# Understanding meat crust formation. Validate mathematical models from quantitative microscopic MRI

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# Understanding meat crust formation
## Validate mathematical models from quantitative microscopic MRI

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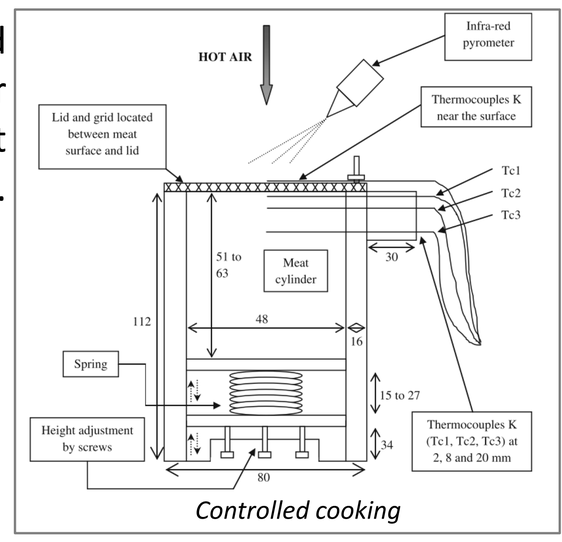
During cooking, meat crust is where both flavour and carcinogenic compounds are formed. To control and predict crust formation, mathematical models have been build [1]. To refine and validate these models, **water content profiles** were collected by **quantitative proton density (PD) magnetic resonance imaging (MRI)** on samples cooked under different temperatures [2].

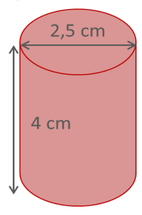

**Samples controlled cooking** : *Longissimus thoracis* muscles from 18-month-old heifers were cooked using an open jet system with IR and thermocouples (Tc) for respectively surface and internal temperature measurement in a device that compensates for heat shrinkage.



*Controlled cooking*

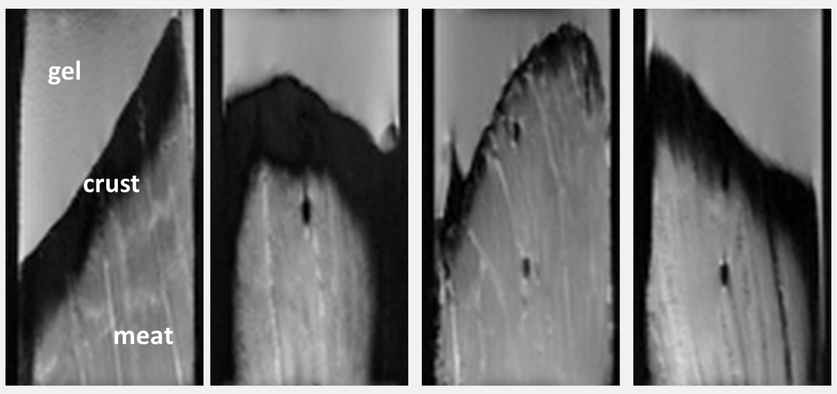
**Samples preparation**: After cooking, tubes containing meat cylinders were filled with gel to

- reduce artefacts at the air-crust interface
- detect crust beginning
- provide an PD internal reference.




**Imaging**: at 400 MHz on a Bruker Avance system equipped with a 30 mm actively shielded gradient birdcage coil for micro-imaging. Multi-slice single-echo spin-echo images (0.15×1×1 mm) were acquired at eight short echo-times (4 to 11 ms).

**Profiles extraction**: After mono-exponential fitting, quantitative PD "z"-profiles were computed, averaged on the whole sample and normalized to the gel intensity. If x,y-B1-errors were mitigated by such 2D integrations, those along the z-direction were neglected thanks to the large PD differences between crust and cooked meat.



20 min 192°C | 30 min 192°C | 20 min 124°C | 40 min 124°C

This figure presents a high-resolution central longitudinal slice showing raw meat (bottom), crust area and gelatin area (top).

The gelatin area is homogeneous and its intensity depends on water content (between 49.7 and 54.0% depending on the experiment).

Crust is a dry area and give almost no NMR signal. We observe the good contrast between gel and crust facilitating crust beginning detection during profiles extraction.

**Qualitative analyze** shows that crust thickness obviously increase with -Temperature
-Cooking duration

**Profiles analysis**:

A fully dried area appeared below the surface of the product after 40 min of heat treatment at 124 °C, 30 min at 192 °C, and 20 min at 210 °C.

Shorter treatments (10 min at 210 °C or 20 min at 124 °C) led to a gradual water loss in the first 3 mm but without crust formation.

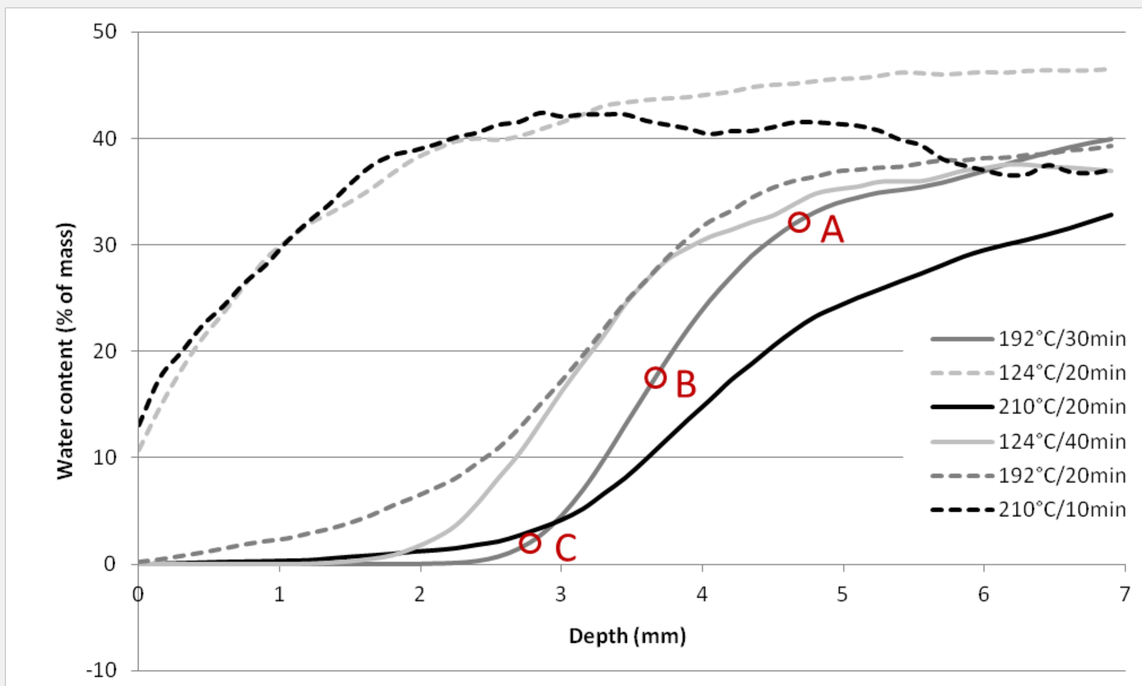
The water content profiles have a sigmoid shape in accordance with the profiles calculated by the analytical model.

The water content at the three inflection points can be linked to the water activity of the meat:

A- separates a liquid-dominant area where the meat temperature does not exceed 80–95 °C from a mixed liquid/vapor area ($a_w \approx 1$)

B- corresponds to the evaporating front, which separates the mixed liquid/vapor area from the steam-dominated area ($a_w \approx 1$)

C- saturated vapor temperature is around 150 °C ($a_w < 0,2$).



*Water content as a function of distance to surface measured from MRI PD with a resolution of 0.15 mm*

The high definition of PD MRI profiles is useful to refine and validate numerical models of real complex food processes

[1] Kondjoyan, A., et al. (2014). "Towards models for the prediction of beef meat quality during cooking." Meat Science 97: 8.

[2] Portanguen, S., et al. (2014). "Mechanisms of Crust Development at the Surface of Beef Meat Subjected to Hot Air: An Experimental Study." Food and Bioprocess Technology 7(11): 3308-3318.

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