Effect of freezing temperature on cooling rate and quality of salmon: experimental research and numerical modeling

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Proper thermal processing allows to deliver healthy and quality foods to the consumer. The evolution of the temperature of the salmon meat during the freezing process affects the microstructure and quality parameters such as color and texture due to the formation of ice crystals in the food. Consequently, the objective of this investigation was to study the ice crystal size, color, and texture of Atlantic salmon samples frozen at -20°C and -80°C. A three-dimensional unsteady conjugate model of turbulent heat natural convection in the air inside the freezer and heat conduction with the phase change of water in the salmon meat allowed to estimate the cooling rate and predict changes in food quality parameters. Then, the methodology used incorporates experimentation and computational modeling of the salmon freezing process. Color and texture profile analysis were carried out on the frozen salmon samples and the results were compared with a fresh sample stored at 4°C. In addition, a histological technique was used to observe by light microscopy the spaces left by the ice crystals in the salmon tissue during freezing. On the other hand, the Finite Volume Method with the SIMPLEC algorithm and a non-uniform structure staggered mesh solved the conjugate turbulent mathematical model, including the continuity, linear momentum, energy, and k - ? turbulence model equations. The numerical simulations were performed with an in-house code written in Fortran. The experimental results indicated that when the freezing temperature decreased, a whitish effect was observed on the surface of the food and the size of the ice crystals decreased by an average of 40%. Lightness increased from 15% up to 30% when the food was frozen at -20°C and -80°C, respectively. The numerical results obtained include the unsteady description of streamlines, temperature, cooling rate, and dimensionless heat flux, calculated in terms of the local Nusselt number on the meat surface. The conjugate model allowed to relate the calculated freezing rate with changes in the luminosity of salmon samples using the experimental results to predict the changes in the color of the pieces of salmon which is a key quality parameter in salmon price.