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Modelling the colour changes of chicken breast meat during convective roasting

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The color of cooked chicken meat is the first quality parameter evaluated by the consumer even before the actual consumption. The aim of this study was to combine the mechanistic model of heat and mass transfer with kinetic models to predict the color development (CIELAB lightness parameter, *L) of chicken breast meat during convective roasting. This will further our understanding of the cooking process and improve predictions and control of the product quality.**

Model of heat and mass transfer

Heat transfer:

$$c_{p,cm}\,\rho_{cm}\,\frac{\partial T}{\partial t} = \nabla(k_{cm}\,\nabla T) - \rho_w\,c_{p,w}\,u_w\,\nabla T$$

Mass transfer:

$$\frac{\partial C}{\partial t} = \nabla(-D\,\nabla C + C\,u_w)$$

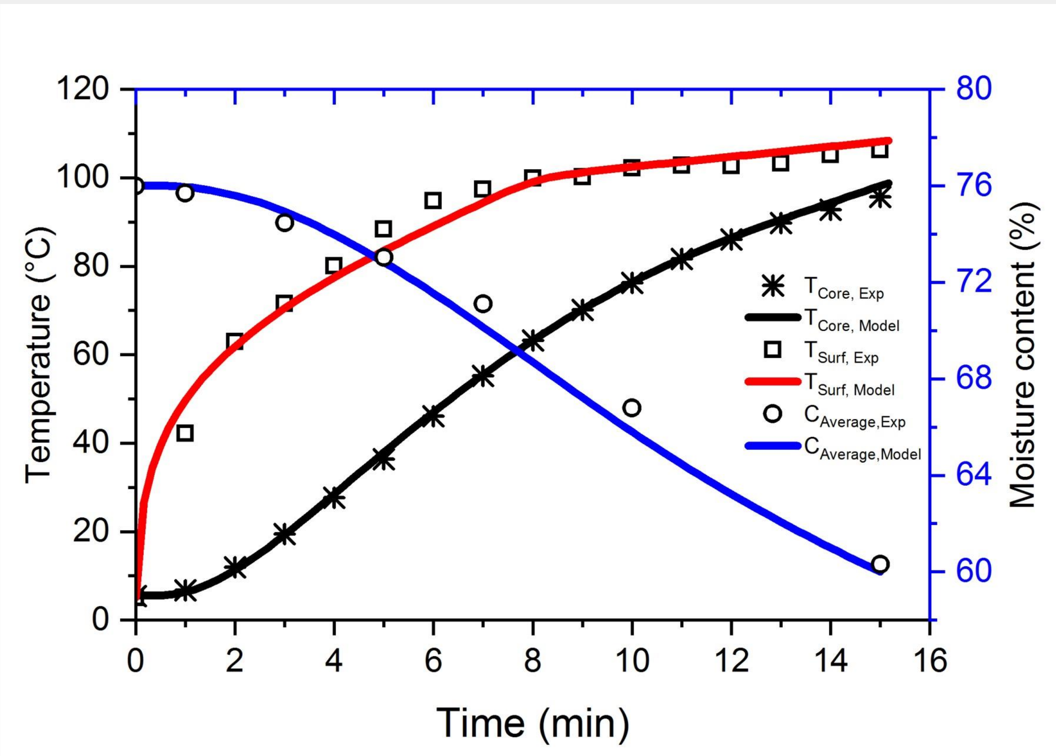

Fig. 1: Model validation: The simulated (solid lines) temperature development at the core and surface of the chicken meat sample during convective roasting at 230 °C agrees with the experimental data (symbols). Furthermore, a good agreement between measured and predicted moisture content development was found. [1]

Modelling the whitening process

Chicken breast meat becomes white during heating mainly due to heme-protein denaturation. The temperature dependent development was modeled with a modified reaction rate law and the Arrhenius equation [2]

$$\frac{\partial L_w^*}{\partial t} = k_w(T)\,(L^*_\infty - L_w^*)^n$$

$$k_w = k_0\exp\left(-\frac{E_a}{R\,T}\right)$$

By combining the kinetic model with the model of heat and mass transfer, the color development inside the chicken meat was predicted, as shown in **Fig. 2**.

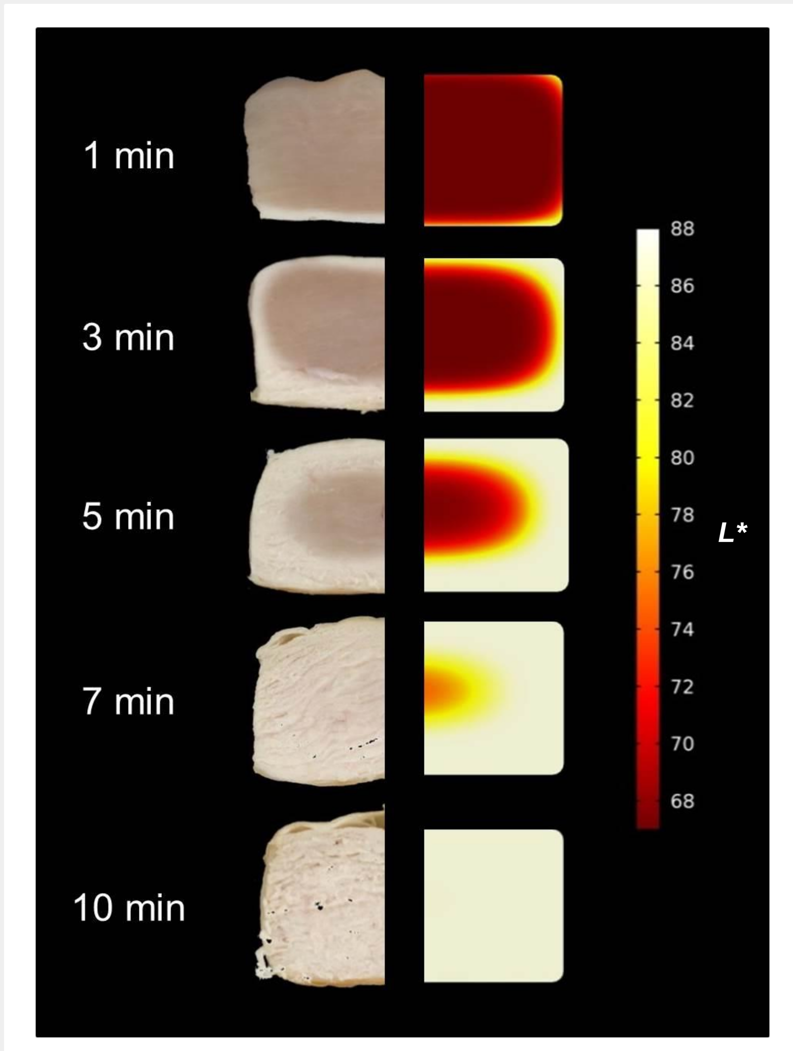

Fig. 2: Model visualization: Comparison between the experimental and simulated color development inside the chicken meat during roasting at 230 °C.

Modelling the browning process

The browning of the surface is mainly a result of Maillard reactions. It was modeled with a first order reaction and the reaction rate constant described as function of temperature and water activity:

$$\frac{\partial L^*_b}{\partial t} = -k_b(T, a_w)\,L^*_b$$

$$k_b = p_0 + \frac{p_1}{a_w(t)}\,exp\left(-\left(\frac{p_2 + \frac{p_3}{a_w(t)}}{T(t)}\right)\right)$$

Combined modelling of color changes

The kinetic model for whitening and browning was combined with a step function *f* which allows the prediction of the color development of both stages

$$\frac{\partial L^*}{\partial t} = f\,\frac{\partial L_w^*}{\partial t} + (1-f)\,\frac{\partial L_b^*}{\partial t}$$

First, the missing kinetic parameters (p_0, p_1, p_2, p_3) were estimated (**Fig. 3 A**). Subsequently the model was validated with an independent data set, as shown in **Fig. 3 B and C**.

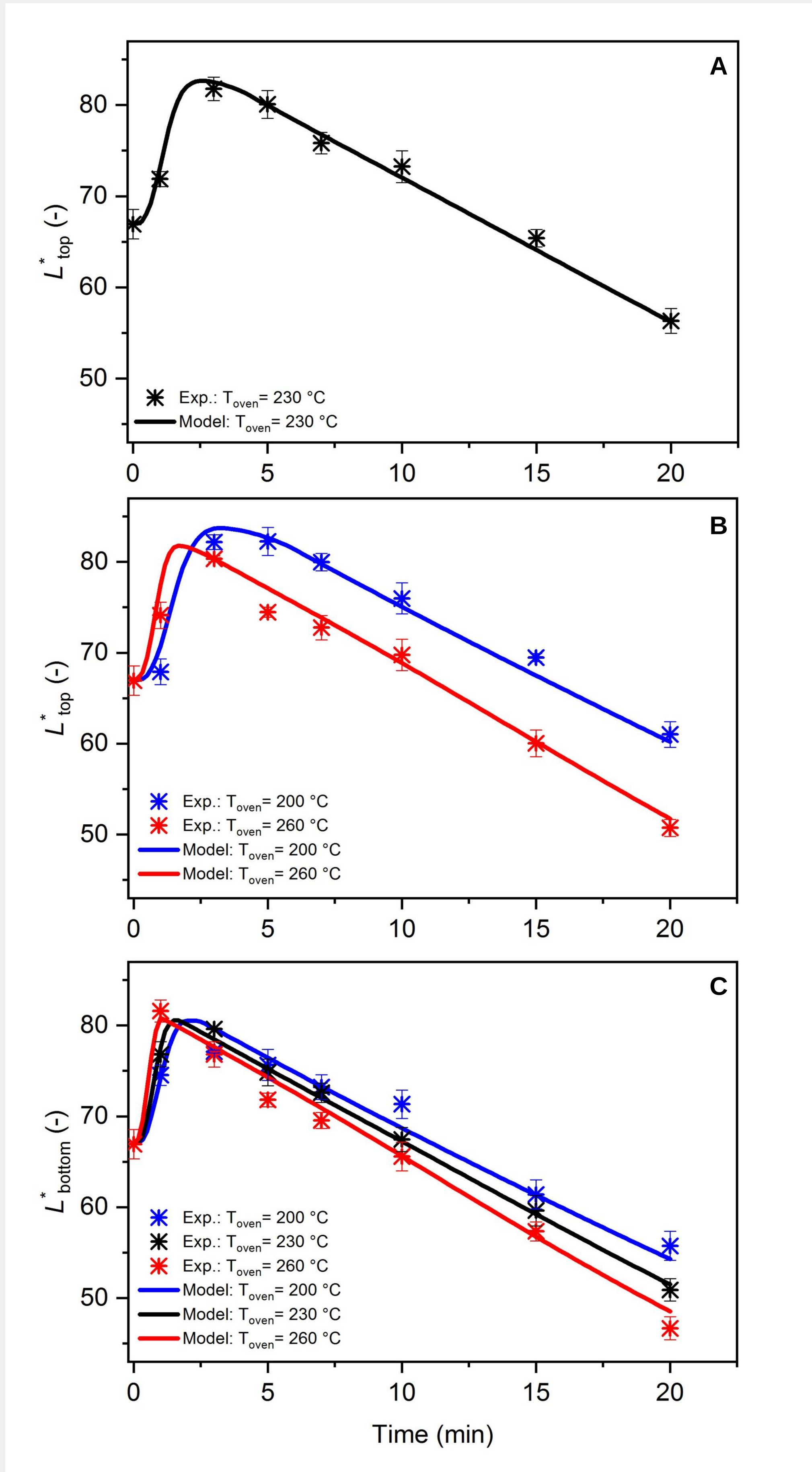

Fig. 3: A) Model calibration: The kinetic parameters were estimated by fitting the model to the experimental top surface color data for the roasting at 230 °C. **B)** and **C)**: Model validation: The simulated (solid lines) color development at the top and bottom surface of the chicken meat sample during convective roasting at 200, 230 and 260 °C agrees with the experimental data (symbols).

Conclusion

- A combined modelling approach was used to simulate the color changes of chicken breast meat during roasting.
- The developed model is able to predict the color change inside and at the surface during roasting for different process temperatures.
- The developed model can be used to control and optimize the roasting process to ensure the safety and quality of the product for the consumer.

1) Rabeler, F., Feyissa, A.H., 2018. Modelling the transport phenomena and texture changes of chicken breast meat during the roasting in a convective oven. *Journal of Food Engineering, 237, 60-68.*
2) Rabeler, F., Feyissa, A.H., 2018. Kinetic Modeling of Texture and Color Changes During Thermal Treatment of Chicken Breast Meat. *Food and Bioprocess Technology, 11:1495–1504.*

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