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

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Validate mathematical models from quantitative microscopic MRI

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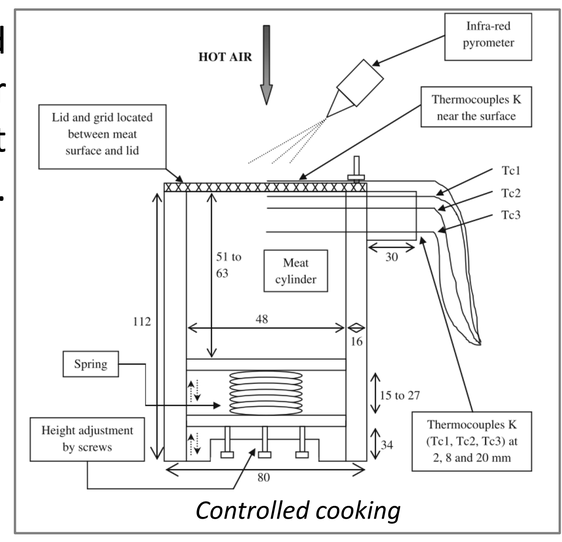
During cooking, meat crust is where both flavour and carcinogenic compounds are formed. To control and predict crust formation, mathematical models have been build [1]. To refine and validate these models, **water content profiles** were collected by **quantitative proton density (PD) magnetic resonance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

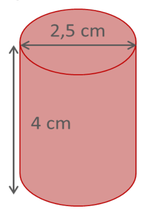
Samples controlled cooking : *Longissimus thoracis* muscles from 18-month-old heifers were cooked using an open jet system with IR and thermocouples (Tc) for respectively surface and internal temperature measurement in a device that compensates for heat shrinkage.



Controlled cooking

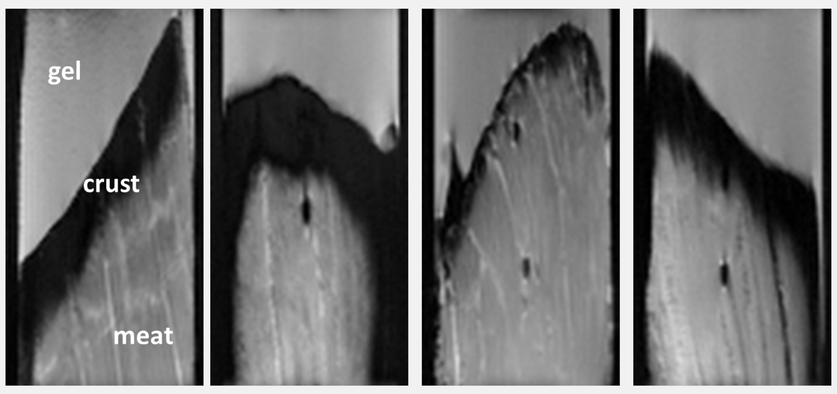
Samples preparation: After cooking, tubes containing meat cylinders were filled with gel to

- 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.

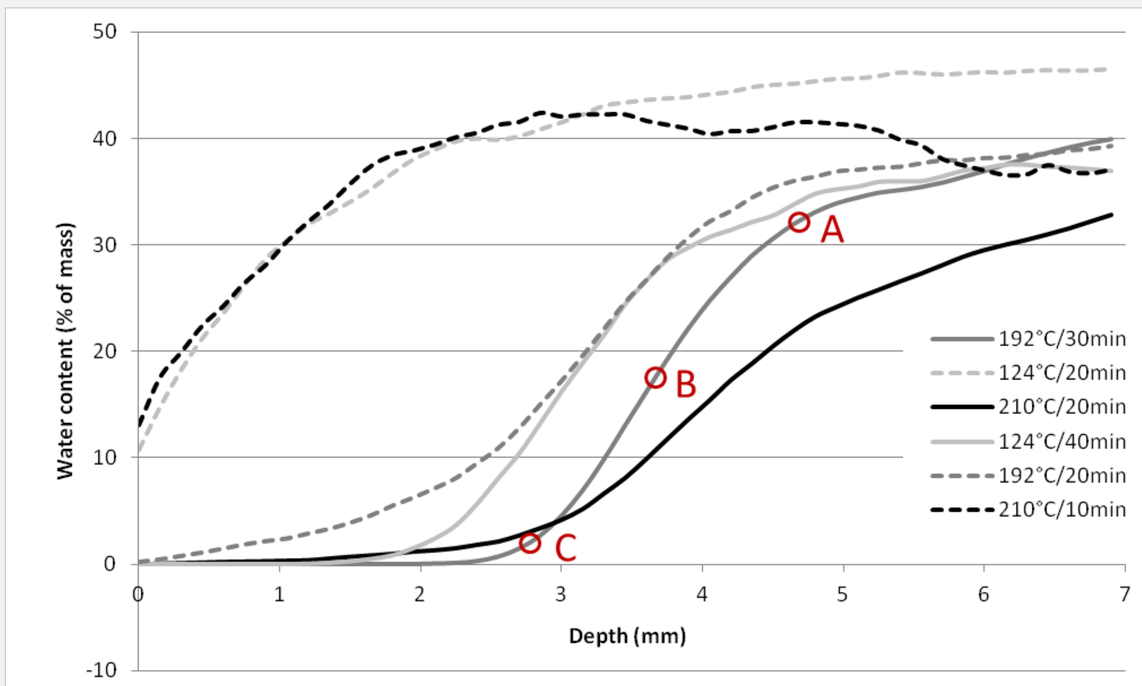
The water content profiles have a sigmoid shape in accordance with the profiles calculated by the analytical model.

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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