Comparative study of supercooling freezing with conventional freezing in different foods（様々な食品における過冷却凍結と通常凍結の比較研究）

[博士]

博士学位論文内容要約
Summary

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論文題目 Title	過冷却を利用した食品の高品質凍結 Comparative study of supercooling freezing with conventional freezing in different foods		

1. Introduction

Freezing is one of the latest food preservation methods which can preserve the original color, texture, taste and nutritional quality in the foods compared to other methods of preservations. However, the formation of the large ice crystals has the main hurdles in the freezing. To reduce the ice crystals sizes and microstructure damage supercooling freezing process was used. During the supercooling process, the water cools below the freezing point, after breaking supercooling homogenous small ice crystals were formed which helps to reduce the microstructural damage in the foods. The supercooling freezing by using different methods was widely studied but no previous study presented on the quality effect of supercooling freezing at atmospheric pressure.

2. Objectives

The objective of this research was to investigate the freezing after supercooling enabled with slow and constant cooling on the atmospheric pressure in different foods and compare the quality with conventional freezing methods.

3. Materials and materials

3.1 Sample

Different food sample (tofu, pork loin, potato) was purchased from the supermarket, and paneer was prepared in the laboratory from non-homogenous milk.

3.2 Freezing trials

Different trials have been executed for the freezing and supercooling. The supercooling was realized with the help of a low-temperature incubator (Fukushima Company FMU-0541) and for the conventional freezing, the static air freezer of -80°C and -20°C was used. The Hioki data logger (HI Logger series LR8431-20) was used to measure the temperature. After completion of the freezing, the samples were stored on the -80°C and -20°C deep freezer for storage.

3.3 Texture

The compression profile after thawing was obtained by the textural analyzer (TA, XT Plus, Stable Microsystem U.K). The parameter setting was the probe P/75(Paneer, Tofu, Potato), P/3 (Pork) test speed was 1 mm/s, final displacement was 80% of the original height.

3.4 Drip loss

The drip loss was measured individually for every frozen sample after completion of air thawing at 20°C for 20 min inside the incubator. Every sample was kept inside the dry porcine disc separately; initial and final weight was noted. Drip loss was measured as:

$$\text{Drip loss } = \frac{(\text{Initial weight} - \text{Final weight}) \times 100\%}{\text{Initial weight}}$$

3.5 Microscopic observation

The microscopic observation was carried out by the 1. Optical microscope and 2. X-ray CT scan methods. 1. Optical microscopic method: The sample was prepared in the cryo- film and observed in the Keyence BZ9000 fluorescence microscope. 2. X-ray CT scan methods: The sample was prepared by freezing drying and scan with the X-ray CT scan, further different software was used to obtain 3D (dimension) and 2D images.

3.6 Ice crystals morphology

The ice crystals morphology was carried out by the structure separation methods from the 3D images automatically from the software.

3.7 Statistical analysis

One way analysis of variance was carried out using SPSS (IBM SPSS 1.60) where differences between averages were resolved by the Turkeys test for comparison. Values with a $p<0.05$ were considered as significantly different. Where the p-value is the probability of obtaining a result under the null hypothesis during experiments.

4. Result and discussion

The effect of the supercooling freezing application on the quality in different foods; paneer, tofu, pork tenderloin, and potatoes was analyzed. The supercooling freezing tends to reduce the microstructure damage by the formation of the small ice crystals in all foods. The food which has no cell structure such as paneer, tofu, and blanched potatoes has the most effective compare to the food having cell structure (pork tenderloin and non- blanched potatoes).

The supercooling freezing was firstly introduced in the paneer sample. The different trials were made in different types of the freezer. For the sample, different milk was used to prepared paneer in the laboratory. However, the quality parameters have highly fluctuated. The non-homogenous milk was used to obtain a

good quality of paneer. After the preparation of the paneer, it was frozen by three different methods i.e., slow freezing, rapid freezing, and supercooling freezing. After the freezing, the quality was analyzed by observing texture, drip loss, and microstructure and compared with a fresh sample. In this research, the supercooling freezing was found as the best method of freezing to reduce microstructure damage and drip loss as well as good texture close to the fresh sample. It is finally concluded that the supercooling freezing has the tendency to produce small homogenous ice crystals, which makes less damage in the microstructure, resulting in small textural degradation and less drip loss.

Furthermore, supercooling freezing was applied to the momen tofu and the quality was compared with the conventional freezing, including the influence of storage at different temperatures (-20°C and -80°C) for one month. Different freezing rate after the breaking of supercooling was analyzed and sensory evaluation was carried out after frozen storage. From this research, a higher rate of freezing after the breaking of supercooling was found to have the ability to reduce drip loss, increase the textural quality and improve the microstructure damage. Similarly, it was investigated the homogenous ice crystals had low potential in recrystallization. From the result of sensory evaluation after the different methods of freezing, the tofu sample prepared by supercooling slow freezing was rejected even it had the small ice crystals, low microstructure damage, and high texture. The tofu stored at a low temperature below -40°C was only acceptable during a week's storage period.

In addition, the effect of supercooling freezing was applied in the pork tender lion and analyzed the quality up to 3 month storage period at -20°C. The impedance, texture, drip loss and ice crystal observation were carried for the freezing damage assessment. The different methods of thawing were carried out to analyze the drip loss. According to the results, the impedance and texture didn’t show any significant difference in the quality after freezing. The ice crystals sizes are found small in supercooling rapid freezing compared to other methods with low drip loss in the RT thawing process. Similarly, the drip loss after different freezing conditions has no significant difference in the low-temperature thawing i.e., refrigeration thawing and ice water thawing, compared to high temperature thawing i.e., room temperature thawing and tap water thawing. In conclusion, for the good frozen quality of pork tenderloin, it should be frozen with supercooling rapid freezing and thawed in the refrigeration temperature.

Moreover, the effects of supercooling freezing on the plant cell (blanched and non-blanched potatoes) were studied and tried to find out the proper freezing methods for potatoes in terms to achieve good quality. The quality after freezing in non-blanched potatoes shows different characteristics from blanched potatoes. The application of supercooling freezing reduces the ice crystals sizes, although the quality after thawing is almost unchanged in drip loss in the non-blanched potatoes. However, in the blanched potatoes, the quality after freezing has well improved in terms of drip loss and ice crystals sizes but the texture remains almost unchanged. In conclusion, it was noticed the supercooling freezing shows the ability to reduce the ice crystals sizes but the quality may not depend upon the sizes of the crystal.

5. Conclusion

These studies demonstrate that supercooling freezing tends to reduce the ice crystal sizes although the rate of freezing is small. The ice crystals sizes were further reduced when the rate of freezing is increased after the breaking of supercooling. However, it is indicated the ice crystals sizes may not dominate the acceptability of the food products. Each food has own structure and chemistry due to which quality parameter may vary. In the case of animal meat, the quality remains almost constant after applying supercooling rapid freezing and thawing in refrigeration temperature. Overall, the supercooling freezing can reduce the ice crystals sizes than conventional methods of freezing; however, the effect of quality improvement may be different which depends on the different nature of the foods.