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The extraction of passion fruit oil with green solvents

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ABSTRACT

In the present paper, the extraction of passion fruit oil with acetone, ethanol and isopropanol of passion fruit seeds under three different techniques (ultrasound, shaker and soxhlet) were studied. The influence of seed to solvent ratio, time and type of solvent were investigated during ultrasound, shaker and soxhlet process. Hexane was used as well, as an extraction solvent to evaluate the extraction of oil in all extraction process studied to make a comparison among the employed solvents. The temperature was kept isoterminally at 40 °C in both shaker and ultrasound process. The highest yield when green solvents were was 23.8%, during ultrasound process, with acetone was used. Our results indicate that ultrasound can greatly replace the conventional extraction.

1. Introduction

The worldwide consumption of natural products such as fruit juice has contributed to increased fruit production in Brazil. Different types of fruits are being used for the production of concentrated and natural fruit juices such as oranges, lemons, guavas, cashew nuts, and passion fruits. The industrial production of fruit juices produces large amounts of wastes such as seeds and peels, as in the case of industrial production of passion fruit juice. The amount of waste discarded to the environment is becoming an increasing environmental problem. A large part of the solid waste is derived from the seeds of the passion fruit, which is a source of oil that has not been explored greatly. This oil can be utilised by the food, cosmetics and pharmaceutical industries.

In general, the extraction of oil from the seeds utilise processes such as pressing or solvent extraction. Hexane is the solvent of choice for extraction because of the low cost and the high solubility of these oils in hexane. However, other solvents have been used in the extraction process because of concerns relating to the environment and public health. In addition to the prevention of environmental risks that have already been cited, the connection between the management of technology and the environment has been emphasised lately by different companies, indicating that industrial companies can perform small actions that can result in significant changes to their environmental quality profiles especially in industrial areas. In this context, it should be noted that there is a growth of green chemistry philosophy as described by Yadav and Jadhav (2003). Lenardão et al. (2003) emphasise that this idea of green chemistry is not only ethically but also politically powerful. From their point of view, chemical processes that generate environmental problems should be replaced by alternatives that are either less polluting or not polluting at all.

Recently, new solvents have been tested in the extraction process, including acetone, ethanol and isopropanol (Toma et al., 2001; Gallegos-Infante et al., 2003; Li et al., 2004; Cho et al., 2006; Rout et al., 2007; Proestos and Komaitis, 2008; Rodrigues et al., 2008; Aryee and Simpson, 2001; Cuevas et al., 2009; Lou et al., 2010, Sun et al., 2011, Aquino et al., 2011, Rodríguez-Rojo et al., 2012). However, only ethanol, isopropanol and occasionally acetone are allowed to be used as solvents in the food industry because they generate less waste than the other solvents. Therefore, the solvents used in this study were acetone, ethanol and isopropanol and were compared to hexane.

In addition to the use of other solvents in the extraction operation, many other extraction techniques have been used and developed to extract the oil from the seeds, which include shaker extraction with ultrasound, among other techniques (Li et al. (2004), Cuevas et al. (2009), Lou et al. (2010), Dai et al. (2010), Rodríguez-Rojo et al. (2012)).

The objectives of this paper were the following: (i) proceed with the extraction of oil from passion fruit seeds using non-conventional solvents such as acetone, ethanol and isopropanol; (ii) compare the results of the non-conventional solvent extractions (using acetone, ethanol and isopropanol) with the extractions conducted with a conventional solvent (hexane); and (iii) investigate the shaker, soxhlet and ultrasound extraction techniques and compare these techniques.

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2. Materials and methods

2.1. Seed characterisation

Yellow passion fruit seeds (*Passiflora edulis f. flavicarpa*) that were obtained from a local industry were employed in this study. In the laboratory, the seeds were placed in a bowl and washed with the application of light frictional forces to eliminate the arils. These washed seeds were then heated in boiling water for 40 min and dried in a forced convection drier at 60 °C with an air flow of 4.54 $m^3 s^{-1}$. The seeds were ground with a Marconi Tecnal grinder (model T345, São Paulo, Brazil) for 30 s.

A seed lot sample was characterised based on a physicochemical analysis the moisture content, fixed mineral residues, raw fibre content, total lipid content, and crude protein content, according to the procedures of the BRASIL - Adolfo Lutz Institute (2010). Analyses were conducted in triplicate, and the results are presented as the means in this study. The samples were also subjected to granulometric analysis of the solid particles using a set of standard sieves.

The fatty acid profile of the oil and quantification of the ethyl esters were measured by gas chromatography using a Varian model CP-3800 coupled with a flame ionisation detector (FID) and a 30 m × 0.25 mm BP-X70 capillary column that was specifically designed for fatty acid separation. The carrier gas used was helium at a split rate of 1:10. The analysis was conducted with a column temperature program starting at 140 °C and heating up to 250 °C at 5 °C/min. The detector temperature was maintained at 220 °C, and the injector temperature was 260 °C. The internal standard used was 99% methyl tricosanoate, purchased from Sigma–Aldrich.

2.2. Solvents

Lenardão et al. (2003) suggest the replacement of hexane with other solvents that are less detrimental to human health and have less impact on the environment. Acetone, ethanol and isopropanol were tested as green solvent and hexano as conventional solvent. Acetone (boiling point = 56 °C, density = 0.79 g cm^{-3}, 99% purity), ethanol (boiling point = 78 °C, density = 0.79 g cm^{-3}, 99% purity), isopropanol (boiling point = 82 °C, density = 0.79 g cm^{-3}, 99% purity) and hexane (boiling point = 69 °C, density = 0.66 g cm^{-3}, 99% purity) were supplied by F-maia (São Paulo, Brazil).

2.3. Soxhlet extraction

The methodology described by the Adolfo Lutz Institute (BRASIL, 2010) was used by replacing petroleum ether with one of the solvents. Extraction times of 4, 8, 16, and 24 h were used. Five grams of passion fruit seed were prepared as described in Section 2.1. The assays were conducted in triplicate and the means are presented in this study. A Tecnal soxhlet extractor (São Paulo, Brazil) operating at a nominal power of 1500 W was used. The soxhlet extraction temperature was kept constant in all assays five Celsius degrees above the boiling point of the solvent. The soxhlet extraction balloon was coupled to a condensation column in a Marconi thermo bath (São Paulo, Brazil) that was operated at 10 °C to ensure the complete condensation of the boiling solvent.

2.4. Ultrasound extraction

An Ultracleaner Unique (São Paulo, Brazil) ultrasound bath with a frequency of 44 kHz was used. The ground passion fruit seeds were placed in an Erlenmeyer flask, and one of the solvents were added at seed-to-solvent (w/v) ratios of 1:4, 1:6, and 1:8. The extraction times were 15, 30, and 60 min. The assays were performed in duplicate and the mean values of the assays are presented in this study. Fig. 1 shows the ultrasound extractor set up.

2.5. Shaker extraction

The extraction was performed in Erlenmeyer flasks with rubber tops containing the ground passion fruit seeds and one of the three solvents used in the extraction step. The solvents were added to the flasks at seed-to-solvent (w/v) ratios of 1:4, 1:6, and 1:8. The extraction times were 4, 8 and 16 h. The Erlenmeyer flasks containing the solvent and the ground seeds were placed in a Tecnal (São Paulo, Brazil) shaker at 40 °C and shaken at 40 rpm. The assays were conducted in duplicate and the mean values of the assays are presented in this study.

2.6. Extraction yield

The extraction yield was calculated using Eq. (1):

$$\text{Yield} = 100\frac{m_o}{m_s} \tag{1}$$

where m_o is the weight of the oil that was obtained, and m_s is the weight of the seeds that were used in the extraction process.

2.7. Experimental design and statistical analysis

The experimental design was based on a 3^3 complete factorial design in duplicate for the ultrasound and shaker extractions and a 3 × 4 factorial design in triplicate for the soxhlet extraction. In the ultrasound and the shaker extraction experiments, the variables that were investigated were the extraction duration (T), the solvent type (S), and the ratio of the seed weight to the solvent volume (R). In the soxhlet extraction experiments, the variables that were investigated were the extraction time (T) and the type of solvent (S). The experiments were designed according to the methodology described by Barros Neto et al. (1995). The mean yield values were calculated and compared via variance analysis (ANOVA) with SAS software (Version 8.2) at a 5% level of significance by using Tukey's test.

2.8. The physical and the chemical properties of the seed oil

The oil that was obtained from the seeds was subjected to physical and chemical characterisations similar to those proposed by

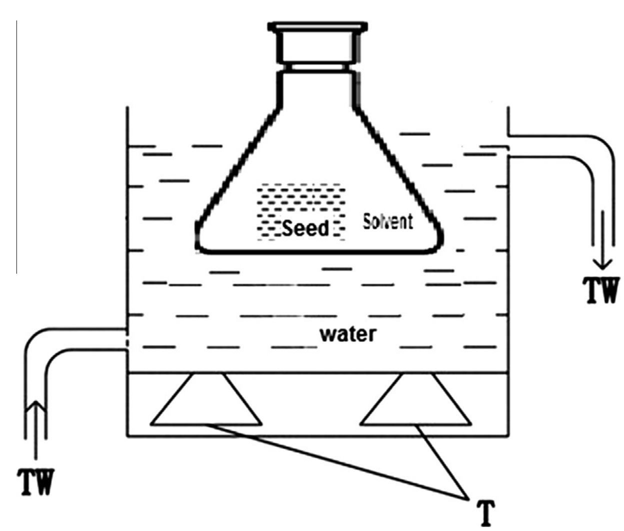

Fig. 1. Ultrasound extractor set up (TW: Thermostatic water; T: Transducer).