(8) 2022-23

Materials Today: Proceedings 76 (2023) 47–55

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

# Optimization of turmeric oil extraction in an annular supercritical fluid extractor by comparing BBD-RSM and FCCD-RSM approaches

Sutapa Roy*, Asit Kr Saha, Shreyadhrita Panda, Gopal Dey

*Department of Chemical Engineering, Haldia Institute of Technology, Haldia-721657, WB, India*

ARTICLE INFO

*Article history:*
Available online 22 September 2022

*Keywords:*
Supercritical carbon dioxide extraction
Turmeric oil
Annular extractor bed
Face Centered-Central Composite Designs
Box–Behnken Designs

ABSTRACT

Comparison between the performances of two important statistical response surface modelling methods of Face Centered-Central Composite Designs (FCCD-RSM) and Box-Behnken Designs (BBD-RSM) were performed to find the optimum operating conditions of extraction pressure, temperature and particle size that can maximize the yield obtained from grated turmeric rhizomes when extracted under the influence of a specially designed annular extractor bed using supercritical carbon dioxide extraction ($SCO_2E$). The effects of operating pressure, temperature and particle size were investigated at the extraction pressure of 21.6 MPa, 24.55 MPa or 27.5 MPa; the extraction temperature of 40°C, 50°C or 60°C; and the particle sizes of 0.3 mm, 0.6 mm or 0.9 mm. Yield of turmeric oil was varied from 1.84 wt% – 4.45 wt% for different combinations of operating parameters used in extraction following FCCD-RSM and BBD-RSM. Both the methods were identified as efficient to build the experimental design and optimize the process by fitting the experimental data in quadratic models within the design range. FCCD-RSM based optimization furnishes a set of optimal conditions of 26.859MPa extraction pressure, 59.886°C extraction temperature and 0.301 mm particle size with a slightly better yield (4.452%) as compared with BBD-RSM based optimization (27.325MPa extraction pressure, 58.417°C extraction temperature and 0.31 mm particle size with a yield of 4. 403%). Considering the time of performing all experiments, labour, and cost involved in three factors-three levels of optimization, BBD-RSM is proposed as a well-accepted alternate method of experimental design in the RSM study of $SCO_2E$ of turmeric oil under the influence of annular extractor along with the more acceptable FCCD-RSM.

Selection and peer-review under responsibility of scientific committee of the International Conference on Advances in Chemical and Material Science.

## 1. Introduction

The extraction unit or the extractor is the key element of the supercritical fluid based green promising extraction system used in the production of essential oil from various plant resources. Geometry of this high pressure extraction vessel has strong influence on the solvent distribution, flow characteristics of solvent and solute–solvent interaction that affect the extraction kinetics and scale-up of supercritical fluid extraction (SFE) processes significantly [1–5]. The solid–fluid interaction inside the extractor are highly influenced by the factors like extraction pressure, particle size of plant mass and bed geometry of the extractor. Since cell walls of plant material are cracked during milling operation and under high pressure of SFE, oil enclosed inside the cells expose to direct contact with solvent easily. Extractor geometry provides also the necessary environment to enhance the contact between oil rich ground plant mass and supercritical carbon dioxide ($SCO_2$) solvent. Thus, it contributes significantly to control the time of oil extraction that is related with the performance of SFE process [6]. The introduction of annulus geometry inside the extractor by inserting one dead-end smaller diameter perforated channel inside the conventional perforated cylindrical channel and loading the ground plant material within the annulus space were reported to improve the essential oil extraction in some recent works [7,8]. Besides

*Abbreviations:* ANOVA, Analysis of variance; AICc, Akaike Information Criterion; BBD-RSM, Box–Behnken Design; FCCD-RSM, Face Centered-Central Composite Design; % OY, Percentage oil yield; RSM, Response surface methodology; $SCO_2$, Supercritical $CO_2$; $SCO_2E$, Supercritical carbon dioxide extraction; SFE, Supercritical fluid extraction.

* Corresponding author at: Department of Chemical Engineering, Haldia Institute of Technology, Haldia-721657, W.B., India.
*E-mail address:* sutaparoymasanta@gmail.com (S. Roy).

https://doi.org/10.1016/j.matpr.2022.09.039