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Comparative evaluation of rice bran oil obtained with two-step microwave assisted extraction and conventional solvent extraction

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A B S T R A C T

In the present study, an innovative approach for microwave assisted solvent extraction of rice bran oil (RBO) in two steps termed two-step microwave assisted extraction (TSMAE) has been adopted. Microwave treatment and solvent washing were done alternately in two steps. The effect of microwave power (200, 320, 450, 560 W), microwave exposure time (30, 60, 90, 120 s) and solvent to bran ratio (1.6, 2.3, 3 mL/g) per step on percentage of oil recovery in TSMAE were evaluated. Bran milled at 3–6% degree of polish was evaluated for oil recovery. Oil recovery of more than 95% was obtained in total extraction time of 8–10 min with only 1.6–2.3 mL/g solvent to bran ratio (per step). The overall oil quality obtained in TSMAE was found to be superior to that of conventional solvent extracted oil especially with respect to phospholipid content (0.64 ± 0.11 vs 1.02 ± 0.15%), α-tocopherol content (7.85 ± 0.19 vs 6.83 ± 0.12 mg/g RBO), antioxidant activity (1.50 ± 0.05 vs 1.27 ± 0.08 trolox equivalent antioxidant activity) and free fatty acid content (4.88 ± 0.26 vs 5.77 ± 0.25%). Microstructure analysis revealed cell rupture due to microwave treatment that suggests the reason for faster oil extraction in TSMAE.

1. Introduction

Rice bran oil (RBO) is one of the most nutritious edible oils due to its balanced fatty acid profile. Typically, rice bran contains 15–20% lipids, 12–16% protein, 7–11% crude fibre, 34–52% carbohydrate and 7–10% ash (Wang et al., 2008). In addition, it also contains significant amounts of bioactive phytochemicals such as tocopherols, tocotrienols, γ-oryzanol and other plant sterols (Cicero and Gaddi, 2001; Tian et al., 2004; Aguilar-Garcia et al., 2007). It is also reported to be a good source of B group vitamins, dietary fiber and essential minerals (Saunders, 1985; Fuh and Chiang, 2001; Lebiedzińska and Szefer, 2006). During milling, approximately 73.5% of white rice, 3.5% of broken rice, 15% of husk and 8% of rice bran are obtained from paddy (Shwetha et al., 2011). Since rice bran is rich in oil and one of the most abundant by-products of rice industry, it is a commercially feasible feedstock for oil extraction.

Asian countries viz. India, China, Thailand and Vietnam are among major producers of RBO. As per the current scenario, RBO is extracted using food grade hexane by keeping bran in contact with excess amount of hexane under hot condition for 2–2.5 h (information gathered from factory visits). Rapid rise in free fatty acid (FFA) content of rice bran after milling has always posed problem for extracting edible grade oil. Hence, steaming is done as a necessary pre-treatment for bran stabilization. However, it calls for heavy energy investments for steam generation and drying. Alternatively, microwave treatment for short duration has been found to be an effective method for bran stabilization (Tao et al., 1993; Patil et al., 2016). This gives rise to the possibility that using microwaves for oil extraction will simultaneously stabilize the bran thus yielding superior quality oil compared to conventional extraction.

Microwave assisted extraction (MAE) of fats and oils have recently gained popularity due to its reduced extraction time, energy and solvent consumption. Microwave (MW) irradiation causes molecular friction due to dipole rotation, thus generating heat. The low specific heat of lipids makes them susceptible to this radiation, thus facilitating their solubility in the extractant. Also, thermal stress and localized high pressure developed by microwave heating in the mixture (solid matrix and solvent) ruptures the cells thus enhancing the leaching of oil bodies in surrounding solvent (Virot et al., 2008; Shams et al., 2015). It has been reported that MW preheating creates permanent pores in seeds resulting in higher yield (Azadmard-Damirchi et al., 2010). Microwave-assisted solvent extraction is reported as a promising alternative to conventional

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solvent extraction method; major benefits being reduced extraction time energy and solvent consumption (Longares-Patrón and Cañizares-Macías, 2006; Flamini et al., 2007).

Microwave assisted extraction of oils from herbs and spices (Chemat and Cravotto, 2011), poultry feed (Mahesar et al., 2008), castor seed (Mgudu et al., 2012), soybean and rice bran (Kanitkar and Sabliov, 2011; Terigar et al., 2011; Kumar et al., 2016) have been reported. Most of them have carried out extraction by exposing the solvent solid mixture to microwaves for definite time either above or at atmospheric pressure. Oil extractions are reported to have been carried out using polar solvents (ethanol and methanol) due to their better microwave absorption ability. According to Kumar et al. (2016), around 96% RBO recovery was obtained in closed MAE system in 60 min when methanol was used as a solvent. Optimized extraction time for RBO using ethanol in pressurized batch type MAE as reported by Kanitkar and Sabliov (2011) was 20 min when solvent to bran ratio (STBR) was around 4 (mL/g). In addition, this kind of extraction required extra 20 min for heating and cooling of the extraction mixture. Continuous MAE of RBO using ethanol carried out at atmospheric pressure by Terigar et al. (2011) yielded recovery of around 82% oil in 21 min. Kumar et al., 2016 reported lower oil recovery with non-polar solvents in MAE. This could be attributed to the fact that non-polar solvents have lower microwave absorption ability compared to polar solvents due to poor dielectric properties. Other reason could be extraction of more polar substances by polar solvents (Kim and Godber, 2014) resulting in higher yield. In such a case, TSMAE could be a promising method for using non-polar solvents in an efficient way for oil recovery in MAE. Exposing only bran to microwaves will cause cell wall rupture thus making maximum oil accessible in washing stage. This followed by solvent washing of heated bran will extract more oil due to presence of oil bodies on cell surface and higher solubility of lipids in hexane under hot condition. Repeating same thing several times could by-pass long diffusion stage of extraction leading to high oil recovery in significantly lesser time compared to conventional and other MAE methods. There exists a scope of simplification and increasing the yield in the process of MAE of rice bran oil. This will be helpful in exploiting the untapped potential of rice bran. Considering above discussed problems and identified research gaps, this study has been conducted to evaluate the simplified TSMAE for improving the rice bran oil yield and quality.

2. Materials and methods

2.1. Chemicals

Appropriate laboratory grade reagents needed in experimentation were procured from standard manufacturers. Alpha-tocopherol (PubChem CID:14985), 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox; PubChem CID:40634), and 2,2-diphenyl-1-picrylhydrazyl (DPPH; PubChem CID:74358) were purchased from Sigma-Aldrich (St. Louis, MO). HPLC grades of hexane and isopropanol were purchased from Merck. All other chemicals and reagents were analytical grade.

2.2. Rice bran collection

Paddy (*Oryza sativa*) cv. Lal Swarna was procured from local farmer near Kharagpur, West Bengal. Bran was collected by milling around 100 kg paddy in pilot scale modern rice mill (Satake Engineering, Co., Tokyo, Japan) at 8 ± 0.3% degree of polish (DOP) with respect to brown rice. The collected bran was sieved through 30 mesh sieve (ASTM). Sieved bran, having a moisture content of 11.8 ± 0.3%, was stored in zipper pouches at −20 °C to prevent

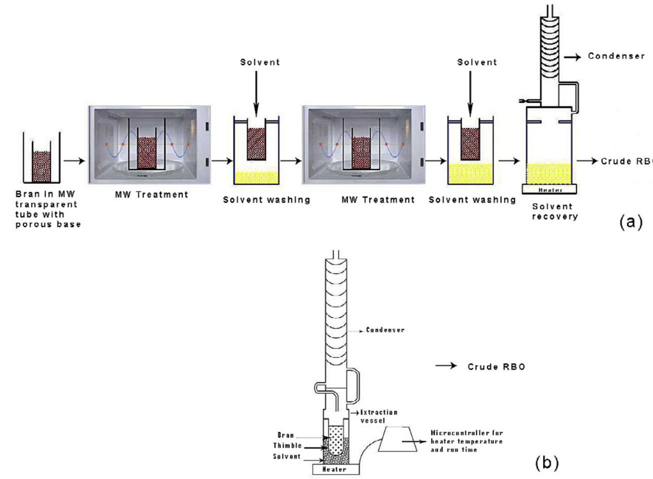

Fig. 1. Schematic of (a) TSMAE process and (b) CSE.

mould growth and an increase in FFA content (Amarasinghe et al., 2009). To evaluate the effect of DOP on oil recovery in TSMAE, the paddy was also milled in lab scale modern rice mill (Satake Engineering, Co., Tokyo, Japan) at three different DOP viz. 3.0 ± 0.2%, 5 ± 0.1%and 6 ± 0.1%.

2.3. Two-step microwave assisted extraction

TSMAE at atmospheric pressure was carried out to obtain RBO (Fig. 1 a). Domestic microwave oven (frequency 2.45 GHz, M1739N, Samsung, India) fitted with a variable autotransformer (to regulate input voltage in turn regulating input power) was used for heating of rice bran. Four different input powers *viz.* 300, 500, 700 and 900 Watt (SD ± 20 Watt) were selected for the study. The corresponding output power of the microwave at selected input powers were determined by standard IEC 60705 method and were found to be 200, 320, 450 and 560 Watt respectively. Four different MW exposure durations (30, 60, 90 and 120 s per step) and three different STBR (1.6, 2.3 and 3 mL/g per step) were selected for the study. Bran temperature during microwave (MW) heating was measured using shielded thermocouple fabricated according to the design given by Ramaswamy et al. (1991). Hexane (boiling point 67–69 °C) was used as the extracting solvent. 15 g bran was weighed in a polycarbonate tube with porous base (height 9.7 cm, diameter 2.5 cm) and tapped 10 times for settling, finally occupying the height of 6 ± 0.1 cm. It was treated in MW oven at selected power-time combination followed by solvent washing with selected STBR outside the MW oven (first step). When solvent stopped dripping out of the bran, it was again placed in MW oven and everything mentioned in first step was repeated (second step). The collected miscella was distilled to remove solvent in a rotary vacuum evaporator (Superfit, PBV 7D, India) and then kept at 75 °C to remove traces of hexane (Mahesar et al., 2008). Percentage of oil recovery in TSMAE was determined by following formula:

$$\text{Oil recovery } (\%) = \left(\frac{W_{TSMAE}}{W_{soxhlet}}\right) \times 100 \quad (1)$$

Where, W_{TSMAE} is the weight of oil extracted in TSMAE and $W_{soxhlet}$ is the weight of oil extracted in soxhlet extraction.

2.4. Conventional solvent extraction

Rice bran oil was extracted by conventional solvent extraction