Nano-emulsions: A Novel Approach in Seafood Preservation

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Abstract

Seafood industry has become progressively growing worldwide with fish being the most demanded as it is a rich source of many nutrients including proteins, vitamins and carbohydrates. Fish usually undergo spoilage due to microbial, oxidative, enzymatic and chemical activities. Fish is highly perishable and if not handled properly, its sensory attributes, quality and freshness will be affected. Preservation of fish is mandatory so to assure quality and to extend shelf life. Besides traditional preservation methods including chilling, freezing, drying, salting, smoking, some new methods have also been introduced for preservation that includes, modified atmospheric packaging, irradiation, ozone technology and nano-emulsion. Nano-emulsion is the latest innovation that is being used for preservation to improve food properties such as taste, odour, texture and quality. The advancement in the research showed the several benefits of nano-emulsions for the usage of bioactive and antimicrobial substances due to its minute size ranges and volume to the surface ratio that can increase the ability of digestion and durability of these emulsions. Therefore, it was objected to discuss the application of nano-emulsion as a novel preservation technology in seafood.

Keywords: Seafood, nano-emulsions, preservation techniques, spoilage, emulsifiers

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INTRODUCTION

Seafood plays an important role in a person's diet as the reliable source of protein. Moreover, seafood is the rich source of other nutritious compounds as omega-3 polyunsaturated fatty acids, vitamin, and minerals. There is a clear relation of health and life probability in association with the use of seafood. For example, fish is a rich source of protein and it requires a vigilant handling (Eyo, 2004). Seafood freshness is generally termed as the time period for which fish upholds its shelf life, which usually defined by various factors, as the initial presence of different bacteria, their specificity, temperature, pH and surrounding environment.

The concept of quality of fish is very complicated (Bremner, 2000). It is often narrated as nutritional, microbiological, biochemical and physiochemical properties but it must also include perception of quality sensory and acceptability of consumer. Sensory evaluation can either be objective or subjective. In objective sensory evaluation, trained team is used to define freshness. In subjective sensory evaluation, satisfaction and acceptability of consumer and trends of market (Singham et al., 2015).

Spoilage of fresh fish is quite rapid after it is caught. The key to provide high quality of fish need attention throughout the process including catching, handling, transportation and storage. At high temperature, it took 12h after fish catch to begin spoilage process (also known as rigor mortis) (Berkel et al., 2004). In rigor mortis process, after few hours of fish death, it tends to lose its flexibility due to mussels stiffens (Adebowale et al., 2008). Fish is evidently unusable that has become spoiled or addled (Gopakumar, 2000). If the fish is badly handled, it may not be clearly spoiled, but due to off-odour, off-flavours, spongy texture, or substandard colour, it loses its desirability (Burt, 2003). Degradation of fish occur due to digestive enzymes activity, microbe's activity, and oxidation (AMEC, 2003). When spoilage of fish occurs, many components break and new compounds are formed. These newly formed compounds in fish meat result in change of physical attributes like odour, flavour, texture, color of gills and softness of muscles (Baird-Parker, 2000).

Due to the high temperature, bacterial activity, enzymes, chemical changes and fat oxidation in the fish accelerates. Generally, numerous bacteria are present on the skin and gill of fish. When a fish is caught, a series of bacterial, enzymatic and chemical changes occur that results in spoilage of fish (Burt, 2003). Warm climate usually accelerates the rate of spoilage. Stomach of the fish contains enzymes which helps a living fish in digestion (Lima Dos Santos et al., 2011). Enzymes start digesting the stomach itself once the fish is dead. Ultimately the enzymes enter into the fish meat and digest it too. This is the reason why fish becomes mushy and the odour of the fish becomes more prominent. Chemical changes cause spoilage results in enzymatic digestion and bacterial decomposition (Putro, 2005).

Shelf life of seafood is short as it is highly perishable and may cause aerobic spoilage of fish in the presence of air and oxygen. Therefore, it is important to preserve freshness and quality of seafood. Seafood is preserved in order to lessen or inhibit the metabolic changes that cause deterioration of fish quality. By controlling temperature, water content, microbial activity and oxygen availability, shelf life of seafoods can be extended. The purpose of preservation of fish is to reduce or stop the enzymatic, chemical and bacterial deterioration, so that fish meat remains fresh (Bate and Bendall, 2010). Besides traditional techniques, there some minimal processing technologies like high-pressure processing (Ucak et al., 2019; Ucak et al., 2018; Ucak and Gokoglu 2020), irradiation technology, ozone technology, advanced packaging technology such as edible films and coatings (Ucak et al., 2020; Ucak et al., 2019; Ucak 2019), and nano-emulsion applications.

Chilling is the simplest method to preserve fish. Although cool and uncool fish can be spoiled in a matter of few hours but comparatively cool fish remains fresh for a longer period (Tawari and Abowei, 2011). It is essential for fish preservation to store it at 0°C after it is caught as at that time spoilage can be very fast (FAO, 1973). Cooling of fish can be done by covering the fish with layers of ice. But this method of icing is successful only for a short duration such as for transportation purpose. Berkel et al. (2004) stated that fish can either be stored at cooling temperature +1°C to +4°C, that hinders the microbial growth or by freezing at -18°C to -30°C that stops the growth of microorganisms. Fish preservation can be done by adding salt on fish. However, there is usually no choice in remote places other than to use salt in any way to preserve fish. Another way to preserve fish is to keep it in brine solution. The ratio to make brine solution is four parts of water and one part of salt (4:1). If the salt grain size is large, it should be grinded first (Tys and Peters, 2009).

By using a stirrer, it is then dissolved. Modified atmospheric packaging is a type of packaging in which air is eliminated from the pack replacing it with a single gas or mixture of gases. To meet consumer demand, MAP has been progressively accepted preservation technique to fulfil seafood distribution.

A lot of applications in food products are being implemented using MAP techniques that include raw and cooked meats, poultry, sea foods etc (Church, 1998). MAP along with refrigeration is proficient of prolonging the shelf life of sea foods. To preserve fish for a long duration and to improve its quality, irradiation technology is used in which electrons or electromagnetic rays are exposed to food products (Lacroix and Ouattara, 2000). For ionizing radiation, gamma rays, X-rays and electron beams are used to preserve food. Most important material is cobalt 60 that is being used for food irradiation (Clucas and Ward, 1996). Ozone technique is a latest method of food preservation that is being used to examine quality of fish and extending its shelf life (Kim et al., 2000; Campos et al., 2006). Ozonation is a successful technique which is being used to destroy microbes that includes virus, bacteria etc. (Hobbs, 1991; Campos et al., 2006). Ozone technique is promising as it lessens the apparent contamination of fish and reduces formation of volatile nitrogen which ultimately improves sensory attributes and quality of fish for many days (Dondo et al., 1992). Besides all these techniques, the application of natural extracts to fish products are commonly used (Ucak and Zahid 2020; Ucak 2020a; Ucak 2020b).

Nano-emulsions

The food sector has made significant advancements in nanotechnologies known as nano-liposomes, nano-emulsions, nano-fibers, and nano-capsules (Raj et al., 2013). Nanotechnology is an advanced approach that deals with controlling and preventing diseases, extending the shelf-life of food products (Wang et al., 2014). Nano-emulsions are colloidal systems of particular interest because they can be made from elements mainly food graded used in the food sector such as mixing, heat treatment and homogenization (Rao and McClements, 2011). The technologies in food industries are used to transform numerous food products (McClements, 2010). The improvement of appearance, texture or taste is considered as the main benefit for applying nano-emulsions in the food industry by the careful selection process and use of products wisely (McClements, 2015). On the other hand, emulsions can have improved stability against the combination of droplets (Mc-Clements and Rao, 2011). Moreover, droplets are clear when dispersed, so they are appropriate for the accumulation of food without altering the characteristics (Mason et al., 2006). Nanoparticles are being used in advance food processing technology to enhance attributes like flavour, texture, colour and other antimicrobial properties (Chaudhry et al., 2008).

McClements (2012), explained that nano-emulsion is a thermodynamically uneven exhibit dispersal comprising of two immiscible points, particle combinations and gravitation phase separation because of their small droplet sizes as related to other methods. For instance, phases comprised of discrete particles around $r<100$ nm and minute droplets showing dispersal in a translucent manner this resultant. It can also comprise of oil-in-water emulsions or water-in-oil. Moreover, nano-emulsions can be made up of essential oils, acylglycerols and free fatty acids (Shah et al., 2010). On a wider basis, nano-emulsions have been prepared to condensed sustenance with a lipophilic property because these components may not be well dispersed in an aqueous phase. However, with rheological behaviour such as color, appearance, texture, and stability, it is probable to manufacture water in oil type nano-emulsions in food applications (Jafari et al., 2008).

The free energy of the emulsion is larger than the free energy of the discrete stages (oil and water). Instability in thermodynamics happens by sedimentation, coalescence, occultation, molecular diffusion and Ostwald ripening (Gharib Zahedi et al., 2012; Gupta et al., 2016). This mainly happens when a huge droplet increases its size, incorporating a minute droplet by molecular diffusion (Ahmed et al., 2012).

Nano-emulsions are widely being used in different industries including food, pharmaceutical, medical and cosmetic in order to encapsulate, protect, and release bioactive lipids (McClements et al., 2007). It is vital to know about size of droplet in emulsion as ultimately it will affect emulsion properties including texture, stability of shelf life, rheology (Wolf et al., 2009).

Preparation of nano-emulsion can be done by high-pressure homogenization, ultrasonic homogenization, micro fluidization, phase inversion temperature, solvent displacement, emulsion, and phase inversion (Lovelyn and Attama, 2011; Bradley et al., 2005; Kentish et al., 2008; Shah et al., 2010; Solans et al., 2005; Tadros et al., 2004; Ganachaud and Katz, 2005; Trimaille et al., 2001; Solè et al., 2006; Uson et al., 2004; Shinoda and Saito, 1969; Ahari, 2017). Moreover, these bioactive complexes comprised of ketone, aldehyde, ester bonds and they are beneficial for oxidative deterioration, on the other hand, micro capsulation inhibits light without manipulating the taste and texture of the food products. They can also enhance the stability, solvability in the final by-product (Barani et al., 2018). However, nano-emulsion can be comprised of four components: (a) oil stage (b) water stage (c) surfactant and (d) energy needed to generate.

Nano-emulsions ingredients

Oil phase

The oil phase is comprised of bioactive compounds such as fish oil, essential oils, oil flavors, and Vitamins which are dissolved in carrier oil. Moreover, several oils are associated with the production of nano-emulsions due to their low cost, nontoxicity, and abundance of their raw sources, containing acyl glycerol, essential oils, free fatty acid, organic oils, and waxes.

Water phase

The production of the nano-emulsion water phase is one of the unique ingredients in the creation of nano-emulsion. It can be described that the percentage of water to the oil phase is a significant factor in the formation of nano-emulsion. The other materials are polysaccharides, cosurfactants, proteins, salts, and nutritious materials which are included in the water phase these could alter the pH, polarity, surface tension and ionic structure. Moreover, liquid phase elements can be a definite factor in defining the physicochemical features of the nano-emulsion. While, compounds like proteins, agar resin, alginate could aid the consistency of nano-emulsion

Stabilizers

As described before, nano-emulsions are thermodynamically unstable; hence, their formation requires stabilizers. Emulsifiers are one kind of stabilizer, which has application information of tiny droplets during homogenization; meanwhile, they prevent the aggregation of droplets either during or after homogenization. Another kind of stabilizers used as a texture modifier prohibits gravity separation and Oswald ripening in nano-emulsion (McClements and Rao, 2011).

Emulsifier

Emulsifiers are those materials that are active on the surface and have amplification properties. Lipophilic and hydrophilic compartments are present in the structure emulsifiers. Hence, one part is dependent on the nonpolar (oil) phase, while the other part on the polar (water) phase (Qian and McClements, 2011).

Texture modifier

To change the structural characteristics of nano-emulsion fabrication; a compound used during the continuous step of nano-emulsion fabrication; named as texture modifier. Texture modifier can also be used as a thickening object (McClements and Jafari, 2018)

Weighting agents

These compounds are added to the dispersed phase to change the density of the droplets with the density of the continuous phase. The objective is to lessen the impulsion force of gravity and delaying the creaming or sedimentation (Salvia et al., 2017).

Methods used to form nano-emulsions

Understanding the formation of nano-emulsions; it is necessary to produce a small droplet size; these dispersions are representatively formed in a different procedure in which a macro emulsion is developed and then transformed into nanodroplets (Gupta et al., 2016). Nano-emulsions are created using a series of species methods, and they can be grouped based on the energy input, i.e., low energy and high energy. However, low energy is used for making nano-emulsion elements and the particles size ranges (Ostertag et al., 2012)

Low-energy methods

Low interfacial tension is reached due to differences in the conditions of the suspension and a state of phase inversion is obtained by nano-emulsion (Gupta et al., 2016). The most commonly used methods that are used in low energy methods are phase inversion composition and phase inversion temperature (Jin et al., 2016).

High-energy methods

High-energy methods are made using numerous types of different mechanical apparatus, such as ultrasonic homo-genizers, high pressure homogenizers or micro fluidizer, that produce sufficient levels of concentrated energy to oil and water, producing minute droplets (Jin et al., 2016).

Materials used in the development of nano-emulsions

Nano-emulsion application in the food industry used to encapsulate components with possible biological activity comprised of fatty acids, liposoluble flavors, vitamins, etc. (Rao and McClements, 2011). Emulsifiers aids in the making of emulsions during homogenization by adsorbing at the water-oil interface during homogenization to decrease surface tension (Yan et al., 2013).

The emulsifier must have following features: It must rapidly lessen the facial tension in water and oil interface, once adsorbed it must be strongly bound to the interface, in destabilization it should be protective.

Based on their usage it may differentiate as emulsifiers, foaming agents, wetting agents and dispersants. Moreover, according to physical features their stability for water and oil will be most commonly used. The replacement of synthetic emulsifiers with natural emulsifiers is a rising propensity as numerous synthetic emulsifiers are not allowed for use in different areas (Rao and McClements, 2011). Because of this situation, naturally occurring emulsifiers are an improved option for the development of nano-emulsions. Proteins, polysaccharides, and gums are known as natural emulsifiers. Proteins have the ability to absorb oil and water by having amphiphilic characteristics (Silva et al.,2015). Due to the controlled release of emulsion, there is an improvement for the presence of bioactive compounds (that are extracted mainly from fruits) in terms of antimicrobial process (Ranjan et al., 2017; Angel Robles-Garcia et al., 2016; Lu et. al., 2016; Oehlke et al., 2014; Hernandez-Fuentes et al., 2015; Pimentel-Gonzalez et al., 2015).

CONCLUSION

The usage of nano-emulsions is as useful as the encapsulation system. It has several advantages in the food industry including minute droplet size range, transparency, and high stability. Customer response should be attained by investigations showing that these substances cannot be gathered in the human body because of the low toxic level. In contrast, there must be a need for establishing some laws in the food industry for use of nanotechnology that provides functionality and expand features linked to human health. The advancement in the research showed the several benefits of nano-emulsions for the usage of bioactive and antimicrobial substances due to its minute size ranges and volume to the surface ratio that can increase the ability of digestion and durability of these emulsions.

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