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Development of W/O emulsion to form harmless ice slurry to human being

Koji Matsumoto[a,*], *Kengo Matsumoto*[b]

[a]*Department of Precision Mechanics, Chuo University, 1-13-27 Kasuga, Bunkyo-ku, Tokyo 112 8551, Japan*
[b]*Nissan Motor Co., Ltd., 17-1, Ginza 6-chome, Chuo-ku, Tokyo 104-8023, Japan*

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ABSTRACT

In order to form ice slurry in ice storage, W/O emulsion was made from water–oil mixture with a small amount of surfactant. And, it was proved that ice slurry could be formed even in a metal vessel, which is expected to improve ice formation rate, without ice adhesion to a cooling vessel wall because of a structural feature of the emulsion. In this paper, authors proposed application of ice slurry to cold storage of foods. In order to apply ice slurry to cold storage of foods, a new harmless ice slurry to human being was formed by cooling a new W/O emulsion made from tap water–edible oil mixture with a small amount of edible emulsifier. And, the fundamental characteristics and availability of new W/O emulsion-ice slurry formed were clarified. Finally, it was concluded that new harmless ice slurry to human being could be fully applied to cold storage of foods.

Développement d'une émulsion huile/eau sans toxicité pour l'homme, pour les coulis de glace

Mots clés : coulis de glace ; émulsion ; huile ; eau ; additif ; entreposage frigorifique ; produit alimentaire

1. Introduction

In a dynamic ice storage system, ice slurry used as the thermal storage material has good fluidity. And a large amount of cold energy can be transported with less pumping work. The dynamic system can also respond quickly to changes in heat load because the ice particles have a large surface area (Moriya et al., 1995; Davies, 2005). However, in the case using a solution, depression in latent heat of fusion of ice due to depression of the freezing temperature occurs, and in the process of ice slurry formation, ice adhesion to a cooling wall also often occurs. In order to solve the above problems, W/O (water in oil) emulsion was developed by one of authors (Matsumoto et al., 2006, 2007, 2008; Matsumoto and Sonoda, 2008). A silicone oil, an amino group modified silicone oil and

* *Corresponding author*. Tel: +81 3 3817 1837; fax: +81 3 3817 1820.
E-mail address: matsumoto@mech.chuo-u.ac.jp (K. Matsumoto).
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tap water were used to form the W/O emulsion. The silicone oil and amino group modified silicone oil are industrial products. And, the silicone oil is hydrophobic, hence, the latent heat of fusion of ice does not drop. Moreover, ice slurry can be formed from the emulsion without ice adhesion to the cooling wall, as water in the emulsion did not directly contact the cooling wall.

Now, application of ice slurry to cold storage of foods is proposed to promote use of ice slurry. As mentioned above, since the conventional W/O emulsion developed by one of the authors is made from the industrial products, it is difficult to apply ice slurry formed by the conventional W/O emulsion to cold storage of foods from the viewpoint of its harmfulness to human being. Therefore, on the basis of authors' past results, harmless W/O emulsion and ice slurry to human being have been developed for application to cold storage of foods. The harmless W/O emulsion is made from a tap water, edible oil and edible emulsifier with a function of surface activity, and the harmless ice slurry is formed by the harmless W/O emulsion.

In this paper, in order to estimate validity of application of the ice slurry to cold storage of foods, the optimal formation conditions of the harmless W/O emulsion and ice slurry are discussed. Moreover, the fundamental characteristics and adaptability of the formed harmless emulsion and ice slurry are estimated from the viewpoints of latent heat of fusion, viscosity, structure of the W/O emulsion, ice formation rate, propagation of supercooling dissolution of the W/O emulsion and ice adhesion to the cooling wall. And, considering a practical application, repetitive formation of ice slurry from the emulsion and reduction in formation cost and viscosity are also discussed.

2. Experimental apparatus and procedure

2.1. Experimental apparatus

An experimental apparatus is shown in Fig. 1 (Matsumoto et al., 2008). A PMP (polymethylpentene) vessel with a volume of 2 l was used. Its height and inner diameter were about 190 and 130 mm, respectively. The number of rotations of stirring was 250 rpm. When ice slurry was made from a W/O emulsion, a cold brine temperature was set to −5.4 °C. Hereafter, the word "emulsion" represents a W/O emulsion. The representative temperature of the emulsion and ice slurry was measured using a platinum resistance thermometer located at a distance of 15 mm from the wall towards the center of the vessel and 60 mm upward from the bottom. A stirring wing made of acryl resin was used because of prevention of ice adhesion to the wing. For detailed description of the experimental apparatus and procedure, please see reference Matsumoto et al. (2007, 2008). In the following discussions, in the case of no note, the vessel used is PMP vessel.

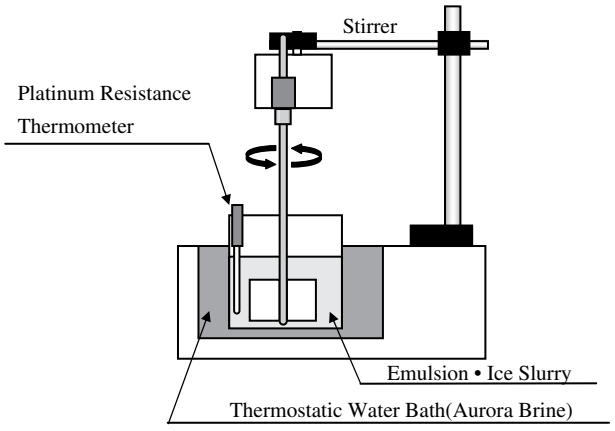

Fig. 1 – Experimental apparatus for formation of ice slurry (Matsumoto et al., 2006).

2.2. Formation condition of emulsion

The emulsion was made from a tap water, edible oil and edible emulsifier. The oil was used to prevent ice adhesion. The composition of the emulsion is shown in Table 1. In the experiments, water contents of the emulsions were 70 and 80%. For example, an emulsion with a water/oil volumetric ratio of 7:3 is designated (7:3). The edible emulsifier must have a function of surface activity and hydrophobic property.

A polyglycerol fatty acid ester was used as an edible emulsifier. Its constitutional formula is shown in Fig. 2. The emulsifier is widely used to process various foods.

A medium chain triglycerides and rapeseed oil, which are edible oils, were used. Hereafter, the word "MCT" represents medium chain triglycerides.

After the edible oil and emulsifier were put into the vessel, they were stirred with 250 rpm for 3 min under room temperature. The edible oil and emulsifier were continuously stirred with 250 rpm, dropping gradually a small amount of water into them, and the emulsion was formed. At that time, temperature of the formed emulsion was about 58 °C. After that, the emulsion was gradually cooled to room temperature (cooling rate: about 0.3 °C/min) with 250 rpm.

In this paper, the definition of stable emulsion is that W/O type structure can be kept without demulsification due to stirring. While, authors judge that the emulsion is unstable, when the existence of water droplets separating partially from the emulsion is confirmed even if the emulsion is stirred.

2.3. Optimal dosage of emulsifier

It is supposed that an amount of emulsifier added affects greatly the characteristics of the formed emulsion and ice slurry. So, three standards were given to determine optimal dosage of emulsifier:

(1) It is possible to form an emulsion stably.
(2) Ice slurry can be formed stably by the stable emulsion for 3 h after end of propagation of supercooling dissolution without ice adhesion to a cooling wall.

Table 1 – Composition of emulsions.

Ratio of water to oil	(7:3)	(8:2)
Tap water (ml)	770	880
Oil (ml)	330	220
Emulsifier (vol%)	0.01–0.3	0.01–0.3