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A novel approach in icing medium for chilled storage of fish and shellfish

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Abstract
Fish and shellfish are a highly perishable commodity, their quality, and freshness decline rapidly after post-harvest. Therefore, efficient storage and preservation technologies are needed to be employed to overcome the post-harvest quality losses as well as to increase the shelf-life of products until it reaches to the consumer. The present review focus on recent efforts carried out on some new and advanced strategies related to chilled storage preservation by using novel icing medium having a bio-based preservative effect. To maintain good quality and retard fresh fish and shellfish spoilage a wide number of preservative strategies has been combined with icing medium and tested satisfactorily. Among them, the inclusion of natural preservatives in the icing medium such as low-molecular weight organic acids, plant extracts, algae extracts and fruit extracts have shown a remarkable quality loss inhibition and increase shelf-life of fish and shellfish.

Keywords: Fish, shellfish, preservation, shelf-life, novel icing medium

1. Introduction
Compared with terrestrial animal, fish and shellfish are more vulnerable to spoilage after post-mortem storage because of their high levels of moisture, free amino acids, polyunsaturated fatty acids, and the presence of autolytic enzymes and near neutral post-mortem pH, render them as an easily perishable commodity [3]. The changes caused by biochemical, physicochemical and microbial activity results in the accumulation of deleterious substances and unpleasant off-odors and eventually lead to economic or health-related problems [13].
Maintaining good quality and shelf life extension of fresh fish and shellfish are now a days mandatory. To keep the original properties of the fish species and offer a high-quality fresh product, ice storage has been recognized as the most commonly employed method [4]. As the ice melts, chilled water is formed which helps to wash away surface bacteria and contaminants. The ice melt-water keeps the surface of the fish wet which prevents dehydration and preserves the glossy appearance when ice melt-water come in contact with the fish it acts as a good conductor of heat and facilitates cooling. Fish have traditionally been cooled and stored in either flake ice, refrigerated sea water, ice slurries or by exposure to chemical agents [11]. The seafood industry is always looking for new preservation strategies to increase the shelf-life of fish so that it can be available to consumers with the best quality. Recently to prevent the quality deterioration of fish and shellfish novel icing medium having bio-based preservative strategies applied.

2. Novel icing medium
2.1 Organic acids
Natural low molecular weight organic acids and their sodium salts have shown to represent a relevant choice because of their easy availability, low commercial cost and the wide range of permitted concentrations for their use. Commonly used organic acid include Ascorbic acid, Citric acid, Lactic acid, etc.

Organic acid mode of action
Organic acids are soluble in lipids in their un-dissociated forms, which allow them to cross the microbial membrane into the microbial cytoplasm, where the acids tend to dissociate and deliver hydrogen ions and a particular anion. As a result, microorganisms are forced to export

The excess hydrogen ion to maintain a physiological pH inside the cell, which is an energy-depleting process that limits bacterial growth.

Application in icing medium

An aqueous solution including a mixture of organic acids (Citric, ascorbic, and lactic 0.050% (w/v) of each acid was employed as icing medium (kept frozen at −20 ◦C); its effect on the microbial activity development in mackerel muscle was monitored for up to 13 days of chilled storage and compared to a counterpart fish batch kept under traditional water ice considered as control. Results indicated a lower bacterial growth in mackerel muscle subjected to storage in the organic acid-icing system by comparison with control fish [22].

2.2 Plant extract

Wide range of food phytochemicals such as flavonoids, phenolic acids, and glycosides are found in plants. Many plant extracts are considered bio-preservatives or green chemicals, or green additives, as they have potential alternatives to chemical preservatives.

Plant extract mode of action

The presence of a second hydroxyl group in the ortho or para position of a phenolic derivative is known to increase ant oxidative activity due to the additional resonance stabilization and o-Quinone or p-Quinone formation [9]. Thyme, oregano, rosemary, and clove extracts have increasingly gained the interest of researchers and food processors due to their high concentrations of phenolic compounds they act as a potential natural antimicrobial and antioxidant agents. The preservative effect of polyphenols is mainly due to their antimicrobial properties and to the inhibition of some enzymes activities, as well as the free radical scavenging ability that prevents lipid oxidation [24].

Application in icing medium

Quitral, *et al*. (2009) [23], found that ice prepared from aqueous extracts of rosemary (*Rosmarinus officinalis*) and oregano (*Origanum vulgare*) leaves improved the chemical changes of Chilean jack mackerel (*Trachurus murphyi*) when compared to traditional ice. Oral *et al.* (2008) [17], worked on the changes in shelf-life of fish (*Capoeta capoeta capoeta*) stored in ice prepared with the wild-thyme hydrosol and the shelf life extended by 15–20 days compared to the control samples. Bensid, Abdelkader, *et al* (2014) [2]. Worked on the preservative effect of ice containing rosemary extract for extending the shelf life of sardines (*Sardinella aurita*). Sensory, microbiological and chemical analyses indicated that the storage of the fish on ice with rosemary extract had a significant increase in shelf life and a positive effect, causing low biogenic amine content, especially histamine and putrescine.

2.3 Fruits extract

Phenols extracted from fruits, vegetables, and agro-processing by-products which help to maintain the quality of fish during chilled storage. Pineapple, grape, pomegranate, berries, etc. are well established to be a good source of polyphenols [26].

Application and mode of action in icing medium

Indian mackerel that was treated with grape seed and papaya seed extracts during ice storage demonstrated an improved sensory score and a 3–5 days shelf life extension compared to the control samples [26]. In citrus peel extract, polyphenol compounds such as p-coumaric, ferulic and sinapic acids and narirutin are present which shows good preservatives effect [16]. Nazeri1 *et al*. (2017) [19] in his study revealed that icing with pistachio (*Pistacia vera*) green hull is known as a byproduct of pistachio extract could significantly improve chemical quality and prolong shelf-life of rainbow trout throughout cold storage. The presence of phenolic compounds in pistachio extract could protect unsaturated fatty acids against oxidation and partially prevented the formation of volatile basic nitrogen and biogenic amine, histamine.

2.4 Algal extract

The algal extract can be used as a source of bioactive compounds for pharmaceutical, seafood processing, and biotechnological industries. Algae comprise a wide number of preservative metabolites such as polyphenols, terpenes, phlorotannins, steroids, halogenated ketones and alkanes, fucoxanthin, polyphloroglucinol or bromophenols. According to European Council Regulation 258/ 1997, marine algae are considered as a food or food ingredient, so their use in the icing medium does not pose a health problem for consumers [8].

Algal extract mode of action

Red, green and brown macroalgae have offered the possibility of exploring a wide variety of natural compounds with potentially antioxidant and antimicrobial activities susceptible to be applied to seafood [10]. The preservative effect of the algal extract is mainly due to their antimicrobial properties as well as antioxidant activities [21].

Application in icing medium

Miranda *et al*. (2016) [15]. had studied the effect of ethanolic extracts of alga *Bifurcaria bifurcata* in the icing medium employed for the chilled storage of megrim (*Lepidorhombus whiffiagonis*) for 14-day storage. Miranda *et al.* (2016) [15] had also studied the effect of an icing medium containing the ethanolic extract of the alga *Fucus spiralis* on the microbiological activity and lipid oxidation in chilled megrim (*Lepidorhombus whiffiagonis*) for 14 days and there was a protective effect on refrigerated megrim quality. Arulkumar *et al*. 2018 [1] studied that the icing medium containing *Gracilaria verrucosa* red algae extract improves the quality and safety of Indian mackerel during storage and can be explored by the seafood industry as a bio preservative.

2.5 Chitosan nanoparticles glazing

Chitosan is composed of β (1→4)-linked 2-acetamido-2-deoxy-β-D-glucose (N-acetyl glucosamine) a natural polysaccharide that is a partially deacetylated derivative of chitin known as the second largest source of carbohydrates on Earth [16]. Due to its biochemical and mechanical properties, chitosan (CH) has been extensively used in the food industry as food packaging material, especially in edible films and coatings. Chitosan also offers protection from free radicals with antioxidant activity that varies with its molecular weight and viscosity [22].

Application and mode of action in icing medium

Solval *et al.* (2014) [27] had studied the potential effect of chitosan (CH) combined with sodium tripolyphosphate (TPP) nanoparticles as a glazing material for shrimp. Glazing

containing chitosan nanoparticles reduced the lipid oxidation, reduced total aerobic counts of yeast and molds without affecting the color and texture properties of frozen shrimp during 30 days of storage at -20 ºC.

2.6 Ozonized slurry ice

Ozone has been traditionally used as a water-disinfecting agent. The FDA considered ozone a GRAS substance for use in different food applications, which has increased its use worldwide [14].

Ozonized slurry ice mode of action

Strong oxidizing nature of ozone makes it a useful tool for the inactivation of microorganisms. The bactericidal effect of ozone depends on several factors, such as temperature, relative humidity, pH and the presence of organic matter [14].

Application in icing medium

Campos *et al*. 2006 [5] worked on storage of farmed turbot (*Psetta maxima*) in the novel refrigeration system that was developed by combining an ozone generator with a slurry ice system, allowed better maintenance of sensory and microbiological quality. Biochemical analyses also confirmed that the presence of ozone did not exert any obvious negative effect on fish quality, and even allowed the inhibition of certain mechanisms involved in lipid hydrolysis and oxidation.

2.7 Slightly acidic electrolyzed water ice

Slightly acidic electrolyzed water (SAEW) is prepared by electrolysis of an aqueous mixture containing dilute HCl and NaCl solutions using an oxidizing redox potential water generator equipped with an electrolytic cell without a separating membrane between anode and cathode. It is considered as a novel non-thermal sterilizing agent and it is already regarded as a legitimate food additive in the US, Japan, and Korea.

Application and mode of action in icing medium

Xuan, *et al*. (2017) [30] has investigated the effect of slightly acidic electrolyzed water ice (SAEW-ice) on the preservation of squid. The results showed that SAEW-ice was more efficient at maintaining squid quality during storage than TW-ice. The total bacterial counts were significantly reduced in SAEW-ice and maintained relatively slow microbial growth during storage. It delayed the appearance of browning and softening. SAEW-ice had the potential to ensure microbial safety and control the quality deterioration of squid during storage, which could be a new approach worthy of further investigation.

2.8 Jumbo squid skin extract and their application as an icing medium

Ezquerra-Brauer *et al*. (2017) [8] developed new icing media for quality enhancement of chilled hake (*Merluccius merluccius*) using a jumbo squid (*Dosidicus gigas*) skin extract (JSS). Aqueous solutions containing acetic acid-ethanol extracts of JSS were included into icing media of chilled European hake and the microbial, chemical and sensory quality of hake was evaluated throughout 13-day chilled storage. There was remarkable microbial inhibition and a significant shelf life extension of chilled hake and the ommochrome pigments (i.e., lipophilic-type compounds) was considered responsible for the preservative effect.

3. Conclusion

Bio-based or eco-friendly development in icing medium for chilled storage of fish and shellfish are increasingly attracting research attention now a day. This review has introduced many aspects of alternative chilled storage preservation including those formulated with composites of natural additives or eco-friendly methods and their benefits as well as the protective effects as determined using microbial, physicochemical and sensorial evaluations. There is no obvious negative effect on fish or shellfish quality by using this novel technique. To better promote the commercial application of icing medium for chilled storage of fish and shellfish, effort should be directed toward further optimization of alternative icing medium for chilled storage formulas and exploring the potential preservation mechanisms.

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