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Sono–Soxhlet: In Situ Ultrasound-Assisted Extraction of Food Products

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Abstract An improvement of Soxhlet extraction was designed and developed. The extraction process (Sono–Soxhlet) of oils from crushed dried olives was performed using an ultrasonic horn in situ to provided rapid and complete recovery of analytes from the matrix. The results were compared to conventional Soxhlet extraction using physicochemical characterization and gravimetric analysis and showed a substantial reduction in the extraction time without interfering on composition and quality of target extracts.

Keywords Soxhlet · Extraction · *N*-hexane · Oil · Ultrasound

Introduction

The usual analytical method of oils and fats recovery from solid samples is the Soxhlet system, which has become the reference technique for a whole range of compounds in solid–liquid extractions (ISO 1988). This method involves repeated percolation of fresh solvent through a solid matrix, which presents a number of advantages over simple solvent extraction such as smaller quantities of solvent used, reduced isolation time together with ease of handling and better reproducibility. The solid phase is leached repeatedly by a fresh volume of solvent generated from condensed vapors until it reaches a certain level, which triggers the return of the solvent to the reservoir (Fig. 1c, conventional Soxhlet). Despite the acknowledged efficiency of this process, Soxhlet extraction does have certain shortcomings in terms of the length of time required for a complete extraction and an eventual decomposition of some recovered analytes in the boiling solvent reservoir. Over the past few years, some improvements of the orthodox technique have been suggested by either reducing the extraction time, the amount of solvent employed and/or the energy consumption (Luque de Castro and Priego-Capote 2010). In this scenario, Garcia-Ayuso and Luque de Castro (2001), Luque-García and Luque de Castro (2004), and Virot et al. (2007) suggested microwave-assisted extraction of oils whereas Chemat et al.(Virot et al. 2008) have proposed the replacement of hexane by limonene.

The first Soxhlet extraction assisted by ultrasound, named ultrasound-assisted Soxhlet was developed in 2004 by Luque-Garcia & Luque de Castro (2004). The system comprises an ultrasonic probe immersed on a water bath that circulates around the Soxhlet chamber (Fig. 1b). This innovative use of ultrasound in the Soxhlet process leads to a reduced extraction time without degradation of the extracts. This process is analogous to the use of ultrasonics in chemical reactions performed in a vessel containing the reaction system immersed in the ultrasonic bath, i.e., the application of ultrasound is indirect and the energy must be transferred from the water bath through the glassware and then to the solvent surrounding the cellulose cartridge on the Soxhlet chamber.

The present work proposes a modification of a Soxhlet system by inserting an ultrasonic probe directly into the extraction chamber, i.e., ultrasound is applied directly in the extraction reactor. The lipid extracts obtained from the

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