Comparison of Supercooling Probability in Carbonated Water with Different Levels of Dissolved CO_2

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Summary

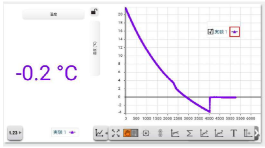
The purpose of this study was to clarify how dissolved gas (CO_2) affects the probability of supercooling. These experiments were conducted using carbonated water samples prepared at three different levels of degassing. The results showed that as degassing increased, the probability of freezing decreased, indicating that dissolved CO_2 promotes ice nucleation and suppresses stable supercooling. In addition, some carbonated water samples remained at a supercooled state even below the freezing point and did not freeze in response to external stimuli. This behavior cannot be fully explained by previous studies on supercooled pure water, suggesting that factors specific to carbonated water may be involved.

1.Background

Water can remain in a liquid state even when it is cooled below its freezing point(0℃); This phenomenon is called supercooling.

Supercooling

When supercooling occurs, water remains in a liquid state even when it is cooled below its freezing point (0℃). A supercooled liquid can easily crystallize when subjected to a small external disturbance or when impurities within the liquid act as nucleation sites.*1



Picture.1
Temperature change of supercooling water

Supercooling can control the freezing in liquids.
⇒Supercooling can be applied to long-term preservation of fresh foods.*2

avoiding quality deterioration caused by freezing / preserving under temperatures lower than a typical fridge.

2.Purpose and Signification

Although many previous studies have investigated impurities that promoted freezing in supercooled water, **the amount of dissolved gas** is often neglected and treated as a fixed condition.

In this research, we systematically varied the amount of the dissolved gas content in water, and examined the effects of **dissolved CO_2** and **gas bubbles** on the breakdown of the supercooled state.

3.Method

【expt1. Probability of Supercooling at Different Levels of Dissolved CO2】

Carbonated water was degassed to three different levels. Twenty 100mL samples were prepared at each level.

To quantify degassing, the procedure was standardized by "dropping each sample from a height of 20 cm a set number of times"

Sample A
No degassing

Sample B
Degassed 10 times

Sample C
Degassed 20 times

All samples were completely immersed in an **ice–salt bath** at **−3.0 ℃** for **1 hour**. Immediately after cooling, each sample was observed based on the following three points: 1)Water temperature 2)Presence or absence of freezing 3)Freezing response to external stimulation.

【Pre-expt. Evaluation of Dissolved CO_2 Content】

To confirm that the three degassing levels were clearly distinguishable, the degree of degassing was evaluated using the following three indicators: 1)pH 2)Mass 3)Volume of gas contained in bubbles per unit volume

4.Results

【Pre expt.】

Table1. Comparison of Evaluation Methods for Dissolved CO_2 Content(rank)

	Clarity of Results	Reliability of its Results
pH	3rd	1st
Mass	2nd	3rd
Volume of gas per unit volume	1st	2nd

The dissolved CO_2 content was successfully distinguished using **the volume of gas in bubbles per unit volume.**

【expt1.】

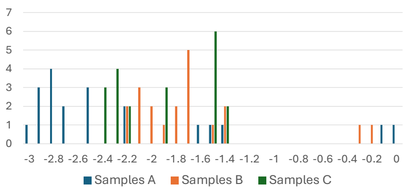
Table2. The Results of expt.1

	The Number of Frozen Samples (rate) [個]	The Average Temperature [℃]	The Number of Samples Frozen by Stimulation
Samples A	4 (20%)	−2.23	0
Samples B	1 (5%)	−1.83	1
Samples C	0 (0%)	−1.96	1

・As the dissolved CO_2 content decreased, the number of frozen samples decreased.

・Even when samples were cooled below the freezing point (the freezing point of carbonated water is 0℃), most samples did not form ice crystals, even after external stimulation was applied.

Graph2. Number of Samples at Each Post-Cooling Temperature



5.Discussion

As the probability of freezing decreased with increased degassing, dissolved CO_2 is likely to promote ice nucleation in supercooled water.
Furthermore, carbonated water that remained supercooled after cooling exhibited an unusually stable supercooled state and resisted freezing even when stimulated. This behavior differs from that of typical supercooled water.

6.Conclusion and Future work

This study revealed that the probability of supercooling in carbonated water increases as the amount of dissolved CO_2 decreases. In future studies, we aim to improve quantitative control of dissolved CO_2 content and its agitation conditions. Additionally, control experiments using pure water and fully degassed carbonated water will be conducted to determine whether the observed behavior is specific to carbonated water.

7.References

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