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Investigation on influence of dimensions of ice containing ozone micro-bubbles on characteristics of ozone concentration

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ABSTRACT

Addition of sterilization and deodorization capabilities to ice is effective for a cold storage of food. Therefore, authors clarified the characteristics of ozone micro-bubbles (MBs) concentration fixed in the ice and ozone gas concentration released due to melting. In this paper, ice with different dimensions are prepared by cutting and crushing the formed ice containing ozone MBs, after which influences of dimensions of cut and crushed ice on the above characteristics are examined. Furthermore, using ice slurry is more effective to cool fresh food; therefore, a pseudo ice slurry formed by mixing crushed ice containing MBs with pure water is investigated. Cut ice and original uncut ice mixed with pure water, respectively, are also investigated as a reference. And validities of above ice mixed with pure water, respectively, are shown by measuring ozone concentration in water. Finally, oxidation characteristics due to ozone gas released into fish oil are also clarified.

Étude de l’influence des dimensions de glace contenant des micro-bulles d’ozone sur les caractéristiques de concentration d’ozone

Mots clés : Glace ; Dimensions ; Micro-bulles ; Concentration d’ozone ; Pseudo coulis de glace

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Nomenclature

C	mass concentration of ozone in water [ppm mass]
C t	volumetric concentration of ozone micro-bubbles fixed in ice [ppm]
C t'	volumetric ozone gas concentration released by melting [ppm]
POV	peroxide value [meq kg^{-1}]

1. Introduction

The functions of sterilization and deodorization would be useful additions to ice used for the cold storage of food (Ikeda et al., 1998; Matsumoto et al., 2015; Mohammad et al., 2009). However, the decomposition rate of ozone is typically very high, while ozone becomes harmless immediately, regardless of it being in liquid or gas phase (Park et al., 2001; Sugimitsu, 1996), so that it is difficult to maintain the sterilization and deodorization functions of ozone for an extended period.

A method for the formation of ozone ice by freezing water in which ozone gas has been dissolved was developed for the purpose of cooling fish in a fish market (Yoshimura et al., 2007). However, a pressure vessel is required for the production of ozone ice, which results in an increase in cost and the amount of equipment necessary for production.

The trapping of air micro-bubbles in ice was reported when water containing the micro-bubbles was frozen in a copper cylinder, and the behavior of the micro-bubbles trapped in the ice was investigated (Inada et al., 2009). However, investigation of the paper was insufficient to effectively trap the micro-bubbles in ice. Thus, as a first step, one of the authors has investigated the trapping of oxygen micro-bubbles in ice. As such, a method of ice formation that effectively traps oxygen micro-bubbles in the ice was developed, and it was clarified that the addition of a surfactant contributed to more effective trapping of oxygen micro-bubbles in the ice (Matsumoto et al., 2013).

In the previous paper (Matsumoto et al., 2015), the concentration of ozone micro-bubbles fixed in ice formed using the developed method was reported to be sufficient to sterilize most of the bacilli that cause food poisoning, such as colon bacillus and Salmonella, even after 7 days. In addition, the characteristics of the ozone gas released from ice due to melting, and the relation between the concentration of ozone micro-bubbles fixed in the ice and that of the ozone gas released due to melting were also clarified.

In this paper, ice pieces with different dimensions are made by cutting and crushing the formed ice containing ozone micro-bubbles, after which, the effect of those ice pieces dimensions on the ozone micro-bubbles concentrations fixed in those ice pieces and the ozone gas concentrations released from those ice pieces due to melting are examined.

Moreover, it is well known that ice slurry is more effective at cooling fresh food such as fish and fruits; therefore, pseudo ice slurry is made by mixing crushed ice pieces containing ozone micro-bubbles with pure water. The pseudo ice slurry is then melted and the ozone concentration in the water is measured to investigate whether the pseudo ice slurry can be used as ice slurry. Similar investigations are conducted after the original and cut ice pieces are mixed with pure water, respectively.

Finally, ozone gas is known to be a strong oxidizer of food. Therefore, as an example, the oxidation level of fish oil (sardine oil) due to ozone gas released by melting of the ozone micro-bubbles containing ice is estimated by measuring the variation of peroxide values (POVs) due to the presence of ozone gas.

2. Experiment

The experimental apparatus for forming ice containing micro-bubbles (MBs) and the methods used for measurements of the concentration of ozone MBs fixed in the ice and the ozone gas concentration released from the ice due to melting have been fully explained in previous reports (Matsumoto et al., 2013, 2015). Therefore, these are only briefly explained here.

2.1. *Experimental apparatus for the formation of ice containing ozone MBs*

Fig. 1 shows the experimental apparatus used for the formation of ice containing ozone MBs. The apparatus is placed in a room with the temperature below 0 °C. A box-like cooling device (ice formation component) with an incidence angle of 30° is set in an acryl resin water tank with dimensions of $350 \times 300 \times 250$ mm^3. The device has an inner volume of 192 cm^3, five walls made of acrylic resin, and a cooling plate (bottom face) made of copper plate with dimensions of 80×80 mm^2. The copper surface is coated with nickel by electroless plating to protect from corrosion due to ozone. The surface temperature of the copper plate is defined as the temporal average of temperatures measured on the copper plate at the inflow and outflow sides of cold brine circulated through the cooling device.

Table 1 shows the experimental conditions used for ice formation. Approximately 20 L of pure water in the tank is precooled to about 2 °C by circulating cold brine into a stainless

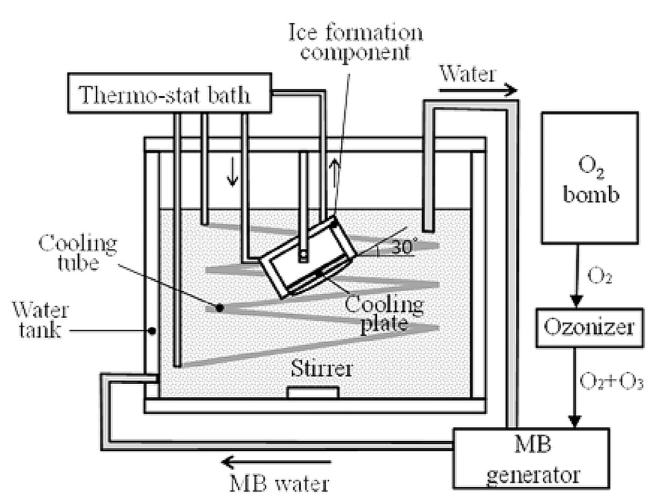

Fig. 1 – Experimental apparatus for formation of ice containing ozone micro-bubbles (Matsumoto et al., 2013).