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Pre-processing and Oil Extraction from the Seeds of Tomato Wastes using Microwave and Ultrasound Treatments

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ABSTRACT

Tomato wastes are considered a waste product mainly used as animal feed. The seeds of the tomato wastes are a good source of unsaturated fatty acids. As a result, the oil extraction of the seeds is an economical and useful product. The pre-processing of oily seeds influences and increases the efficiency of extraction. In this study, the seeds' pre-processing was applied by using water in 40 ^{o}C and ultrasound waves in different intervals and oil extraction was performed using microwave and ultrasound waves with a certain power, frequency . Results showed that by hot water, ultrasound and existing oil extraction via ultrasound waves, seeds' pre-processing can increase extraction efficiency upto 22.61% and via microwave, after ultrasound pre-processing, the extraction will increase efficiency upto 23.03%. In addition, the analysis of extracted samples of fatty acids indicated that microwave and ultrasound waves did not have oxidation and degradation effect on the structure of fatty acids. Moreover, by using the method of microwave and ultrasound extraction, the time of extraction process decreased to 1.5 and 30 minutes, respectively.

KEYWORDS: oil extraction, microwave, ultrasound, tomato wastes, oily seeds.

1. INTRODUCTION

Tomato wastes are produced during the sauce making process and it contains peel, pulp and grains. The main part of tomato wastes is its grains considered as a very good source of vegetable oils (Lasoz & Kalathenos, 1988; Takasova et al., 1995), protein and lycopene (Liadakis et al., 1998) and its compound is studied by various scientists (Lasoz & Kalathenos, 1988; Cantarelli et al., 1993; Canella et al., 1979;, Tsatsarovis & Boskou, 1975; Kramer & Kwee , 1977b). Generally, extracting oil from oily seeds is employed by solvent in soxhlet. So far various methods and solvents and their analysis have been done for increasing the efficiency and reducing the time of oil extraction from different oily seeds (Deferne & Pate , 1996; , Wang et al., Vinatoru, 2001). Of these methods, it can be addressed to extraction by ultrasound waves [Hughes and Nyborg , 1962;, Chemat and Lucchesi, 2006), ultra critical fluid (Pourmortazavi and Hajimirsadeghi, 2007; Sahena et al., 2009; Riera et al., 2004), microwave (Rafie et al. 2011; Pan & Niu, 2003) and also water below critical point (Ozel et al., 2003). According to previous studies, ultrasound method is a simpler (Luque-Garcí´a & De Castro, 2003) and quicker (Lopez-Avila et al., 1996) method and it has less amount of solvent usage (Jacques et al., 2006). Oil extraction via solvent and soxhlet is time-consuming. Additionally, it is not ideal to use organic solvents excessively; it can be harmful for human and the environment (Dunnuck, 1991). In 2001, Vinatoru studied the effect of ultrasound waves on soybean grain and concluded that these waves increase the contact surface of solvent and considered parts of soybean which contribute to more sinking of solvent into soybean tissue (Vinatoru, 2001). Also similar results have been reported for extraction of oil from rapeseed seed by ultrasound waves and evaluation of the effect of different solvents (Stanisavljevic & Lazic, 2007). In recent years, microwave and ultrasound waves are used commonly in food industries (Mason & Riera, 2005; , Chemat et al., 2011; Stasiak, 2005). Extraction by these waves is one of the most important methods of solubility of valuable herbal compounds (Vilkhu & Mawson, 2008) applicable in industrial scales (Vinatoru, 2001). Using ultrasound waves in food industries, especially for oil extraction of oily seeds increase mass transfer and destroy the surface of particle (Vinatoru, 2001). Main mechanism of extraction by ultrasound waves contributes to cavitation during which very tiny bubbles are created in liquid mass and rapidly grow to critical size and then explode. This explosion is with the release of large amount of energy which applies to the environment in the form of shear tension (Ji & Lu, 2006). In conclusion, using ultrasound in herbal extraction increases the mass transfer, better influencing of solvent, low temperature of extraction process, less relation to solvent, reduction of process time, and desirable efficiency (Jayasooriya et al., 2004;,Dolatowski,et al. 2007; Porto et al., 2013). Utilization of microwave has also many advantages, including effective heating, more rapid transfer of energy, reduction of thermal changes, selective heating, reduction of the size of equipment used, faster response to heating control process, faster start-up, increasing of product and reduction of process steps (Chemat et al., 2011). According to recent research of scientists about comparison of ultrasound and common methods of oil extraction of pomegranate seed, using ultrasound with certain power can be a suitable alternative for oil extraction by solvent in soxhlet (Porto et al., 2013). Oil extracted by solvent with the help of ultrasonic and microwave will be completed and a satisfactory performance is achieved (Ondruschka & Asghari, 2006; Liangfu & Zelong, 2008). Shan et al. used ultrasound pre-processing method for oil extraction of watermelon seed and reported the increase amount of efficiency as 21% (Shan et al., 2011). Therefore, the waves in both steps of pre-processing and extraction can be very effective. It should also be

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noted that ultrasound waves don't have an oxidation and destructive effect of oil (Li & Pordesimo, 2004; Zhang & Wang, 2008). According to investigation of Chemat et al., the time of ultrasound and microwave radiation are specified between 10-60 and 3-30 minutes, respectively (Chemat et al., 2011). The purpose of this study is evaluation of the effect of pre-processing and oil extraction of tomato wastes by ultrasound wave and microwave in mentioned time limit and outside of it is on extraction efficiency. Also, it considers the study of some physiochemical properties, the achieved oil compound and fatty acid profiles.

2. MATERIALS AND METHODS

Some wastes of wet tomato are provided from Golnoush sauce production (Karaj, Iran) and are dried for two weeks in environment under the sunlight. Seeds of wastes are removed by deposition method and according to seeds' density difference and other parts. Then, pre-processing and extraction stages are done on the sample.

2.1. Pre-processing

Removed seeds are placed in ben murry in 40 ^{o}C water for 24 hours (Memert WB 14 Germany). After pre-processing with hot water, seeds are employed under the effect of ultrasound waves with the power of 550 watt, frequency of 37 kHz and the temperature of 25-40 ^{o}C in times of 30 and 60 minutes.

2.2. Extraction

Wet seeds are dried after pre-processing so that their humidity becomes less than 3% (Lang & Wai, 2011; Taylor et al., 2003). Then they are rolled for 40 seconds for passing the sieve with the mesh of 0.4. Milled seeds are extracted after the adding hexane solution (b.p: 68-69 (Merk) with proportion of 1 to 10 (Talei et al., 2011). Ultrasound waves affect seeds by the power of 550 watt, frequency of 37 kHz at 30 and 60 minutes (Chemat et al., 2011). Microwave extraction by the means of microwave appliance (Matsushita Electric industrial co. Ltd, japan) was done with varied powers of 250 and 600 watt, each for 90 minutes (Chemat et al., 2011). Soxhlet extraction (Gerhardt Soxtherm 2000, Germany) was performed by using hexane solvent at 70 °C for 6 hours (Cantarelli et al., 1993). The combination of milled seed, solvent and oil by centrifuge (Velocity 14; Dynamica UK) were separated in 3000 Rpm and for 5 minutes (Lasoz et al., 1998). The oil of oil solution and solvent was isolated by rotary of distillation under vacuum at 50 °C (Porto et al., 2013) and a vacuum pressure of 650 mbar and then it was located in oven at 70 °C for 2 hours in order to remove the remained possible solvent. The preparation of methyl esters of fatty acids, oil of tomatoes were performed by standard methods (ISO 5509, 1978). Identification of fatty acids took place using Model YL-6000 gas chromatograph (YoungLin-6000; Korea) with CP-Sil-8 column (60 m * 0.25 mm, film thickness 0.2 mm) and the carrier gas hydrogen with flow rate of 1 mL per minutes. Process operating conditions include oven temperature at 175 °C, detector temperature at 300 °C and 280 °C for injector. Based on standard test procedures, iodine value (AOAC 920, 1998; AOAC Vol 1, Food Chemical Codex, 1981) and saponification Value (ISO 3657, 2002) were measured and the obtained results were recorded.

2.3. Method and Statistical Analysis

All the experiments were repeated three times. Results were analyzed using SPSS version 18 in a completely randomized design. Comparison was performed using analysis of variance (ANOVA) at the 0.05 level of error and diagnostic tests were exerted using Tukeys.

3. DISCUSSION AND CONCLUSION

3.1. Pre-processing by ultrasound waves

Seeds' pre-processing by ultrasound extraction mode was performed within 60 minutes and microwave waves in 600 watt. The results of ANOVA of effect of pre-processing on oil solubility showed that considered factors of 0.05 confidence level did not have a significant effect on oil extraction. From among the methods of pre-processing and extraction by ultrasound and microwave in constant time, hot water with ultrasound radiation for 60 min and milling, the highest obtained yield of the oil solubility was 23.03 percent. However, there was no significant difference between them by reduction of ultrasound time in processing. By soaking the seeds in water 40 °C, the texture of moisturized seed prevents entrance of hydrophobic or non-polar solvents and the flowing out of oil. Diagram 1 shows the average of oil extraction efficiency by using ultrasound waves in ultrasound extraction mode in 60 min and 600 watt microwave waves.

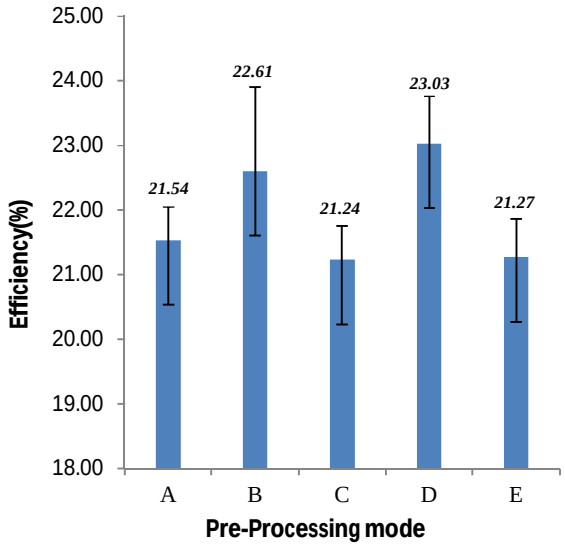

Diagram1. The effect of pre-processing by ultrasound waves

A: (hot water + ultrasound (30 min) + mill + ultrasound (60 min (extraction)); B: (hot water + ultrasound (60 min) + mill + ultrasound (60 min (extraction)); C: (hot water + ultrasound (30 min) + mill + microwave (600 watt (extraction)); D: (hot water + ultrasound (60 min) + mill + microwave (600 watt (extraction)); E: (mill + soxhlet (extraction)).

Table1. Combination of fatty acids (%) and physiochemical properties of extracted oil

Fatty Acids	A	B	C	D	E
Saponification value	195.27±2.05	194.6±4.39	193.87±3.26	193.53±3.96	192.37±2.15
Iodin Value	116.62±1.93 [a]	111.49±1.57 [ab]	113.08±3.37 [ab]	107.65±1.99 [b]	112.5±2.45 [ab]
Myristic C14:0	0.13±0.06 [a]	0.13±0.06 [a]	0.29±0.02 [b]	0.28±0.07 [b]	0.31±.04 [b]
Palmitic C16:0	13.6±0.36a	15.08±0.44 [b]	14.77±0.75 [ab]	13.84±0.39 [ab]	14.92±0.34 [b]
Stearic C18:0	6.5±.62	7.6±.56	7.43±0.06	7.69±0.66	6.75±0.52
Arachidic C 20:0	0.47±0.06 [a]	0.71±0.02 [ab]	0.82±0.07 [b]	0.85±0.08 [b]	0.62±0.08 [ab]
Myristoleic C14:1	0.1±0.0	_	0.13±0.06	_	0.12±0.01
Palmitoleic C16:1	0.13±0.06 [a]	0.4±0.05 [b]	0.41±0.02 [b]	0.27±0.12 [ab]	0.33±0.04 [b]
Oleic C18:1	24.27±0.95 [a]	25.04±0.67 [a]	25.93±0.4 [a]	25.95±0.95 [a]	24.84±1.02 [a]
Linoleic C18:2	51.6±0.66 [a]	47.46±0.37 [b]	47.65±0.35 [abc]	47.74±0.39 [abc]	49.25±1.03 [c]
Linoleic C18:3	2.23±0.06 [ab]	2.13±0.12 [ab]	1.7±0.26 [a]	1.73±0.21 [a]	2.77±0.4 [b]
Gadoleic C 20:1	0.1±0.0 [a]	0.17±0.06 [abc]	0.1±0.0 [b]	0.27±0.06 [c]	_

A: (hot water + ultrasound (30 min) + mill + ultrasound (60 min (extraction)); B: (hot water + ultrasound (60 min) + mill + ultrasound (60 min (extraction)); C: (hot water + ultrasound (30 min) + mill + microwave (600 watt (extraction)); D: (hot water + ultrasound (60 min) + mill + microwave (600 watt (extraction)); E: (mill + soxhlet (extraction)).

Each number has been experimented 3 times (± standard deviation)
In each row, numbers with different letters have significant difference (P<0.05)

These results clearly indicated that by ultrasound waves in pre-processing and extraction, as well as microwave in extraction, efficiency van be achieved in oil extraction by common soxhlet methods. The comparison of the amount of oil extraction in ultrasound pre-processing for ultrasound extraction in 60 min, microwave of 600 watt, and total average of 22.075 and 22.135, showed that the extraction efficiency was increased 0.865% and 0.805% in comparison to the mode which lacks pre-processing and soxhlet extraction. Table 1 shows the structure of fatty acids and some physiochemical properties of tomato wastes' oil for ultrasound pre-processing and microwave and ultrasound extraction in constant power and time.

As these data show, by ultrasound pre-processing in 30 and 60 min and microwave in 600 watt, a significant difference has not been found of these values for soapy number. Iodine number for this method hasn't had a significant relationship in respect to soxhlet extraction. In some cases, the amount of fatty acids has a significant relationship by soxhlet extraction. But, generally, the total amount of unsaturated fatty acids do not have a significant difference for soxhlet extraction in comparison with

ultrasound pre-processing and microwave and ultrasound extraction in constant power and frequency. A sample of fatty acid carrier is measured (mode B (hot water + ultrasound (60 min) + mill + ultrasound (60 min (extraction)) (see figure 1).

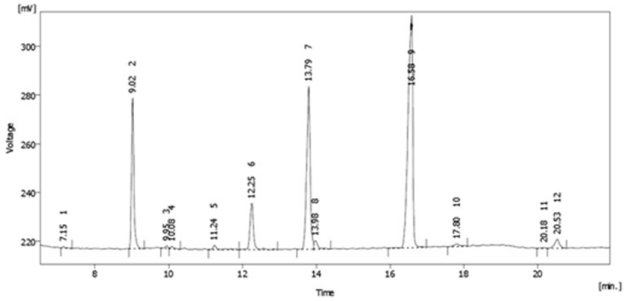

Figure1. Carrier of fatty acids for pre-processing by hot water + ultrasound (60 min) + mill + ultrasound (60 min (extraction)

3.2. Ultrasound and microwave extraction

In ultrasound pre-processing, oil extraction was performed in 60 min. As the time and power of ultrasound and microwave extraction increases, the amount of extracted oil also increases. According to the result of ANOVA, the effect of extraction mode on efficiency of extracted oil showed that considered methods in confidence level of 0.05 don't have a significant effect on extraction efficiency. The average yield of oil extraction using ultrasound and microwave extraction is shown in diagram 2.

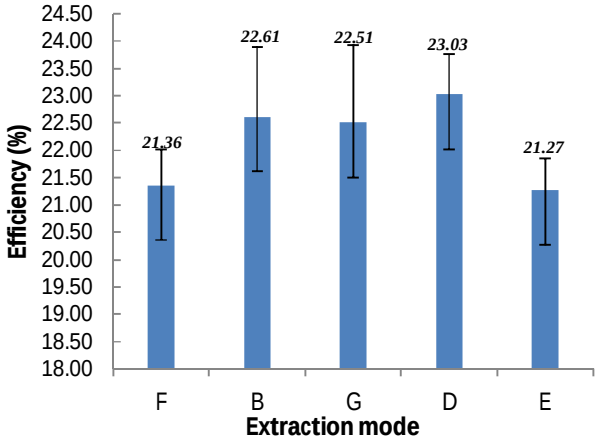

Diagram2. The effect of ultrasound and microwave extraction

(F: hot water + ultrasound (60 min)+ mill + ultrasound(30 min(extraction)); B: (hot water + ultrasound (60 min) + mill + ultrasound (60 min (extraction)); G: (hot water + ultrasound (60 min) + mill + microwave (250 watt (extraction)); D: (hot water + ultrasound (60 min) + mill + microwave (600 watt (extraction)); E: (mill + soxhlet (extraction)).

As you see in the diagram, by ultrasound and microwave extraction, efficiency of common soxhlet method will be achieved. The comparison of extracted oil amount in ultrasound and microwave with total average of 21.98% and 22.77% shows an increase of 1.5 and 0.71 percent of extracted oil yield in respect to common soxhlet method. Thereby, by the half of minimum time reported for microwave extraction (Chemat et al., 2011), an optimum efficiency can be obtained. Using ultrasound waves in extraction stage leads to about 83% time consuming and 64.28% in solvent usage in respect to common soxhlet methods.

Table 2 presents fatty acids' profiles and some physiochemical properties of above mentioned extraction.

Fatty Acids	F	B	G	D	E
Saponification value	196.63±1.11	194.6±4.39	196.4±2.07	193.53±3.96	190.04±4.71
Iodin Value	110.93±2.1	111.49±1.57	110.64±0.6	107.65±1.99	112.5±2.45
Myristic C14:0	0.1±0.0a	0.13±0.06a	0.17±0.06 ^{ab}	0.28±0.07 ^{ab}	0.31±0.04^{b}
Palmitic C16:0	14.63±0.35 ^{ab}	15.08±0.44^{a}	13.92±0.43 ^{ab}	13.84±0.39^{b}	14.92±0.34 ^{ab}
Stearic C18:0	6.35±0.48	7.6±0.56	6.43±0.42	7.69±0.66	6.75±0.52
Arachidic C 20:0	0.6±0.09 ^{ab}	0.71±0.02^{a}	0.43±0.06 ^{ab}	0.85±0.08^{b}	0.62±0.08 ^{ab}
Myristoleic C14:1	_	_	_	_	0.12±0.01
Palmitoleic C16:1	0.43±0.06	0.4±0.05	0.34±0.05	0.27±0.12	0.33±0.04
Oleic C18:1	24.7±0.44	25.04±0.67	26.33±0.42	25.95±0.95	24.84±1.02
Linoleic C18:2	48.53±1.19	47.46±0.36	48.17±0.85	47.74±0.39	49.25±1.02
Linoleic C18:3	1.97±0.12 ^{a}	2.13±0.12 ^{ab}	1.5±0.44 ^{a}	1.73±0.21 ^{a}	2.77±0.4 ^{b}
Gadoleic C 20:1	0.1±0.0 ^{a}	0.17±0.06 ^{a}	0.34±0.1 ^{b}	0.27±0.06 ^{ab}	_

Table2. The combination of fatty acids (%) and physiochemical properties of extracted oil extraction (F: hot water + ultrasound (60 min)+ mill + ultrasound(30 min(extraction)); B: (hot water + ultrasound (60 min) + mill + ultrasound (60 min (extraction)); G: (hot water + ultrasound (60 min) + mill + microwave (250 watt (extraction)); D: (hot water + ultrasound (60 min) + mill + microwave (600 watt (extraction)); E: (mill + soxhlet (extraction)).
Each number has been experimented 3 times (± standard deviation)
In each row, numbers with different letters have significant difference ($P<0.05$)

According to table 2, there is no significant difference between soxhlet extraction method and ultrasound and microwave one in physiochemical properties. The amount of unsaturated fatty acids except linoleic acid which its amounts is lower in average 1.03% of the value obtained in the Soxhlet method, in remained cases, no significant differences were observed based on analysis of variance. Figure 2 illustrates the resultant carrier of mode D (hot water + ultrasound (60 min) + mill + microwave (600 watt (extraction)).

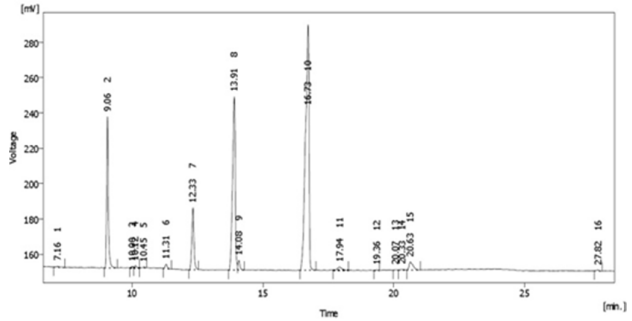

Figure2. The carrier of fatty acids for pre-processing by (hot water + ultrasound (60 min) + mill + microwave (600 watt (extraction)

4. Suggestions

According to performed experiments and achieved results, it is predicted that combination of ultrasound and microwave for oil extraction from the seed of tomato wastes can be effective in increasing of extraction efficiency. Therefore, it is proposed that some research about combined method of ultrasound and microwave perform in future.

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