International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:5, No:9, 2011

Microwave Pretreatment of Seeds to Extract High Quality Vegetable Oil

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***Abstract*—**Microwave energy is a superior alternative to several other thermal treatments. Extraction techniques are widely employed for the isolation of bioactive compounds and vegetable oils from oil seeds. Among the different and new available techniques, microwave pretreatment of seeds is a simple and desirable method for production of high quality vegetable oils. Microwave pretreatment for oil extraction has many advantages as follow: improving oil extraction yield and quality, direct extraction capability, lower energy consumption, faster processing time and reduced solvent levels compared with conventional methods. It allows also for better retention and availability of desirable nutraceuticals, such as phytosterols and tocopherols, canolol and phenolic compounds in the extracted oil such as rapeseed oil. This can be a new step to produce nutritional vegetable oils with improved shelf life because of high antioxidant content.

***Keywords*—**Microwave pretreatment, vegetable oil extraction, nutraceuticals, oil quality

I. INTRODUCTION

THE use of microwave and dielectric heating in analytical researches began in the late 1970s and was first seized upon by the food industry. Microwave energy is a superior alternative to several thermal applications owing to its efficient volumetric heat production [1]. Microwave ovens use radio waves to convey energy and convert it to heat at a frequency which is approximately 300 MHz to 300 GHz [2]. Waves in this frequency range are mostly absorbed by water with a sufficiently polar oxygen group. In the food technology, microwave operation have been applied with increasing success in oil extraction, pasteurization, sterilization, baking, blanching, cooking, drying, and thawing of different food products [3].Microwave penetration depths within a food sample are significantly determined by the electrical and physical properties, chemical composition, heating patterns, microbial inactivation and quality control [4].Extraction techniques are widely employed for the isolation of bioactive compounds and vegetable oils from plant materials [5]. The technique used to extract oil determines the value of extracted oil which can be reported and there are discrepancies between the results of different extraction methods. Extraction of oils from oilseeds can be carried out by pressing or with solvent. Solvent oil extraction is usually applied to seeds with low content of oil (<20%), such as soybean. Pressing method is applied for seeds with a high amount of oil, such as rapeseed, but this method is relatively inefficient and a large portion of the oil is left in the meal [6]. However, residual oil in the meal can be extracted afterwards by solvent. Solvent extraction method is the most efficient method with less oil remaining in the meal, but this method has some industrial disadvantages, such as plant security problems, emissions of volatile organic compounds into atmosphere, high operation costs, poor quality products caused by high processing temperatures, low extraction yield and a relatively high number of processing steps [7, 8]. Oil extraction by mechanical pressing is simpler, safer and contains fewer steps compared with oil extraction by solvent [9].There are two types of oil pressing: cold press and hot press. Thermal treatment is not used in the cold press method, in contrast to hot press, where seeds are pretreated by heat, this is known as cooking [6]. Oil obtained from cold pressing of oilseeds has generally better preserved native properties. Therefore, there is a growing demand in the market for cold pressed oil, such as cold pressed rapeseed oil. However, cold pressing has a lower oil extraction yield compared to hot pressing.Among the different and new available methods, microwave pretreatment of seeds is a simple and desirable technique for production of high quality vegetable oil with coupled high nutritional aspects. The new pretreatment allows for better retention and availability of desirable nutraceuticals such as phytosterols and tocopherols in the extracted oil. Instead of thermal treatment, microwave radiation of seeds is receiving attention [10, 11].Compared with conventional methods, microwave pretreatment for oil extraction has many advantages such as: improvement of extracted oil yield and quality, direct extraction capability, lower energy consumption, faster processing time and reduced solvent levels [1].

A. *Effects of microwave pretreatment on oil extraction*

Microwave pretreatment provides a potential to induce stress reactions in plant systems or oil seeds. By using microwave radiation in oil seeds, a higher extraction yield and an increase in mass transfer coefficients can be obtained because the cell membrane is ruptured. In addition, permanent pores are generated as a result, enabling the oil to move through the permeable cell walls [11]. According to Azadmard-Damirchi *et al.* [12] microwave pretreatment can increase oil extraction yield. In addition, they have been observed that increasing microwave treatment time can increase oil extraction yield. Uquiche *et al.* [11] have reported that pretreatment of hazelnuts with microwaves can increase

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the oil extraction yield and increasing the treatment time also had a positive effect on the oil extraction yield. It has also been shown that the time of exposure to microwave radiation has a significant effect ($p < 0.05$) on oil extraction yield rather than level of potency (400 W and 600 W). Moreno *et al.* [13] used microwave pretreatment to the oil extraction from avocado and found that extraction efficiency was 97% in Soxhlet-hexane extraction coupled with microwave pretreatment when compared (54%) to only the Soxhlet-hexane extraction. This data concur with the previously published data [14, 15, 16, 17].A combined ultrasound and microwave pretreatment method for extraction of essential oil from caraway seeds has been proposed by Chemat *et al.* [18]. They found that significant improvement in extraction was obtained using simultaneous ultrasound and microwave pretreatment.

B. *Effects of microwave pretreatment on major compounds*

Soxhlet extraction method would degrade the poly-unsaturated fatty acids in vegetable oil and thus the resulting profile would not be truly representative of the fatty acids in the oil seeds. Cossignani *et al.* [19] reported that there is significant decrease ($p < 0.01$) in the TAG fraction and increase ($p < 0.01$) in the DAG and MAG fractions after microwave pretreatment in olive oil. Many authors have reported the results of the microwave pretreatment on fatty acid compositions in vegetable oils. Kanitkar [20] reported that the fatty acid compositions obtained for rice bran oil extracted using microwaves differed slightly from previously published data, but microwave extracted rice bran oil also contained a considerable proportion of arachidic acid (C21:0) in compared with conventional extracted rice bran oil. Linoleic and palmitic acids are usually used as indicators of the extent of oil deterioration. Tan *et al.* [3] found the C18:2/C16:0 for microwave-radiated oil decreased with increased heating power settings. According to Anjum *et al.* [21] the levels of oleic and linoleic acids were dramatically affected by microwave pretreatment than palmitic and stearic acids. The longer the pretreatment time, the lower was the percentage of the linoleic acid and the higher was that of oleic acid. Yoshida *et al.* [22] found a decrease in the amount of PUFA in soybean oil during roasting time.

C. *Effects of microwave pretreatment on minor compounds*

Phospholipid, tocopherols, phenolic compounds and phytosterols are minor components of vegetable oils. The results revealed that microwave pretreatment has no significantly effects ($p > 0.05$) on phospholipid content in microwave extracted rice bran oil that can increase the overall refining loss of the oil in compared with conventional methods. Hence, the use of microwave pretreatment does not have the deleterious effects on the oil quality from the perspective of phospholipid composition [20]. The results also showed that the phospholipids content in soybean oil is directly dependent to the amount of oil extraction [23].Azadmard-Damirchi *et al.* [12] showed that pretreatment of rapeseeds by microwave prior to oil extraction by press increased the tocopherols significantly ($p < 0.05$) in oils. These results suggested that damage to the oilseed cell membrane by microwave pretreatment allow increased release of tocopherols and enhance their amount in extracted oil. According to Zigoneanu *et al.* [24] there is no significantly difference ($p > 0.05$) in the vitamin E content or antioxidant activity of rice bran oil obtained microwave pretreatment when compared with conventional solvent extraction.

The results revealed that oil extracted from microwave-treated rapeseed shows a markedly improved oxidative stability, most likely due to the increase of phenolic antioxidants [25].

The levels of α-, β- and γ-tocopherol in rice bran oil were significantly ($p < 0.05$) increased when the rice bran was subjected to microwave heating for up to 30 s [26]. This data concur with the previously published data [27, 28]. Lee *et al.* [29] reported that the levels of α-tocopherol in safflower oil gradually increased with roasting temperature with increasing up to 160°C but then decreased up to 180°C. According to Yen [30], the contents of tocopherol in sesame oils prepared by microwave pretreatment increased with processing temperature up to 200 °C but decreased up to 260 °C. However, it has been reported that the level of α-, β-, γ- and δ-tocopherols reduced during microwave heating and α-tocopherol showed the highest rate of loss due to unsaturation of the TAG system under their conditions [21, 22].

Phytosterols in vegetable oils are important from a nutritional point of view because they contribute to lowering serum cholesterol levels and are also considered to have anti-inflammatory, anti-bacterial, anti-ulcerative and antitumour properties in humans [31, 32], as well as contributing to the oxidative and thermal stability and shelf life of vegetable oils [33]. The previously published results revealed that solvent extraction is more efficient in extracting phytosterols of rapeseed oil in compared with microwave pretreatment extracted oil [12]. It has recently been reported that microwave pretreatment of rapeseed could increase the canolol content. However, higher temperatures (>160 °C) can cause a reduction in the canolol content [34].

Martino *et al.* [35] found that employing 50% aqueous ethanol either with microwave pretreatment or with ultrasound pretreatment is the best method for extraction of phytocomponents from flowering tops of *Melilotus officinalis*.

D. *Effects of microwave pretreatment on physicochemical properties*

Changes in physicochemical composition and levels of minor compounds affect the functional and nutritional aspects of vegetable oils [22]. Anjum *et al.* [21] evaluated microwave roasting effects on the physicochemical composition and oxidative stability of sunflower seed oil. They found that with increasing microwave roasting time the refractive index, unsaponifiable matter and iodine value of the oils significantly decreased. It also has been reported that high roasting time increases saponification value, free fatty acid content of sunflower oil and changes color of extracted oil from light yellow (5 min of roasting) to yellow (10 min of roasting) to brown. It has been addressed to Maillard-type nonenzymatic reactions, caramelization and phospholipid degradation and formation of browning substances [30, 36, 37]. Behera *et al.* [38] reported that there are no significant differences on refractive index between extracted oils from microwave pretreatment cumin seeds and conventional methods.

There is also an increased on anisidine, Iodine, peroxide values and free fatty acid content in corn and soybean oil when applied to high-power setting. The results also revealed that high unsaturated oils are deteriorated higher than low unsaturated oils [3, 39]. The acid values of the microwave extracted soybean oil was the lower than rice bran oil. It may be due to the fact that the bran is not stabilized prior to oil extraction and the presence of native lipase broke down the triglyceride structure [20]. Terigar *et al.* [23] found that treatment time has higher effect on acid value in compared with temperature.

E. Effects of microwave pretreatment on extracted oil quality

Improvement of oil extracted quality depended on power, time and temperature of microwave pretreatment. So that longer microwave heating times, temperatures and high-power setting resulted in a greater degree of oil deterioration [3]. The chemical components of oils that are degraded during microwave radiation achieved at rates that vary with process temperature and time, as with other domestic processing methods. Therefore, suitable quality properties can be used as temperature-time integrators of quality deterioration of oils during microwave treatment [3]. In general, microwave heating have significant effects on quality parameters of vegetable oils. Oxidative stability of vegetable oils is influenced by many factors, mainly fatty acid composition, antioxidants and minor compounds. The effects of microwave pretreatment on the thermo-oxidative degradation and quality of several vegetable oils and fats, i.e. olive oil, sunflower oil, rapeseed oil and lard have been studied [40, 12]. Higher stability of oils extracted from microwave pretreated rapeseeds may arise from their high antioxidant content e.g. tocopherols [12].

II. CONCLUSION

The present study indicates microwave pretreatment can be used as a desirable alternative to conventional oil extraction techniques. The oil yield values extracted by microwave-assisted extraction are higher than those obtained by conventional oil extraction under the same conditions. The major advantage of microwave pretreatment is the reduced time of extraction and energy consumption costs, when is compared to conventional methods. On the obtained results, microwave extracted oil also show similar characteristics to conventionally extracted oil, indicating that quality of oil is not affected by microwave pretreatment. It allows also for better retention and availability of desirable nutraceuticals, such as phytosterols and tocopherols, canolol and phenolic compounds in the extracted oil such as rapeseed oil. This can be a new step to produce nutritional vegetable oils with improved shelf life because of high antioxidant content.

REFERENCES

[1] B. Ramanadhan, "Microwave extraction of essential oils (from black pepper and coriander) at 2.46 Ghz," *Master of Science thesis*, 2005, pp. 1–51.

[2] R. P. Singh, D. R. Heldman, "*Introduction to Food Process Engineering*," 3Ed edition. Academic Press. 2001. pp. 30–47.

[3] C. P.Tan, Y. B. Che Man, S. Jinap, M. S. A. Yusoff, "Effects of Microwave Heating on Changes in Chemical and Thermal Properties of Vegetable Oils," *Innovative Food Science & Emerging Technologies*, vol. 3, pp. 157–163. 2001.

[4] R. E. Mudgett, "Microwave food processing," *Food Technology*, vol. 43, pp. 117–126. 1989.

[5] R. Self, "Extraction of Organic Analytes from Foods," *A Manual of Methods*, Royal Society of Chemistry. Cambridge. 2005. pp. 1–43.

[6] D. Anderson, "A primer on oils processing technology," in: *Bailey's industrial oil and fat products*," Y. H. Hui, Eds. John Wiley and Sons, 1996. pp. 10–17.

[7] M. Buenrostro, C. López-Munguía, "Enzymatic extraction of avocado oil," *Biotechnology Letters*, vol. 8, pp. 505–506. 1986.

[8] J. M. Del Valle, J. M. Aguilera, "Extracción con CO2 a alta presion. Fundamentos y aplicaciones en la industria de alimentos," *Food Science and Technology International*, vol. 5, pp. 1–24. 1999.

[9] A. Oyinlola, A. Ojo, L. O. Adekoya, "Development of a laboratory model screw press for peanut oil expression," *Journal of Food Engineering*, vol. 64, pp. 221–227. 2004.

[10] S Takagi, H. Yoshida, "Microwave heating influences on fatty acid distribution of triacylglycerols and phospholipids in hypocotyls of soybeans (glycine max L.)," *Food Chemistry*, vol. 66, pp. 345–351. 1999.

[11] E. Uquiche, M. Jeréz, J. Ortíz, "Effect of pretreatment with microwaves on mechanical extraction yield and quality of vegetable oil from Chilean hazelnuts (Gevuina avellana Mol)," *Innovative Food Science and Emerging Technologies*, vol. 9, pp. 495–500. 2008.

[12] S. Azadmard-Damirchi, F. Habibi-Nodeh, J. Hesari, M. Nemati, B. Fathi Achachlouei, "Effect of pretreatment with microwaves on oxidative stability and nutraceuticals content of oil from rapeseed," *Food Chemistry*, vol. 121, pp. 1211–1215. 2010.

[13] A. O. Moreno, L. Dorantes, J. Galindez, R. I. Guzman, "Effect of Different Extraction Methods on Fatty Acids, Volatile Compounds, and Physical and Chemical Properties of Avocado (Persea americana Mill.) Oil," *Journal of Agricultural and Food Chemistry*, vol. 51, pp. 2216–2221. 2003.

[14] H. Li, B. Chen, N. Nie, S. Yao, "Solvent effects on focused microwave assisted extraction of polyphenolic acids from Eucommia ulmodies," *Phytochemical analysis*, vol. 15, pp. 306–312. 2004.

[15] S. Chemat, H. Ait-Amar, A. Lagha, D. C. Esveld, "Microwave-assisted extraction kinetics of terpenes from caraway seeds," *Chemical Engineering and Processing*, vol. 44, pp. 1320–1326. 2005.

[16] W. H. Duvernay, J. M. Assad, C. M. Sabliov, M. Lima, Z. Xu, "Microwave Extraction of Antioxidant Components from Rice Bran," *Pharmaceutical Engineering*, vol. 25, pp. 1–5. 2005.

[17] G. Cravotto, L. Boffa, S. Mantegna, P. Perego, M. Avogadro, P. Cintas, "Improved extraction of vegetable oils under high-intensity ultrasound and/or microwaves," *Ultrasonics Sonochemistry*, vol. 15, pp. 898–902. 2008.

[18] S. Chemat, A. Lagha, H. AitAmar, F. Chemat, "Combined ultrasound and microwaveassisted extraction of essential oil from caraway seeds. *in Conf. Rec. 2003. Application of Power Ultrasound in Physical and Chemical Processing, Becanson France*, pp. 349–353.

[19] Cossignani, L., Simonetti, M. S., Neri, A., & Damiani, P. (1998). Changes in olive oil composition due to microwave heating. Journal of American Oil Chemists' Society, 75(8), 931–937.

[20] A. V. Kanitkar, "Parameterization of microwave assisted oil extraction and its transesterification to biodiesel," *Submitted to Transactions of the ASABE*. 2009. pp. 1–82.

[21] F. Anjum, F. Anwar, A. Jamil, M. Iqbal, "Microwave roasting effects on the physico-chemical composition and oxidative stability of sunflower

seed oil," *Journal of American Oils Chemists Society*, vol. 83, pp. 777−784. 2006.

[22] H. Yoshida, J. Shigezaki, S. Takagi, G. Kojimoto, "Variations in the Composition of Various Acyl Lipids, Tocopherols and Lignans in Sesame Seed Oils Roasted in a Microwave Oven," *Journal of the Science of Food and Agriculture*, vol. 68, pp. 407–415. 1995.

[23] B. G. Terigar, S. Balasubramanian, C. M. Sabliov, M. Lima, D. Boldor, "Soybean and rice bran oil extraction in a continuous microwave system: From laboratory- to pilot-scale," *Journal of Food Engineering*, vol. 104, pp. 208–217. 2011.

[24] I. G. Zigoneanu, L. Williams, Z. Xu, C. M. Sabliov, "Determination of antioxidant components in rice bran oil extracted by microwave-assisted method," *Bioresource Technology*, vol. 99, pp. 4910–4918. 2008.

[25] J. W. Veldsink, B. G. Muuse, M. M. T. Meijer, F. P. Cuperus, R. L. K. M. Van De Sande, K. P. A. M. Van Putte, "Heat pretreatment of oilseeds: Effect on oil quality," *Fett/Lipid*, vol. 7, pp. 244–248. 1999.

[26] S. N. Ko, C. J. Kim, C. T. Kim, H. Kim, S. H. Chung, S. M. Lee, S. M, "Changes of vitamin E content in rice bran with different heat treatment," *European Journal of Lipid Science and Technology*, vol. 105, pp. 225–228. 2003.

[27] B. D. Oomah, J. Liang, D. Godfrey, G. Mazza, "Microwave heating of grapeseed: Effect on oil quality," *Journal of Agriculture and Food Chemistry*, vol. 46, pp. 1017–4021. 1998.

[28] B. D. Oomah, M. Busson, D. V. Godfrey, J. C. G. Drover, "Characteristics of hemp (Cannabis sativa L.) seed oil," *Food Chemistry*, vol. 76, pp. 33–43. 2002.

[29] Y. C. Lee, I. H. Kim, J. Chang, Y. K. Rhee, H. I. Oh, H. K. Park, "Chemical Compositions and Oxidative Stability of Safflower Oil Prepared with Expeller from Safflower Seeds Roasted at Different Temperatures," *Journal of Food Science*, vol. 69, pp. 33–38. 2004.

[30] G. C. Yen, "Influence of Seed Roasting Process on the Changes in Composition and Quality of Sesame (Sesamum indicum) Oil," *Journal of the Science of Food and Agriculture*, vol. 50, pp. 563–570. 1990.

[31] T. H. J. Beveridge, T. S. C. Li, J. C. G. Drover, "Phytosterol content in American ginseng seed oil," *Journal of Agricultural and Food Chemistry*, vol. 50, pp. 744–750. 2002.

[32] R. A. Moreau, "Plant sterols in functional foods," in: *Phytosterols as functional food components and* nutraceuticals, P. C. Dutta, Eds. Marcel Dekker, Inc, 2004. pp. 317–346.

[33] R. Przybylski, N. A. M. Eskin, "Minor components and the stability of vegetable oils," *Inform*, vol. 17, pp. 186–188. 2006.

[34] A. Spielmeyer, A. Wagner, G. Jahreis, "Influence of thermal treatment of rapeseed on the canolol content," *Food Chemistry*, vol. 112, pp. 944–948. 2009.

[35] E. Martino, I. Ramaiola, M. Urbano, F. Bracco, S. Collina, "Microwave-assisted extraction of cumarin and related compounds from Melilotus officinalis (L.) Pallas as an alternative toSoxhlet and ultrasound-assisted extraction," *Journal of Agriculcure and Food Chemistry*, vol. 1125, pp. 147–151. 2006.

[36] M. G. Megahad, "Microwave Roasting of Peanuts: Effects on Oil Characteristics and Composition," *Nahrung*, vol. 45, pp. 255–257. 2001.

[37] I. H. Kim, C. J. Kim, M. J. You, K. W. Lee, C. T. Kim, S. H. Chung, B. S. Tae, "Effect of Roasting Temperature and Time on the Chemical Composition of Rice Germ Oil," *Journal of American Oil Chemists' Society*, vol. 79, pp. 413–418. 2002.

[38] S. Behera, S. Nagarajan, L. J. M. Rao, "Microwave heating and conventional roasting of cumin seeds (Cuminum eyminum L.) and effect on chemical composition of volatiles," *Food Chemistry*, vol. 87, pp. 25–29. 2004.

[39] A. K. A. Dandjouma, C. Tchie´gang, C. Kapseu, J. Fanni, M. Parmentier, "Changes in Canarium schweinfurthii Engl. Oil quality during microwave heating," *European Journal of Lipid Science and Technology*, vol. 108, pp. 429–433. 2006.

[40] W. L. Clark, G. W. Serbia, "Safety aspects of frying fats and oils. Food Technology," vol. 45, pp. 68–72. 1991.