Mass Transfer Matrix Espresso extraction model

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This document describes an espresso extraction model which is influenced by the work presented in [1] and [2]. The model uses the coffee flow data collected during the espresso shot and the grind parameters along with other assumptions to predict the TDS (total dissolved solids) in the coffee drink. The model needs to be calibrated first to the TDS measurement data.

The main differences of this model compared to [2] is that 1) this model uses directly the coffee flow data (which can be collected with e.g. Bluetooth scale) instead of trying to model it. This improves the accuracy of the model. And 2) that the model uses natural discretisation of the coffee grains into "cells" to model the extraction dynamics, instead of using partial differential equations which are then discretised for numerical solution anyway. With this approach the particle size distribution can be used directly to create families of grains with different sizes. This improves the accuracy of the model even further.

The model is implemented in C# https://github.com/AndyZap/EspMod and is designed to work with DE1 espresso machine shot files.

Possible usage of the model

The coffee TDS measurements are common in assisting the search to a good brew recipe. The modern coffee brewing methods involves considerable range of the brew ratio, pressure and flow profiles. The TDS values obtained by different methods might be difficult to relate to each other. An espresso extraction model could tell if the differences are "the first order" effects, predictable by the model, or something more complicated (and possible undesirable) going on – e.g. like channelling.

Model description

Following [1] and [2], we model an espresso extraction as a water flow through a cylindrical packed coffee bed (the puck).

References

1. K. M. Moroney, Heat and mass transfer in dispersed two-phase flows, Ph.D. thesis, University of Limerick (2016). https://ulir.ul.ie/handle/10344/6592
2. M.Cameron,D.Morisco,D.Hofstetter,E.Uman,J.Wilkinson,Z.Kennedy,S.Fontenot,W.Lee,C.Hendon,J.Foster,Systematically Improving Espresso: Insights from Mathematical Modelling and Experiment. Matter 2, 1–18March 4, 2020, https://doi.org/10.1016/j.matt.2019.12.019