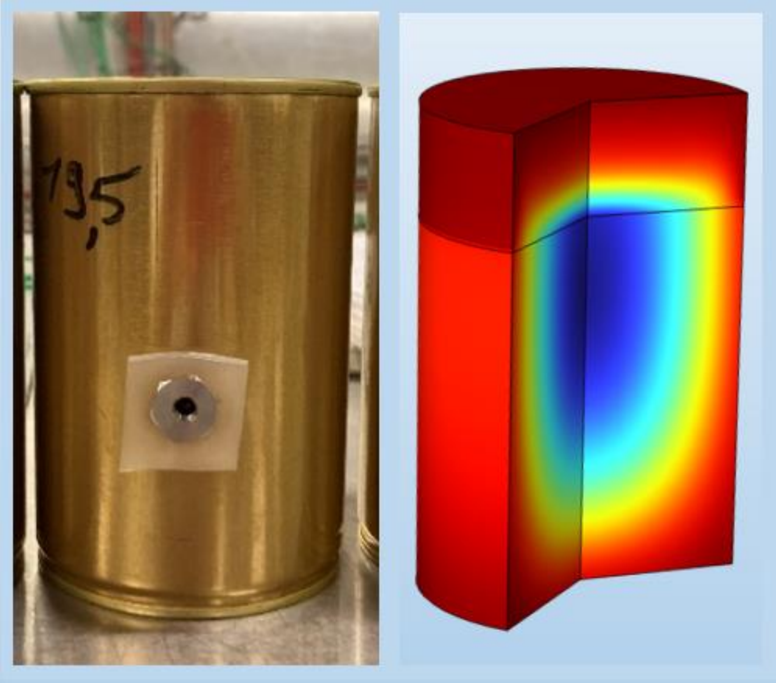
CFD-based Approach For Prediction Of Headspace Pressure In Can During Thermal Sterilization Of Foods



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What is Thermal Sterilization?

Raw Food

Thermal sterilization using Retort

- Heat treatment above 100°C
- Destroys heat-resistant spores

Canned Foods with longer shelf life (eg. ≥ 2 years)

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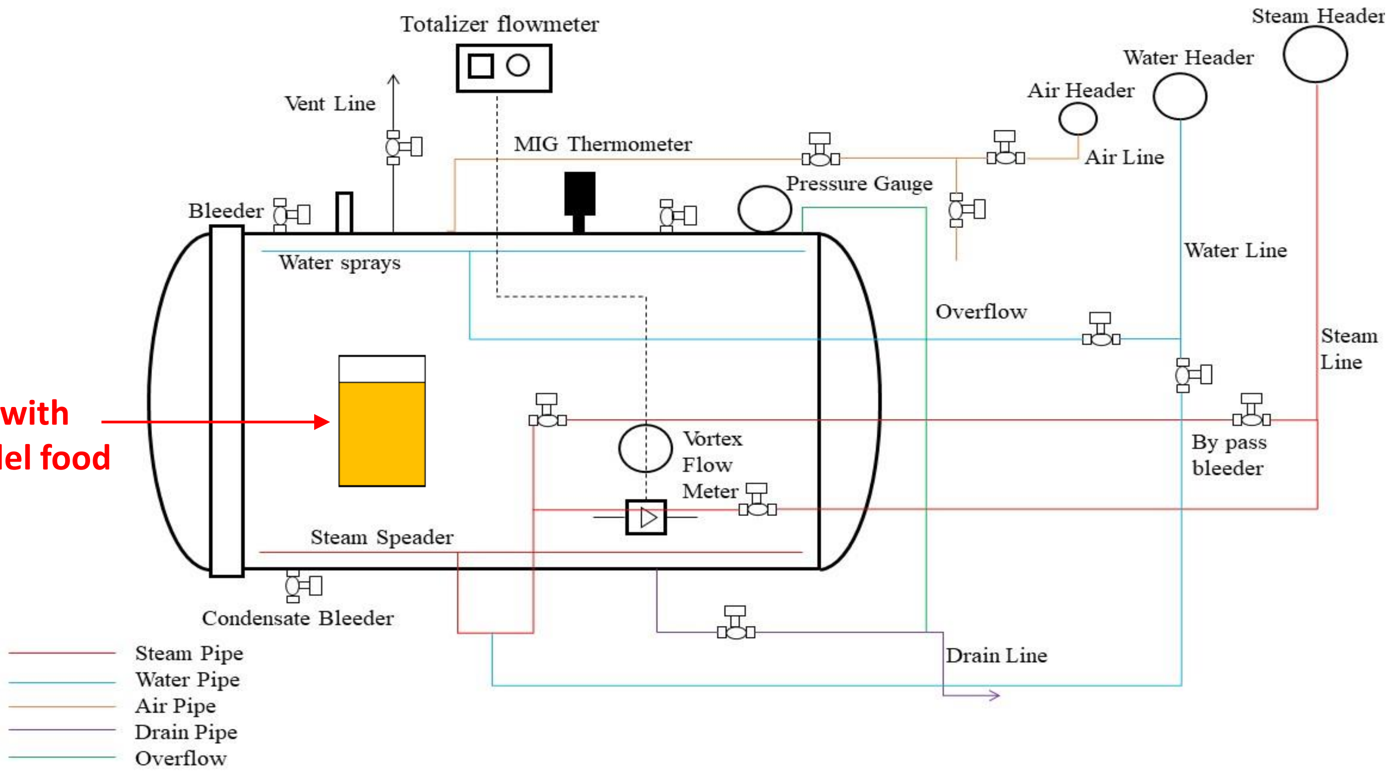
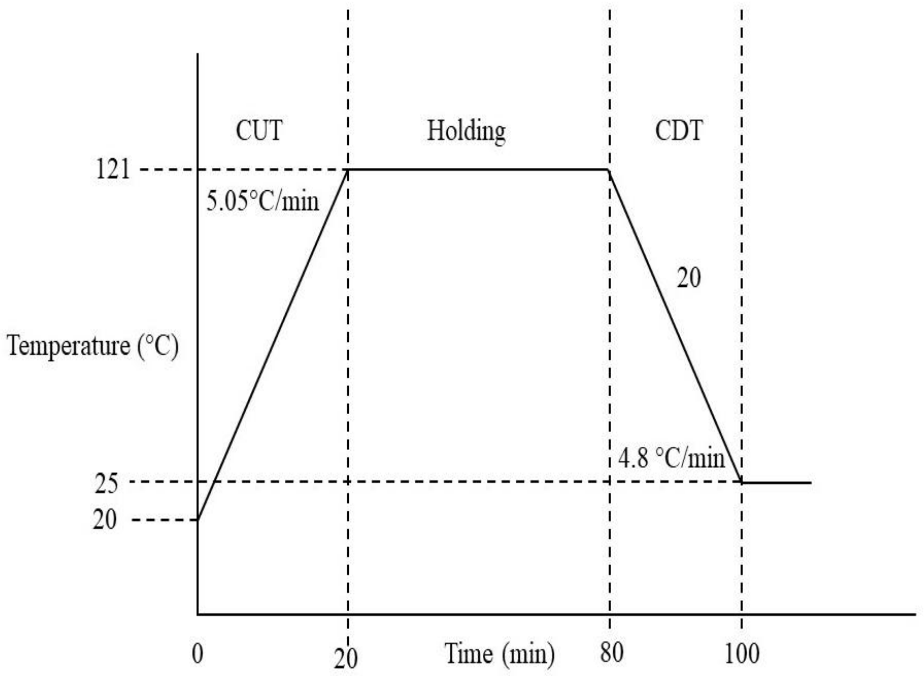
Context

Retort Overview

Can with model food

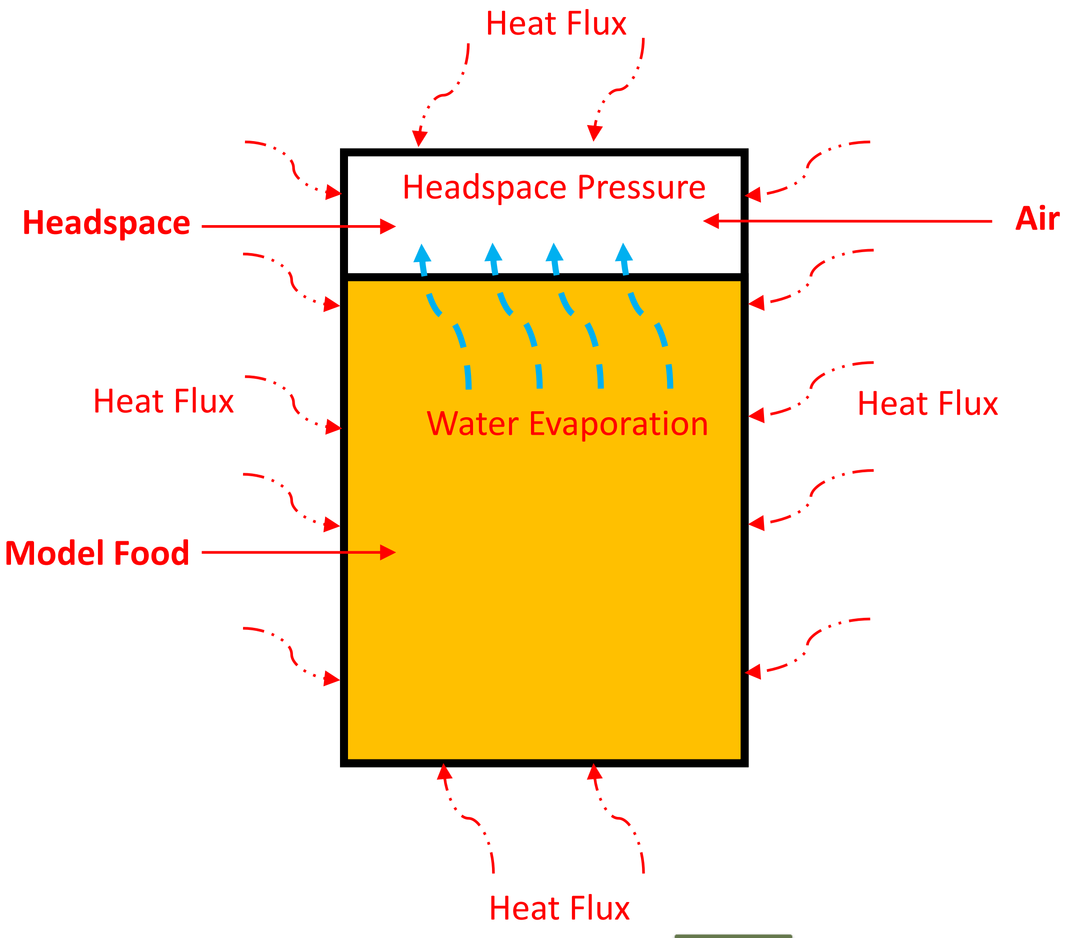


Schematic of a conventional retort for thermal sterilization



Temperature profile during thermal sterilization

Headspace Pressure



Challenge

- **Measuring headspace pressure due to water vapour in the food industry is a big challenge.**
- External counter-pressure is required to tackle **inner pressure** generated in canned foods which is related to headspace pressure.

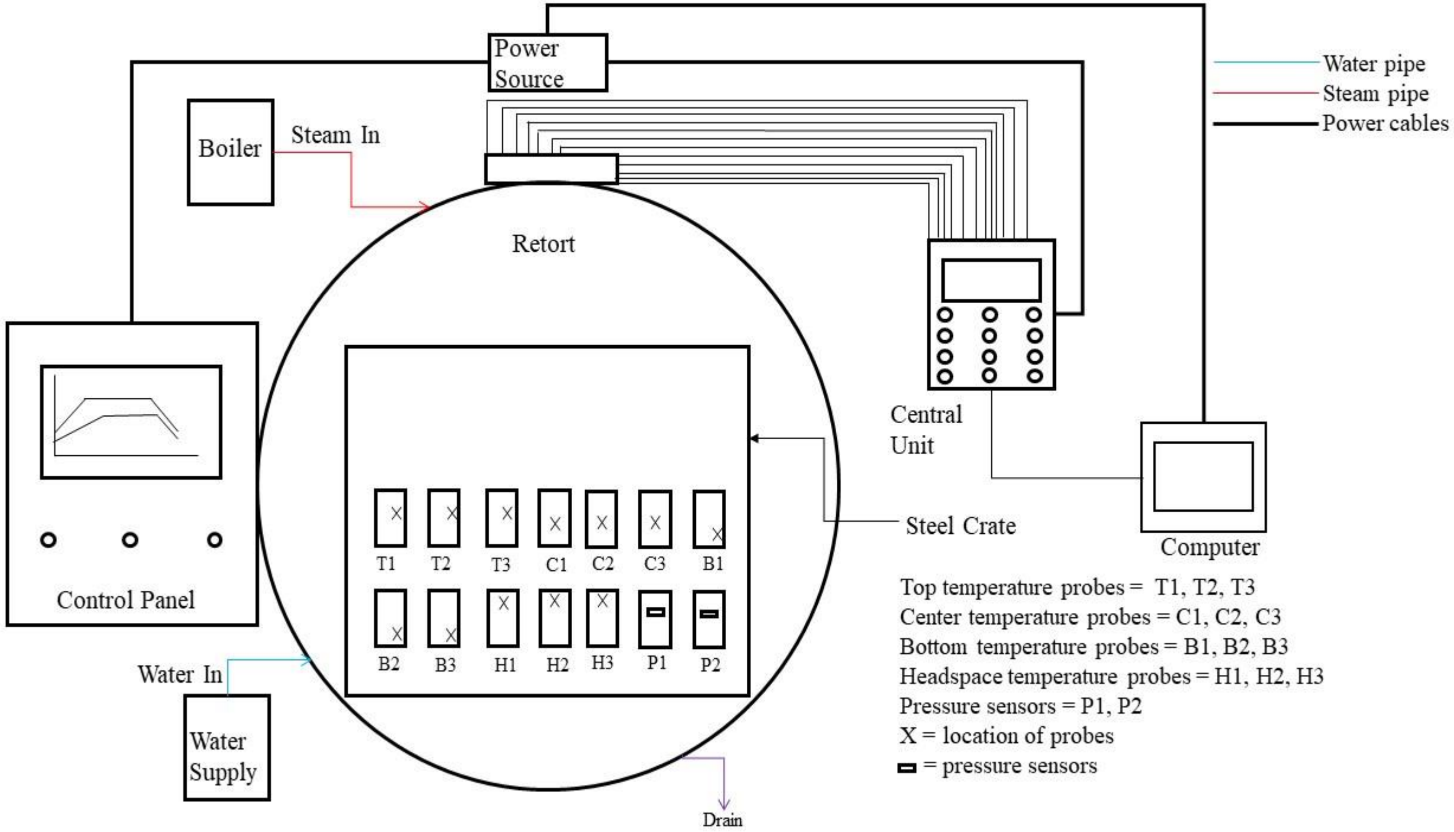
Goal

- To predict **local temperatures** and **internal headspace pressure** in cans during thermal sterilization process, which accounts for **water vapor generation and dry air pressure in the headspace**.

Materials and Methods

Experimental Setup

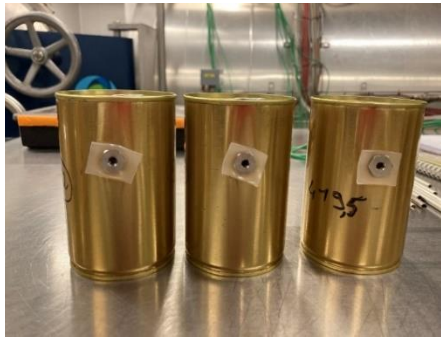
STERITECH Retort in Oniris, Nantes, France



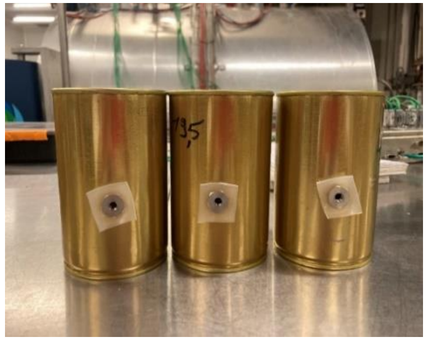
Schematic of experimental setting

Materials and Methods

Experimental Setup

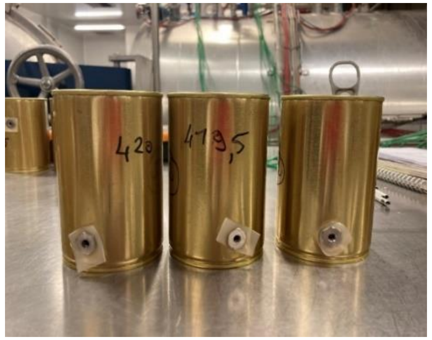


3 cans for top temperature



3 cans for center temperature

3 cans for headspace temperature

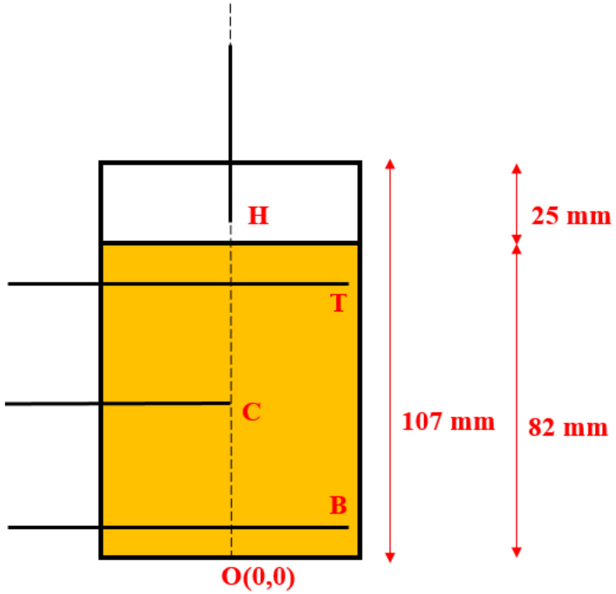


3 cans for bottom temperature

Mass of mashed potato = 279.96 ± 0.42 g

Temperature probes

Pressure sensor inside cans



Location of temperature probes in the cans

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Numerical Modelling: Governing Equations

Heat Transfer in Solids (mashed potato)

$$\rho C_p \frac{\partial T}{\partial t} - \nabla.(-k\nabla T) = 0 \quad (1)$$

+Initial Conditions +Boundary Conditions

$T_{initial} = 20°C$

$$-n.q = q_0 \quad (2)$$

$$q_0 = h_{global}(T_{retort} - T) \quad (3)$$

Heat Transfer in Fluids (air at the headspace)

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \boldsymbol{u}.\nabla T - \nabla.(k\nabla T) = 0 \quad (4)$$

+Initial Conditions + Boundary Conditions

Fluid Mechanics : Navier-Stokes equations with the Boussinesq approximation (air at the headspace)

$$\rho \frac{\partial \boldsymbol{u}}{\partial t} = -\nabla p + \mu \nabla^2 \boldsymbol{u} + F \quad (5)$$

$$F = \rho g \quad (6)$$

+Initial Conditions +Boundary Conditions

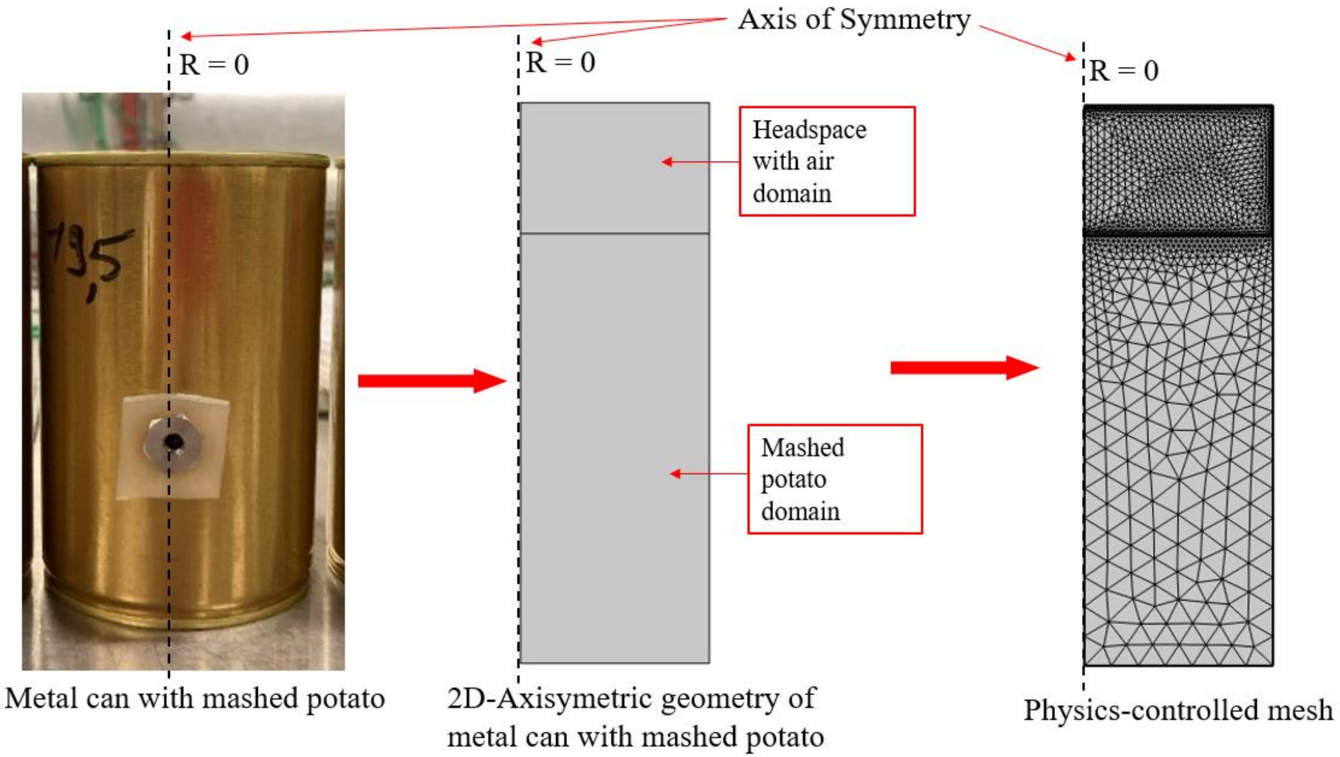
p = 1 [atm]

$$\boldsymbol{u}_{initial} = \boldsymbol{0} \quad (7)$$

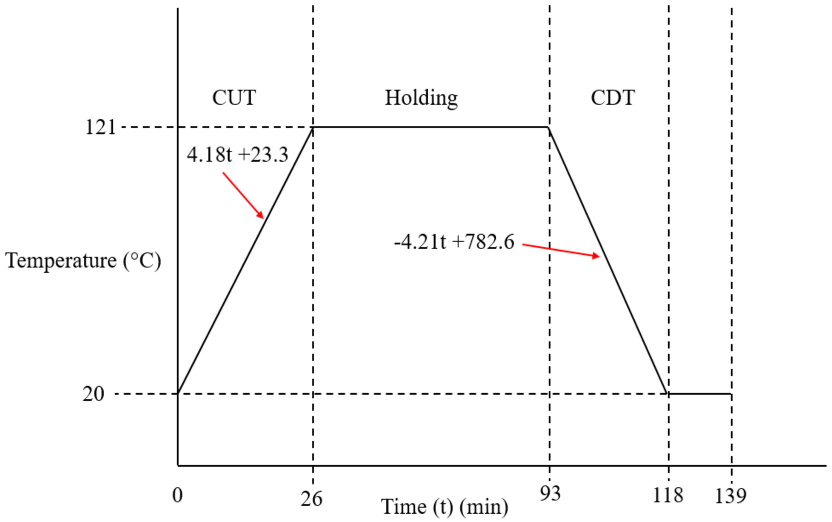
Ideal gas law for dry air at the headspace

$$PV = nRT \quad (8)$$

COMSOL Modelling: Implementation



Model geometry

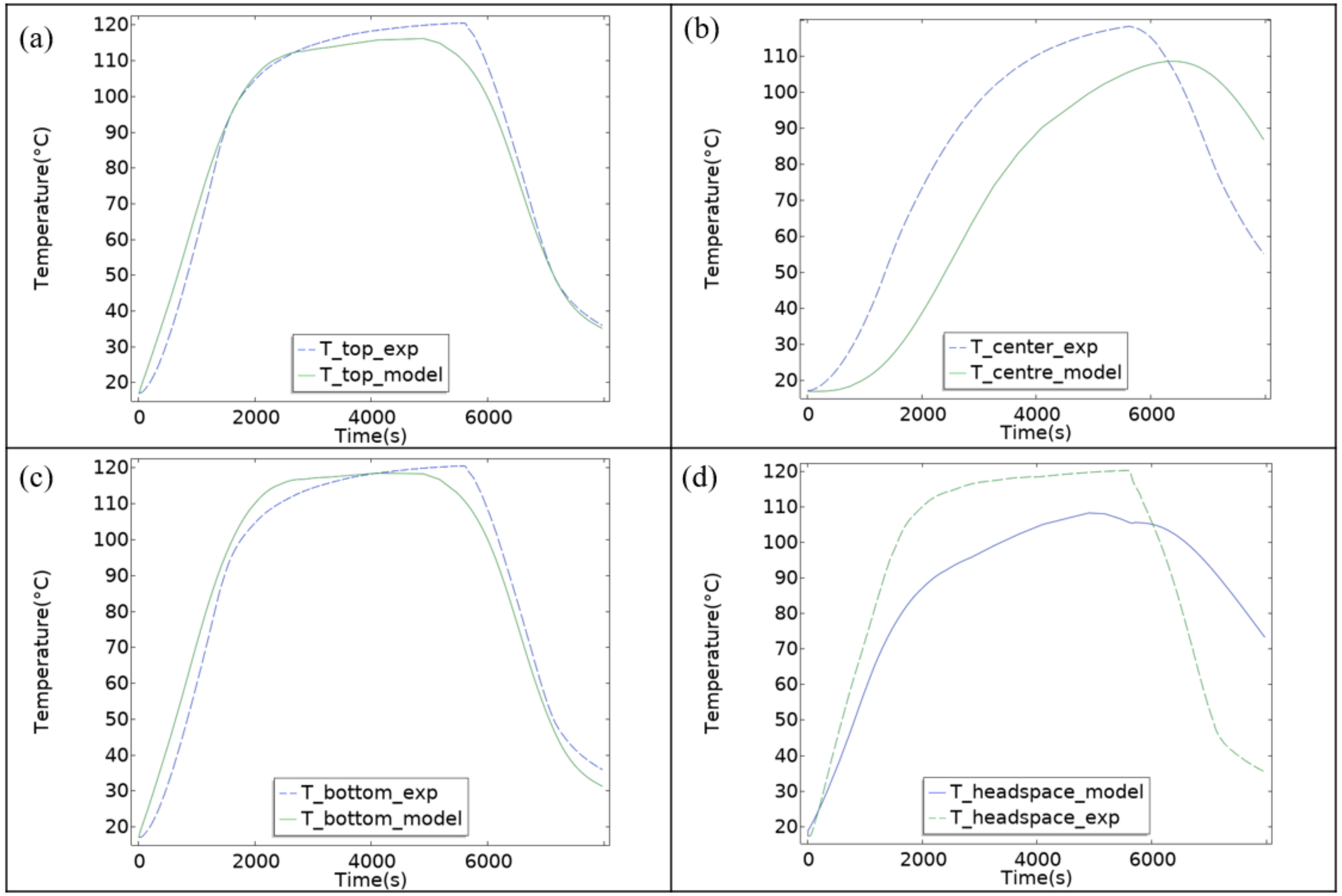


Experimental temperature profile for model input

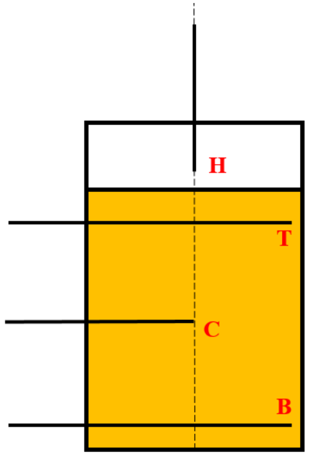
Parameters		Values
Density of model food (mashed potato)	ρ_{mp}	$1052.96\ kg/m^3$
Thermal conductivity of model food (mashed potato)	k_{mp}	$0.55\ W/m/K)$
Specific heat capacity model food (mashed potato)	Cp_{mp}	$0.0576\ T^2 - 33.551\ T + 8445.2\ J/kg/K$
Density of metal can	ρ_{can}	$7900\ kg/m^3$
Thermal conductivity of metal can	k_{can}	$45\ W/m/K$
Specific heat capacity of metal can	Cp_{can}	$213\ J/kg/K$

Simulation Results

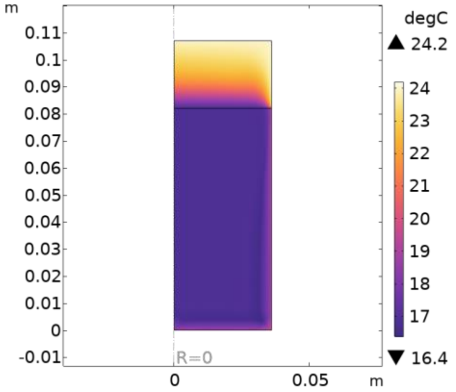
Temperature evolution



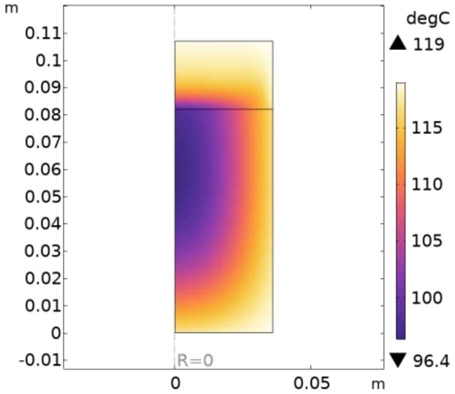
Experimental and simulated temperature profile at (a) Top location (b) Center location (c) Bottom location (d) Headspace location.



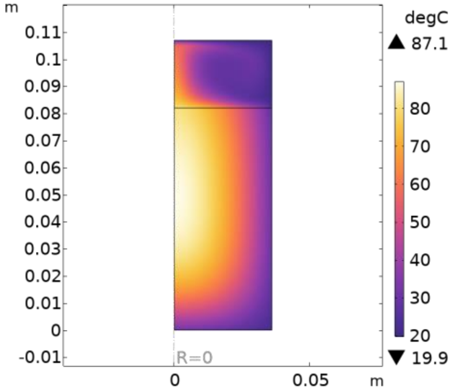
Location of temperature measurement



Temperature distribution at 10 s



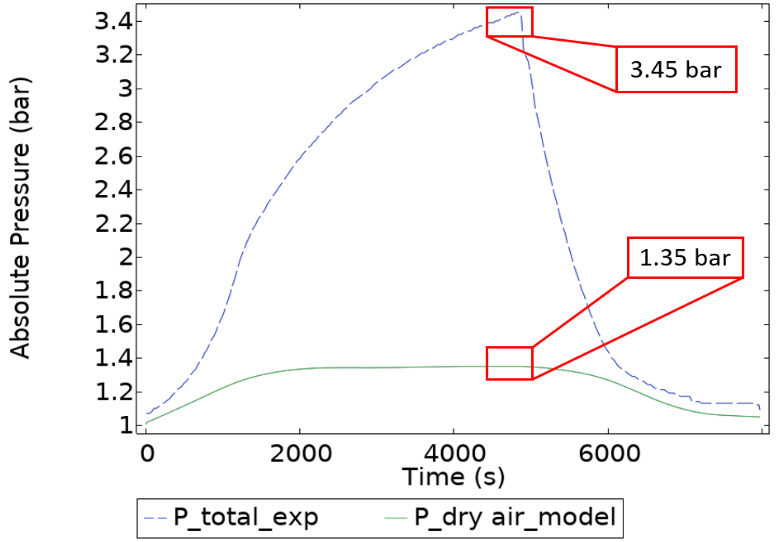
Temperature distribution at 4821 s



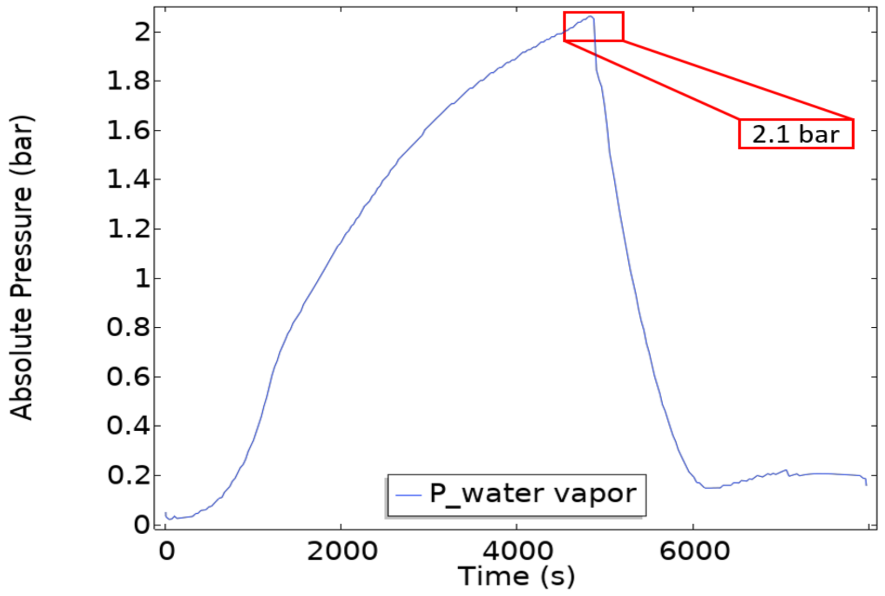
Temperature distribution at 7968 s

Simulation Results

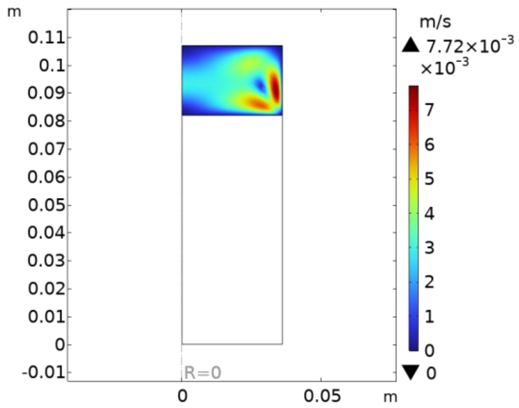
Pressure and Velocity



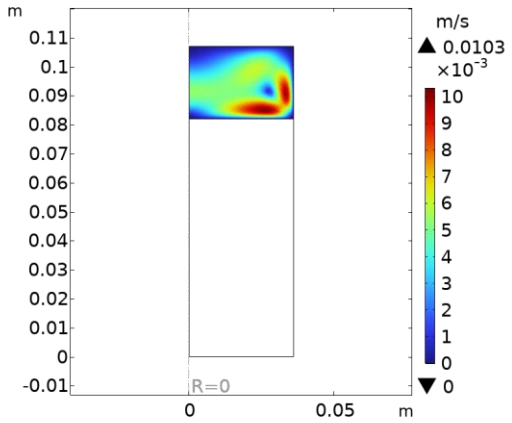
Experimental pressure profile of total pressure in comparison to simulated pressure profile of dry air.



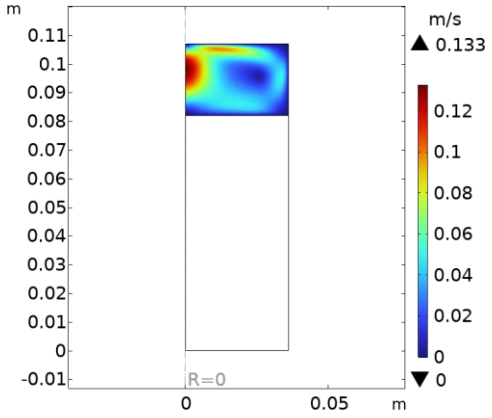
Estimated water vapor pressure profile.



Air velocity field at 10 s

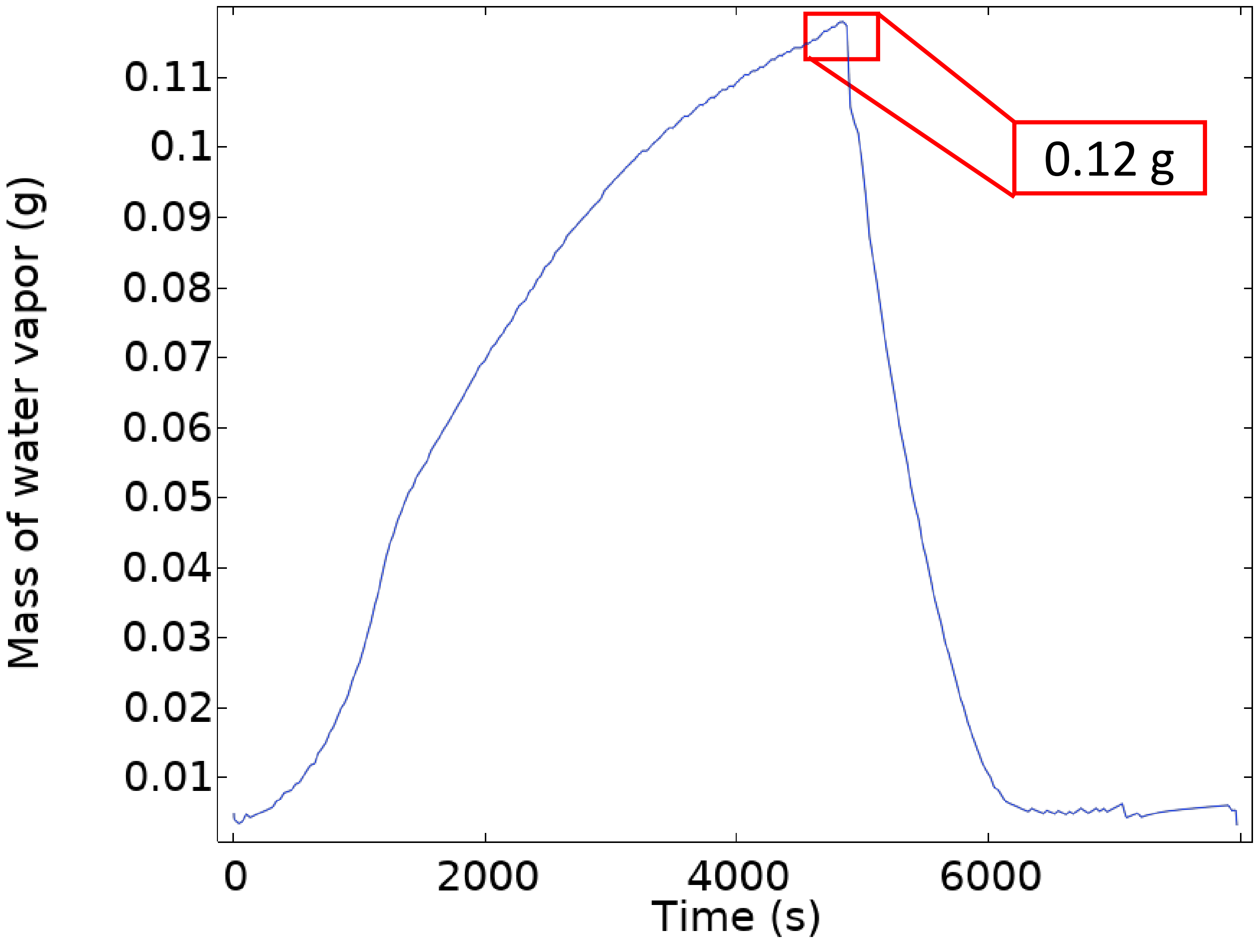


Air velocity field at 4821 s



Air velocity field at 7968 s

Water Vapour Generation



$$P_{air} V_{headspace} = n_{air} RT$$

$$P_{vapour} V_{headspace} = n_{vapour} RT$$

$$P_{total} = P_{air} + P_{vapour}$$

Experimental measurement for water vapour generation was of the same order of magnitude: less than 0.5 g

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Conclusions and Perspectives

The numerical model coupled to the experimental investigation enables to:

- Predict **local temperature profiles at different locations** in canned foods.
- Predict **dry air pressure in the headspace**.
- Estimate the **water vapour pressure** contributing towards headspace pressure
- Evaluate the **mass of water vapour generated** during the thermal sterilization process.

Perspectives

- Improvement of the numerical model by integrating water vapour evaporation flux in the CFD model.

Thank You Very Much For Your Attention

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