28th Conference Asic 2021
From 28 June to 1 July 2021

In-silico espresso coffee: formulation, test and future perspectives

S7-P-01

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Introduction

Brewing coffee is primarily considered an art rather than a business and drinking coffee is a practice spread worldwide. Its daily consumption has scientifically proven health benefits. Thus, such interesting features of coffee have stimulated a wide coffee-oriented scientific research. An important component of this research is an in-depth knowledge of the physico-chemical processes occurring in the coffee preparation. In fact, properly controlled extraction processes are able to enhance the coffee market services and sustainability.

Materials/Methods

The proposed espresso extraction model is based on fluid-dynamics laws [1] to fully describe the main aspects of water percolation in the coffee powder. In particular, each chemical compound has two reserved equations to properly describe the dissolution/erosion and transport processes [2]. A finite element procedure for the numerical solution of this model allows the computation of the chemical compounds in the cup, knowing the physico-chemical properties of the coffee powder and the extraction parameters.

References:

[1] Bear, J. and Bachmat, Y., *Introduction to modelling of transport phenomena in porous media*, 1990

[2] Giacomini, J. et al., *Int. J. Multiph. Flow*, 2020

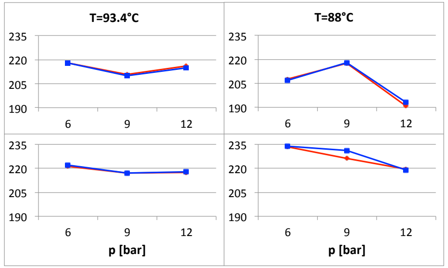

Figure 1: Caffeine amount [mg] in cup. First row: optimal granulometry; second row: fine granulometry. Blue line: numerical results; red line: laboratory results.

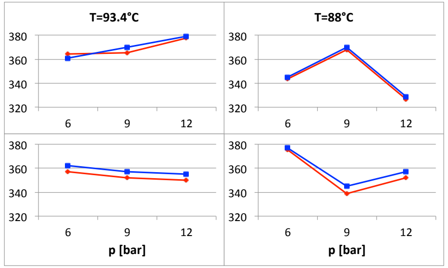

Figure 2: Chlorogenic acids amount [mg] in cup.

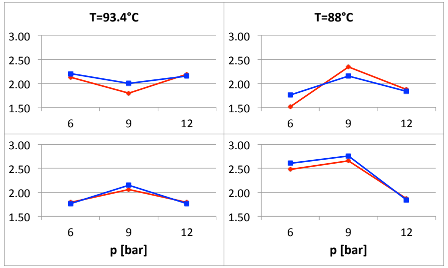

Figure 3: Lipids amount [mg] in cup.

Results/Discussion

The reliability of the model is experimentally assessed: the numerical results are compared with the chemical lab analyses of the samples of two coffee varieties (Arabica, Robusta), having different granulometries and extracted under different conditions (water temperature and pressure). The model calibration work considers these key compounds in a coffee cup: caffeine, chlorogenic acids, trigonelline, citric acid, acetic acid, tartaric acid, ferulic acid and lipids. In Figures 1-3, some results about caffeine, chlorogenic acids and lipids are shown as pressure varies, for two temperature values and two granulometries (optimal, i.e., 20g in–40 g out in 25 s, and fine) of Arabica coffee. A very good agreement between numerical and laboratory results can be observed. The other extraction settings and the remaining chemical substances reveal a similar behaviour.

Conclusion/Perspectives

The strongly promising results show that the proposed model gives a reliable approximation of the main physico-chemical processes of the espresso extraction. This makes feasible the implementation of a control procedure of espresso machines, where the proposed model is the core element. Moreover, the model opens fascinating perspectives for the coffee world, like the customisation of the coffee cup and the optimisation of the extraction process in terms of coffee powder used.