

Optimisation of Active Packaging for Microwaveable Food Products Using COMSOL Multiphysics®

2014-09-18

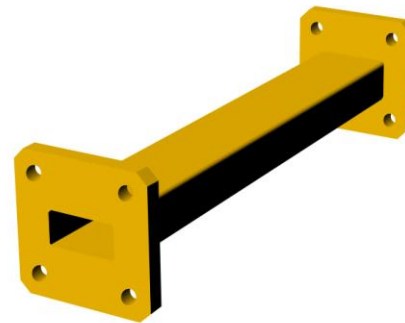
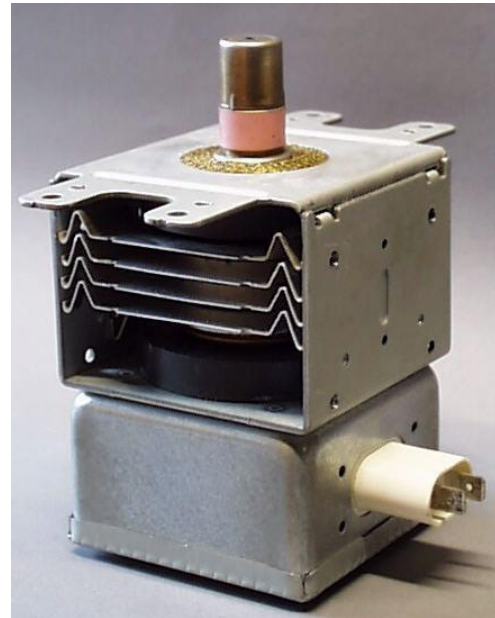
Comsol Conference 2014 Cambridge
Stanislav Landa, Alexander Bardenstein

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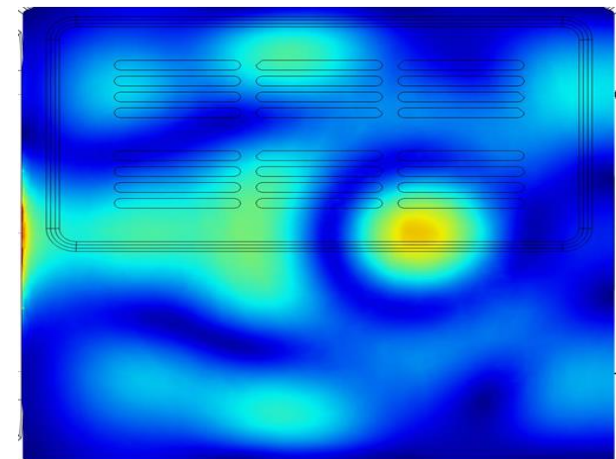
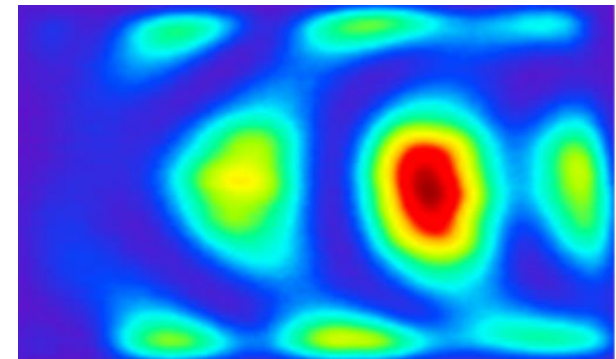
- Microwave oven
 - Construction and inhomogeneity
 - Heating of food
 - Oven EM-field
 - Reflectors
 - Sandwich example
- The Performance project
 - Project outline
 - Usage of reflective bands and patterns

A microwave oven

- Magnetron
 - 2.45 GHz
- Waveguide
 - Directs and scatters
- Cavity
- Turntable or mode stirrer

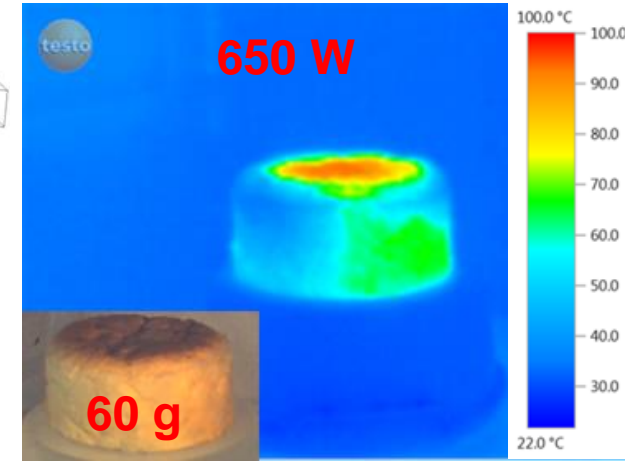
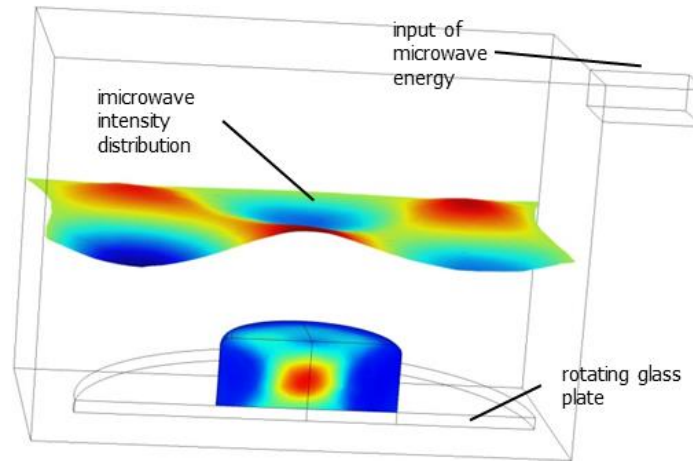
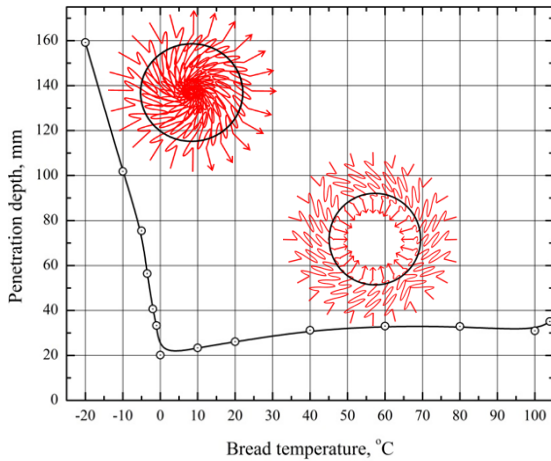


- The oven cavity is designed for an optimal introduction of electromagnetic energy.
- The distribution of the cavity EM-field in a domestic MW-appliance is necessary inhomogeneous due to a pattern of standing waves.
- Inhomogeneous absorption.
- Simulation results can be tested using thermochromatic gels or susceptors.



Microwave heating of a frozen bun

After 30s of heating



0 s
MW focusing
in the core

5 s
Thermal runaway
in the core

15 s
Water vapor pumping
toward crust and
condensation

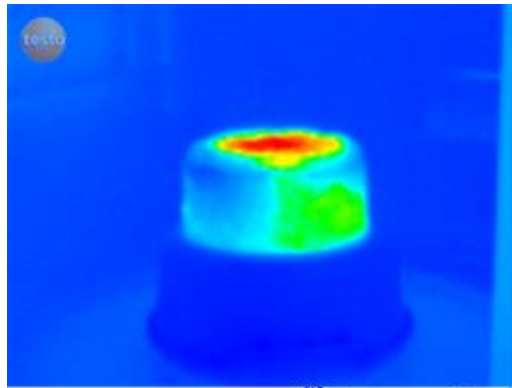
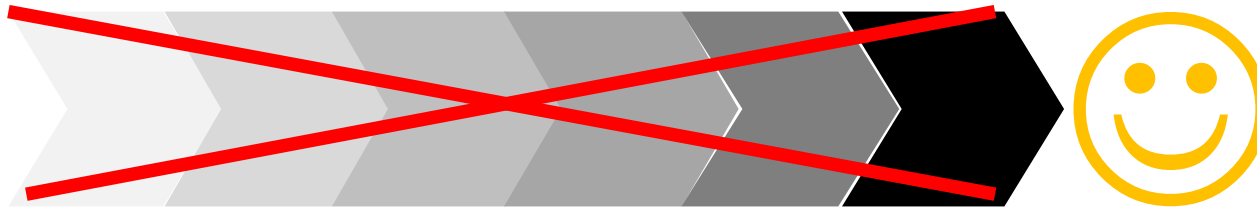
30 s
Dehydration of starch
in the core and soakage
of the crust

45 s
Thermal runaway in
the crust

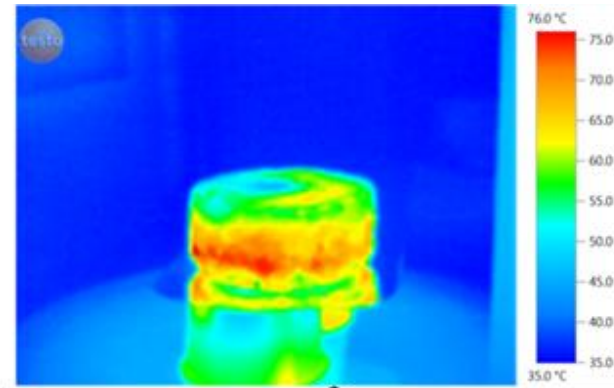
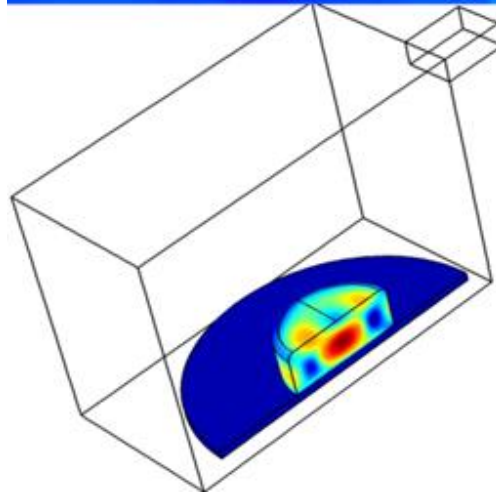
60 s
Complete dehydration
and staling of the bun



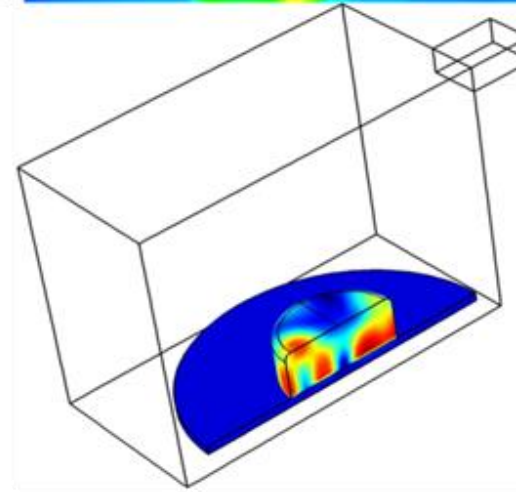
Defocusing – metal plate



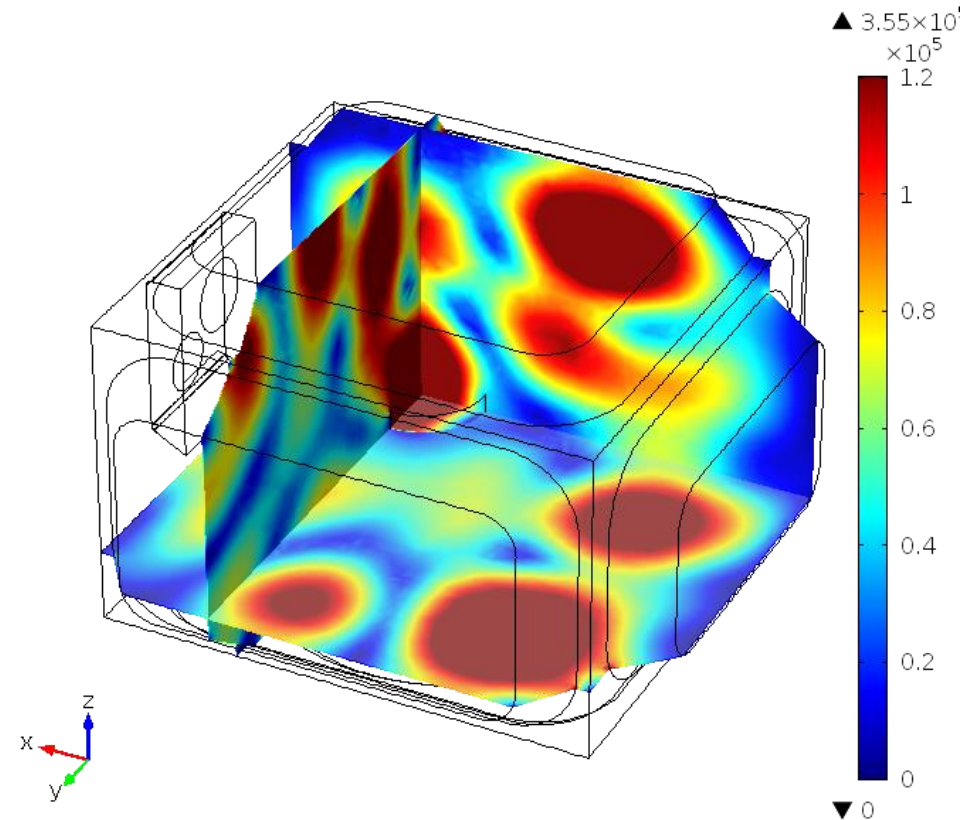
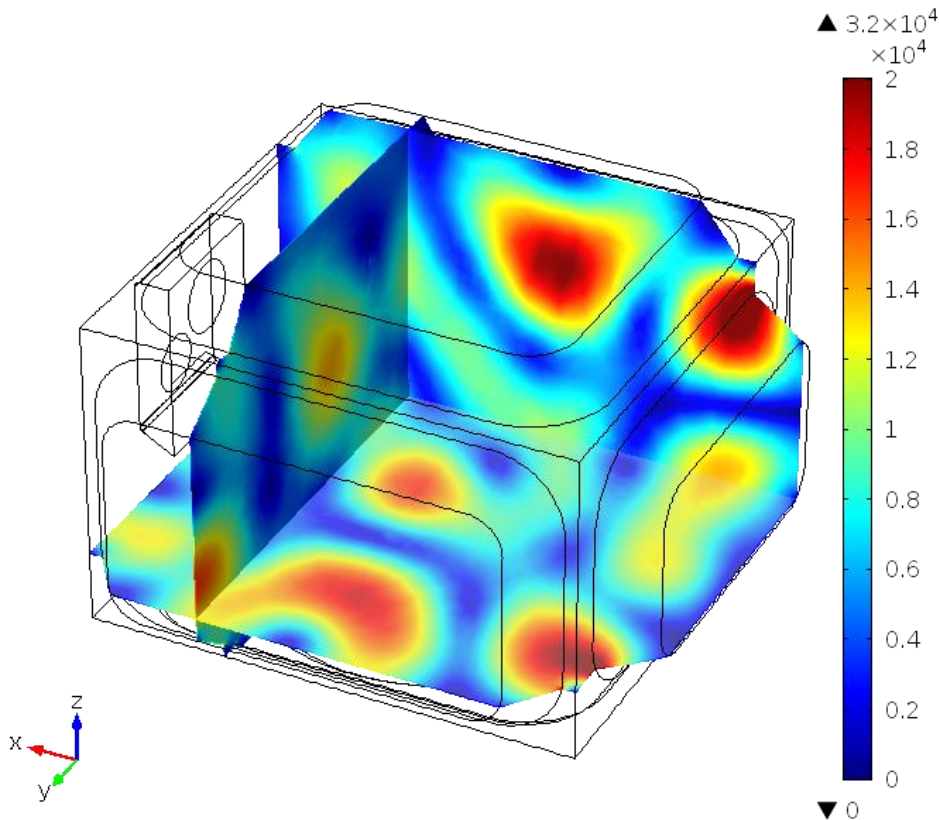
No reflector



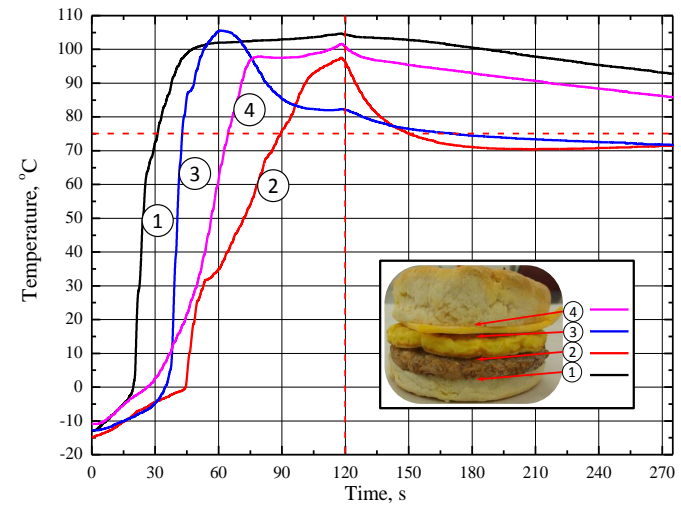
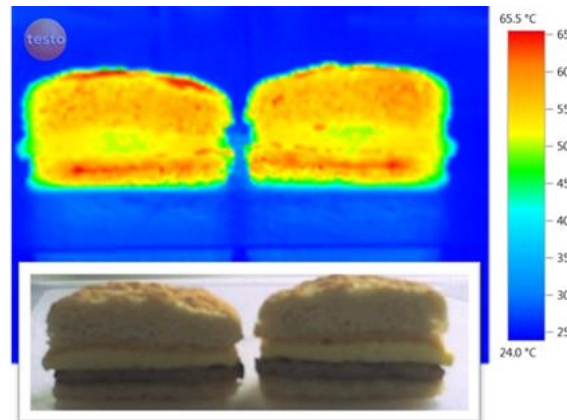
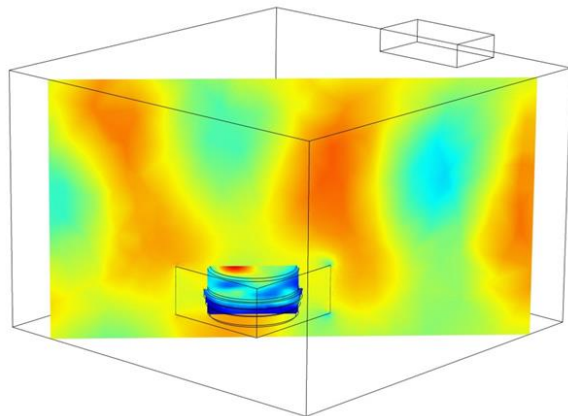
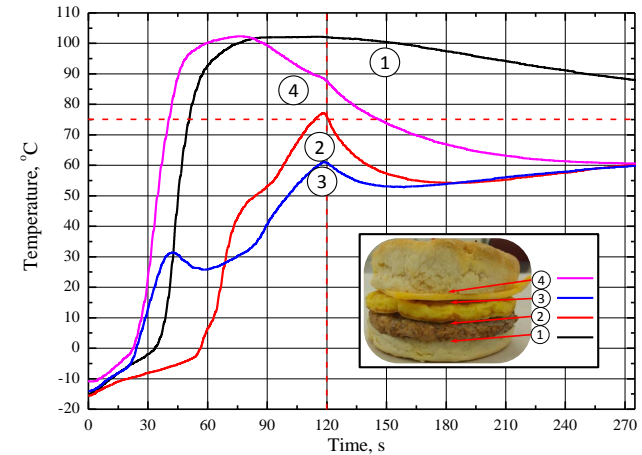
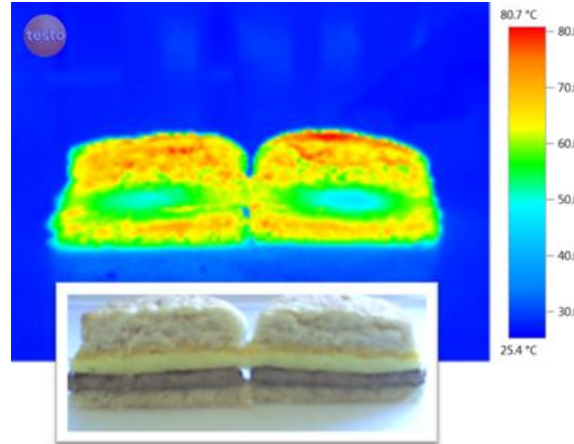
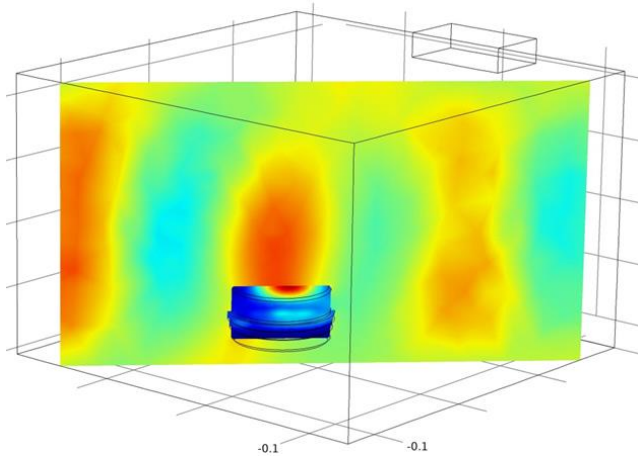
Totally reflective support



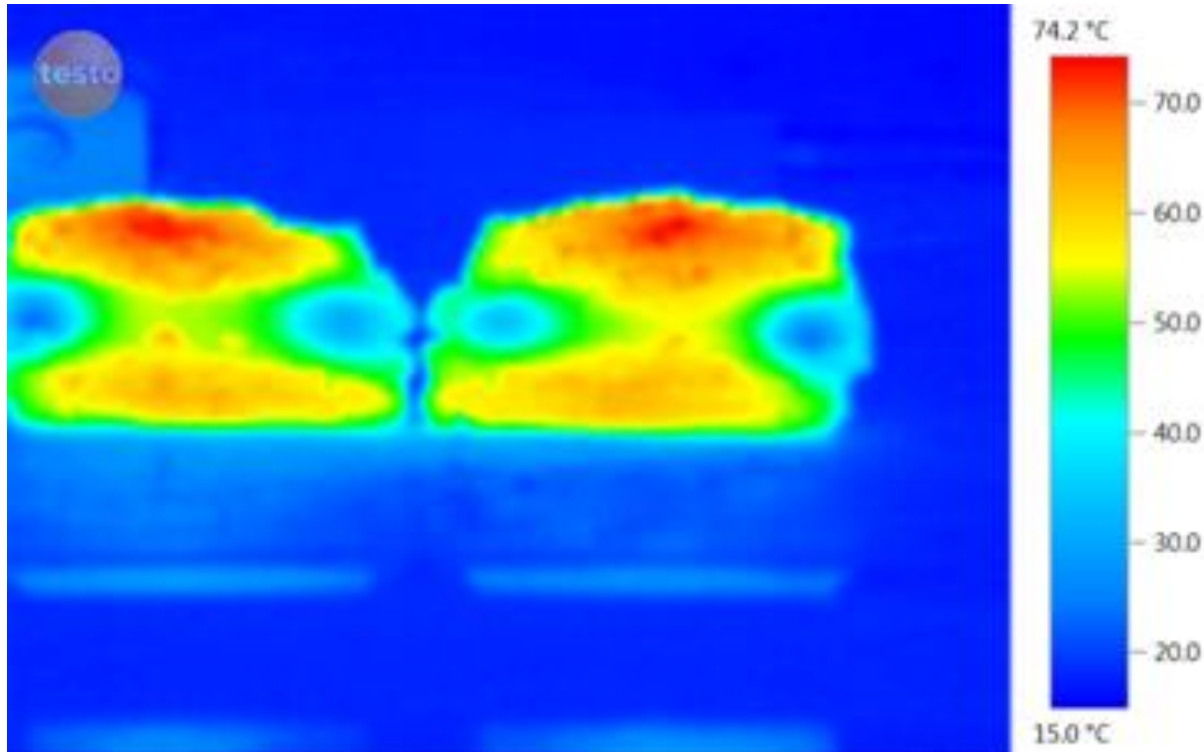
Reflective band

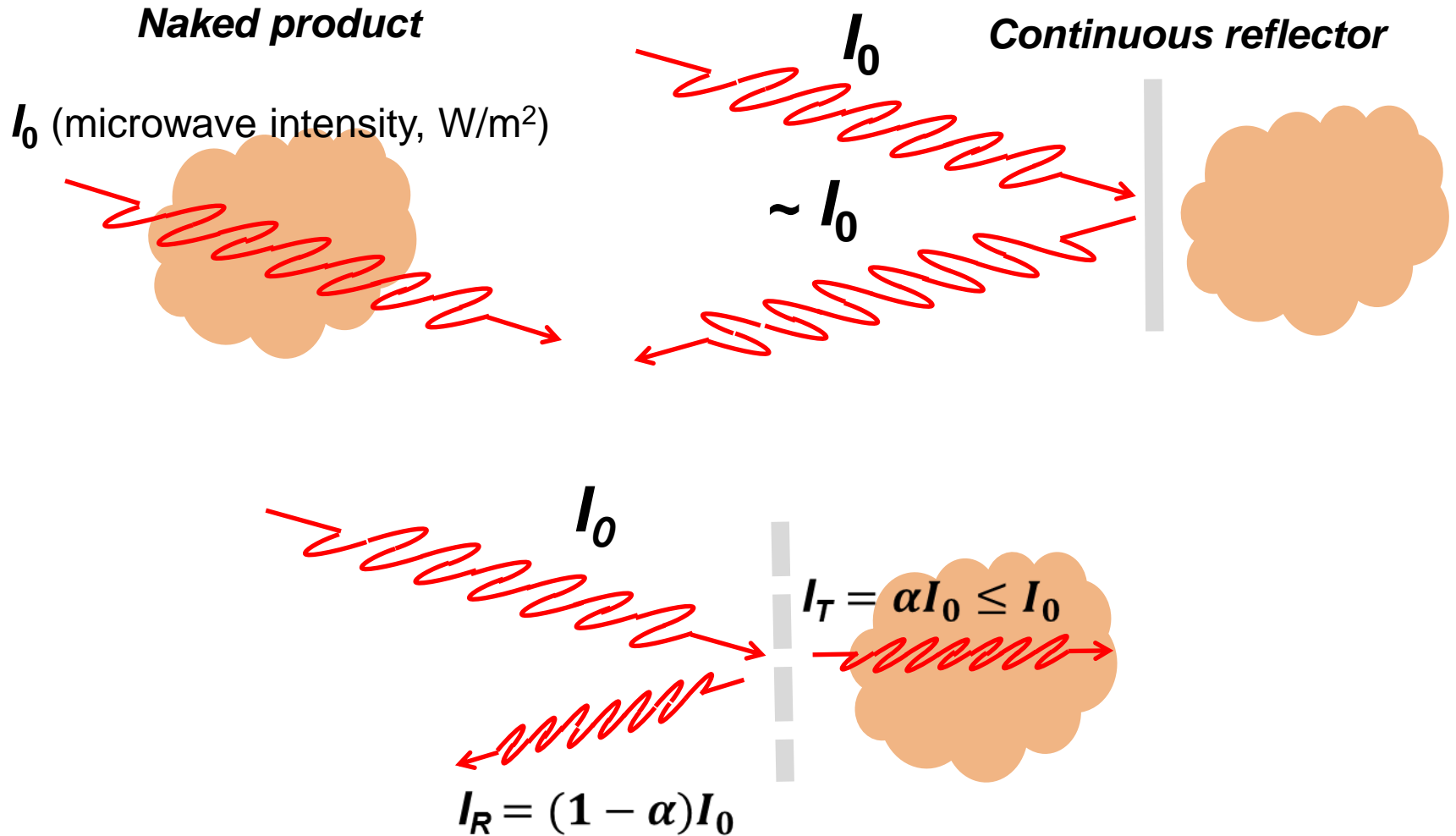


Focusing



Overfocusing





The necessity of

PERsonalized FOod using Rapid MAanufacturing for the Nutrition of elderly ConsumERs

PERFORMANCE



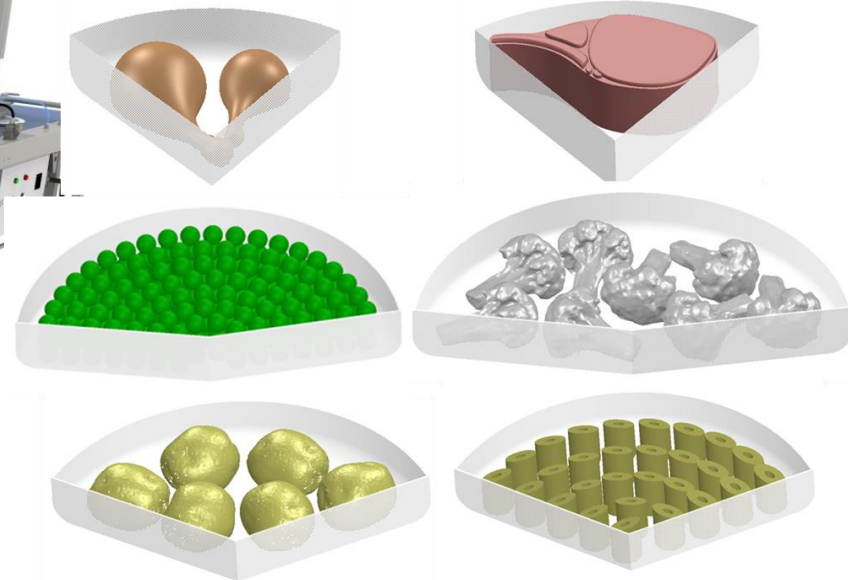
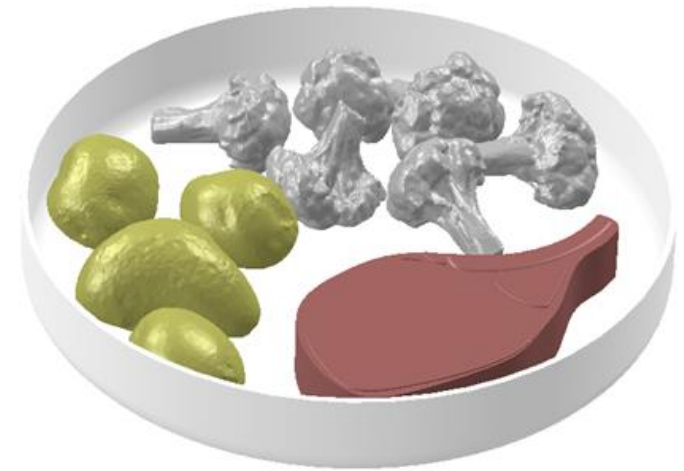
- 150 million European citizens will be over 65 years of age by 2050.
- Up to 50% of residents in nursing homes are malnourished.
- Due to their limited physical and physiological capabilities such as mastication and swallowing, anorexia and reduced sensorial capabilities, their meal has to have a special texture (pureed, thickened or gelled) and an intensified aroma.



- The PERFORMANCE project pursues the goal to develop, implement and validate a holistic personalised food supply chain for frail elderly persons living either in nursing homes, ambient assisted living facilities or simply at home (visited by nursing services).
- Personalised meals go beyond composition and portion size to include individual nutrient requirements and modified textures, which have the appearance and natural taste of traditional meals.

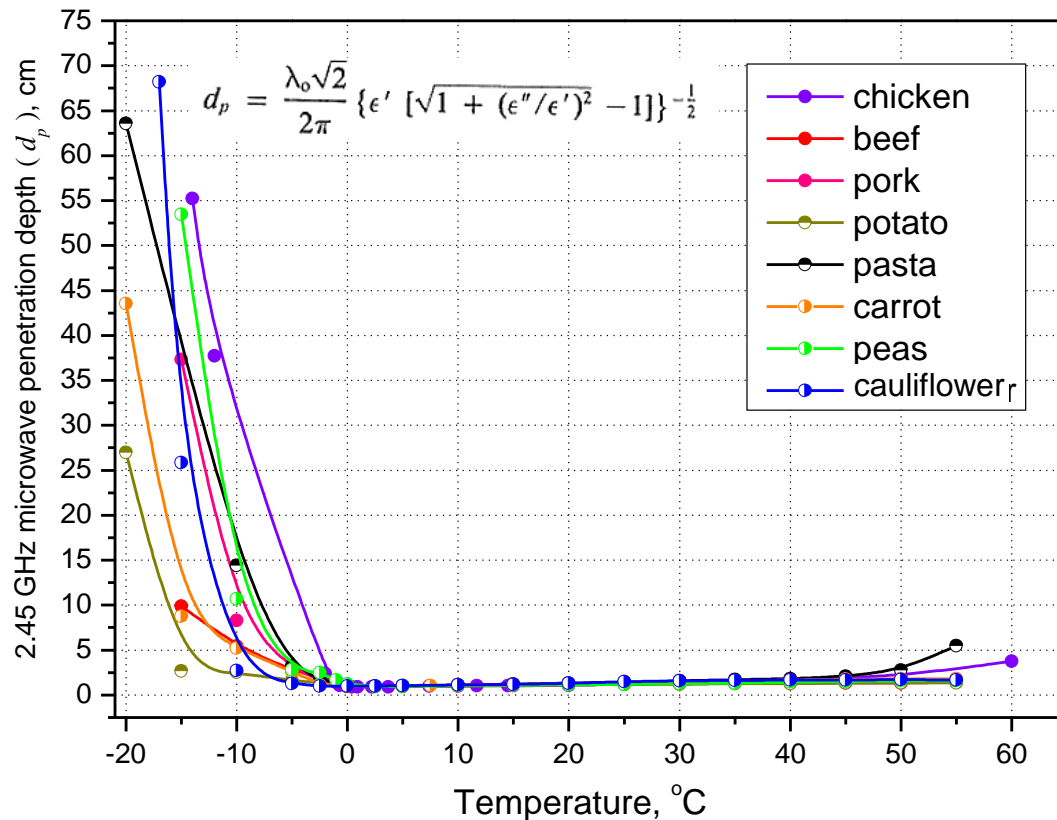
PERFORMANCE 3D food printers

courtesy of



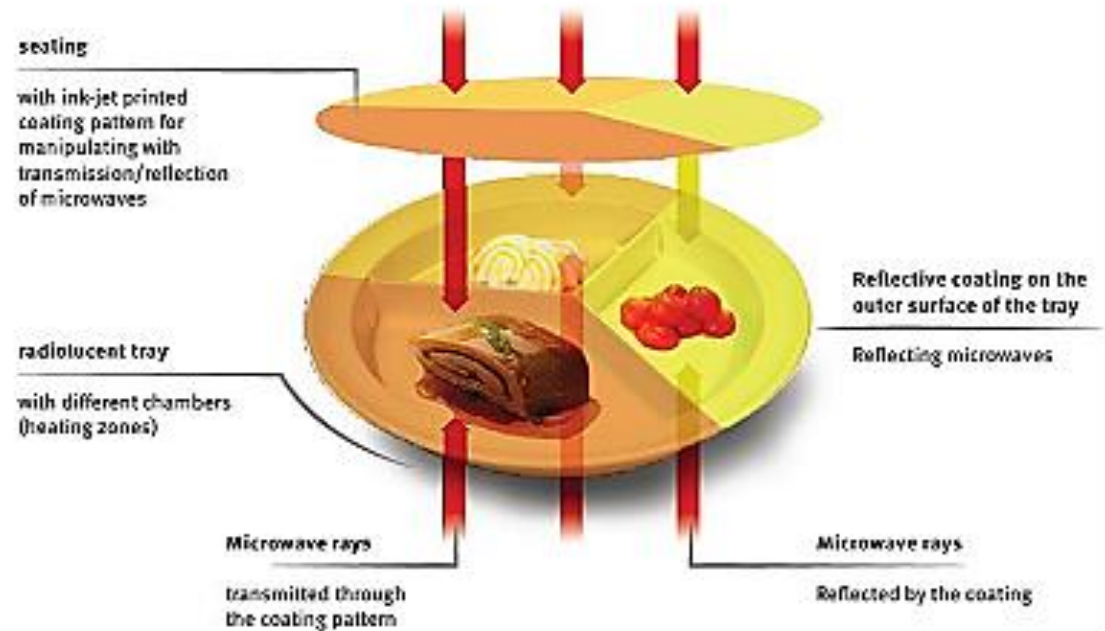
Microwave penetration depth (dielectric constant and loss factor)

Specific heat capacity (Differential Scanning Calorimetry)

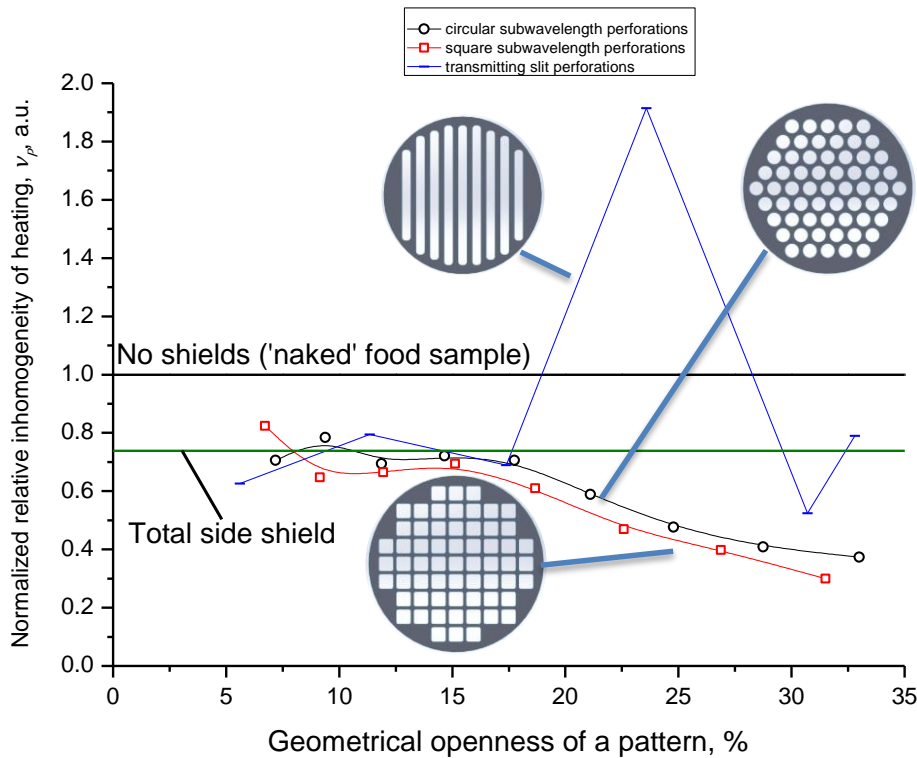


Samples	Heat capacity	
	J/gK	SD+-
Cauliflower	3.85	0.05
Beef	3.51	0.1
Pork	3.52	0.02
Carrot	3.88	0.07
Chicken	3.16	0.02
Potato	3.48	0.09
Pasta	3.57	0.11
Peas	3.75	0.05

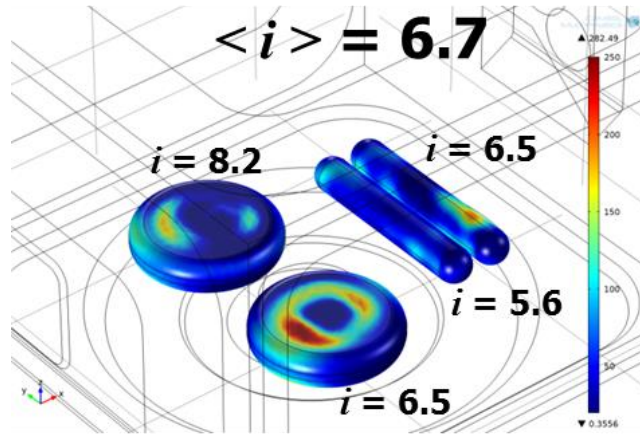
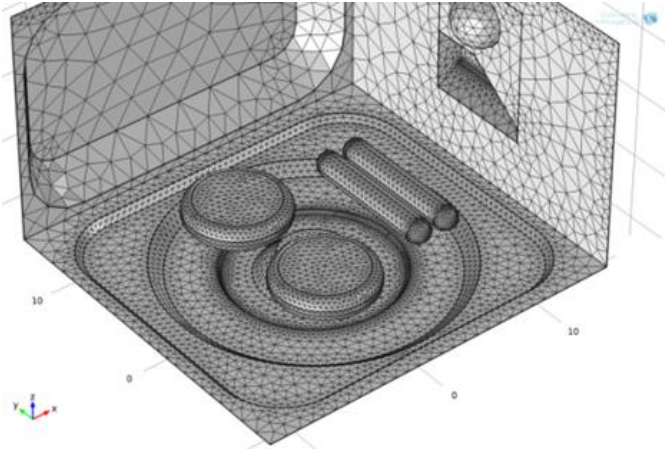
- Ink-jet printed partially reflective patterns of perforations control microwave power losses in each component of the personalised meal.
- Each personalised meal composition will be re-heated homogeneously and with the same rate regardless of the mass and type.



Optimisation of partially transmitting shields



Active packaging based on the shields with square perforations whose geometrical openness is in the range of 20...40% improve heating homogeneity by 50...80%

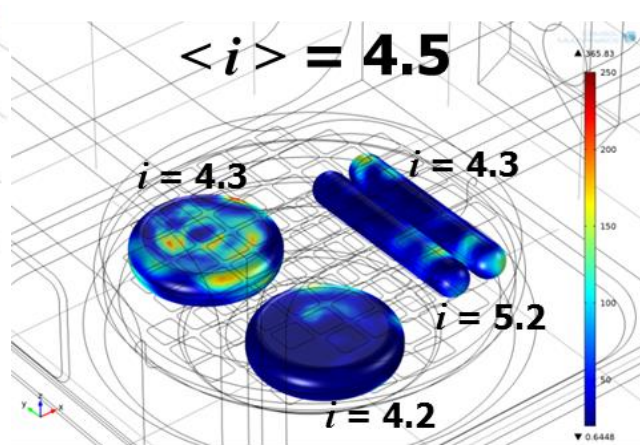
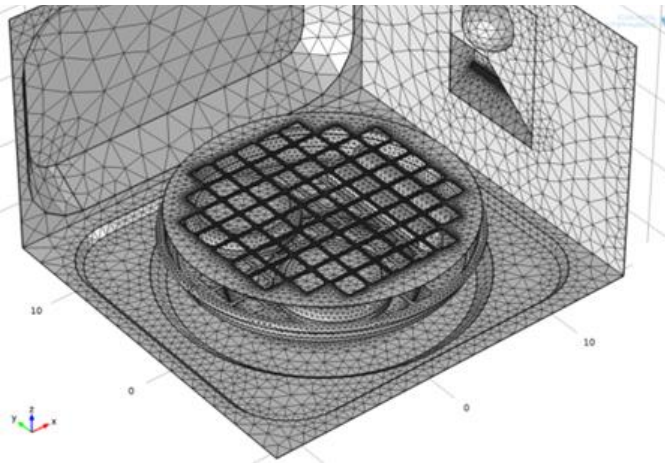


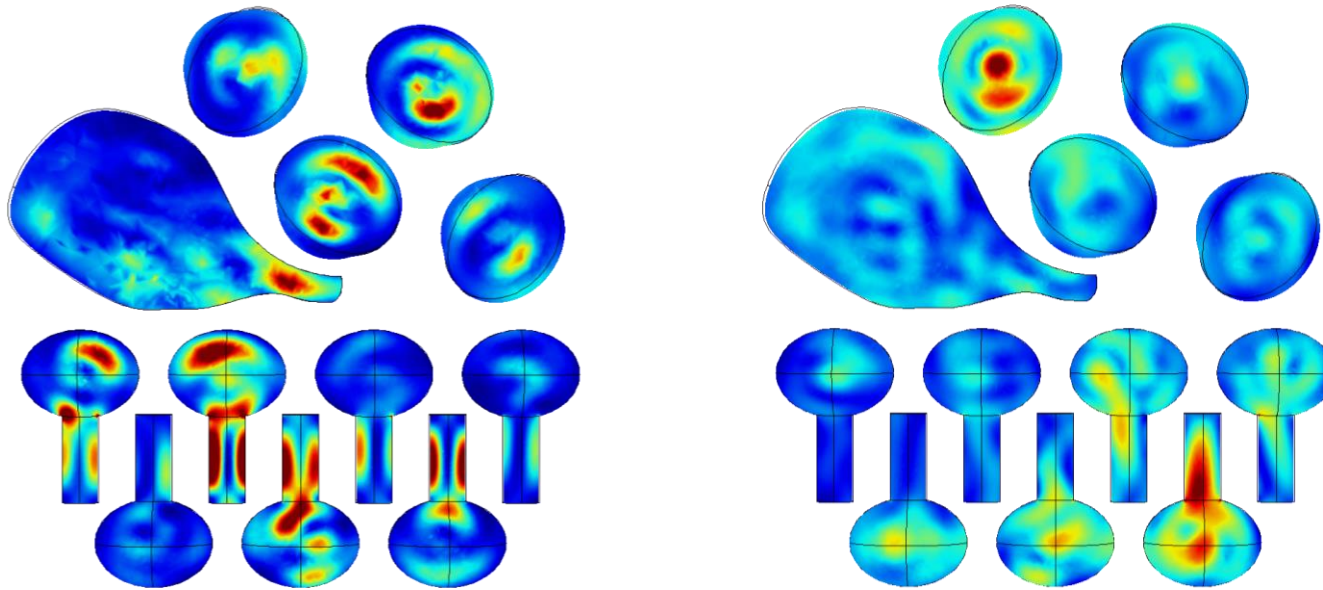
Microwave power losses

$$P = 2\pi f \epsilon_0 \epsilon'' |E|^2 \text{ (W/m}^3\text{)}$$

Inhomogeneity index

$$i = (P_{\max} - \langle P \rangle) / \langle P \rangle$$





Pattern	Absorbed energy [W/cm ³]	Std. Deviation [W/cm ³]
No reflectors	2.79	0.549
No. 1	1.50	0.317
No. 2	1.03	0.200
No. 3	0.93	0.199

- Patterns of sub-wavelength square perforations can be unhesitatingly recommended for the implementation of partially-transmitting shields.
- They can improve microwave heating homogeneity by a factor of 3 if geometrical openness of the pattern is within the range from 20 to 35%.
- Implementation of the pattern should be based on the sub-wavelength square perforations of the side length of 1.0...1.5 cm.
- Positional relationship of perforations in the pattern is not important, however its geometrical openness must exceed 20%.

Thank you ...

... for your attention!

For more information find us on
www.performance-fp7.eu



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