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Effect of ultrasound irradiation on some freezing parameters of ultrasound-assisted immersion freezing of strawberries

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ABSTRACT

In this study, the effect of ultrasound irradiation temperature and ultrasound intensity on the freezing and nucleation in strawberry samples was studied. The application of ultrasound irradiation at different temperatures was able to induce nucleation at lower degree of supercooling compared to the control samples. The achieved degree of supercooling in the ultrasound irradiated strawberries was linearly correlated to the ultrasound irradiation temperature. At the ultrasound irradiation temperature of −1.6 °C, the characteristic freezing time (CFT) was significantly shorter than that in the control sample ($p < 0.05$). The application of ultrasound at higher intensities was found to effectively shorten the CFT. The degree of supercooling in ultrasound irradiated samples was not linearly correlated to ultrasound intensity. In conclusion, the combination of ultrasound irradiation temperature and intensity can be effective in controlling nucleation and freezing processes of perishable fruits such as strawberry.

Effet du rayonnement aux ultrasons sur certains paramètres de congélation de la congélation des fraises par immersion assistée par ultrasons

Mots clés : Nucléation ; Congélation ; Ultrasons ; Fraises ; Surfusion

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1. Introduction

Strawberry (*Fragaria* × *ananassa Duch.*) is a very popular fruit available during the spring-summer period. Compared to other fruits, strawberry is highly appreciated for its excellent organoleptic properties, such as red color, smooth texture, and unique taste and flavor. Moreover, it is a good source of ascorbic acid and other antioxidants (Patras et al., 2009). However, it is also readily perishable due to its high softening rate and susceptibility to fungal attacks (Lara et al., 2004). Therefore, it is important to find a suitable method to extend its shelf-life and maintain its quality for better commercialization.

Freezing is the most suitable method to preserve the quality of food products and has gained widespread attention. Generally, preservation by freezing provides food products with better taste, texture and nutritional value than any other preservation methods. This is because freezing combines low temperature and low water activity (a_w) which results from cryo-concentration of liquid phase during ice crystal formation (Blanda et al., 2009). However, if freezing method is used inappropriately, it can easily result in cellular damage and several physico-chemical and organoleptical deteriorations which ultimately lower the product quality.

The crystallisation of ice in food product is considered to be the critical step in determining the efficiency of the freezing process and the quality of frozen foods (Inada et al., 2001). It well-known that the crystallisation phenomenon takes place through the formation of nuclei (nucleation) followed by subsequent crystal growth. Nucleation is the preliminary requirement of the commencement of freezing, and the occurrence of nucleation needs a driving force called supercooling. The degree of supercooling before the commencement of the phase transition stage is strongly related to the freezing parameters and ice crystal size. In general, high supercooling degrees can induce smaller ice crystals occurring evenly inside or outside the cells. On the other hand, low supercooling degrees result in the formation of large ice crystals in the intercellular space (Kiani et al., 2013a). In addition, the crystals growth is also an important step during the freezing of food products and can affect the size and distribution of ice crystals (Kiani et al., 2011). Therefore, a method to control and affect the nucleation and/or crystal growth stages would be favourable for protecting the cells or tissues.

Power ultrasound is increasingly being researched and has been as a novel technology to improve the freezing and crystallization process. It has been reported that ice nucleation in different experimental materials can be controlled by the application of ultrasound irradiation (Comandini et al., 2013; Inada et al., 2001; Kiani et al., 2012a, 2013a). Chow et al.(2003, 2005) also reported that ultrasound can induce secondary nucleation and affect the crystal growth by fracturing the ice crystals. Moreover, other studies have shown that ultrasound irradiation is effective in enhancing the convective heat transfer rate (Kiani et al., 2012b; Li and Sun, 2002).

Although the potential of power ultrasound in assisting and accelerating the freezing processes of fruit and vegetable products have been studied quite extensively (Comandini et al., 2013; Delgado et al., 2009; Li and Sun, 2002), however, only a few research is available to quantify the effects of power ultrasound on the freezing parameters such as the degree of supercooling and nucleation temperature. So in this study strawberry was used as the experimental material to quantify the effects of ultrasound irradiation temperature and ultrasound intensity on freezing and nucleation. In particular, the effects of power ultrasound on the duration of supercooling phase and on the start of ice nucleation have been systematically investigated.

2. Materials and methods

2.1. Raw materials

Fresh strawberries (*Fragaria* × *ananassa* Duch.) were purchased from a local market in Wuxi, China and used in this study. The strawberries of uniform size, shape and ripening stage were selected and then stored in a household refrigerator at a temperature of 5 ± 1 °C until used. All the strawberry samples used in these experiments were from the same batch.

2.2. Ultrasound assisted freezing equipment

An ultrasound-assisted freezing equipment (Ningbo Scientz Bio-technology Co., Ltd, Ningbo, China) was used for immersion freezing of strawberry samples. The freezing unit consisted of an ultrasonic bath system and a refrigeration system. The ultrasonic bath was equipped with six piezoelectric transducers, an ultrasonic generator, and a stainless steel tank (Internal dimensions: 30 × 25 × 25). Unidirectional ultrasound waves were applied to the freezing medium in the tank at a frequency of 30 kHz. 30% (w/v) $CaCl_2$ solution was used as the freezing medium, and its temperature was maintained at −25 °C by the aid of a refrigeration unit (see Fig. 1).

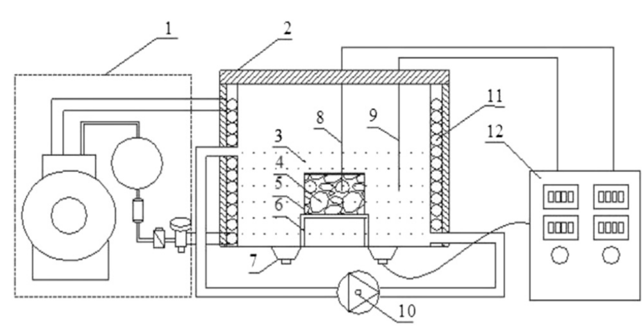

Fig. 1 – Schematic diagram of experimental apparatus (1. refrigerating system; 2. ultrasonic tank; 3. coolant; 4. samples; 5. a perforated cage; 6. samples holder; 7. ultrasonic transducer; 8 and 9. thermometer probe; 10. refrigerated circulator; 11. evaporator; 12. control panel).