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Starch recovery from turmeric wastes using supercritical technology

Ádina L. Santana [a, *], Giovani L. Zabot [b], J. Felipe Osorio-Tobón [c], Júlio C.F. Johner [a], Alessandra S. Coelho [d], Marcio Schmiele [d], Caroline J. Steel [d], M. Angela A. Meireles [a, **]

[a] LASEFI/DEA/ School of Food Engineering, University of Campinas (UNICAMP), R. Monteiro Lobato, 80, 13083-862, Campinas, São Paulo, Brazil
[b] Federal University of Santa Maria (UFSM), Av. Presidente Vargas, 1958, 96506-302, Cachoeira do Sul, Rio Grande do Sul, Brazil
[c] Faculty of Health Sciences, University Institution Colegio Mayor de Antioquia (COLMAYOR), Carrera 78#, 65-46, 050036, Medellín, Colombia
[d] LABCER/DTA/ School of Food Engineering, University of Campinas (UNICAMP), R. Monteiro Lobato, 80, 13083-862, Campinas, São Paulo, Brazil

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ABSTRACT

Extraction processes that employ supercritical fluid technology has been extensively applied for the obtaining of high-quality extracts from turmeric rhizomes. Nevertheless, these processes generate high quantities of wastes, which are potential sources of antioxidant constituents and carbohydrates. In this work, mixed biopolymers composed of starch and curcuminoids were recovered from supercritical fluid and pressurized liquid extraction processes. The quality of these materials was investigated in terms of experimental and economic approaches. The application of supercritical fluid and pressurized liquid extraction resulted on products with relevant quality in terms of curcuminoids and modified polymer matrix, which can attribute inclusion in industry as a colorant agent, and in human diet as a resistant starch source. Economic evaluation reports that recovery of biopolymers from turmeric wastes is a feasible alternative considering 80% yield and capacities of 50 L and 500 L.

1. Introduction

The composition of turmeric rhizomes in terms of starch and curcuminoids are responsible for the wide application of this crop as dietary food ingredient (Lim and Han, 2016; Mancini et al., 2015; Park et al., 2012) and therapeutic agent for treatment of diseases (Irving et al., 2011; Nguyen et al., 2017; Sahne et al., 2016).

The isolation of starch from crude turmeric has been performed with the application of several washings with water, followed by a final washing with alcohol with further drying (Kuttigounder et al., 2011; Leonel et al., 2003). Nevertheless, extraction of curcuminoids has been performed in several different ways with the application of nonpolar solvents hexane, chloroform, ethyl acetate, ethanol and acetone (Osorio-Tobón et al., 2014; Revathy et al., 2011).

Global starch consumption is projected to reach 133.5 million metric tons by 2018, driven primarily by the diversity and sheer number of end-use applications in both food and non-food industries (GIA, 2016). Although there is a large consume of conventional sources of starch, such as corn and potato, the application of non-conventional raw materials as complementary sources may provide cost reduction of raw material in industries, besides offering new products with differentiated characteristics (Santana and Meireles, 2014).

Nowadays methods that employs supercritical fluids and pressurized liquids were successfully applied in the field of starch chemistry for the production of fermentable sugars from the starchy wastes from annatto (Alcázar-Alay et al., 2016) with the employment of partial hydrolysis with pressurized water, and total hydrolysis from ginger wastes using subcritical water and carbon dioxide (Moreschi et al., 2006). In addition, critical water and ethanol were applied for lipid extraction of corn starch (Peterson et al., 2008), while supercritical carbon dioxide induced gelatinization of potato starch (Muljana et al., 2009), and was used for the obtaining of corn starch aerogels (De Marco and Reverchon, 2017).

Supercritical fluid extraction (SFE) with carbon dioxide has been used to extract volatile oils from crude turmeric (Carvalho et al., 2015) and pressurized liquid ethanol has been applied on deflavored turmeric waste for the obtaining of extracts composed of curcuminoids (Osorio-Tobón et al., 2014). As consequence of these processes, solid wastes with high quality in terms of curcuminoids and fermentable sugars are generated (Santana et al., 2017; Santana and Meireles, 2016).

* Corresponding author.
** Corresponding author.
E-mail addresses: adina.santana@gmail.com (Á.L. Santana), maameireles@gmail.com (M.A.A. Meireles).

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In this context, we investigate the effects of extraction technologies that employs supercritical carbon dioxide and pressurized liquid ethanol on the recovery of starch and curcuminoids from turmeric wastes. In order to evaluate the feasibility of inclusion of these materials in industries as a complementary starch source, economic evaluation was performed.

2. Materials and methods

2.1. Material

2.1.1. Raw material

Crude turmeric (CT) was purchased from the Oficina de Ervas Farmácia de Manipulação Ltda (lot 065DM, Ribeirão Preto, Brazil).

2.1.2. Reagents

Carbon dioxide (99.9%) was obtained from White Martins (Campinas, Brazil). Ethanol (99.5%, pure) was purchased from Dinâmica (São Paulo, Brazil). Glacial acetic acid (Ecibra, Brazil), Milli-Q water (Millipore®), and acetonitrile (JT Baker, USA) were used in high-performance liquid chromatography (HPLC) analysis. Chloroform (Merck, Darmstadt, Germany), glacial acetic acid (Synth, Diadema, Brazil) and ethanol (Sinergia, Campinas, Brazil) were used in thin-layer chromatography (TLC) analysis. Curcuminoids standards of curcumin (≥94% curcuminoids; ≥80% curcumin), demethoxycurcumin, bisdemethoxycurcumin and the volatile standard of ar-turmerone were purchased from Sigma-Aldrich (Darmstadt, Germany).

2.2. Supercritical fluid extraction

Supercritical fluid extraction (SFE) was carried out using a homemade equipment, described by Johner and Meireles (2016). Approximately 70 g (dry basis) of CT was placed inside the extraction cell occupying its total volume, i.e., 100 mL. The solvent was carbon dioxide, which was cooled with the aid of a cooling bath (Thermo Haake, C10, Eindhoven, Nederlands) and was fed into the pneumatic pump (Maximator, M-111L, Nordhausen, Germany) entrance in a liquid form.

The extraction vessel was heated using a heating jacket using circulating water from a heating bath (Thermo Haake, DC30/DL30, Eindhoven, Nederlands) at 333 K. When the extraction vessel achieved the desired temperature, the extraction vessel was pressurized with carbon dioxide at 24 MPa for 20 min (static time). Afterward, the blocking valves were opened, and the micrometering valve was carefully adjusted to maintain the constant carbon dioxide flow of 4.5×10^{-4} kg/s and a solvent-to-feed ratio (S/F, dimensionless) of 12.1. The time of extraction was 31 min (dynamic time).

The applied conditions of 333 K and 25 MPa were selected, according to the highest yield of volatile oil, obtained elsewhere (Osorio-Tobón et al., 2014).

2.3. Pressurized liquid extraction

After the SFE process was completed, deflavored turmeric (DT) was depigmented using ethanol. The curcuminoids extraction was performed in a pressurized liquid extraction (PLE) apparatus described elsewhere (Farias-Campomanes and Meireles, 2013). Approximately 47 g of DT was placed inside the extraction vessel. During the PLE process, the solvent was first pumped into the extractor using a HPLC pump (Thermo Separation Products, ConstaMetric, 3200 P/F, Fremont, USA).

The extraction vessel was heated as previously described. After reaching the desired pressure, the extraction cell was maintained at the desired temperature for a static period carefully adjusted to maintain the system pressure and a constant solvent flow of 1.24×10^{-4} kg/s. The dynamic extraction time was 60 min, and the S/F was 9.5. The resulted waste was identified as deflavored and depigmented turmeric (DDT). The applied conditions of 333 K and 10 MPa were attributed to the higher curcuminoids removing from DT (Osorio-Tobón et al., 2014).

2.4. Recovery of starches

Starches from solid turmeric were recovered using a methodology applied for several starchy crops (Bello-Pérez et al., 1998, 2005; Leonel et al., 2003). The flowchart of this process is showed on Fig. 1.

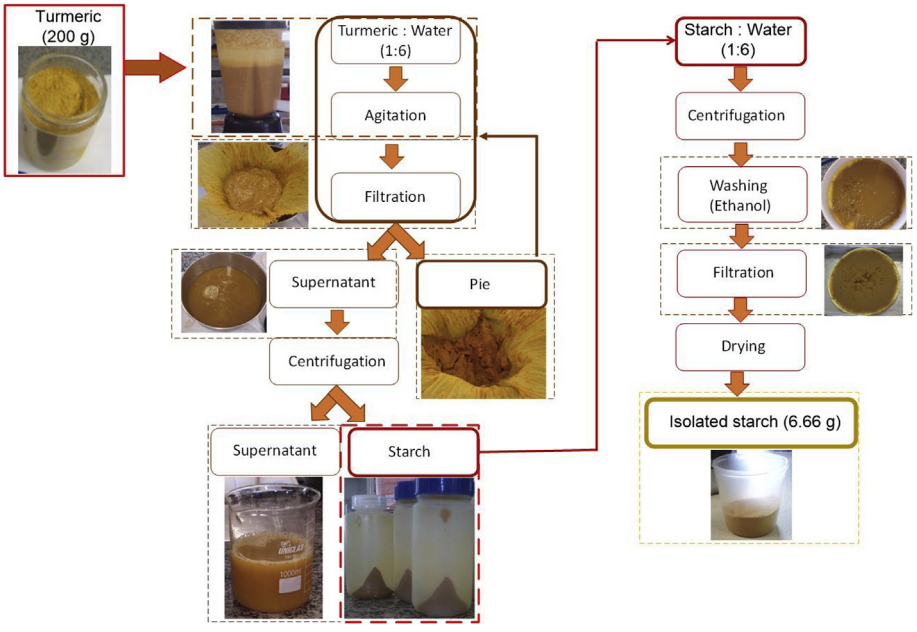

Fig. 1. Flowchart for the turmeric starch recovery experimental procedure.