

## Mathematical modelling of turmeric compounds extraction using high pressurized solvents mixture



Mara E.M. Braga<sup>a,\*</sup>, Sócrates Quispe-Condori<sup>b</sup>, Paulo T.V. Rosa<sup>c</sup>, M. Angela A. Meireles<sup>d</sup>

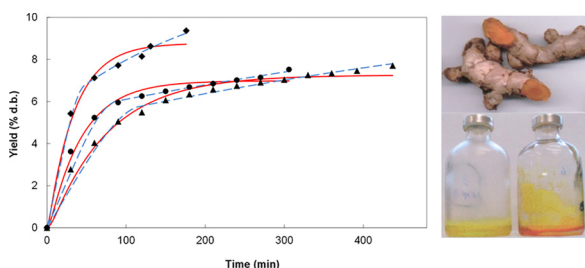
<sup>a</sup> CIEPQPF, Department of Chemical Engineering, FCTUC, University of Coimbra, Rua Sílvio Lima, Pólo II – Pinhal de Marrocos, 3030-790, Coimbra, Portugal

<sup>b</sup> Ingeniería in Industrias Alimentarias, Facultad de Ingeniería y Arquitectura, Universidad Peruana Unión, Alt. Km 19, Carretera Central, Ñaña, Lima, Peru

<sup>c</sup> Institute of Chemistry, State University of Campinas (UNICAMP), 13083-970, São Paulo, Brazil

<sup>d</sup> LASEFI/DEA/FEA (School of Food Engineering) – State University of Campinas (UNICAMP), Rua Monteiro Lobato, 80, 13083-862, São Paulo, Brazil

### GRAPHICAL ABSTRACT



### ARTICLE INFO

#### Keywords:

Solvent mixture extraction

*Curcuma longa*

Kinetic

Mathematical modelling

### ABSTRACT

Mathematical modelling was carried out in order to study the kinetics of the sub- and supercritical fluid extraction from turmeric, using carbon dioxide with either ethanol or isopropyl alcohol and their mixture (1:1 v/v) as co-solvents. The variables studied were pressure, solvent flow rate, co-solvent percentage and bed height to bed diameter ( $H_B/D_B$ ) ratio. Using the previously obtained experimental data, four mathematical models were evaluated in the present work to identify those that accurately fit the overall extraction curves. The models of Goto and Sovová were the ones that best correlated most of the experimental overall extraction curves obtained for turmeric extraction, even when using pressurized liquid solvent mixtures.

Sovová model  $k_{xa}$  Mass transfer in the solid phase  $[1/s]$   $k_{ya}$  Mass transfer coefficient in the fluid phase  $[1/s]$   $t$  The extraction time  $[s]$   $t_{CER}$  and  $t_{FER}$  Time related to the steps of CER and FER periods  $[s]$   $m_{is}$  The initial mass of inert solid material  $[kg]$   $X_0$  The maximum extract obtained in the solid  $(kg/kg)$   $Y^*$  Extract solubility in the  $CO_2$   $[kg/kg]$   $x_i$  The mass fraction of easily accessible solute in the inert material  $[kg/kg]$   $\rho$  Density of  $CO_2$   $(kg/m^3)$   $\rho_p$  Density of the particles  $(kg/m^3)$   $\epsilon$  Particles porosity  $[-]$

### 1. Introduction

In the last years, several applications of supercritical fluid extraction (SFE) from turmeric (*Curcuma longa*) mainly using  $CO_2$  as solvent, have been reported in the literature. The influence of pressure, temperature, and flow rate on the extract global yield was studied by Began et al. [1]. Gopalan et al. [2] measured the extraction rate as a function of pressure, temperature, flow rate, and particle size. The mass transfer of the

\* Corresponding author.

E-mail address: [marabraga@eq.uc.pt](mailto:marabraga@eq.uc.pt) (M.E.M. Braga).

<https://doi.org/10.1016/j.supflu.2018.07.014>

Received 29 March 2018; Received in revised form 10 July 2018; Accepted 11 July 2018

0896-8446/ © 2018 Elsevier B.V. All rights reserved.

Nomenclature	
SFE	Supercritical fluid extraction
$H_B$	Bed height [m]
$H_B/D_B$	Bed height to bed diameter ratio [m/m]
IsoP	Isopropyl alcohol
EtOH	Ethanol
CC	Curcuminoids
$\rho_{Ap}$	Apparent bed density [kg/m <sup>3</sup> ]
$V_B$	Extractor volume [m <sup>3</sup> ]
$D_p$	Particle diameter [m]
$S^2$	Mean square deviation
OEC	Overall extraction curves
CER	Constant extraction rate
FER	Falling extraction rate
$Y_{CER}$	The solute mass ratio in the fluid phase at the extractor exit in the CER period
$M_{CER}$	Extraction rate in the CER period
DF	Diffusional region
<i>Crank model</i>	
$m_{extract}$	The mass of extract [kg]
$X_0$	Initial solute mass (kg)
F	Mass of feed [kg]
$n$	The number of the series expansion
$D$	Effective diffusion coefficient [m <sup>2</sup> /s]
$t$	The extraction time [s]
$r$	The particle radius [m]
<i>Naik model</i>	
$e$	The extract/solvent ratio [kg/kg]
$e_\infty$	The extract/solvent ratio [kg/kg] in the infinite time of extraction
$k$	The adjustable parameter [-]
$t$	The extraction time [s]
<i>Goto model</i>	
$\phi$	Mass transfer coefficient [-]
K	Adsorption equilibrium constant [-]
$\beta$	Porosity of solid [-]
$X_0$	The maximum extract obtained in the solid (kg/kg)
$\rho_s$	True density of solid [kg/m <sup>3</sup> ]
$Q_{CO_2}$	Mass flow rate of supercritical CO <sub>2</sub> [kg/s]
$\rho_{CO_2}$	Density of CO <sub>2</sub> [kg/m <sup>3</sup> ]
$\tau$	Is the solvent residence time in the extraction cell [s]
$\varepsilon$	Particles porosity [-]
$\phi$	The dimensionless mass transfer coefficient
$k_p$	Global mass transfer coefficient [1/s]
$a_p$	Specific surface area [1/m]

SFE was studied by Chassagnaz-Méndez et al. [3]. However, because of the low SFE yield in curcuminoids (CC), the addition of a co-solvent (ethanol or isopropyl alcohol) is necessary to improve their extraction [4,5,6]. The amount of CC extracted was found to be significantly affected when using ethanol as co-solvent [4]. Yadav et al. [7] studied the accelerated solvent extractor (ASE) of curcuminoids at low pressure, and the maximum yield and purity were obtained using ethanol and acetone, respectively. Braga et al. [5] and Braga and Meireles [6], studied the influence of the pressurized ethanol, isopropyl alcohol, and their mixture (1:1 v/v) on the recovery of CC and concluded that the best co-solvent was the mixture ethanol:isopropyl alcohol (1:1 v/v), at 30 MPa and 303 K. The use of co-solvents in the SFE process has been widely reported, and the solubility of a solute and the selectivity of CO<sub>2</sub> towards that solute can be modified by the addition of a co-solvent. Additionally, the use of co-solvent decreases processing costs [8]. Osorio-Tobón et al. [9] studied the pressurized liquid extraction (PLE) with ethanol and the scale-up of curcuminoids extraction using the extractor volumes from 0.05 up to 0.5 m<sup>3</sup>; they also studied the cost of manufacturing for the turmeric extraction process.

The successful design of SFE processes requires studies on the solubility, kinetics and mass transfer data for solutes in supercritical fluids. Several studies have reported mass transfer models to describe the kinetic profile of SFE [10,8,11–17]. Cocero and García [11,12] studied several mathematical models to represent the SFE of lipids from sunflower. Because the experimental data showed a sigmoidal shape, the overall extraction curve (OEC) was modelled by the desorption model [11]. Two adjustable parameters (desorption equilibrium and mass transfer coefficient in the fluid phase) were considered. Cocero and García [12] evaluated three shortcut methods and concluded that the Fast Adjusting Method (FAM) predicted properly the OEC. This model is similar to the empirical model, but the difference is that it considers two adjustable parameters:  $n$  and  $k$ , where  $n$  is directly related with the curve, sigmoidal for  $n = 1$ . Zancan et al. [13] used the Sovová [18] model to represent the OEC from ginger rhizomes. Mantell et al. [14] proposed a penetration model and concluded that the controlling stage of the process was the internal diffusion. From these studies it can be concluded that the effect of the temperature, pressure, flow rate and

co-solvent (percentage and type) on the kinetics of the SFE process can be complex.

Some mass transfer models have been used to fit data also obtained with co-solvents, mainly using the Sovová's model [19,20,21]. However, models applied to processes using co-solvents are scarce. Cygnarowicz-Provost et al. [8] used the Lee et al. [22] model to represent the OEC from fungal lipids. The mass transfer coefficient was the only adjustable parameter. These authors showed that the mass transfer coefficients with pure CO<sub>2</sub> and CO<sub>2</sub> + 10% of ethanol, can be represented by the same equation as a function of the Reynolds number. In this case, the mass transfer coefficients increased with increasing flow rate. Nevertheless, for extraction processes design purposes, information related with the kinetics and the mass transfer of the process is essential to predict the bed extract depletion. Thus, the objective of this work was to extend the previous studies, by applying four mathematical models to evaluate the OEC's obtained under the influence of different process variables that included pressure, co-solvent type, flow rate, co-solvent percentage and bed heights to bed diameter ( $H_B/D_B$ ) ratio.

## 2. Materials and methods

The raw material and the SFE unit that were used to obtain the overall extraction kinetic curves modelled in the present work were previously described in Braga et al. [5] and Braga and Meireles [6]. Particles sizes 24, 32, and 48 mesh were selected for the assays, based on previous works considering the higher mass transfer into the fixed extraction bed. The mean particle diameter ( $D_p$ ) was estimated using the procedure recommended by ASAE [23]. The real or true density ( $\rho_s$ ) of the particles was measured by helium gas pycnometry (Multivolume Pycnometer Micromeritics, model 1305, Georgia, USA). The bed bulk density ( $\rho_{Ap}$ ) was calculated using the extractor volume ( $V_B$ ) and the mass of feed ( $F$ ). The bed particles porosity ( $\varepsilon$ ) was calculated using the apparent bed density and the particles real density, as an approximation, with the hypotheses of these particles do not have pores.

Download English Version:

<https://daneshyari.com/en/article/6670218>

Download Persian Version:

<https://daneshyari.com/article/6670218>

[Daneshyari.com](https://daneshyari.com)