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CFD modelling of combined blast and contact cooling for whole fish

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Introduction

Fish quality is highly influenced by the cooling method which is applied during processing. Earlier research has shown that precooling whitefish fillets to a superchilled temperature ($T_{f,i}$= -0.9 °C) in a CBC (Combined Blast and Contact) - cooler (see Fig. 1) results in prolonged storage life. A CFD (Computational Fluid Dynamics) model which can simulate the effects of the CBC-cooling might save time and cost when predicting the necessary chilling time for a product when its thermal properties are known.

The main purpose of this work is two fold: (1) conduct experiments to determine the required settings in the CBC-cooler which cause superchilling of the flesh for whole fish, (2) to generate CFD models in 2D and 3D to simulate the temperature behaviour inside a whole cod fish during CBC-cooling and succeeding storage.

Figure 1. Inside the CBC-cooler, fillets are laid down on the skin and superchilled with blast and contact cooling.

Materials and methods

CFD models were built in two and three dimensions in ANSYS FLUENT 12 (see Fig. 3) to simulate the superchilling process inside the CBC-cooler, and were compared with experimental results from two tests. The temperature inside the CBC-cooler and the chilling period for the first test were -7.4 °C and 6 minutes, respectively. The corresponding values for the second test were -14.1 °C and 14 minutes.

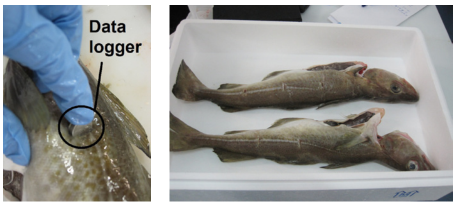

Figure 2. The temperature inside the fish (cod) was monitored with temperature data loggers, which were inserted into the fish flesh (left). After the CBC-cooling the fish were placed in EPS boxes (right) which were stacked on a pallet inside a chilled storage.

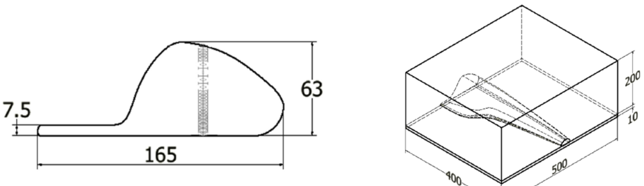

Figure 3. Two models were used for the comparison, a 2D model (left) and a 3D model (right). The 2D model is a cross section of the 3D model where it is thickest, therefore including the highest amount of flesh.

Conclusions

From the results presented in this work it is assumed that a 2D model with a refined surface mesh gives a good prediction of the temperature distribution within a cod fish during CBC-cooling. The comparison of the storage period was not as good, indicating that the boundary conditions were not accurate enough. One should, on the other hand, not neglect the 3D effects which cause heat extraction from the tail part of the cod.

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Results

A thermal contact resistance between the aluminium belt and fish was determined to be R = 0.028 m2K/W and the RNG turbulence model was selected to simulate the air flow in the computational domain. The CFD model which simulated the settings in the second test resulted in a good comparison with measurements. Three meshes were compared (containing 18,000; 120,000 and 130,000 cells) and the one, which was most refined at the fish surface, generated the best results.

The three dimensional model (containing 1,345,000 cells) was applied to the latter test to investigate the effect of the variable thickness along the fish on the temperature distribution. The CFD model resulted in a good comparison, and showed that 3D effects were in place (see Table 1 and Figure 4).

A simulation of a 30 minute CBC-cooling and a storage period of one hour showed that the fish flesh did not reach initial freezing. Hence, it was assumed that a lower temperature or a longer chilling period needed to be applied for a whole fish of this size (m = 2.5 kg).

Table 1. Comparison of the RMS error (°C) for the best 2D case and the 3D case.

Pos. no.	Dist. From belt [mm]	2D	3D
1	45	0.19	0.09
2	13	0.18	0.28
3	8	0.32	0.35

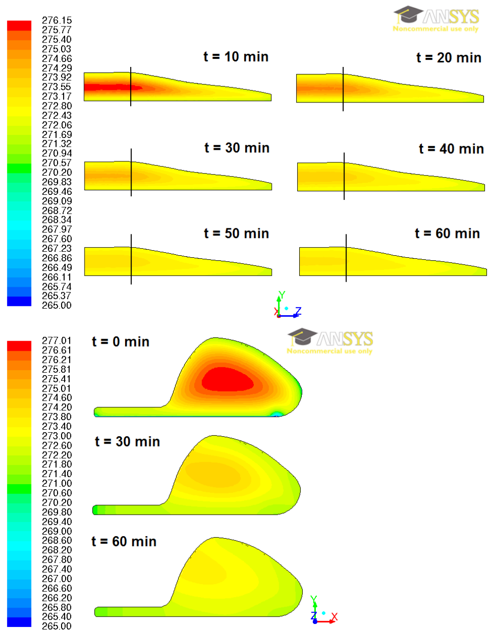

Figure 4. Temperature distribution (K) in the length cross section (above) and the width cross section (below) of the fish after the CBC-cooling to a storage period of one hour.

Acknowledgements

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