Modelling a High-Pressure Shift Freezing Process

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Freezing is a widespread food preservation technology, as it ensures high food quality with long storage duration, and also because it has an extended implementation area (meat, fish, fruit and vegetables, dairy and egg products, etc.). Despite the benefits, freezing of foods can also cause undesirable changes in their texture and organoleptic properties, and its main drawback is the risk of food damage due to the formation of ice crystals. The size and location of the crystals formed during the freezing process depend on the freezing rate (slow freezing produces large crystals, whilst rapid freezing promotes intensive nucleation and the formation of small ice crystals) and the final temperature of the process. The general purpose of food technologists working on this area has been to create a homogeneous matrix of small ice crystals. Improvement of known freezing methods and development of new techniques are important research goals for the food industry at present. With the recent increasing impact of High-Pressure technology on Food Processing, there has been a lot of research dealing with the potential applications of High-Pressure effects on ice-water transitions, given that pressure decreases the freezing and melting point of water to a minimum of $-22°$C at 207.5 MPa, namely High-Pressure Freezing and Thawing.

One particular case of High-Pressure Freezing is High-Pressure Shift Freezing (HPSF), in which phase transition occurs due to a pressure change that promotes metastable conditions and instantaneous ice production. On expansion, pressure release occurs instantaneously throughout the product (Pascal principle), and subsequently, its temperature decreases. Large-scale supercooling takes place throughout the sample, which implies high ice nucleation velocities. Different authors have proved experimentally that ice nucleation occurs homogeneously throughout the whole volume of the product and not only on the surface, as they have found small granular shape ice crystals disperse throughout the resulting sample for several products. When comparing HPSF to classical freezing processes, important reductions of freezing times have been reported.

In this work we derive a model for a HPSF process of a solid type food, with a big and small filling sample vs pressurizing media ratio. We present a heat transfer model derived from an enthalpy formulation based on volume fractions dependent on temperature and time, that simulates the temperature profile during a HPSF process, calculating also the amount of ice instantaneously formed after expansion and the supercooling of the sample.

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