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CFX Analysis of the Heat and Mass Transfer During the Chilling of a Lamb Carcass using a 3D Model

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CFX ANALYSIS OF THE HEAT AND MASS TRANSFER DURING THE CHILLING OF A LAMB CARCASS USING A 3D MODEL

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Introduction

- Lamb meat is a popular meat product which must undergo a complex refrigeration process before being served at the dinner table to ensure sustained quality, food safety and to prolong its shelf life.
- A major disadvantage of meat chilling is the associated drip losses which contribute to a carcass weight loss of between 2 and 3%.
- Drip losses occur when water diffuses from within the carcass and evaporates away from the surface due to a difference in pressure between the surface layers of the carcass and the surrounding chiller.
- The analysis of chilling processes involving complex shapes such as beef and lamb carcasses is difficult using empirical formulae.
- Therefore, the use numerical models is vital to simulate complex geometries.

Aims

- To determine the temperature history of a lamb carcass in a +4°C chilling scheme using a 3D solidworks model in Ansys CFX

Materials & Methods

- A representative 3D model of a lamb carcass was created in the Solidworks program using photographs [1], X-rays and CT-scans sections [2].

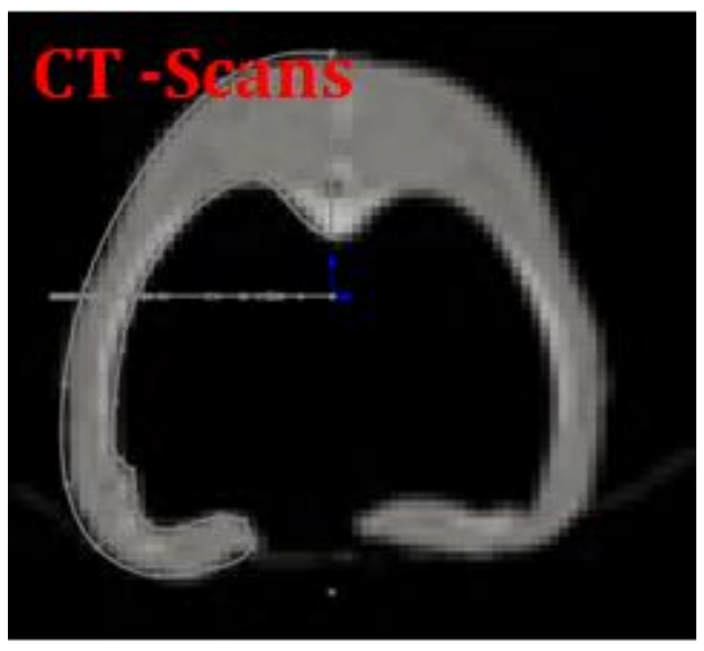

Figure 1. One of the 15 CT-scans used

Figure 2. Photograph of a lamb carcass

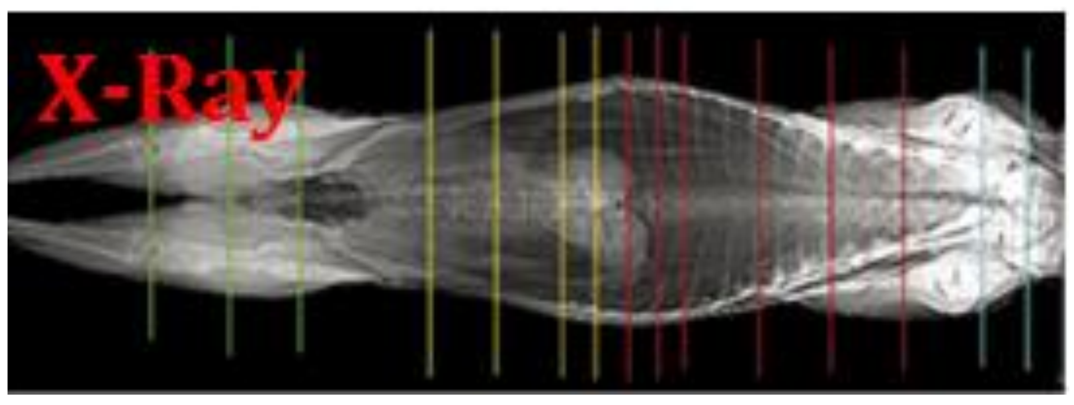

Figure 3. X-ray of the lamb carcass showing the 15 CT-scan sections (coloured lines)

- The lamb chilling simulations were carried out in two stages:
  1. Determination of the flow field and heat transfer coefficient using a 3D model (Chiller included)
  2. Determination of the temperature history of the carcass applying the heat transfer coefficient from the previous simulation to the outside of the carcass (Chiller excluded)
- A cylinder of similar dimensions to the carcass was used to establish the modelling methods.

Materials & Methods

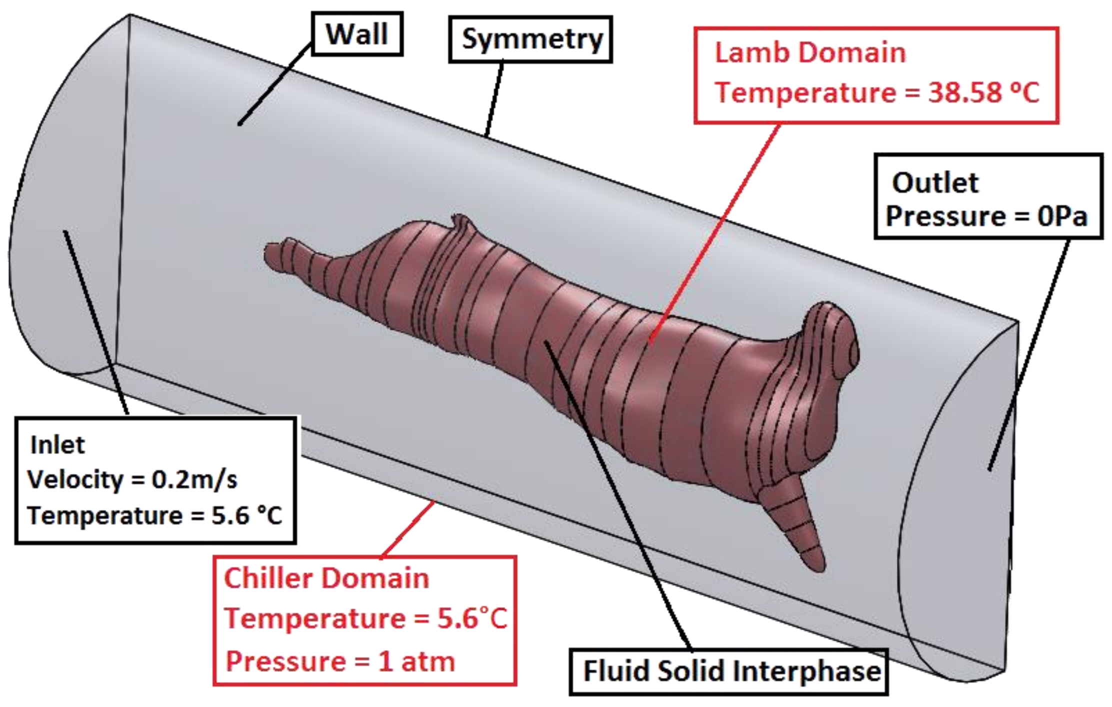

Figure 4. Setup for the steady state heat transfer coefficient simulation

- An inflated mesh was used at the interphase between the carcass and chiller to reduce the number of elements of the model.

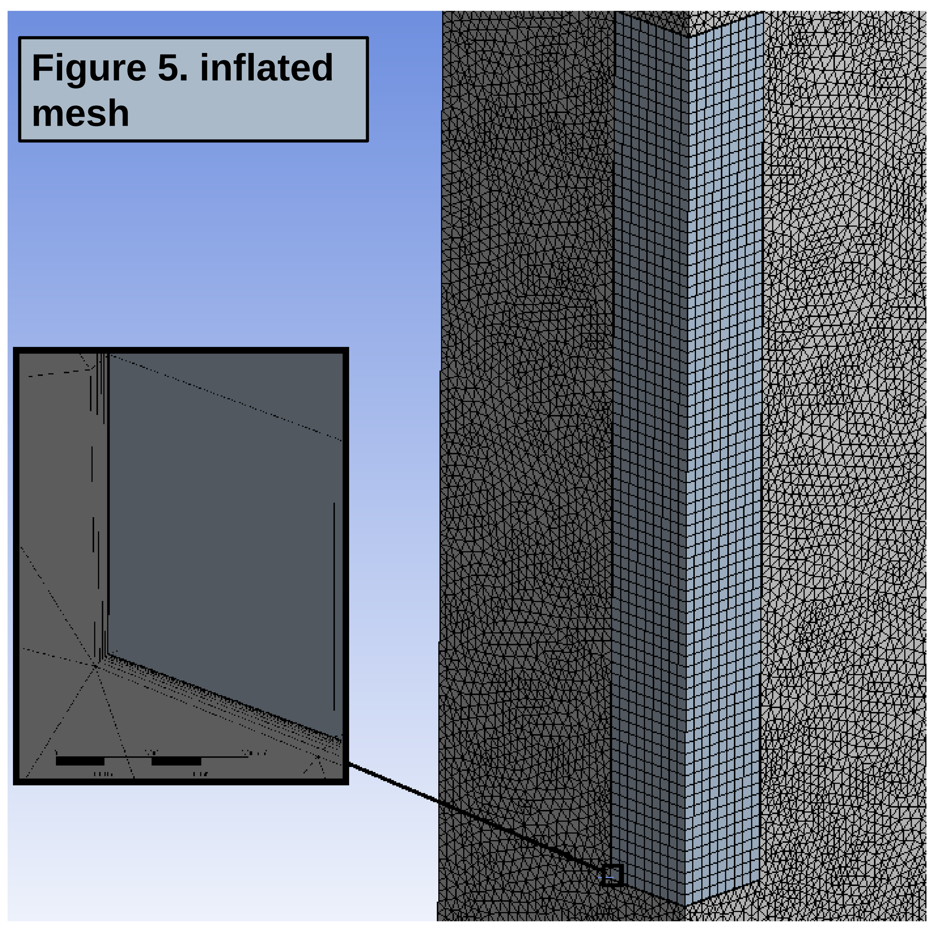

Figure 5. inflated mesh

- A mesh convergence test was carried out using a cylindrical model with similar dimensions to the carcass to prove the accuracy of the mesh.
- To include the effects of mass transfer on the heat transfer in the system an effective heat transfer coefficient was used [3].

Radiation

$$h_{eff} = h\frac{T_a - T_s}{T_{max} - T_s} + F\varepsilon\sigma\frac{T_{rad}{}^4 - T_s{}^4}{T_{max} - T_s} + kh_{fg}\frac{P_{Tdew} - a_w P_{Ts}}{T_{max} - T_s}$$

Convection

Evaporation

Figure 6. Equation for effective heat transfer coefficient

- Simulation results were compared to experimental lamb carcass histories from "Further Investigation into the Ultra-Rapid Chilling of Lamb Carcasses" by Grainne Redmond [4]

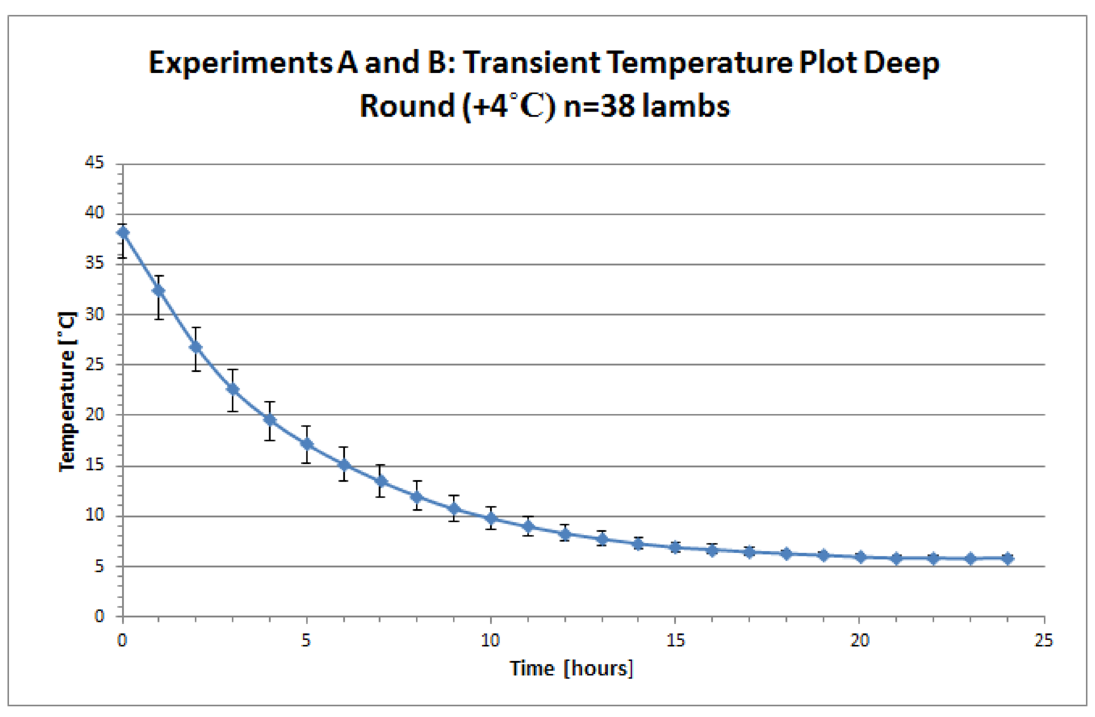

Figure7. Experimental lamb carcass temperature history

Results

- Temperature histories for the deep round of the lamb carcass were plotted over 24 hours as seen in Figure 8 and 9.

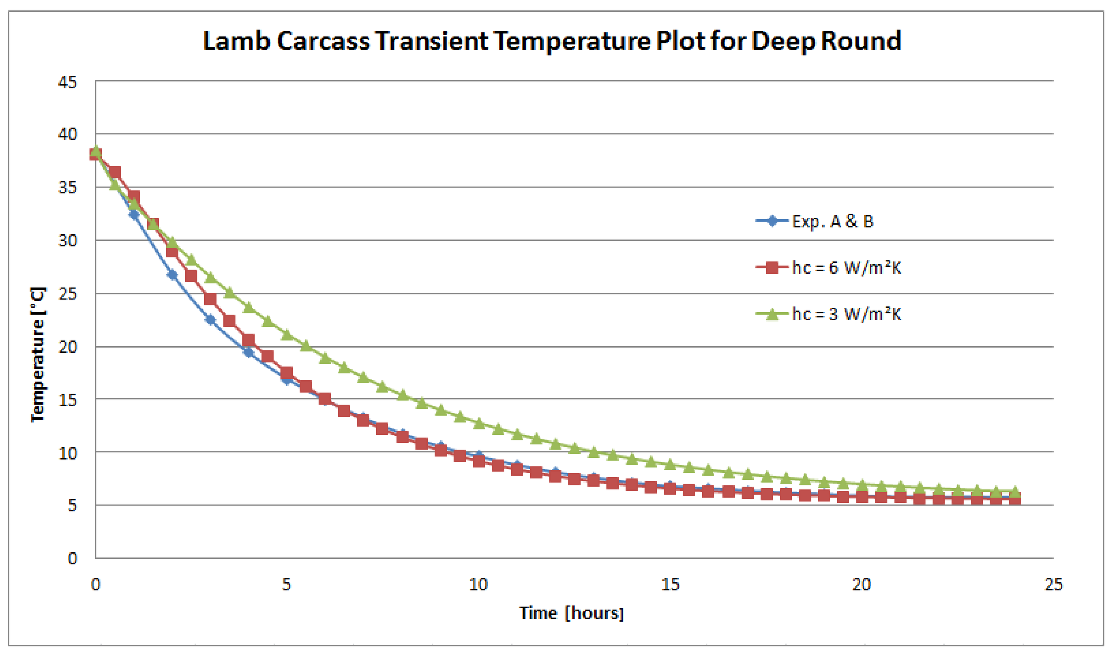

Figure 8. Temperature history of the lamb carcass at two different air velocities (green = 0.2m/s , red = 0.75m/s)

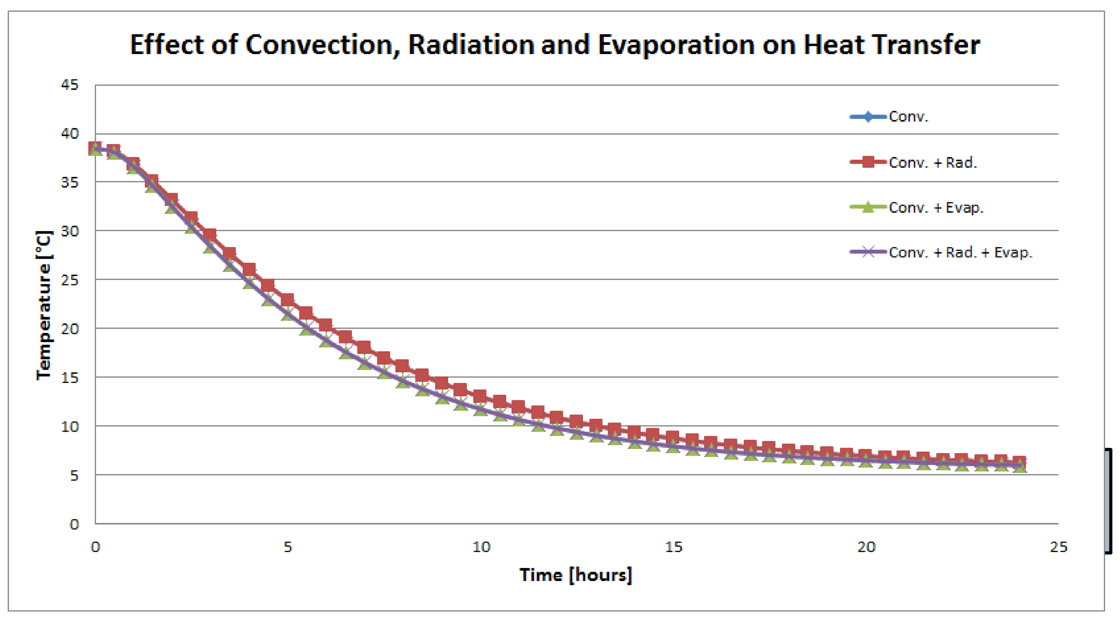

Figure 9. Setup for the steady state heat transfer coefficient simulation

Discussion & Conclusions

- This study has led to the development of a 3D CFX model of a lamb carcass chilling process.
- Using a cylindrical model to establish the mesh and modelling methods in ANSYS saved time and computational power.
- Including a two step (transient and steady state) process to simulate the lamb chilling process contributed to a reduction in time and computational power required for the simulations.
- The position of the temperature probes within the lamb carcass and chiller air velocity were found to have the greatest effect on the temperature history of the lamb carcass.
- The inclusion of an inflated mesh was vital to the success of the simulations.
- Convection and evaporation had a significant effect on the heat transfer in the system.

References

[1] Keane, G. Food Sceince Conference, UCC, 1997
[2] Johansen, et al. Chem. & Intel. Lab. Sys., Vol. 87, 303-311
[3] Kondjoyan, et al. Journal of Food Eng. Vol.76, 53-62, 2006
[4] Redmond, et al. PhD Thesis, Dpt Agri. & Food Eng., UCD, 2000

Acknowledgements

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