Recovery of spent coffee grounds phenolic compounds through optimized extraction processes

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Coffee is among the top commercial commodities worldwide and one of the most important export crops, with its consumption reaching more than 165 thousand 60-kg bags in 2018 (ICO, 2019; Okur *et al*, 2021).Spent coffee grounds(SCG) are the primary by-product produced during coffee beverage preparation,accounting for more than 6 million tons of waste that are being discarded annually (Zuorro and Lavecchia, 2012; Kim et al., 2016). It should be noted that SCG is characterized by a high ecotoxicity due to its significant content in polyphenols and tannins (Kookos, 2018). The lack of efficient methods to manage these high amounts of produced SCG, led the scientific community to search for alternative solutions to landfilling. Several studies have been published regarding the use of SCG as a resource for biofuel production (Pacioni et al., 2016; Sakuragi et al., 2016), soil fertilizers (Cruz et al., 2015), or the recovery of valuable chemicals, with high antioxidant activity such as polyphenols (Ballesteros et al., 2017). Phenolics like caffeic and chlorogenic acids can potentially be isolated from SCG and serve as added-value components in a variety of applications in the food, cosmetics, and pharmaceutical industries.

The aim of this study is to develop an efficient alternative and "green" method for the recovery of bioactive compounds from spent coffee grounds. Currently, for this purpose, conventional maceration extraction (CME) utilizing organic solvents is used. The drawbacks of these methods are mainly concerned with increased cost (time, energy, solvent consuming), and more importantly environmental burdens. The green chemistry trend led to the advent of innovative solvent types, such as deep eutectic solvents (DES) that are believed to be "the organic reaction medium of the century" (Alonso et al., 2016), as well as aqueous solutions of cyclodextrins, since upon formation of complexes between the hydrophobic cavities and extractants could enhance the yield of extraction (Diamanti et al., 2017). In addition, among the non-conventional extraction methods, the technology of ultrasound-assisted extraction (UAE) has shown high extraction efficiency and low energy and solvent consumptions and thereby its usage as an alternative method has been on the rise. Furthermore, microwave-assisted extraction (MAE) is one of the most employed alternative extraction methods. Among the advantages, reported for MAE, are its low extraction duration and solvent consumption.

In the present study, the effect of the solvent system and also the effect of ultrasound and microwave technologies on the extraction yield of phenolic compounds were investigated. Solvents studied were, a deep eutectic solvent (DES) and the system of aqueous solutions of b-cyclodextrin (CD). The parameters affecting the efficiency of phenolic compounds recovery of each method were optimized and the results were compared with the conventional extraction with ethanol. Finally, the effect of SCG moisture and fat content on extraction yield were studied under the optimum conditions of the novel methods (MAE, UAE, DES, CD).

This optimization of extraction parameters is helpful to systematically understand the interaction between independent factors and obtain the optimal parameter combination for optimum extraction. It should be underlined, that the extraction efficiency depends on several variables which may not be generalized for all plant materials due to the diverse nature of the existing bioactive phytochemicals. It is thus mandatory to select and optimize the processing conditions as a function of the used matrix and taking into account the desired response.

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