28th Conference ASIC 2021

From 28 June to 1 July 2021

Variability of espresso brewing in capsule systems.

S7-P-02

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Introduction

Espresso brews are variable. There are multiple causes of this: both due to the brewing system and the physics of flow through a packed bed of coffee grind , Andrews et al (2018). In the context of On Demand (OD) home brewer systems, this poster will show how modelling can be used to quantify the relative contributions of different effects.

Methods

Data from a home OD commercial brewer, an experimental rig and multi-scale modelling are used to give insight into the variability of brewing from packed beds of coffee grind.

Many OD home brewsers (e.g. Nespresso™,) use a vibration pump to drive water flow through a capsule and coffee bed. Such pumps have a *characteristic* response: the flow rate produced by the pump *reduces* as the back pressure on the pump increases Conversely, the capsule and coffee bed provide a resistance to flow such that the back pressure at the pump *increases* linearly with flow. **Fig. 1** illustrates. if flow resistance was constant then the combined system would stabilise at an *operating point (blue dot in the figure)*.

Fig. 1

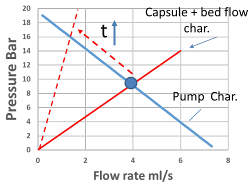
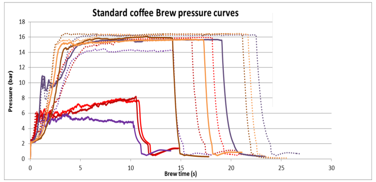
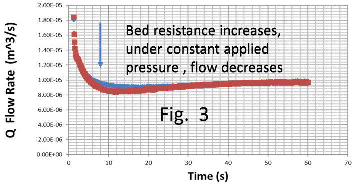


Fig. 2



In reality **resistance to flow increases with time** , and the operating point moves up the pump characteristic , the flow reduces. Changes in resistance are variable so there is a flow history, that varies from brew to brew ; OD systems produce a target cup volume, hence there is a variable brew time. **Fig .2** shows data for back pressure at the pump over time for a variety of capsules in a Nespresso system - the brew times range over 10 - 25 secs. Note, capsules that have foil bases pierced by the system to allow the flow out show wobbles in pressure ca 2-3 sec; ones open at the start and do not show these.

Corrochano et al (2015) measured the flow rate through a coffee bed with constant pressure driving the flow. **Fig 3**. shows a typical result. The flow rate drops over 15 s as the flow resistance of the bed increases - note, over a time scale comparable to that of espresso brewing.



Change in flow resistance is due to : fines plugging the bed, bed height consolidation, gas from the grinds – the slight rise in flow in Fig 3. ca. 20s is likely related to the gas leaving the bed. The rate of change of resistance increases with increasing flow rate. (Aside: Melrose et al (2019) also discuss how fines in beds affect brew yield differently from dilute slurry conditions.)

The capsule design also affects the flow resistance , in particular, the capsule exit holes also increase resistance , see **Fig. 4**

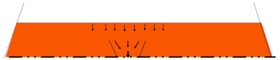
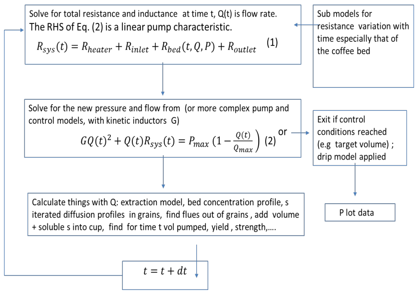
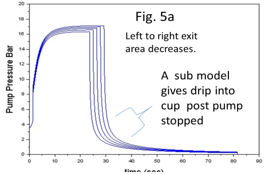
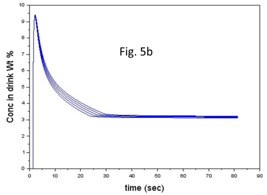


Figure 4 : The flow in the bed must converge to exit the hole. Finite element models and experiments (Andrews et al 2019) show that if the holes are just 10% of the base area , then resistance is increased by x2.

The author has built a simulation tool combining the pump and flow resistance physics with a model of extraction of coffee solubles; its design is shown right. **Fig. 5a,b** show an example output – for an espresso brew, exit area was varied and the effects on brew strength predicted - this simulation tool is used in Andrews et al (2018) for system design .







Conclusion/Perspectives

Effects leading to the variability of brewing flow rates can be modelled and simulated. By combining with extraction modelling of molecules, the relationship between brew compositions and variability can also be simulated.

References: . Andrews R. J., Harpley, P. J., Graaff, G. K., Melrose, J.R., 2018. Capsule and system for preparing double beverages. *Patent Application WO 2018026280 A1.* ;
Corrochano, B. R., Melrose, J. R., Bentley, A. C., Fryer, P. J., Bakalis, *J. Food Eng.* 150, 106–116. ;
Melrose, J. R., Corrochano, B., Bakalis, S., 2019. Polydisperse diffusion kinetics of Coffee Brewing - Pre-prints www.reserachgate.com John Melrose, Coffee Brewing project.
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