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The effects of ultrasound pretreatment processes on oil extraction from tomato wastes

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Abstract

The oily seeds are one of the main components of tomato processing wastes which contain the excellent quality of fatty oils, therefore recycling of these by-products is of interest from either environmental viewpoint due to reduction of potential contaminant charge, or nutritional perspective since the health benefits derived from their bio-active compounds. Pretreatment of oily seeds is one of the main processes of their oil extraction, leading to considerable increase in oil extraction efficiency. The results of this study showed that using combination of ultrasound pretreatment with other physical methods could weaken the particle surface bonds and enhance the extraction yield effectively. The highest improvement in oil extraction from tomato waste seeds was about 28.11% by using ground waste seeds with hot water immersion (25-40C°) and ultrasound (at 550w, 37kHz 90 min). Although the ultrasound pretreatment didn't affect the fatty acids structure and physicochemical characteristics negatively, it also could improve it in some cases.

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Introduction

Tomato (Lycopersicon esculentum) is one of the most popular edible, red color plants, used in various food formulations like salads, juices, soups, purees, ketchup or paste (Kaur *et al.,* 2008). The tomato processing procedures generates relatively large quantities of by-products including tomato peels and seeds (Strati & Oreopoulou, 2011). Tomato waste seeds as a good supply of bioactive compounds can be used as functional components in food, nutracutical or cosmetic products providing a wide range of health benefits (Jiao, 2004). Several pretreatment and main extraction techniques have been suggested by different researches for extraction of various bioactive compounds such as carotenoids, fibers, proteins and oils from tomato by-products (Shao *et al.,* 2013, Machmuda *et al.,* 2012, Shao *et al.,* 2012, Eller *et al.,* 2010, Kumcuoglu *et al.,* 2013, Sogi *et al.,* 2002, Sogi *et al.,* 2005)

It was shown that the solvent based conventional procedures with proper choice of solvent in addition to the use of complete agitation procedures, are the easiest, cheapest and the most efficient techniques in this regards. Although the confirmed positive effects of process temperature on extraction efficiency of most lipid based compounds due to decreasing the viscosity (Pan *et al.,* 2000), and increasing the dispersion coefficients (Al-FarsiI and Lee, 2008), the studies is continued to minimize the operation temperature in order to decrease the energy consumption and chemically degradation of these active compounds (Nandes *et al.,* 2008, Simal *et al.,* 1998). Therefore, among agitation techniques, ultrasound received the most attention due to its capability to either disruption of biological cell walls or providing a better solvent diffusion into cellular materials and improving the mass transport because of occurred cavitation phenomenon by ultrasound, which tiny bubbles formed in the liquid bulk, and during a compression cycle, cavitation bubbles collapse (non-symmetric) (Mason *et al.,* 1996) and explode afterward (Ji and Lu 2006, Chemat *et al.,* 2011; Toma *et al.,* 2000, Shotipruk and Kaufman 2001, Arabani *et al.,* 2014, Tang *et al.,* 2010). Consequently, the ultrasound-assisted extraction is known as a proficient extraction technique that can reduce working times and increase yields, considerably (Pico, 2013, Awad *et al.,* 2012). Several studies have evaluated various applications of ultrasound in the amplification of extraction of functional compounds from herbs, seeds and etc. (Mason *et al.*, 1996, Vilkhu *et al.,* 2008, Soria *et al.,* 2010; Shan *et al.,* 2011, Da porto *et al.,* 2013, Tang *et al.,* 2014, Arabani *et al.,* 2014). For example, Shan *et al.,* 2011 used ultrasound pretreatment methods for extracting the oils from watermelon seeds and reported an increase of 20% in efficiency. It was also reported that the ultrasound has no oxidative effect on extracted oils (Zhang & Wang, 2008, Li and Pordesimo, 2004, Arabani *et al.,* 2014).

The aim of this study was the evaluation of pretreatment methods on the efficiency and fatty acid profile of extracted oils from tomato wastes.

Materials and methods

Materials

The tomato wastes (wet form) was obtained from Golnoosh Company (Shahriar,Iran). n-Hexane was purchased from Merck (Darmstadt, Germany).

Pretreatment

The wet tomato wastes were dried under sunlight for two weeks and the precipitation method was used to separate seeds from skins and other gelatinous material (Talei *et al.,* 2011).

In order to study the effects of pretreatment on the extraction yield of tomato seed oil, seeds were prepared with various methods of preparation, as (Table 1).

Table 1. preparation methods.

Pretreatment method	Complete seed plus grinding	Complete seed plus hot water	Complete seed plus hot water plus grinding	Hot water plus US plus grinding ↓ 30min	↓ 60min	↓ 90min

A definite amount of tomato seeds (5g) was immersed in water for 24 h at temperature of 40C in Bon Mary (Memert; WB14; Germany). After adding water with a mass ratio of 1 to 3 (seed to water), the seeds were irradiated by ultrasound at mentioned conditions. For ultrasound pretreatments the ultrasonic device (Elmasonic S60H; Germany) was used. samples were ground in 40 second for passing through a 0.7mm sieve.

Extraction

Samples were continuously extracted with 140ml n-hexane for 6 hr at temperature of 70°C (Cantarelli *et al.,* 1993) in Soxhlet apparatus (Gerhardt soxtherm200; Germany). n-Hexane was removed at 50°C under vacuum pressure (62kPa) using a rotary drier (Heidolph Heizbad bath; Germany), then placed in forced air oven (Heraeus D-64550 Hanau; Germany), at 45°C for 2 hr to remove probable residual solvent (Porto *et al.,* 2013).

Yield determination

The yield of tomato seed oil was calculated using the following formula:

$$\text{Yield}(\%) = \frac{W}{Y} \times 100$$

where W is the mass of tomato seed oil extracted from the sample (g) and Y is the mass of dried sample (g).

Gas chromatographic analysis

The fatty acid methyl esters (FAME) were prepared according to ISO 5509. Gas chromatographic (GC) analysis was performed in a Young Lin 6500 gas chromatograph (YL-6500 GC, Gyeonggi-do, South Korea), fitted with a CP-Sil8 column (60m*0.25mm i.d., film thickness 0.2micrometer). Operating conditions were the flame ionization detector at 300C°, a split Injector at 280°C. Hydrogen was used as carrier gas with flow rate of 1 $ml.min^{-1}$ and the split ratio was used 1:100. The programmed temperature was isothermal condition at 175°C.

Chemical properties analysis

The chemical characteristics of extracted oiles, namely, iodin value and saponification number were determined according to standard methods (AOAC 1990; AOAC 1998; ISO 3657 2002).

Data analysis

All experiments were carried out in triplicate. The results were analyzed using analysis of variance (ANOVA) and significant differences among means were determined followed by the Tukey' s test at $P<0.05$ by the SPSS software version 18.

Results and discussion

The influence of hot-water pre-treatment method

The use of hot water as pretreatment method had a significant effect on oil yield. As shown in table 2, using hot water could increase the oil yield approximately 4% in comparison with conventional pretreatment method (grinding). Also the use of grinding had positive effect on oil yield and could increase it to 10.7% in comparison with non-pretreated extraction process. Therefore, using hot water plus grinding could increase the oil yield from 10.57% to 24.56%. Soaking the seeds in hot water before grinding, provides the moist texture in samples and prevents it from entering non polar and hydrophobic solvent, or flow out the oil. Moreover the grinding process leads to a better penetration of solvent into the sample. Similar results were achieved by Basiri *et al.*, 2011 and Arabani *et al.,* 2014. Therefore, based on the results, using hot water and grinding simultaneously, could increase the extraction yield considerably.

Table 2. The oil extraction yield (%) of ground and non-ground seed wastes with or without the hot water pretreatment process.

Sample	pre-treatment	
	Without hot water	With hot water
Complete seed	10.57±1.45968 d	15.63±0.92361 c
Complete seed plus grinding	21.27±0.58579 b	24.56±1.12476 a

Each data represents the mean of three extraction replicates (standard deviation)

The values with different letters within columns and raws indicates significant difference (p < 0.05).

The Influence of ultrasound pre-treatment time

The effects of ultrasound irradiation time on oil extraction yields of samples with ultrasound pretreatment have been given in Fig. 1. It can be easily seen that using mixed pretreatment processes (US+ H.W+ Grinding), would increase up the oil extraction yield to 28.11%, which was 15.91% higher than for non-pretreated samples.

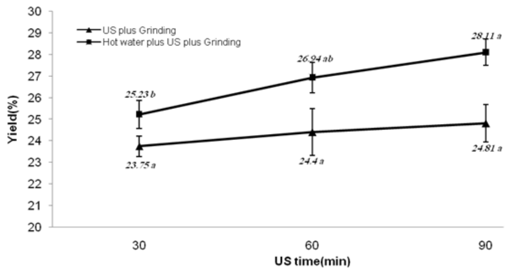

Fig. 1. The effect of ultrasonic pretreatment time on the oil extraction yield (%) of tomato waste.

It may be that ultrasonic wave could disrupt the cell walls, so larger contact area between solvent and material was created and more oil was appeared on the surface. Under optimum condition of physical pretreatment, when the time was increased from 30 to 90 min, oil yield was increased from 25.23% to 28.11%. Without hot water, no significant changes happened while the time increasing. It could be happened because of not having moist texture and flow out the oil content before extraction. The cavitation of ultrasound has also been attributed to the generation of intracellular cavitation and these mechanical shocks can disturb cellular structural and functional components up to the completing of cell lysis (Chemat *et al.,* 2011, Arabani *et al.,* 2014).

The influence of different pretreatment method on fatty acids composition and physicochemical characteristics

The extracted oil profile of samples under various pretreatment processes are shown in Table 3. Using physical pretreatment (without US) could significantly increase unsaturated fatty acids and iodine value, but had no effect on their saponification values. The high iodine values correspond to high degree of unsaturation. saponification value represents the number of milligrams of potassium hydroxide required to saponify 1g of fat under the conditions specified. It can be occurred due to easier transporting phenomena caused by pretreatment. The results also indicated that the major extracted fatty acid for all samples was linoleic, fallowed by oleic, with the concentrations of 46.73% and 22.17%, respectively. Since in this research the level of linoleic acid fell in the range of 46-53%, Swem (1979) reports higher concentration for oliec acid (46%) compared to linoleic acid (35%). Palmitic acid was found to be the main saturated fatty acid among others and its values was in the range reported by Takasova *et al.,* 1995 and Swen *et al.,* 1979. Furthermore, it can be clearly shown by Table 4 that using ultrasound as pretreatment increased the unsaturated fatty acid composition, significantly (p<0.05).

Table 3. Saponification, iodine values and fatty acids composition) extracted oils from various pretreated sample.

Phys.chemical char. and Fatty Acids	Complete seed	Complete seed plus grinding	Complete seed plus hot water	Complete seed plus hot water plus grinding
Saponification Value	192.22±1.51245 a	193.40±1.21243 a	194.01±0.56874 a	193.95±0.98754 a
Iodin Value	100.16±1.35412 c	104.23±1.08445 b	103.56±1.56897 b	110.11±1.6874 a
Myristic C14:0 (% w/w)	0.13±0.05774 bc	0.31±0.04041 a	0.11±0.02887 c	0.20±0.00000 b
Palmitic C16:0 (% w/w)	12.60±0.45826 b	14.91±0.34034 a	14.26±1.32035 ab	13.96±0.83267 ab
Stearic C18:0 (% w/w)	4.66±0.56862 b	6.75±0.52202 a	7.10±0.60826 a	6.68±0.69342 a
Arachidic C:20:0 (% w/w)	0.38±0.07638 b	0.61±0.07638 a	0.55±0.10440 ab	0.49±0.04583 ab
Palmitoleic C16:1 (% w/w)	0.20±0.10000 b	0.33±0.03512 ab	0.28±0.02633 ab	0.41±0.04370 a
Oleic C18:1 (% w/w)	22.17±0.80728 b	24.84±1.01619 a	27.25±1.08669 a	25.85±0.81635 a
Linoleic C18:2 (% w/w)	46.73±0.47258 b	49.25±1.02591 a	49.20±1.04950 ab	50.45±1.11851 a
Linolenic C18:3 (% w/w)	1.66±0.40415 b	2.77±0.4025 a	2.15±0.06227 ab	2.17±0.07506 ab

Each data represents the mean of three extraction replicates (standard deviation)

Values with different letters within raws indicates significant difference ($p < 0.05$).

Table 4. Oil yield(%),Physicochemical characteristics and Fatty acids composition(%) of different pretreatment methods.

Sample	Complete seed	Hot water plus US plus grinding		
		30min	60min	90min
Saponification Value	192.22±1.51245 abcd	192.02±1.64122 abc	193.82±0.95451 a	193.25±1.00251 ab
Iodin Value	100.16±1.35412 c	115.72±1.34125 ab	115.75±0.53600 b	117.42±1.00271 a
Myristic C14:0	0.13±0.05774 a	0.10±0.00000 a	0.10±0.00000 a	0.14±0.06928 a
Palmitic C16:0	12.60±0.45826 b	13.34±1.59534 ab	13.19±1.00450 ab	14.31±1.07974 ab
Stearic C18:0	4.66±0.56862 b	7.06±0.90738 a	7.12±1.00060 a	6.17±0.03773 a
Arachidic c:20:0	0.38±0.07638 b	0.49±0.01155 a	0.50±0.00000 a	0.50±0.00000 a
Palmitoleic C16:1	0.20±0.10000 b	0.49±0.01626 a	0.46±0.01732 a	0.10±0.00000 b
Oleic C18:1	22.17±0.80728 b	25.21±0.98534 a	24.25±1.54390 a	25.18±1.49527 a
Linoleic C18:2	46.73±0.47258 b	51.11±1.00015 a	51.36±0.80829 a	51.46±0.70238 a
Linolenic C18:3	1.66±0.40415 b	2.20±0.00000 a	2.18±0.05280 a	2.18±0.01964 a

Each data represents the mean of three extraction replicates (standard deviation)

Values with different letters within raws indicates significant difference($p < 0.05$).

The analysis of fatty acid compositions of extracted oils resulted that unsaturated fatty acids of tomato seed oils, namely, oleic acid, linoleic acid and linolenic acid, remained constant with increasing ultrasound time, however, the concentration of palmitoleic acid decreased significantly, after 60 minute. This may be caused by destructive effect of high cavitations time. Therefore, 60 minute was chosen as optimum time for ultrasound irradiation due to gained total unsaturated fatty acids and iodin value. These results are in agreement with previous reported optimum ultrasound irradiation time by Chemat *et al.,* 2011 and Arabani *et al.,* 2014.

Conclusion

The major part of waste tomato is seed which is a rich source of unsaturated fatty acids, that is well known as a suitable nutracutical source for human. It was shown that pretreatment process, especially ultrasound irradiation, could positively affect the extraction efficiency significantly. Since, ultrasound irradiation for 90 min combined with physical methods (hot water plus grinding) in pretreatment followed by soxhlet method, could increase the oil yield up to 28.11%, which is 17.54% higher than that of non-pretreated, , 60 minute ultrasound irradiation with hot water and grinding was chosen as optimum pretreatment method because of its total fatty acids and efficiency. These methods had no negative significant effect on unsaturated fatty acids structures.

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