major factors that defining duration of shelf life of the final products [13].

8.2 Fermented fish products

The Southeast Asian countries are well-known for fermented fish products and preservation, similarly in India the northeast region is famous for same [14]. These areas are in rich natural resources and a cauldron of different people and cultures lie deep in the lap of easternmost Himalayan hills [15]. A number of hurdles are used for preparation of the fermented fish products, these hurdles makes the food products more stable, with enhanced sensory quality and are safe at room temperature. According to Erkmén & Bozoglu (2016) [16], the storage stability of fermented fish products could be attained by applying a combination of hurdles at several stages of the manufacturing process.

8.3 Refrigerated fish products

The fish and fishery products preserved by freezing and stored under frozen condition, it can provide a storage life of more than one year, if appropriately carried out. It has enabled fishing vessels to remain at sea for long periods, and allowed the storing of fish during periods of good fishing and high catching rates, as well as extended the market for fish products of high quality (<http://www.fao.org/3/v3630e/v3630e03.htm>) [17]. However, it has been reported that the temperature conditions in the actual cold chain often deviate from the recommended range. For this reason, the preservation of refrigerated fish products is alone is not sufficient. During the past years, the fish mainly gutted fish and fillets are stored under modified atmospheres or in vacuum. According to Tsironi & Taoukis (2010), it has been found that the combined application of modified atmospheres with the low a_w by applying osmotic dehydration along with addition of nisin in the osmotic solution may significantly extend the shelf life of refrigerated gilt-head seabream fillets during storage at 0–15°C.

8.4 Thermally preserved fish products

Preservation by heat is a major method for extending the shelf life of packaged fish because of the advantages of a high safety level, convenience and a healthy product. In thermal processing, food is preserved in hermetically sealed containers in cooked form for storage at ambient temperature, without compromising on the quality. It's mainly depends on hurdle technology and the final products exhibit usually very long storage stability. According to Choulitoudi et al. (2017) [18] the combined application of hot smoking and edible coating based active

packaging enhanced by the incorporation of rosemary essential oil and/or extract at refrigerated storage under vacuum on eel fillets.

9. Public health significance

The quality of fish and fishery products is of major concern to the seafood processors, consumers and public health authorities. The quality of fish degrades, due to a complex process mainly by physical, chemical and microbiological forms of deterioration are implicated. However, some sea foods are processed in a modern fish industry which is technologically advanced and complicated industry in line with any other sea foods industry and with the same risk of products being contaminated with pathogenic microorganisms [19]. However, the greatest risk to human health is due to the consumption of spoiled fish, improper processed, improper preserved fish and fish products. There are several methods of fish preservation and processing one of the among hurdle technology is applied in seafood processing which ensure seafood safety. This technology ultimately improves the public health from food posing, seafood borne pathogen, food borne illness.

10. Advantages of hurdle technology over other methods of preservation

- The main advantage of this technique is affinity to overcome the ability of microorganisms in developing resistance to conventional preservation methods since this technique using combination of different preservation technique which acts synergistically by hitting different targets within the cell of the spoilage microorganism.
- Basically, in this technique, hurdles are use at lower concentrations this prevent the undesirable sensory changes and also provide the lower production cost and save energy.
- Another advantage of this technique is using natural preservatives in combination with synthetic preservatives, this also lower the risk associated with using synthetic preservatives at high concentration.
- Possibility of increasing shelf-stable foods; because food preserved by combined methods (hurdles) remains stable and safe even without refrigeration, and is high in sensory and nutritive value due to the gentle process applied.

11. Limitations of hurdle technology

Hurdles used in seafood preservation can provide various degree of microbial stress reactions, these stress reactions or cross-tolerance may not work when multiple hurdles are used. Mainly three type of possible results while applying hurdles technology for seafood preservation [20].

- i. Addition or additive effect,
- ii. Synergism or synergistic effect,
- iii. Antagonism or antagonistic effect.

Here the term additive effect imply that effects of the individual substances are simply added together. Generally, the combination of hurdles has a higher inhibitory effect than any single one. Synergistic effect means that the inhibitory action of the combination of hurdles at intensity lower than that of the constituent hurdles separately. In an antagonistic effect, the needed hurdle level is stronger than that of the single constituents. Sometimes combination treatments are not much effective in lowering microorganisms than single treatments. These effects of combined hurdles are antagonistic. In some cases, application of the hurdle technology for seafood preservation may inhibit outgrowth but induced tolerance capability of microorganism and hence extended their survivability [20].

12. Conclusion

This hurdle technology is an effective and simple method in food preservation fields but it requires strategic processes. It is an important approach that can be used to improve quality parameters during processing and storage of food. Hurdle technology Smart application of hurdles improve sensory characteristics, chemical and microbiological qualities of food. Hurdles in the food preservatives require varying results on the basis of microbial stress. Undoubtedly, it will help in fulfilling the demand for fresh and natural food products. It will actually slow the emergence of new routes of microorganisms in the food items and thus keeps the foods safe and healthy to eat.

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