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Freezing time of the impingement tunnel freezer enhancement

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Abstract

The quality of frozen foods which have been frozen from the impingement tunnel freezer is not only depending on the fastest freezing time but also the uniformity of the product core temperature along the conveying belt width of the freezer. In this study, the modification of pressured-chamber of the impingement tunnel freezer can enhance the uniformity of the air velocity by changing the wind entry channel. The results of all models which have been analyzed by CFD have vortexes in pressured chamber. The vortexes bring the negative impact on the uniformity of the air velocity along the conveying belt width which can create the over freezing problem. To minimized the over freezing of food product, the author propose to use mix models to use 2 of Existing with DI237 model that can increase the minimum average air velocity 4.3% with better uniformity 14.72%.

Keywords: Impingement freezer, Computational Fluid Dynamic (CFD), Uniformity of air velocity, Pressured chamber, Vortexes

1. Introduction

Air Impingement technology has not been used only in textile, paper, electronic, glass industries but also in food processing such as drying, baking and freezing [1]. The freezing process using the air impingement technology can deliver the high freezing rate. The quality of the frozen food is strongly depending on the freezing rate. Normally, the lower freezing rate causes the formation of large ice crystals which damage the food's cellular structure, leading to bad quality in food texture [2]. The freezing air velocity is one the important factors affecting the freezing rate as same as the food dimension and the freezing air temperature [3].

In production line, the target freezing time of each product must ensure every pieces of product must be under -18°C core temperature. The Shushi shrimp freezing times as shown in Figure 1 are 7 minute to 8 minute and 10 second. The target freezing time at 8minute and 10 second must be selected while some product could expect over freezing.

Many mathematic analysis models have been use in modeling and simulation studies on impingement technology concerned with rate of heat transfer [4-7] which correlate with the freezing rate and freezing time

The objective of this study is reducing the uneven freezing time by increasing the uniformity of the freezing air velocity along the conveying belt width of the tunnel impingement freezer that can minimize the food product over freezing. The CFD is applied to the modification of air entry channel to simulate the air flow and air velocities which are discharged from pressured chamber.

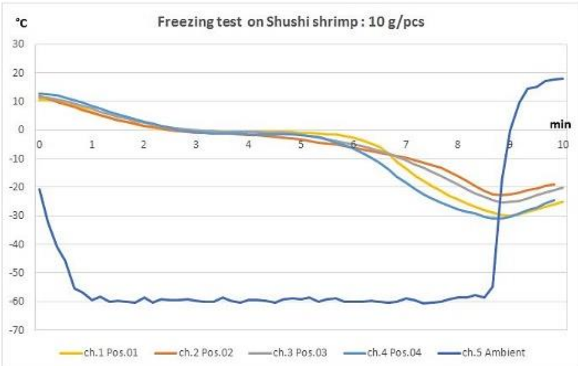

Figure 1 Product core temperature along the conveying belt width

2. Materials and methods

2.1 Tools and equipment

One module of the impingement tunnel freezer contains with 3 pressured chambers is selected to this study as shown in Figure 2. The freezer can perform with low freezing air temperature from -35 to -60 °C. The measurement of air velocities are collected by the portable data logger measuring device, TESTO 454.

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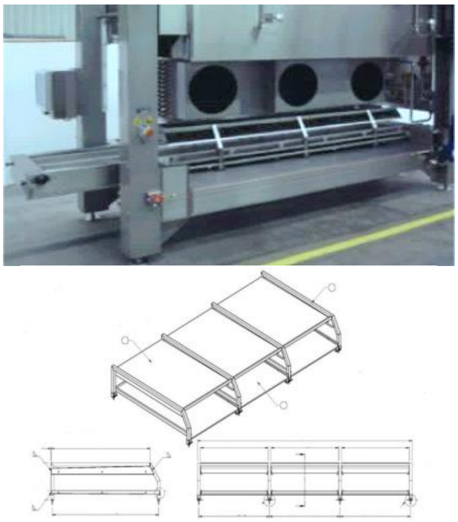


Figure 2 the single module of impingement freezer

2.2 Method

Existing model and five of simulate models have been analyze by CFD,ANSYS version 14. The turbulent fluid flow is applied to the model with the boundary condition as shown in Figure 3.

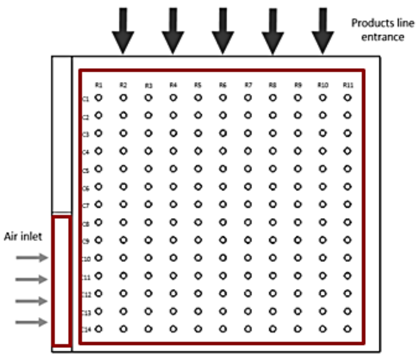


Figure 3 The air inlet and exit airflow boundary areas in Pressured Chamber

The freezing air temperature is -50°C with hexahedral element is applied to the model with 569,982 nodes and 538,063 elements.

2.2.1 Existing model

Using the simplified and mesh model [8] apply to the pressured chamber of the impingement freezer as shown in Figure 4.

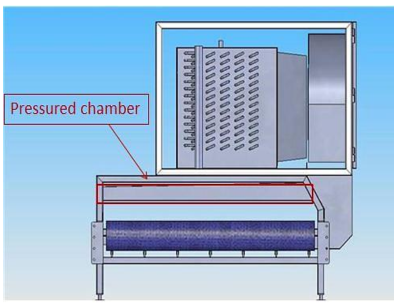
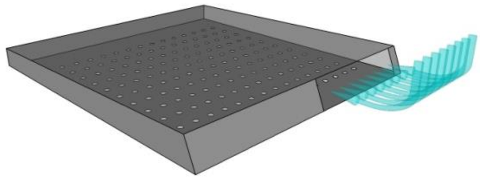


Figure 4 The section of the impingement freezer

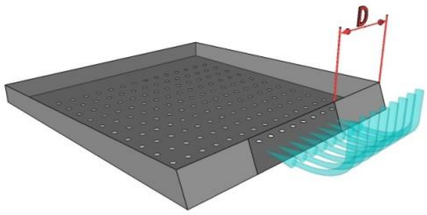
The pressured chamber has 154 nozzles with 20mm diameter. There are 11 nozzles along conveying belt width and 14 nozzles on another side

2.2.2 Simulate model

The air entry channel is the inlet port for the freezing air from the fan blower entering into the pressured chamber. By changing the positions of the air entry channel are proposed to the simulate study. However, due to the limitation of the physical dimension of the freezer, five models of the new positions of the air entry channel can be simulated.



(a)



(b)

Figure 5 Air entry channel to the pressured chamber

The models are DI42, DI107, DI72, DI237 and DI302. All the numbers in the models are represented the distance “D” in mm. as shown in Figure 5.

3. Results

As explained above, the entire models of air entry channel has been simulated with ANSYS with same initial and boundary conditions [8].

3.1 Air streamline

The presence of the air stream line from all simulate models show the vortexes in the difference area in pressured chamber as shown in Figure 6.

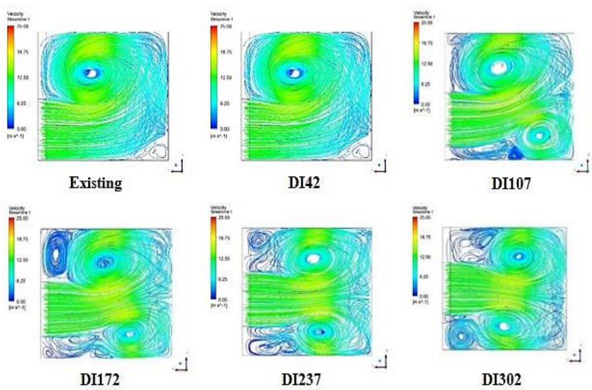


Figure 6 Vortexes in air streamline

3.2 Air velocity

According to Table 1, the vortex phenomenon gives the variation of the average air velocity along the conveying belt width of the tunnel freezer.

Table 1 The Freezing air velocity

	Freezing air velocity (m/s)			
Model	**Average**	**Variation***	**Max**	**Min**
Existing	12.29	1.65	14.18	9.59
DI42	11.16	1.61	13.34	8.38
DI107	11.08	1.49	13.28	8.35
DI172	11.07	1.56	13.22	8.83
DI237	10.98	1.94	13.13	7.04
DI302	11.00	1.56	12.89	8.33

Remark: *Variation: Calculated by standard deviation of average air velocity

Only DI237 model give a higher variation while other new models give lower than the existing model. However, the minimum air velocities are lower than existing which might effect on the freezing time.

4. Discussion

By combine the models for 3 pressured chambers, the 2 of Existing with DI237 can deliver highest minimum average air velocity and the 2 of Existing with DI302 can deliver lowest variation as shown in Table 2.

Table 2 The Freezing air velocity for 3 pressured chamber

	Freezing air velocity (m/s)			
Model	**Average**	**Variation**	**Max**	**Min**
3 Existing	12.29	1.65	14.18	9.59
2 Existing + DI237	11.85	1.39	13.77	10.01
2 Existing + DI302	11.86	1.37	13.68	9.84

5. Conclusions

To minimize the over freezing of food product problem, the author propose to use mix models to use 2 of Existing with DI237 model that can increase the minimum average air velocity 4.3% with better uniformity 14.72 %.

6. Acknowledgements

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7. References

[1] Sarkar A, Singh RP. Air Impingement technology for food processing: visualization studies. LWT-Food Sci Technol 2004;37(8):873-879.

[2] Soto V, Borquez R. Impingement jet freezing of biomaterial. Food Control 2001;12(8):515-522.

[3] Huan Z, He S, Ma Y. Numerical simulation and analysis for quick-frozen food processing. Journal of Food Engineering 2003;60(3):267-273.

[4] Hu Z, Sun DW. Effect of fluctuation in inlet airflow temperature on CFD simulation of air-blast chilling process. Journal of Food Engineering 2001;48(4):311-316.

[5] Ho SY. A Turbulent Conjugate Heat-transfer Model for Freezing of Food Products. Journal of Food Science 2004;5:224-231.

[6] Erdogdu F, Ferrua M, Singh SK, Singh RP. Air-impingement cooling of boiled eggs: Analysis of flow visualization and heat transfer. Journal of Food Engineering 2007;79(3):920-928.

[7] Wan C, Rao Y, Chen P. Numerical Predictions of Jet Impingement Heat Transfer on Square Pin-Fin Roughened Plates. Applied Thermal Engineering, 2015;80:301-309.

[8] Phuekpan K, Tangchaichit K. Design and Development The Pressure chamber of the Continuous belt air-blast freezer in Freezing shrimp process. Advanced Materials Research 2014;931-932:1163-1167.