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Application of atmospheric cold plasma-activated water (PAW) ice for preservation of shrimps (*Metapenaeus ensis*)

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ABSTRACT

In this paper, plasma-activated water (PAW) ice is proposed for the preservation of fresh shrimps. The changes in microbiological, physical, chemical and protein properties were investigated during storage with conventional tap water (TW) ice and PAW ice. Compared with TW ice, PAW ice showed significant advantage for inhibition of microbial growth, extending the storage time by 4–8 days. The pH of shrimps treated with PAW ice remained below 7.7 during storage. The deteriorating changes in color characteristics and hardness were delayed by the PAW ice treatment. The production of volatile basic nitrogen (TVBN) was reduced to below 20 mg/100 g during PAW ice storage, significantly lower ($p < 0.05$) than that of the samples treated with TW ice. In addition, PAW ice did not result in adverse changes in shrimp proteins. Therefore, the study showed that PAW ice may be used in preservation of fresh seafood.

1. Introduction

Seafood products are rich in proteins and lipids (e.g. omega-3 fatty acids) (Elbashir et al., 2017). However, due to the activity of spoilage microbes and endogenous enzymes, seafood easily loses its quality and has limited shelf-life. According to Food and Agriculture Organization of the United Nations (FAO), the supply of seafood around the world has increased from 145.9 million tonnes in 2009 to 167.2 million tonnes in 2014 (FAO, 2016). As the demand for fresh seafood increases, it is necessary to develop novel preservation methods with high antimicrobial efficacy that are low-cost and safe to use in order to maintain the quality of seafood for longer storage. Several methods have been proposed for preserving seafood, including chilling with ice, chemical agents, irradiation, and modified atmospheric packaging (Bono et al., 2016; Nunes, Batista, & Decampos, 1992). Among those, chilling with ice is the most widely applied preservation method. Apart from conventional tap water (TW) ice, some other types of ice, such as ozonated ice, electrolyzed water ice and ice with bio-preservatives have also been proposed for improving the microbiological safety of seafood (Bensid, Ucar, Bendeddouche, & Ozogul, 2014; Lin et al., 2013; Xuan et al., 2017).

Cold plasma has been tested as an alternative non-thermal treatment technology in food industry. Various reactive species produced in the cold plasma, such as free radicals (e.g. reactive oxygen species-ROS, reactive nitrogen species-RNS), negative and positive ions, and ultraviolet (UV), are thought to be responsible for inactivation of microbes (Liao et al., 2017, 2018a). Many previous studies have demonstrated some bactericidal effects against certain microorganisms in food products, including fruits and vegetables, juices, cereals, meat and poultry, and spices (Liao et al., 2018b; Mir, Shah, & Mir, 2016). Recently, cold plasma-activated water (PAW) has been proposed for microbial control of fresh food products, such as strawberries, grapes and Chinese bayberries (Guo et al., 2017; Sarangapani, Patange, Bourke, Keener, & Cullen, 2018). However, there are only limited studies concerning the application of cold plasma for the preservation of aquatic food (Xu, Jiang, Shi, & Chen, 2015). In the study, we investigated and compared the effects of TW and PAW ice on microbial safety, physico-chemical properties and proteins of fresh shrimps. The work here aimed to exam

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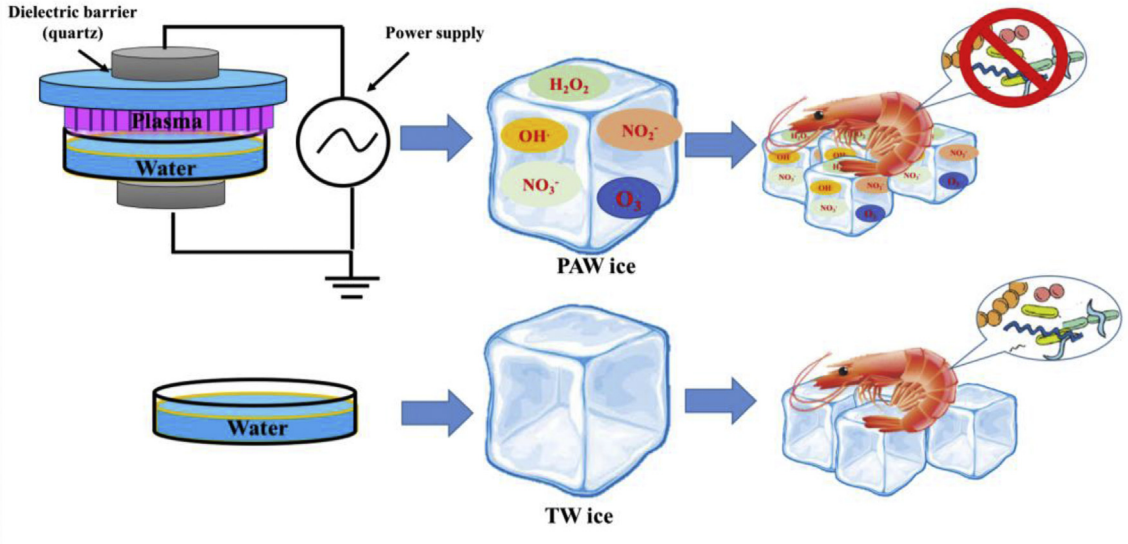

Fig. 1. The schematic graphic of experiment.

the feasibility for using PAW ice to extend the shelf life of seafood products.

2. Materials and methods

2.1. Preparation of PAW ice

A dielectric barrier discharge (DBD)-atmospheric cold plasma (ACP) was used in this study to generate PAW. The DBD-ACP system contains a circular quartz glass dielectric barrier with a diameter of 90 mm, two circular aluminum plate electrodes with a diameter of 50 mm, an aluminum petri dish with a diameter of 150 mm and a high-voltage power supply (CTP-2000K, Nanjing Suman Electronics Co., Ltd., Nanjing, China, Fig. 1). Water (100 ml) was placed in the petri dish and activated by plasma under an input power of 30 W and a gas distance of 5 mm between the upper electrode and the water surface for 10 min. Then, PAW was transferred into a plastic bags and frozen at −20 °C for 24 h. Before experiment, PAW ice was broken into pieces by a hammer. The pH and oxidation reduction potential (ORP) of TW and PW ice were measured with a pH/ORP meter (Lohand Biological Co. Ltd., Hangzhou, China). Electrical conductivity was estimated by an electric conductivity meter (Lohand Biological Co. Ltd., Hangzhou, China). The existence of hydrogen peroxide (H_2O_2), and ozone level in ice was estimated by a Hydrogen Peroxide Assay Kit (Beyotime Biotechnology Co. Ltd., Shanghai, China) and a Spectroquant Ozone Test Kit (Merck & Co Inc., Darmstadt, German). The concentration of nitrate was determined according to the method of Follett and Ratcliff (1963).

2.2. Shrimp preparation and storage condition

Fresh shrimps (*Metapenaeus ensis*) were bought from a local market in Hangzhou, China. Shrimps were divided into two parts randomly and were placed on the layer of TW and PAW ice, respectively. Then, the surface of shrimps was covered with another layer of TW and PAW ice. During the storage, all the samples were placed at 5 ± 1PAW ice. During the storage, all the samples were placed°C for 9 days. Both TW and PAW ice was replaced every 12 h. The quality change of shrimps was estimated every 48 h for the initial 6 days, and every 24 h for the next 3 days.

2.3. Microbiological analysis

Shrimp samples (10 ± 1 g) treated with TW and PAW ice were homogenized with 90 ml of 0.85% (w/v) sterilized saline solution (SS) in a stomacher bags with a bagmixer for 2 min at room temperature (25 ± 1 °C). Then, the homogenate was serially diluted with SS and 1 ml of each dilution was mixed thoroughly with plate count agar (PCA). The plates were then incubated at 37 °C for 48 h for determination of total viable count (TVC).

2.4. Physical quality assessment

2.4.1. pH determination

Values of pH were determined according to the method of Mariaelvira, Oscar, Mariadelcarmea, and Pilar (2007). Shrimp samples (10 ± 1 g) from TW and PAW ice were homogenized with 90 ml deionized water and placed under room temperature (25 ± 1 °C) for 5 min. The pH values were determined by a pH meter (Lohand Biological Co. Ltd., Hangzhou, China) under room temperature (25 ± 1 °C).

2.4.2. Total volatile basic nitrogen (TVBN) measurement

Shrimp samples (10 ± 1 g) from TW and PAW ice was extracted with 100 ml deionized water for 30 min. After filtration, an aliquot (5 ml) was mixed with 5 ml of 0.1% (w/v) MgO. Boric acid (2%, w/v, 10 ml) with 5–6 drops of mixed indicator (0.1% methyl red and 0.5% bromocresol green dissolved in alcohol solution) was placed into the conical flask. After distillation, hydrochloric acid (HCl, 0.01 M) was used for titration. TVBN value was then calculated according to the following equation:

$$\text{TVBN (mg/100 g)} = \frac{(V_1 - V_2) \times C \times 14}{m \times 5/100} \times 100$$

Where V_1 and V_2 represent the volumes of HCl required for titration of the mixture with shrimps and the one without shrimps (ml); C is the concentration of HCl used in this study (M); and m denotes the weight of shrimp sample (g).

2.4.3. Thiobarbituric acid reacting substance (TBARS) determination

TBARS was estimated according to Vymcke, 1975 with some modifications. Shrimp samples (10 ± 1 g) from TW and PAW ice were mixed with 50 ml of 7.5% (w/v) trichloroacetic acid and 0.1% (w/v) ethylenediaminetetraacetic acid (EDTA) with a homogenizer (FSH-2, Jintan Meixiang Instrument Co., Ltd., Changzhou, China). The mixture was