Flow, heat and mass transfer in coffee roasting

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Coffee in-cup flavour and aroma are generated by thermally driven chemical reactions during roasting, where the physicochemical transformation of coffee is governed by the applied time-temperature roasting profile. In the roaster, green coffee is transformed into roasted coffee, and signficant changes in physical and chemical properties occur during roasting.

Through simulation of the heat and mass transfer mechanisms that occur within the bean, and the batch of beans, the aim of this project is to gain better understanding of the engineering formulation of coffee roasting and build a digital twon for the process.

- a fundamental energy balance was used to develop a zero-dimensional simulation of coffee roasting time-temperature profiles at the batch scale and
- particle dynamic studies using Positron Emission Particle Tracking (PEPT) were used to understand the dynamic development of the bean-bed under different process conditions (Al-Shemmeri et al, 2021).

With these works as the basis, the aim of the current study was to combine heat transfer simulations (calibrated using real product and process measurements) and PEPT particle dynamic studies to

- construct a three-dimensional model for the thermal behaviour of a coffee bean within the roaster using accurate product geometry and properties,
- identify regional heat transfer coefficients corresponding to the bean-bed and in-flight regions and
- impose realistic bean surface boundary conditions.

By virtualising the roasting process, the heat transfer processes within the roaster can be identified and the temperature-time profile of the beans established. This creates a platform onto which the chemistry of flavour and colour can be modelled, and also establishes a method by which heat profile of the roaster can be considered as part of optimisation both of energy consumption and product quality.

Al-Shemmeri, M, Windows-Yule, CR, Lopez-Quiroga, E, Fryer, PJ. Coffee bean particle motion in a spouted bed roaster measured using Positron Emission Particle Tracking (PEPT), Journal of Food Engineering. 301, 110709, 2021