CT Observation of State of Fine Ice Crystals in Frozen Foods

Quantitative evaluation of freezing method that keeps texture of foods

Achievements

- Fine ice crystals in foods frozen by a home refrigerator with an instantaneous freezing function based on supercooling* were successfully observed by high-brilliance X-ray computed tomography (CT).
- Conventionally, frozen foods have mainly been evaluated after thawing, but a quantitative evaluation method using high-brilliance X-rays have been developed for frozen foods before thawing. The effects of freezing technology on the growth of ice crystals in foods have been confirmed.

R&D institution: Mitsubishi Electric Corporation

***Supercooling:** The unstable state in which substances such as water exist as liquids even at temperatures lower than its freezing point. For example, supercooled water exists as a liquid even below 0 °C.
****SUNBEAM:** Contract beamlines at SPring-8 managed by the SUNBEAM Consortium consisting of 13 companies. There are two beamlines: an insertion device (ID) beamline (BL16XU) and a bending magnet (BM) beamline (BL16B2).

Principle of freezing based on supercooling

When water starts to freeze, ice nucleus forms. Then ice crystals grow around the ice nucleus. Conversely, water will not freeze even at a temperature lower than its freezing point (0 °C) unless an ice nucleus forms. When a fluctuation in temperature or an impact is applied to supercooled water, an ice nucleus abruptly forms and the freezing process occurs throughout the water upon the formation of ice nucleus. The ice crystals that form in supercooled water are smaller than those frozen conventionally.

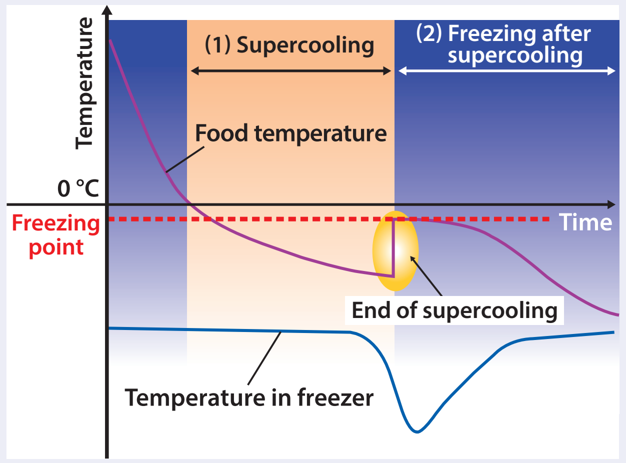
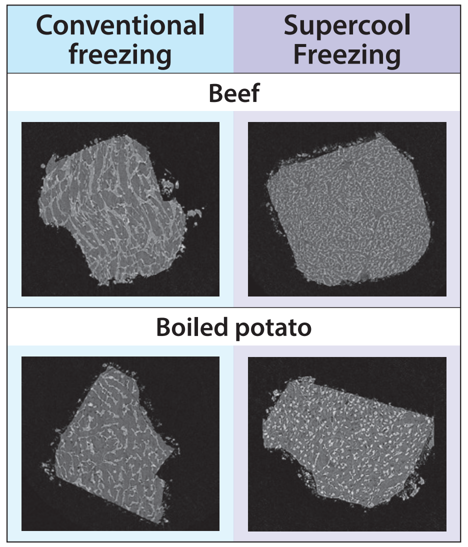


Diagram of transition of temperature in supercooling and subsequent freezing

CT imaging at BL19B2

Beef (upper) and boiled potato (lower) frozen by conventional freezing (left) and Supercool Freezing (right) were compared. The regions with bright contrast are food fibers or proteins, whereas the regions with dark contrast are ice crystals. The ice crystals are distributed more widely in the samples frozen by Supercool Freezing than those frozen by conventional freezing. It was demonstrated that smaller ice crystals have less effect on the tissue structure of frozen foods.



Role of SPring-8

Background

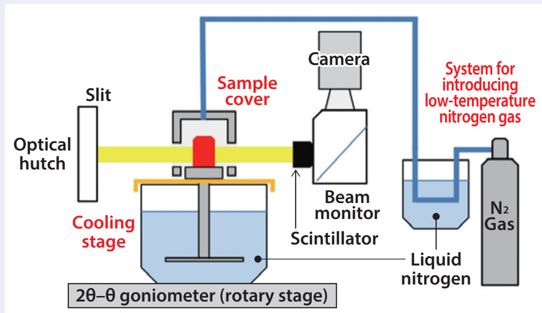
When frozen foods such as meats, fishes, and vegetables thaw, losses of moisture, called drips, from foods often occur because ice crystals grown in foods break the cell tissue of the foods. Drips is considered to deteriorate tastes of foods after thawing. To solve this problem, an instantaneous freezing technique called Supercool Freezing, which is based on supercooling, was developed. It was found that ice crystals in foods frozen by Supercool Freezing are smaller than those in foods frozen by conventional freezing. Smaller ice crystals have a significant effect on suppressing drips and maintain the texture of foods. Methods to measure quantitatively the size of ice crystals in frozen foods are required. The conventional methods involve indirectly observing pieces of stained or frozen/dried foods with limited applications for food samples. Therefore, direct nondestructive methods for observing the state of ice crystals in entire food samples have been required.

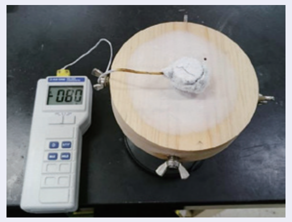
Results

X-ray CT is effective method to observe the internal state of substances nondestructively. However, conventional X-ray CT equipment using a wide energy band of X-ray are unable to distinguish substances with small differences of X-ray absorption coefficients, such as foods and ice crystals.

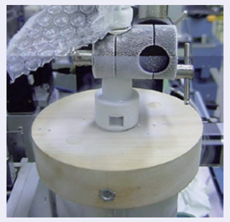
High-brilliance monochromatic X-rays at SPring-8 enables detailed imaging of the internal state of substances such as foods and ice crystals. We carried out a preliminary experiment at BL19B2 (Engineering Science Research I), which is well equipped with sample freezing systems. Afterwards, we introduced a frozen imaging system at BL16B2 of **SUNBEAM****. Using these systems, beef, tuna, and boiled potato, which were frozen with Supercool Freezing and conventional freezing, were photographed while being continuously rotated by 180° to obtain a few hundred tomographic images. The cross-sectional images of the ice crystals were compared accordingly to the freezing methods. Supercool Freezing leads to smaller size of ice crystals and less distort tissues of foods than conventional freezing methods.

Frozen imaging system at BL16B2





(a) Cooling stage

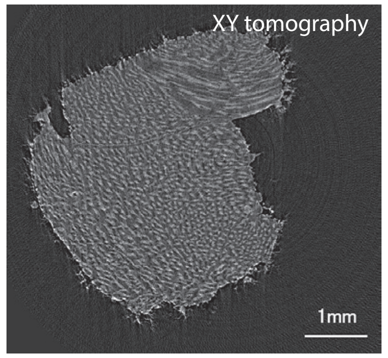


(b) Cooling stage with sample cover

A holder containing a frozen food was placed on a rotary sample stage set in the experimental hutch and three-dimensionally photographed by X-ray CT system. A equipment blowing low-temperature nitrogen gas to samples was set at the upper cover of the holder to prevent thawing of the ice and frost on the holder during photography. This system enabled us to continuously obtain images at intervals of 250 ms while keeping the temperature of samples at approximately −30 °C and rotating the stage by 180° at a rate of 2.2°/s.

CT image obtained at BL16B2

The CT image of a frozen beef indicates that the sample can be clearly photographed with negligible thawing and little frost during observation.



Refrigerator with Supercool Freezing function

This series of refrigerators first appeared on the market in 2007, and such refrigerators with improved functions are still commercially available.