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Ultrasound-assisted extraction and solvent extraction of papaya seed oil: Crystallization and thermal behavior, saturation degree, color and oxidative stability

Shadi Samaram[a], Hamed Mirhosseini[a,*], Chin Ping Tan[a], Hasanah Mohd Ghazali[b]

[a] Department of Food Technology, Faculty of Food Science and Technology, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[b] Department of Food Science, Faculty of Food Science and Technology, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

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ABSTRACT

The main objective of the current work was to evaluate the suitability of ultrasound-assisted extraction (UAE) as compared to different conventional methods (i.e. Soxhlet extraction (SXE) and solvent extraction (SE)) for the recovery of papaya seed oil (PSO) from Malaysian Sekaki papaya variety. The efficiency of different extraction methods was evaluated by comparing the physicochemical properties and oxidative stability of the extracted PSOs. The main analytical tests were iodine value (IV), unsaponifiable matters, color, crystallization and melting behavior, peroxide value (PV), anisidine value (AV), and TOTOX value (TV). Results indicated that extraction method (UAE) considerably influenced the physicochemical properties of the extracted PSO. In this study, UAE provided PSO with significantly ($p < 0.05$) lighter color, lower unsaponifiable matters (1.35%) and higher oxidative stability (PV, 0.18 mequiv./kg; TV, 0.93) than conventional extraction techniques (SXE and SE techniques).

1. Introduction

Papaya is belonged to the family *Caricaceae* from *Carica* genus. *Caricaceae* papayas are originally from tropical and subtropical America and Africa (Yon, 1994). Papaya has no branch tree, height from 3 to 10 m. Fruits and leaves grow from the stump (Fig. 1a) (Tietze, 2003). In the present time, pure papaya varieties are rare due to the uncontrolled pollination between generations (Yon, 1994). Three varieties of papayas (i.e. Sekaki, Eksotika and Eksotika II) are mostly cultivated in Malaysia during last decades (Fig. 1b) (Chan, 2008; Yon, 1994). Sekaki papaya is the popular variety in Malaysia which is large and long with 1.5–2 kg weight. It has attractive yellow color and freckle-free skin. The flesh is red and firm with low sugar content (Fig. 1c). This variety has limited export and is mostly available in local markets in Malaysia (Chan, 2008). Papaya seed constitutes a considerable portion of fruit weight (15–20%). It remains as the biomass waste in fruit processing units (Hameed, 2009). However, it is a potential source of protein, fiber and oil (Puangsri et al., 2005). Papaya seed oil (PSO) is semi liquid with reddish yellow color. This oil is potential to be searched for edibility as it is rich in beneficial triacylglycerols (i.e. triolein > 37%) and monounsaturated fatty acid (i.e. oleic acid > 70%) (Samaram et al., 2013). In addition, PSO is stable against oxidation with considerable antioxidant activity.

The most commonly applied methods for recovery of oil from plant sources are Soxhlet, solvent extraction, aqueous enzymatic extraction, extrusion expelling process and supercritical fluid extraction (SFE). In recent years, ultrasound-assisted extraction technique (UAE) has been employed as an efficient inexpensive method for the extraction of bioactive compounds (such as antioxidants, phytosterols and oil soluble vitamins) and oil from plant sources (Wang and Weller, 2006; Li et al., 2012). As stated by previous study (Bimakr et al., 2012), there are two different ultrasound extraction techniques: (a) ultrasonic bath extraction (Fig. 1) (Kwiatkowska et al., 2011) and (b) extraction with ultrasonic horn transducer. The technical advantages of UAE (e.g., high recovery yield, simple procedure and short extraction time) confirmed that it is an acceptable alternative for conventional extraction methods. As illustrated by Bimakr et al. (2012), UAE was quick procedure resulting in higher extraction yield than conventional extraction methods. In general, ultrasound power causes extra vibration in the sample molecules, improves cavitation and contact surface between sample matrix and liquid solvent phase thereby enhances the recovery yield in short extraction time (Fig. 2) (Pan et al., 2012). Moreover, ultrasonic bath extraction technique with the controlled temperature facilitates the recovery of thermo-sensitive compounds like essential oils. To the best of our knowledge, there is

* Corresponding author. Tel.: +60 3 89468390; fax: +60 3 89423552.
E-mail addresses: hamedmi@food.upm.edu.my, hamedmi2002@gmail.com (H. Mirhosseini).

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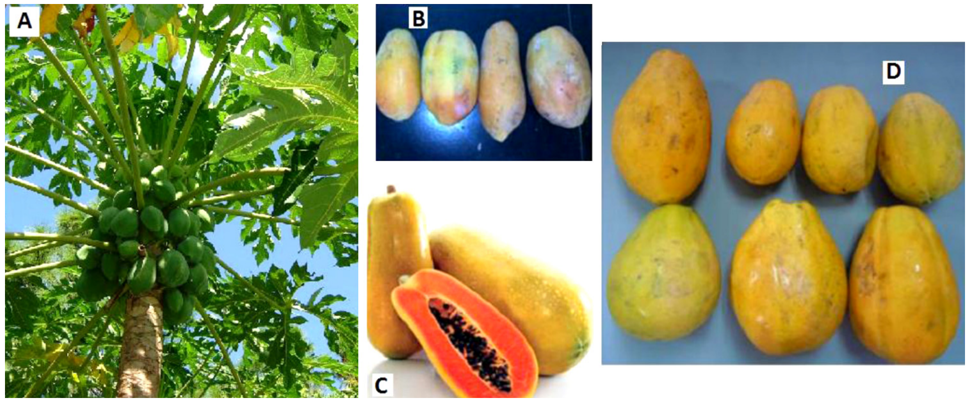

Fig. 1. Papaya tree (a) and Malaysian papaya varieties: (b) Eksotika, (c) Sekaki, and (d) Eksotika II.
Source: Malaysian Agricultural Research and Development Institute (MARDI), Chan (2008), Tietze (2003), and Yon (1994).

no published report comparing the efficiency of ultrasound extraction and solvent extraction for the recovery of oil from papaya seed.

The main objective of the present study was to evaluate the suitability of ultrasound-assisted extraction (UAE) as compared to conventional extraction methods (i.e. Soxhlet extraction (SXE) and solvent extraction (SE)) for the recovery of the oil from papaya seed. It was hypothesized that UAE might result in high quality stable papaya seed oil (PSO) as compared with conventional extraction methods. The efficiency of different extraction techniques was assessed by determining the iodine value (IV), unsaponifiable matters, color, thermal behavior, peroxide value (PV), anisidine value (AV), and TOTOX value (TV) of papaya seed oil (PSO).

2. Materials and methods

2.1. Chemicals and materials

Sekaki papaya fruits were purchased from a hypermarket (Selangor, Malaysia). Aluminum pans for thermal behavior by a differential scanning colorimeter (DSC) were supplied by Perkin-Elmer (Norwalk, CT, USA). *n*-Hexane and petroleum ether (Reagent grade) were purchased from Fisher scientific (Pittsburgh, PA, USA). Other reagent grade chemicals (i.e. ethyl alcohol 96%, potassium hydroxide, acetic acid, chloroform, potassium iodide, sodium thiosulfate, *p*-anisidine, starch indicator and phenolphthalein) were supplied by Merck (Darmstadt, Germany).

2.2. Sample preparation

Ripened papaya fruits were chosen according to their maturity stages (Yon, 1994). Fruits were cleaned and cut into halves in order to collect the seeds. Collected seeds were washed and dried at 45 °C oven with hot air circulation for 2 days (Górnaś et al., 2013). The dried seeds were ground to the powder form and sieved to achieve uniform particle size. The seed powder was kept in 4 °C refrigerator until extraction.

2.3. Solvent extraction (SE and SXE)

Oil extraction was carried out according to AOCS Official Method (Am 2-93, 1993) (AOCS, 1993). *n*-Hexane was utilized as extraction solvent (Sbihi et al., 2013) in all extraction procedures. The prepared seed powder was subjected for Soxhlet extraction (SXE) (Parveen and Rauf, 2008; Nehdi, 2011). For solvent extraction (SE), seed powder was mixed with solvent (1:10 mg/ml) in a blue cap bottle that covered with aluminum foil. In this study, extraction process was performed under different experimental conditions (i.e. time: 3, 6, 9, and 12 h; temperature: 25 and 50 °C) in triplicate. All bottles were shaken by a temperature-controllable water bath shaker at 100 rpm under different extraction conditions (Chua et al., 2009; Li et al., 2009).

2.4. Ultrasound-assisted extraction (UAE)

In the current research, ultrasound-assisted extraction (UAE) was applied for the recovery of oil from *Sekaki* papaya seeds. The

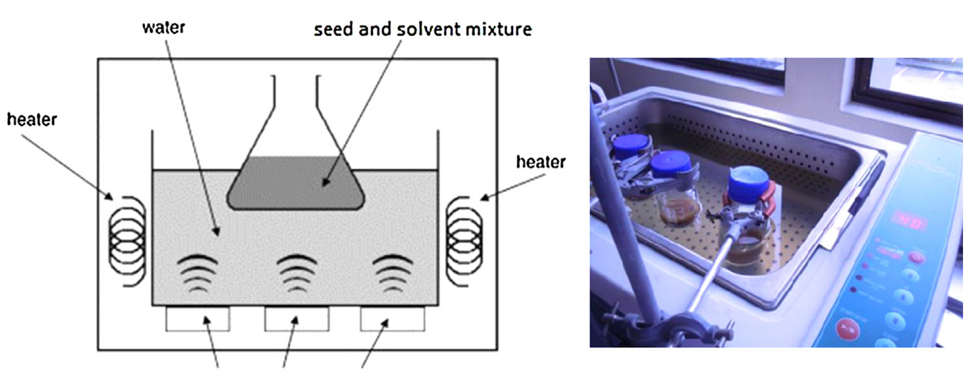

Fig. 2. Schematic figure of ultrasonic bath extractor (Kwiatkowska et al., 2011).