Radio frequency thawing frozen beef of irregular shape —A computational study

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Simulation purpose

① Radio frequency (RF) is a new type of heating method. RF heating can reduce processing time and minimize nutritional damage when applied in meat thawing. Because of its large penetration depth and high heating rate, RF thawing has a great potential for rapid thawing and heating uniformity improvement.

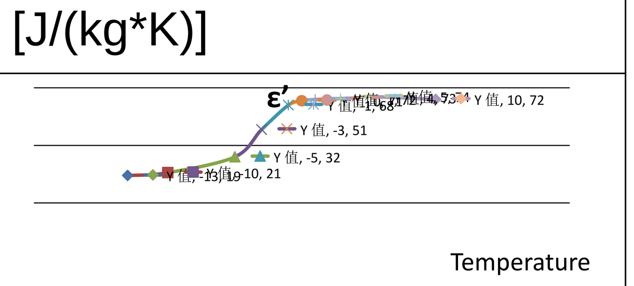
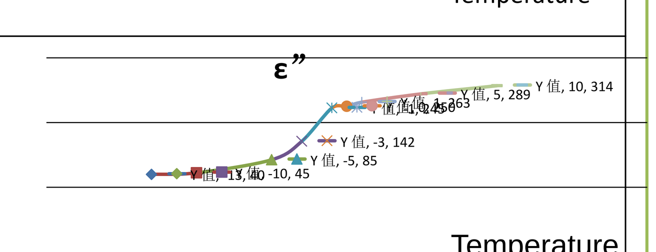
②The purpose of this study was to explore the internal temperature distribution of the irregular beef during RF thawing, and then to determine the influence of thickness, surface area, shape on the uniformity of the thawing of beef.

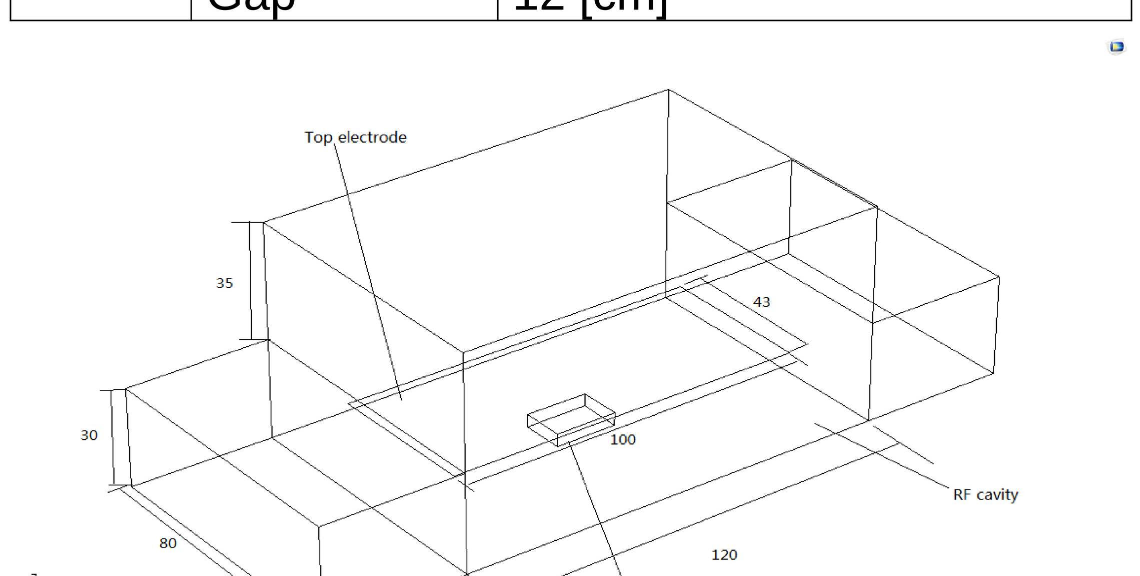
③COMSOL Multiphysics® software was used to simulate the thawing process, by entering the physical properties of frozen beef samples including dielectric properties, thermal characteristics change with temperature to the software. Then the internal temperature change and distribution was simulated.

④After the simulation process was completed, we can obtain the temperature uniformity indexes for beef.

Simulation process

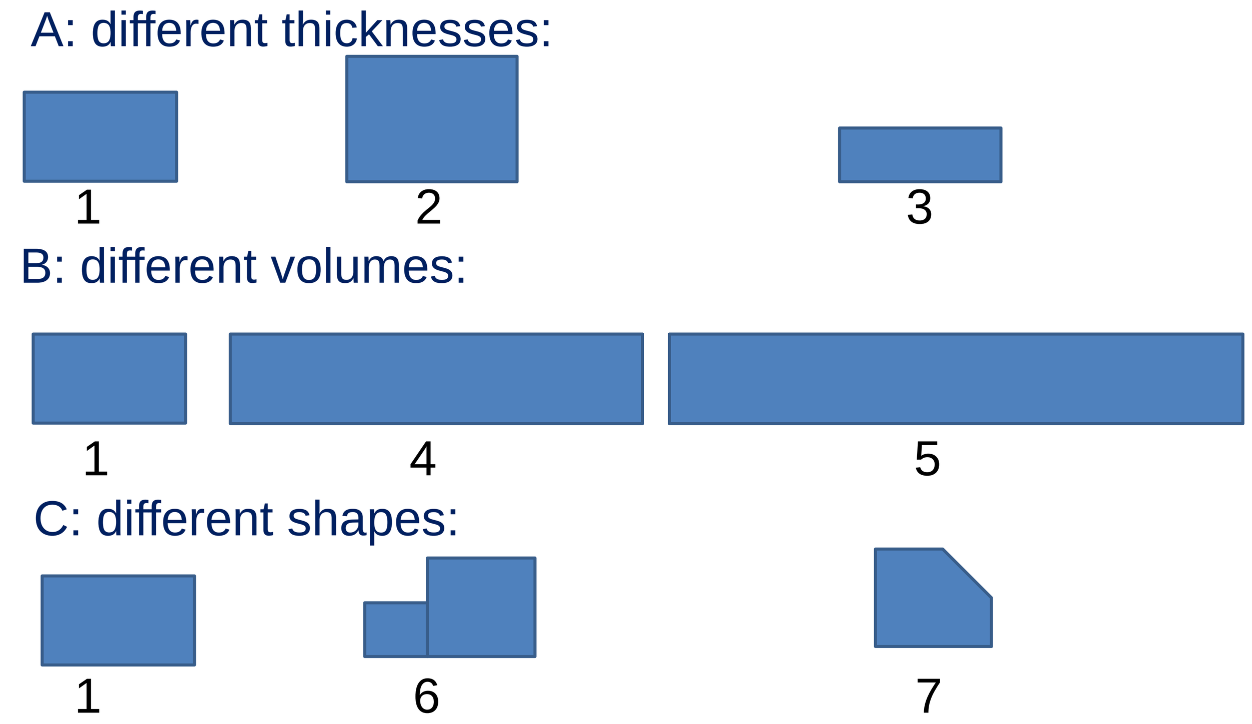
Modeling conditions:

	Name	Values
Sample	Initial temperature	-13[degC]
	Convective heat transfer coefficient	10 [W/(m2*K]
	Density	*T<Tm1,ρ=961 [kg/m³]* *Tm1≤T<=Tm2, ρ=1007 [kg/m³]* T>Tm,ρ=1053 [kg/m³]
	The specific heat values	*T<Tm1,Cp=1935.2 [J/(kg*K)]* *Tm1≤T<=Tm2,Cp=153016.3 [J/(kg*K)]* T>Tm, Cp=3497.4 [J/(kg*K)]
	Dielectric constant	
	Dielectric loss factor	
Others	Voltage	1375 [V]
	Frequency	27.12 [MHz]
	Air temperature	20 [degC]
	Time	6000 [s]
	Gap	12 [cm]



RF system

Samples:



Equations:

$$\rho C_p \frac{\partial T}{\partial t} = \nabla \cdot k\nabla T + Q_{abs}$$

$$Q_{abs} = 2\pi f \varepsilon_0 \varepsilon'' |E|^2$$

$$\nabla(\varepsilon \cdot E) = 0$$

Q_{abs}: the RF power absorbed per unit of volume (W/m³) by the load

|E|: the modulus of electric field (V/m)

T: temperature difference (°C)

Boundary process

Electric currents

Convective heat transfer on the external surfaces:

$-n \cdot \nabla T = h(T - T_{air})$

Sample was assumed at uniform initial temperature

$T_0 = -13℃$

Heat transfer in solids

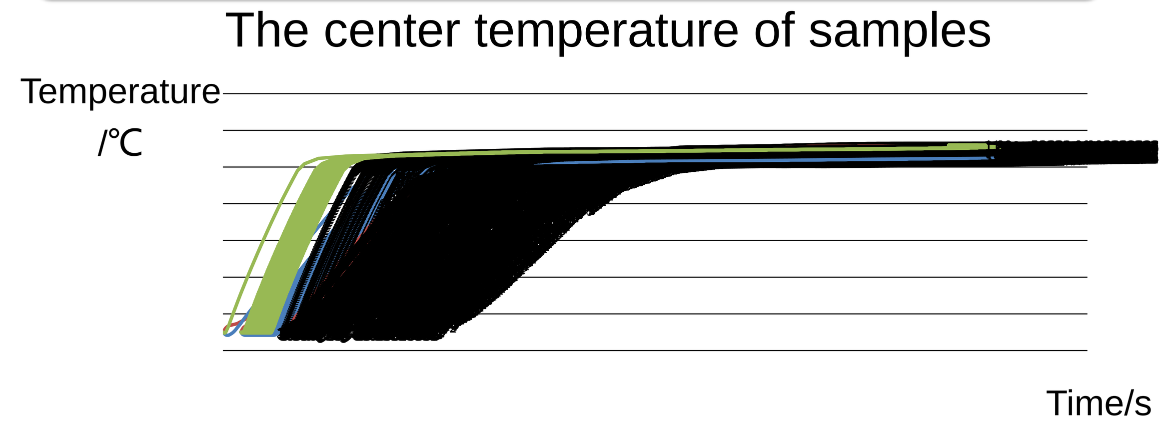
upper electrode was maintained at a certain potential (V_0)

lower electrode was maintained at the ground condition(V=0)

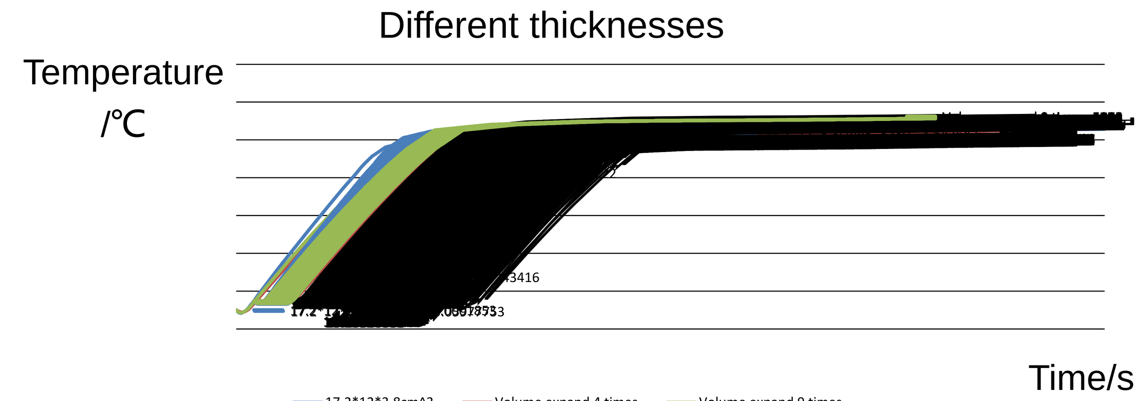
side walls were electrically insulated (▽E=0)

Results

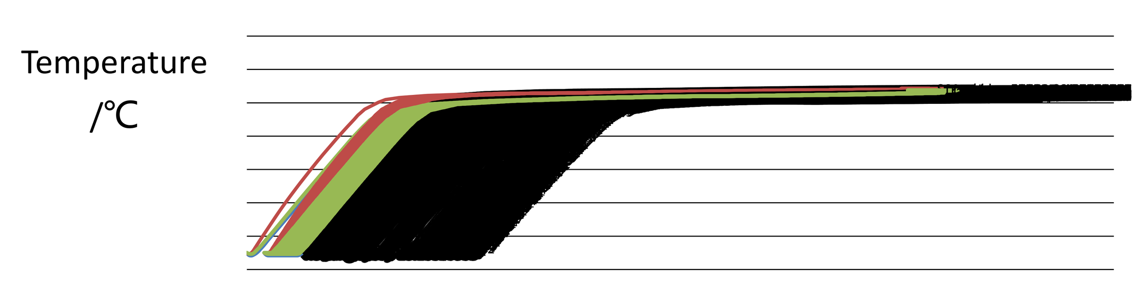
The center temperature of samples



Different thicknesses

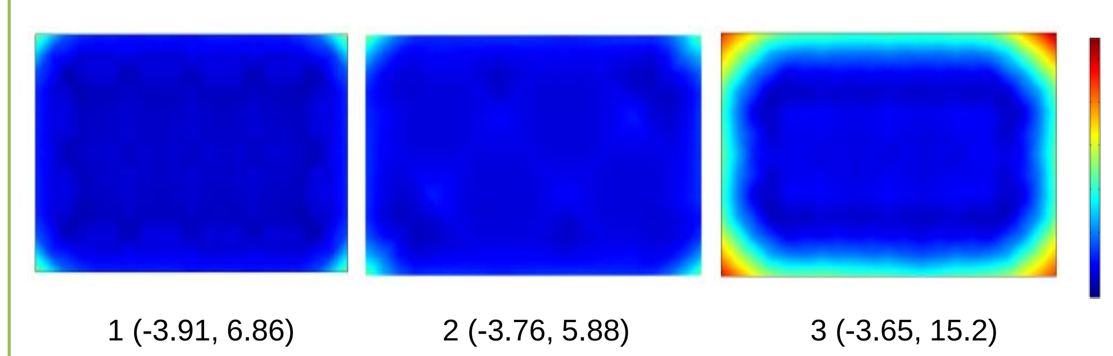


Different volumes

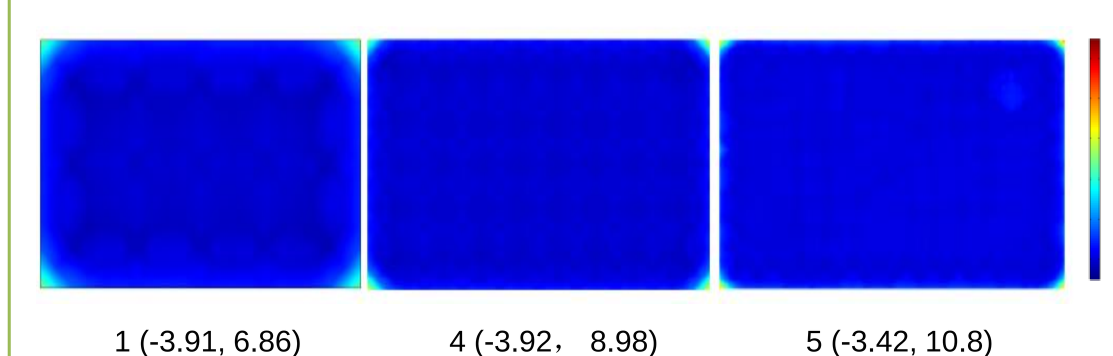


Different shapes

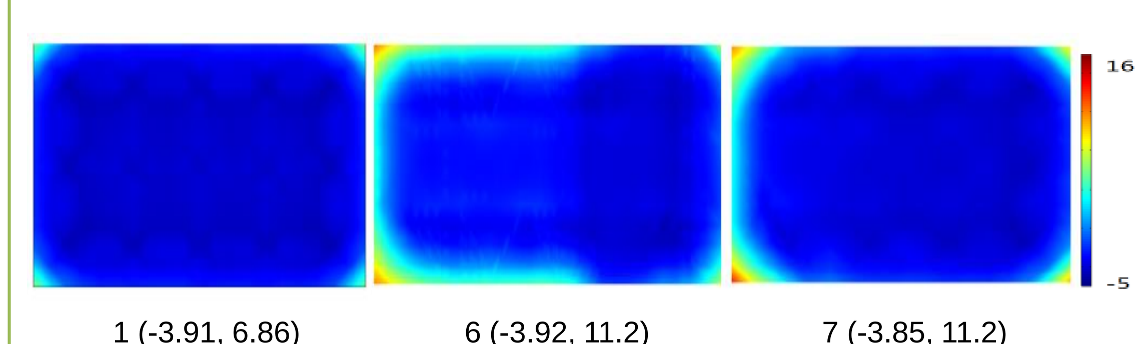
Temperature distribution of cross sections (T_{min}, T_{max})



Different thicknesses



Different volumes



Different shapes

The uniformity index of center point

	1	2	3
Different thicknesses	**0.0023950**	0.0025876	0.0026159
	1	4	5
Different volumes	**0.0023950**	0.0052197	0.01174
	1	6	**7**
Different shapes	0.0023950	0.0023023	**0.0021753**

Conclusion

This study simulate thawing frozen has demonstrated the different thicknesses, volumes, shapes have influence on thawing beef.

The simulation results show that the internal temperature distribution changed significantly with geometrical factors. When the other conditions are constant, the temperature of smaller size beef rises faster. Also, when the surface areas increased, the temperature uniformity decreased.

References

① R Uyar et.al. Radio-frequency thawing of food products-A computational study. Journal of Food Engineering .146 ,163-171(2015)

② Frarag et.al. Dielectric and thermophysical properties of different beef meat blends over a temperature range of -18 to +10℃.Meat Science.79,740-747(2008)

③ Yang Jiao et.al. Improvement of radio frequency (RF) heating uniformity on low moisture foods with Polyetherimide (PEI) blocks. Food Research International.74 , 106-114 (2015)