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The effect of microwave pretreatment and extraction technique on fatty acids profiles and some chemical characteristics of tomato seed oil

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ABSTRACT

Identifying and extracting of new edible oil sources from the food waste such as tomato seeds and optimizing the extraction conditions is a big step forward in edible oil preparing. The effect of the extraction method and microwave pretreatment of tomato seeds on the fatty acids profile of oil samples and their chemical characteristics were evaluated. The seeds were treated with microwaves using various power levels (0, 200 and 500 W) and different process times (0, 1, 3 and 5 min) and their oil was extracted by Soxhlet and press methods. Fatty acids composition of oils was determined by gas chromatography. Fatty acid properties of the oil samples were evaluated by the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA) and oxidative stability (Se Index) indexes. Data was analyzed with factorial treatment structure in a Completely Randomized Design in three replications. The dominant fatty acids in the profile of oil samples were linoleic acid (51.73 %), oleic acid (25.85 %), and palmitic acid (12.84 %). The mean peroxide and acid values of seed oil obtained by press and Soxhlet methods were 0.58 and 2.2 milliequivalents of oxygen per kilogram of oil and 0.1 and 0.14 milligrams of potassium hydroxide per gram of oil, respectively. The increase of the microwave powers (from 200 to 500 W) and process times (from 0 to 5 min) of tomato seeds in both Soxhlet and press extraction methods increased the peroxide value, acid value and SFA index and decreased PUFA and Se index of the tomato seeds oil ($p<0.05$). The quality of the tomato seed extracted oil by two methods of pressing and Soxhlet and following microwave pretreatment seeds (500 W for 5 min) in terms of peroxide value and acid value was found to be in the standard range recommended.

1-Introduction

One of the most effective factors that can increase productivity of edible oils due to the increase in consumer demand is finding novel raw materials. Recently, the study of the edible characteristics of novel oils, such as seed oil obtained from the waste of agricultural products, including pumpkin, watermelon, pomegranate, date, lemon, citrus, and apple seeds, has received attention [1]. Tomato (*Solanum lycopersicum L*) is one of the most consumed food products in the world. A large part of it is eaten fresh and the rest is consumed in processed form such as paste, sauce and pickles [2]. The remaining tomato pulp is the tomato paste production process, which consists of skin (27%), flesh (40%) and seeds (33%) [3]. The annual production of tomato pulp in the world is about 5 to 9 million tons, although part of it is used as animal feed, but it is often buried as waste, which causes many environmental risks [4]. Tomato seeds, which make up 1-5% of the weight of the fruit, contain compounds such as edible oil, protein and pigment. Tomato seed oil is rich in lycopene, antioxidant compounds including tocopherol and carotenoids [5]. The lack of arable land for the cultivation of oil seeds is one of the advantages of producing oil from tomato seeds [6]. Extraction is one of the important processes in the production of oil from oilseeds, which is usually done by two methods: pressing (applying mechanical pressure on the oilseeds) or Soxhlet (saturation of the solvent with the oil in the oilseeds) [7]. Extracting oil with a press is easier, safer, cheaper and less efficient compared to solvent. Oil extraction with Soxhle (hexane solvent) is associated with obstacles such as long process time, high cost, release of volatile organic compounds into the environment and the quality loss of the oil [8]. One of the main obstacles to extracting the oil from oilseeds with solvent is the residual solvent in the oil, which has a toxic effect on health and contributes to the development of Parkinson's disease. Nowadays, according to the tendency of people to consume healthy food with minimal processing, the consumption of pressed oils has been more attention [9]. The use of new pretreatments, including microwaves, with the aim of increasing the extraction efficiency, improving the physical and chemical quality, and increasing the shelf life of oil seeds (chia seeds, rapeseeds, flax seeds, thistle seeds, black seeds, walnut kernels, peanut and apricot kernel) has attracted much attention [10]. Heating food with microwaves is an alternative method to traditional heating. By creating an alternating magnetic field, these waves cause a rapid oscillation of the aligned electric field in the polar molecules of food such as water, protein and polar fats. These oscillations produce heat by creating friction between molecules. The short frequency of microwaves does not damage chemical bonds in food molecules and has the ability to improve the process of extracting oil from seeds by increasing the splitting of cell membranes [11, 12]. Many studies have been conducted regarding the evaluation of chemical properties (anti-oxidation compounds, free fatty acids, peroxides and phenolic compounds) of oil obtained from oil seeds pretreated with microwaves [1]. Ho et al. (2019) reported that microwave pretreatment of oilseeds increases the oxidative stability of extracted oil by increasing the extraction of some polyphenol compounds, phospholipid compounds and the production of anti-oxidation compounds resulting from Maillard reactions during irradiation. increases [13]. Microwave pretreatment of oilseeds increases the shelf life of the produced oil by destroying the structure of enzymes that cause oil spoilage, such as lipase and lipoxygenase [14]. Changes in temperature and pretreatment time of oilseeds using microwaves have a direct effect on extraction efficiency, phenolic content and quality of extracted oil [15]. Ren et al. (2019) reported that microwave pretreatment of rapeseeds (power 200 to 600 W) improved the flavor and oxidative stability of oil extracted from them by pressing [16]. Rezvankhah et al. (2019) investigated the process of qualitative changes of hemp seed oil with the help of microwave pretreatment and announced that with the increase of microwave power and time, the extraction efficiency, acid number and peroxide of the oil increased [17]. The aim of this study was to investigate the effect of microwave pretreatment of tomato seeds on the composition of fatty acids and some chemical characteristics of the resulting oil.

2- Materials and methods

2-1- Purification of tomato seeds

Tomato pulp was obtained from a tomato paste production workshop. The separation of seeds from pulp was done according to Zoro et al.'s method (2013) with some changes [18]. The waste was immersed in a large plastic container filled with water. Due to the difference in the density of the seeds with water and scum, the seeds were deposited at the bottom of the container and the rest of the scum was placed on the surface of the water. The isolated seeds were kept dry at laboratory temperature (25°C) for 6 hours in moisture and oxygen resistant bags. All the chemicals used were of laboratory type, which were obtained from Merck, Germany.

2-2- Tomato seeds evaluation

Moisture (AACC Approved Methods of Analysis 15.02-44), ash (AACC Approved Methods of Analysis 01.01-08), fat (AACC Approved Methods of Analysis 25.01-30) and protein (AACC Approved Methods of Analysis 12.01-46) of seeds Tomatoes were measured according to the standard of the World Association of Cereals and Seeds (AACC, 1998) [19].

2-3- Microwave pretreatment of seeds

80 grams of tomato seeds were distributed in a thin layer with a diameter of about 30 mm on the surface of a microwave-resistant Pyrex glass container and placed in a 50-liter laboratory microwave oven (NN-C2002W, Japan). The samples were subjected to microwave radiation at two power levels of 200 and 500 watts for 1, 3, and 5 minutes, respectively, and after cooling at the laboratory temperature (25 degrees Celsius), they were placed in plastic bags covered with fabric. They were kept at laboratory temperature until the stage of oil extraction. Tomato seeds (**Fig. 1.**) without radiation were used as a control sample [20].

2-4- Tomato seed oil extraction by press method

Tomato seed oil (80 grams) was extracted at a temperature of 35°C for 10 minutes with a single spiral mini press (Bekrdane, Iran) at a speed of 20 rpm according to the method of Yilmaz and Gonser (2017) with some modifications. [21].

2-5- Tomato seed oil extraction by Soxhlet method

Tomato seed oil (80 grams) was extracted using an automatic Soxhlet machine with n-hexane solvent (Merck, Germany) and the standard method of the World Grains and Seeds Association (AACC Approved Methods of Analysis 30-25.01) with some modifications. (**Fig. 1**) [19].

(a) (b)

Fig.1. Tomato seeds (a) and Tomato seeds oil (b)

2-6- Chemical evaluation of tomato seed oil

2-6-1- Fatty acids profile

The fatty acid profile of tomato seed oil was determined based on the standard method (AOAC, 969.33 Method, 2005) [22]. The derivatization of the fatty acids of the samples to methyl ester was done using the solvent of n-hexane and ethanolic potash solution with the aim of removing saponifiable and non-saponifiable compounds. Then 0.5 ml of normal sodium methoxide was added for phase separation in a dark environment. Methylated fatty acids in the hexane phase to a gas chromatography device (Shimadzo 2014, Japan) equipped with a flame detector (FID) with a capillary column with a length of 60 meters, an inner diameter of 0.25 mm and a thickness of 0.25 micrometers were injected. Nitrogen gas was used as a carrier with a flow rate of 1 ml/min. The temperature of the column (100°C), the detector (220°C) and the injection valve (250°C) and the injected sample volume was 2 microliters. The composition of fatty acids of oil samples using (SFA), (MUFA), (PUFA) and (Se Index) indices, which are respectively the amount of saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids. Saturation and oxidative stability index (the ratio of linoleic acid to palmitic acid) were evaluated [23].

2-6-3- Peroxide value

The peroxide value of extracted oil was measured by the standard method (AOAC, 965.33 Method, 2005) [22]. About 5 grams of oil was added to 30 ml of acetic acid-chloroform solution (volume ratio 3:2) and mixed. 0.5 ml of saturated potassium iodide solution was added to it and placed in a dark environment for about one minute. After adding 30 ml of distilled water, 0.01 normal sodium thiosulfate was added to the solution until the yellow color disappeared. About half a milliliter of 1% starch glue was added to the solution and the addition of sodium thiosulfate continued until complete neutralization (disappearance of blue color). The control went through the mentioned steps as a sample without oil. The oil peroxide number (milliequivalent grams of oxygen per kilogram of oil) was calculated based on the formula (Peroxide value = (N(s-b))/W x 1000). (N) is the normality of sodium thiosulfate, (S) is the volume of thiosulfate used in milliliters, (b) is the volume of thiosulfate used in milliliters, and (W) is the weight of the oil sample in grams.

2-6-4- Acid value

The acid value of the extracted oil was determined according to the standard method (AOAC, 969.17 Method, 2005) [22]. 5 grams of oil were dissolved in 25 ml of ethanol and ether mixture and neutralized with 0.1 normal potassium hydroxide in the presence of phenolphthalein until a pink color appeared. The acid number (mg of potassium hydroxide required to neutralize free fatty acids in one gram of oil sample) was calculated according to the formula (Acid value = (V × N × 56.1)/m). (N) is the normality of potassium hydroxide, (V) is the volume of potassium hydroxide in milliliters, and (m) is the weight of the oil sample in grams.

2-7- Statistical method

This research is based on the factorial method and according to a completely random statistical design with three factors of microwave pretreatment power (0, 200 and 500 watts), microwave pretreatment time (0, 1, 3 and 5 minutes) and the type of extraction method (cold press and Soxhlet) tomato seed oil was done in three replicates. Data analysis was done by statistical software (SPSS) and averages were compared based on Duncan's multi-range test at a significance level of 5%.

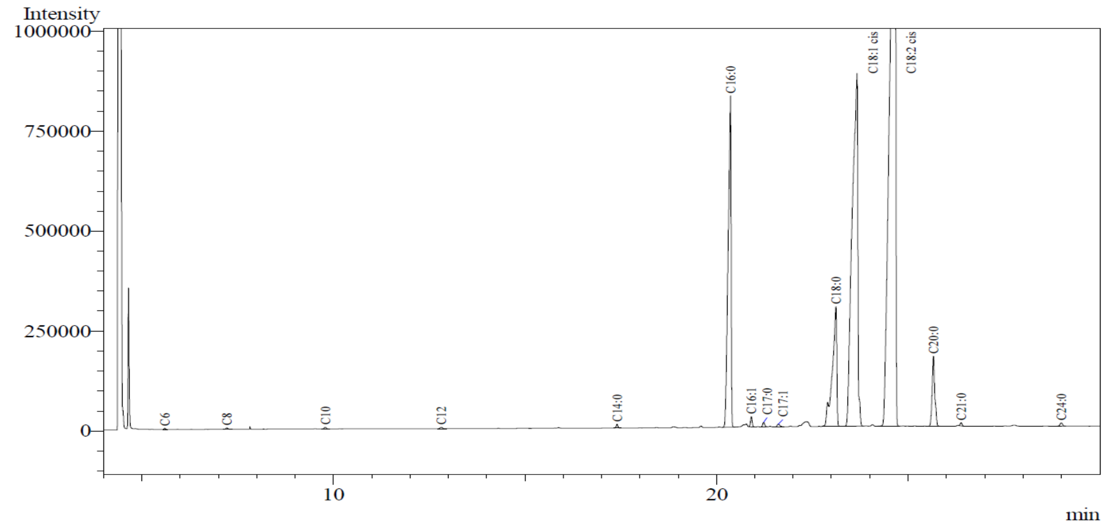
3- Results and discussion

3-1- Chemical characteristics of tomato seeds

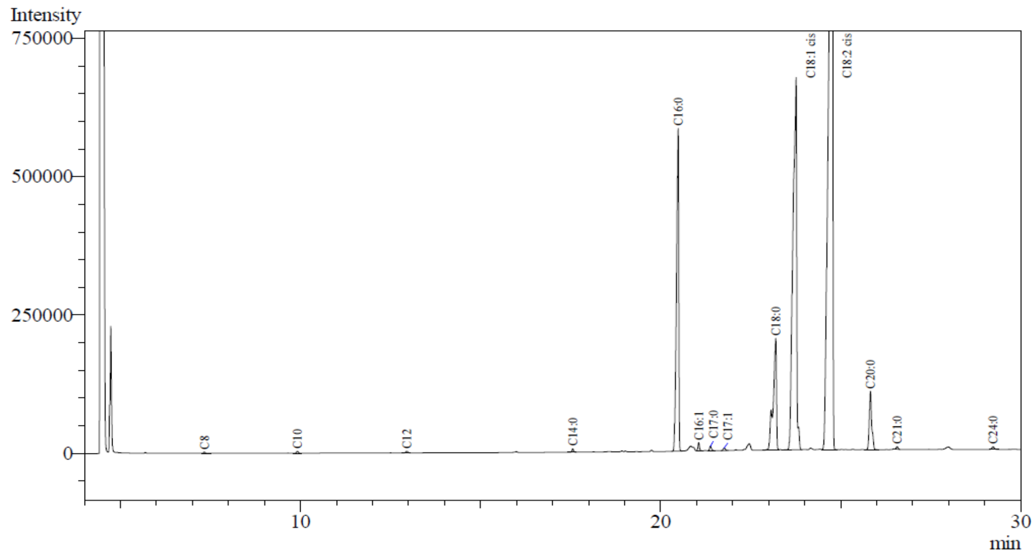
The results of some chemical characteristics of tomato seeds including moisture (3.6% ± 0.1%), ash (3.2% ± 0.3%), protein (14.9% ± 0.7%), and fat (26.1% ± 1.1%) were consistent with the reports of Aksoylovazbek et al. (2020) [24].

3-2- Fatty acids Profiles

Chromatograms of tomato seed oil extracted by pressing and Soxhlet method are shown in **Fig. 2**. The use of gas chromatography method separated almost all the peaks of fatty acids properly within 30 minutes. Palmitic, stearic, oleic and linoleic fatty acids were isolated in the oil obtained from both extraction methods in a completely separated manner. Sulabrita et al. (2022) by examining the fatty acid profile of seed-tomato-frangipani oil using a gas chromatography device equipped with a mass spectrometer, respectively, palmitic, stearic, oleic and linoleic fatty acids were separated and observed in about 30 minutes [25]. The interaction effect of oil extraction method, time and power of microwave pretreatment on the amount of fatty acids in seed-tomato-potato oil is shown in Table 1. The oil extracted from tomato seeds by both pressing and soxhlet methods contains the most palmitic saturated fatty acid (12.84%), oleic monounsaturated fatty acid (25.85%) and diunsaturated fatty acid. Linoleic saturation was (51.73%). Aksvilovazbek et al. (2020) also reported the amount of palmitic, oleic and linoleic fatty acids in tomato pomace oil as equal to 12.17, 28.2 and 50.77%, which was largely consistent with the results of this study [24].



(**a**)



(**b**)

Fig. 2. GC chromatograms of tomato seed oil extracted by press (a) and Soxhlet (b) methods.

Table 1. Effect of extraction method, microwave pretreatment time and power on fatty acids profile of tomato seed oil. Different letters indicate statistically significant differences ($p<0.05$).

		Pretreatment Power (Watt)			
		200		500	
Parameters	Pretreatment Time (s)	Soxhlet Extraction	Press Extraction	Soxhlet Extraction	Press Extraction
C 14:0	0	0.097 ± 0.0007^{i}	0.087 ± 0.0035^{j}	0.097 ± 0.0007^{i}	0.087 ± 0.0035^{j}
	1	0.100 ± 0.0002^{i}	0.102 ± 0.0013^{hi}	0.232 ± 0.002^{c}	0.113 ± 0.0057^{f}
	3	0.106 ± 0.0012^{gh}	0.107 ± 0.0021^{gh}	0.272 ± 0.007^{b}	0.112 ± 0.0064^{f}
	5	0.219 ± 0.0042^{d}	0.109 ± 0.0071^{fe}	0.316 ± 0.0075^{a}	0.137 ± 0.0041^{e}
C 16:0	0	12.86 ± 0.02^{h}	12.84 ± 0.02^{h}	12.86 ± 0.02^{h}	12.84 ± 0.02^{h}
	1	13.14 ± 0.07^{g}	13.07 ± 0.21^{gh}	13.72 ± 0.04^{cd}	13.60 ± 0.05^{de}
	3	13.16 ± 0.01^{g}	13.29 ± 0.24^{fg}	14.01 ± 0.02^{ab}	13.86 ± 0.02^{bc}
	5	13.50 ± 0.01^{def}	13.44 ± 0.15^{ef}	14.16 ± 0.07^{a}	13.89 ± 0.00^{bc}
C 16:1	0	0.3710 ± 0.014^{c}	0.4680 ± 0.02^{a}	0.3710 ± 0.014^{c}	0.4680 ± 0.02^{a}
	1	0.3325 ± 0.014^{d}	0.4267 ± 0.007^{b}	0.2444 ± 0.001^{g}	0.2324 ± 0.001^{gh}
	3	0.2969 ± 0.003^{e}	0.3368 ± 0.009^{d}	0.1979 ± 0.010^{i}	0.2173 ± 0.004^{h}
	5	0.2749 ± 0.006^{f}	0.2428 ± 0.002^{g}	0.1793 ± 0.008^{i}	0.1919 ± 0.002^{i}
C 17:0	0	0.1436 ± 0.001^{g}	0.1415 ± 0.004^{g}	0.1436 ± 0.001^{g}	0.1415 ± 0.004^{g}
	1	0.1633 ± 0.003^{f}	0.1723 ± 0.002^{ef}	0.2361 ± 0.003^{c}	0.2283 ± 0.005^{c}
	3	0.1643 ± 0.004^{f}	0.1826 ± 0.005^{e}	0.2660 ± 0.005^{b}	0.2580 ± 0.004^{b}
	5	0.1725 ± 0.002^{ef}	0.1963 ± 0.003^{d}	0.2684 ± 0.003^{b}	0.2902 ± 0.010^{a}
C 17:1	0	0.1345 ± 0.001^{a}	0.1305 ± 0.001^{ab}	0.1345 ± 0.001^{a}	0.1305 ± 0.001^{ab}
	1	0.1308 ± 0.008^{a}	0.1262 ± 0.002^{bc}	0.1061 ± 0.009^{f}	0.1035 ± 0.004^{f}
	3	0.1232 ± 0.001^{c}	0.1175 ± 0.0005^{d}	0.1026 ± 0.004^{f}	0.0951 ± 0.004^{g}
	5	0.1125 ± 0.001^{e}	0.1018 ± 0.0003^{f}	0.0938 ± 0.0003^{g}	0.0912 ± 0.000^{g}
C 18:0	0	6.568 ± 0.15^{ef}	6.109 ± 0.001^{g}	6.568 ± 0.15^{ef}	6.109 ± 0.001^{g}
	1	6.503 ± 0.003^{f}	6.574 ± 0.002^{ef}	6.834 ± 0.02^{cd}	7.112 ± 0.05^{b}
	3	6.678 ± 0.002^{de}	6.799 ± 0.04^{cd}	6.962 ± 0.04^{bc}	7.302 ± 0.07^{a}
	5	6.842 ± 0.006^{cd}	6.870 ± 0.03^{c}	7.087 ± 0.14^{b}	7.415 ± 0.05^{a}
C 18:1	0	25.85 ± 0.09^{b}	26.06 ± 0.06^{a}	25.85 ± 0.09^{b}	26.06 ± 0.06^{a}
	1	25.75 ± 0.02^{bc}	25.73 ± 0.01^{bc}	25.40 ± 0.07^{efg}	25.35 ± 0.07^{fgh}
	3	25.64 ± 0.07^{cd}	25.46 ± 0.07^{ef}	25.26 ± 0.08^{ghi}	25.24 ± 0.04^{hi}
	5	25.54 ± 0.07^{de}	25.42 ± 0.04^{ef}	25.12 ± 0.03^{i}	24.96 ± 0.06^{j}
C 18:2	0	51.59 ± 0.14^{ab}	51.73 ± 0.06^{a}	51.59 ± 0.14^{ab}	51.73 ± 0.06^{a}
	1	51.31 ± 0.12^{bc}	51.07 ± 0.34^{cd}	50.41 ± 0.06^{fg}	50.38 ± 0.06^{fg}
	3	50.93 ± 0.30^{de}	50.97 ± 0.29^{cde}	50.06 ± 0.06^{gh}	50.19 ± 0.01^{gh}
	5	50.65 ± 0.04^{ef}	50.70 ± 0.12^{ef}	49.88 ± 0.09^{h}	50.01 ± 0.07^{h}
C 20:0	0	2.480 ± 0.23^{bc}	2.404 ± 0.009^{c}	2.480 ± 0.23^{bc}	2.404 ± 0.009^{c}
	1	2.478 ± 0.002^{bc}	2.607 ± 0.004^{abc}	2.636 ± 0.003^{abc}	2.615 ± 0.008^{bc}
	3	2.522 ± 0.001^{bc}	2.616 ± 0.003^{abc}	2.688 ± 0.07^{ab}	2.622 ± 0.003^{abc}
	5	2.558 ± 0.001^{abc}	2.623 ± 0.005^{abc}	2.760 ± 0.14^{a}	2.789 ± 0.01^{a}
C 24:0	0	0.1007 ± 0.003^{d}	0.1034 ± 0.006^{d}	0.1007 ± 0.003^{d}	0.1034 ± 0.006^{d}
	1	0.1040 ± 0.005^{d}	0.1038 ± 0.007^{d}	0.1169 ± 0.004^{c}	0.1079 ± 0.004^{cd}
	3	0.1067 ± 0.001^{cd}	0.1037 ± 0.008^{d}	0.1278 ± 0.001^{b}	0.1273 ± 0.005^{b}
	5	0.1151 ± 0.003^{c}	0.1064 ± 0.006^{cd}	0.1321 ± 0.007^{b}	0.1488 ± 0.002^{a}

The interaction of oil extraction method, microwave pretreatment time and power on the stability indicators of tomato seed oil is shown in Table 2. The average amount of (SFA), (MUFA) and (PUFA) indices in tomato seed oil was 22.2, 26.35 and 51.59%, respectively. Gofari and Kapukasaleh (2016) also reported the amount of the above indicators in tomato seed oil as equivalent to 19.82, 26.29 and 53.89%, respectively, which was consistent with the results of this research.

Table 2. Effect of extraction method, microwave pretreatment time and power on fatty acids indexes of tomato seed oil. Different letters indicate statistically significant differences (p<0.05).

		Pretreatment Power (Watt)			
		200		500	
Parameters	Pretreatment Time (s)	Soxhlet Extraction	Press Extraction	Soxhlet Extraction	Press Extraction
SFA	0	22.20 ± 0.29 g	21.63 ± 0.06 h	22.20 ± 0.29 g	21.63 ± 0.06 h
	1	22.44 ± 0.01fg	22.58 ± 0.14 f	23.72 ± 0.02 c	23.72 ± 0.13 c
	3	22.68 ± 0.06 f	23.04 ± 0.23 e	24.26 ± 0.06 b	24.21 ± 0.01 b
	5	23.38 ± 0.07 d	23.29 ± 0.11 de	24.66 ± 0.21 a	24.60 ± 0.05 a
MUFA	0	26.35 ± 0.11 b	26.66 ± 0.06 a	26.35 ± 0.11 b	26.66 ± 0.06 a
	1	26.22 ± 0.04bc	26.28 ± 0.02 b	25.77 ± 0.07ef	25.69 ± 0.06fg
	3	26.06 ± 0.07 cd	25.92 ± 0.08 g	25.56 ± 0.09 g	25.55 ± 0.08gh
	5	25.93 ± 0.08 de	25.76 ± 0.04 f	25.39 ± 0.04 hi	25.25 ± 0.01i
PUFA	0	51.59 ± 0.14 ab	51.73 ± 0.06 a	51.59 ± 0.14 ab	51.73 ± 0.06 a
	1	51.31 ± 0.12bc	51.07 ± 0.34 cd	50.41 ± 0.06fg	50.38 ± 0.06fg
	3	50.93 ± 0.30 de	50.97 ± 0.29cde	50.06 ± 0.05gh	50.19 ± 0.01gh
	5	50.65 ± 0.04ef	50.70 ± 0.12ef	49.88 ± 0.09 h	50.01 ± 0.07 h
PUFA/SFA	0	2.324 ± 0.03 b	2.391 ± 0.04 a	2.324 ± 0.03 b	2.391 ± 0.04 a
	1	2.286 ± 0.05bc	2.261 ± 0.02 c	2.124 ± 0.05 g	2.123 ± 0.08 g
	3	2.245 ± 0.07 cd	2.211 ± 0.03 de	2.062 ± 0.03 hi	2.072 ± 0.07 h
	5	2.166 ± 0.02 f	2.176 ± 0.01ef	2.022 ± 0.02i	2.032 ± 0.05 hi
Se Index	0	4.012 ± 0.04 a	4.020 ± 0.03 a	4.012 ± 0.04 a	4.020 ± 0.03 a
	1	3.903 ± 0.03 b	3.905 ± 0.08 b	3.672 ± 0.03efg	3.703 ± 0.01 def
	3	3.870 ± 0.02 b	3.835 ± 0.09bc	3.571 ± 0.01 hi	3.620 ± 0.07fgh
	5	3.750 ± 0.08cde	3.771 ± 0.05 cd	3.522 ± 0.08i	3.599 ± 0.09ghi

According to the results of Table 2, increasing the power and time of microwave pretreatment causes an increase in two indices (SFA) and (Se Index) and a decrease in the indices of (MUFA), (PUFA) and (PUFA/SFA) of tomato seed oil. The extracted fennel was pressed and mixed with two methods (p<0.05). Suri et al. (2022) also reported that the pretreatment of black seeds with high power and for a longer time caused an increase in the SFA index and a decrease in the PUFA index of the extracted oil, and they also stated that the effect Compared to the power of microwave pretreatment of seeds, the time was more on changing the fatty acid indices of extracted oil, which was consistent with the results of this research [10]. Other similar results regarding the increase of saturated fatty acids and the decrease of polyunsaturated fatty acids in the oil extracted from oil seeds pretreated with microwaves (buckthorn seed [26], apricot kernel) [27] and seed Flax [28] has been reported. One of the possible reasons for the increase in the amount of saturated fatty acids in tomato seed oil with increasing the power intensity or time of microwave pretreatment is the increase in the breakdown of polyunsaturated fatty acids in the extracted oil, which was reported in the report of Suri et al. (2020) regarding Flax seeds are also mentioned [28]. The decrease of two indices (Se Index) and (PUFA/SFA) in Table 2 confirms the increase of oxidative stability of seed-tomato-rice oil by increasing the power and time of microwave pretreatment of seeds before extraction (p<0.05). The highest oxidative stability in tomato seed oil based on the index (Se Index) after 5 minutes pre-treatment of seeds with a microwave power of 200 watts and then extraction with a press and the lowest oxidative stability of tomato seed oil after 5 minutes pre-treatment Microwave with a power of 500 watts and extraction with Soxhlet was measured (p<0.05).

3-3- Peroxide value

Peroxide number measurement is related to the primary oxidation or the beginning of the oil oxidation process and therefore plays an important role in the quality evaluation of edible oils. This index indicates the intensity of pungency and oxidative spoilage of edible oil [29]. An increase in oil peroxide number indicates that the oil enters the secondary oxidation stage, which will be associated with bad taste and decrease in customer satisfaction [18]. The average number of peroxides in the oil of seeds without microwave pretreatment (control sample) and extracted by pressing and Soxhlet methods was equal to 0.58 and 2.2 milliequivalents of oxygen per kilogram of oil, respectively (**Fig. 3**).

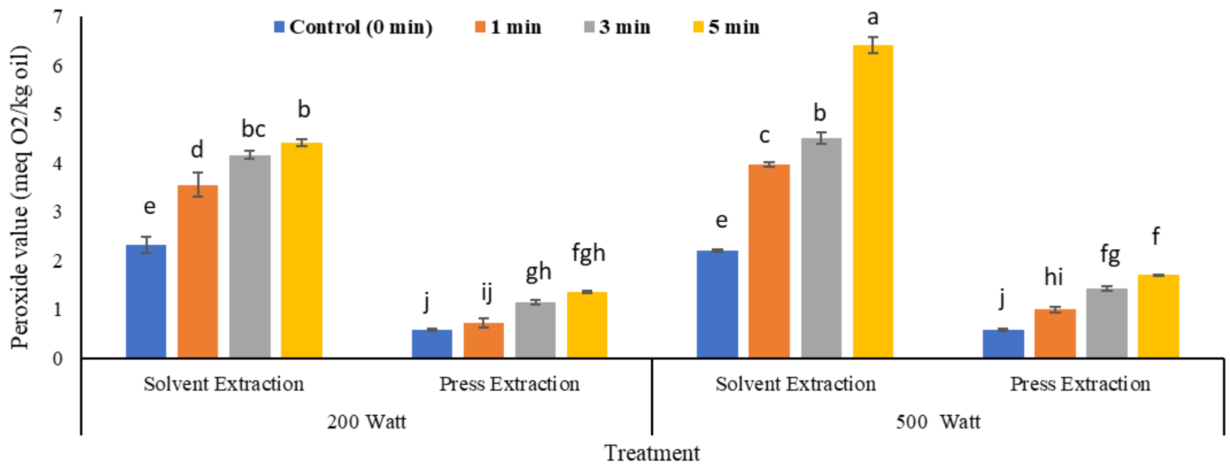


Fig. 3. Effect of extraction method, microwave pretreatment time and power on peroxide value of tomato seed oil. Different letters indicate statistically significant differences (p<0.05)

Shao et al. (2015) [29], Zorro et al. (2014) [30] and Aksvilu-Uzbek et al. (2020) [24] also found the peroxide value for tomato seed oil to be 0.63, 2.01 and They reported 2.2 milliequivalents of oxygen per kilogram of oil. According to **Fig. 3**, the peroxide value of the oil extracted from tomato seeds using the press method (0.58 milliequivalents of oxygen per kilogram of oil) compared to the Soxhlet method (2.32 milliequivalents of oxygen per kilogram of oil) was significantly lower (p<0.05). Singh and Kumar (2023) stated that the reason for the increase in the peroxide number of pumpkin seed oil extracted by Soxhlet compared to the press method is the increase in the extraction temperature and the presence and absorption of oxygen during the process of extracting pumpkin seed oil by the Soxhlet method [31]. Gerji et al. (2015) reported that the peroxide number of oils extracted by the solvent method increases due to the increase in the extraction time compared to other methods and therefore the provision of a suitable opportunity for the oxidation of unsaturated fatty acids [32]. Increasing the power (from 200 to 500 watts) and time (up to 5 minutes) of microwave pretreatment of tomato seeds in both Soxhlet and press extraction methods significantly increased the peroxide value of the extracted oil ($p < 0.05$). The highest amount of peroxide (41.6 milliequivalents of oxygen per kilogram of oil) was measured in the seed oil pretreated with microwave for 5 minutes and with a power of 500 watts during extraction by Soxhlet method. The lowest number of peroxide (0.58 milliequivalent of oxygen per kilogram of oil) was related to the oil extracted by pressing method without microwave pretreatment ($p<0.05$). According to Iranian national standards numbered 13392 and 9131, the permissible amount of peroxide value of unrefined and refined crude oils is 10 and 5 milliequivalents of oxygen per kilogram of oil, respectively [33, 34]. As can be seen in Figure 3, the amount of oil peroxide extracted from tomato seeds without applying microwave pretreatment with both Soxhlet and press methods and even in seeds pretreated with microwaves within 5 minutes and with the power of 500 watts is within the permissible consumption range in terms of peroxide number. Sundar et al. (2023) reported that increasing the power and time of microwave pretreatment of chia seeds increased the peroxide number of the extracted oil due to the intensification of oxidative decomposition and hydrolysis of triglycerides, which was consistent with the results of this study [35]. Boyapati et al. (2023) stated that the microwave pretreatment of dragon oil seeds at very high power or during long periods of time due to the decomposition and thermal evaporation of the extracted oil caused a fluctuating change in the peroxide level of the samples [36].

3-4- Acid value

Acid number is a measure to measure the freshness or hydrolysis or sometimes oxidation of edible oils [29] The increase in acid number is usually associated with the hydrolysis of triglycerides and the release of fatty acids in the oil environment [18]. The average acid number in the oil of seeds without microwave pretreatment (control sample) and extracted by pressing and Soxhlet methods was equal to 0.1 and 0.14 mg of potassium hydroxide per gram of oil, respectively (**Fig. 4.**).

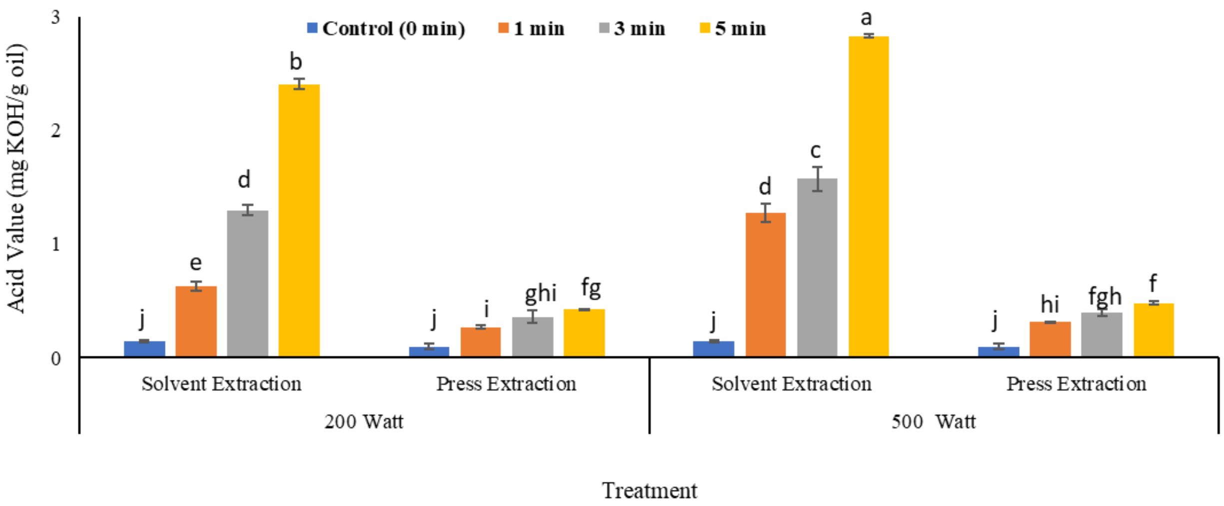


Fig. 4. Effect of extraction method, microwave pretreatment time and power on acid value of tomato seed oil. Different letters indicate statistically significant differences ($p<0.05$)

Shao et al. (2015) [29], Zorro et al. (2014) [30] and Aksvilo-Uzbek et al. (2020) [24] also found the acid value for tomato seed oil to be 0.22, 0.73, and 46 They reported 0.0 mg of potassium hydroxide per gram of oil. According to Figure 4, there is a significant difference in the acid value of the oil extracted from tomato seeds using the pressing method (0.1 mg of potassium hydroxide per gram of oil) compared to the Soxhlet method (0.14 mg of potassium hydroxide). per gram of oil) was not observed. Singh and Kumar (2023) comparing the acid number of the oil extracted from pumpkin seeds with two methods of pressing (1.08 mg of potassium hydroxide per gram of oil) and Soxhlet (1.35 mg of potassium hydroxide per gram of oil) They reported that the oil extraction method with Soxhlet increased the hydrolysis of triglycerides and, as a result, increased the acid number of the extracted oil, which was consistent with the results of this study [31]. Increasing the power (from 200 to 500 watts) and time (up to 5 minutes) of microwave pretreatment of seeds in both Soxhlet and press extraction methods significantly increased the acid value of the extracted oil ($p<0.05$). The highest acid value (41.2 mg of potassium hydroxide per gram of oil) was measured in the oil of seeds pre-treated with microwave for 5 minutes and with a power of 500 watts during extraction by Soxhlet method. The lowest amount of peroxide (0.1 mg of potassium hydroxide per gram of oil) was related to the oil extracted by pressing method without microwave pretreatment ($p<0.05$). According to the national standards of Iran numbered 13392 and 9131, the permissible acid number of unrefined and refined crude oils is 3 and 0.2 mg of potassium hydroxide per gram of oil, respectively [33, 34]. Therefore, the acid value of the oil extracted from tomato seeds without pretreatment and with both Soxhlet and press methods and even in the seeds pretreated for 5 minutes with microwaves with a power of 500 watts, in terms of acid value in It was within the permissible limit of consumption. Karar et al. (2020) reported that increasing the power and time of pretreatment of guaran seeds with microwaves increased the acid number of the extracted oil by accelerating the oxidation and hydrolysis reactions due to the increase in the internal heat of the exposed seeds [1]. Gerji et al. (2015) stated that the reason for the increase in the acid number of the oils extracted by the solvent method compared to other methods is the increase in the extraction time in this method and therefore the provision of a suitable opportunity for the oxidation of unsaturated fatty acids [32]. An increase in the acid value of the extracted oil of chia seeds with increasing the power and time of microwave pretreatment of the seeds has been reported in the researches of Sundar et al. (2023) [35] and Azkan et al. (2019) [37] have also been reported, which is consistent with the results of this research.

4-Conclusion

Tomato seed oil is known as an edible oil with very high nutritional quality. The aim of this research was to investigate the effect of microwave pretreatment and extraction method on fatty acid composition and some chemical characteristics of tomato seed oil. Linoleic (51.73%), oleic (25.85%) and palmitic (12.84%) fatty acids were determined as the most fatty acids in tomato seed oil ($p<0.05$). The oil extracted by pressing and Soxhlet methods had an average peroxide number of 0.58 and 2.2 milliequivalents of oxygen per kilogram of oil, and an acid number of 0.1 and 0.14 milligrams of potassium hydroxide per gram of oil, respectively. Increasing the power (500 watts) and time (5 minutes) of microwave pre-treatment in both Soxhlet and press extraction methods increases the peroxide number, acid number and the amounts of monounsaturated fatty acids and polyunsaturated fatty acids and the oxidative stability index of the oil. decreased ($p<0.05$). The quality of tomato seed oil extracted by two methods of pressing and Soxhlet and after pre-treatment of the seeds with microwaves (power of 500 watts for 5 minutes) in terms of peroxide value and acidity was in the permissible range of standard consumption. This research showed that the tomato seed oil extracted by pressing compared to the oil extracted by soxhlet had more favorable oxidative stability and lower peroxide number. Also, the use of microwave pretreatment was effective in increasing the oxidative stability of extracted oil.

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تأثیر پیش‌تیمار مایکروویو و روش استخراج بر ترکیب اسیدهای چرب و برخی ویژگی‌های شیمیایی روغن دانه گوجه فرنگی

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چکیده

شناسایی و استحصال منابع روغنی جدید از ضایعات مواد غذایی نظیر دانه گوجه‌فرنگی و بهینه‌سازی روش استخراج آن جهش بزرگی در تامین روغن خوراکی است. هدف از این پژوهش بررسی اثر پیش‌تیمار مایکروویو و روش استخراج بر ترکیب اسیدهای چرب و برخی ویژگی‌های شیمیایی روغن دانه گوجه‌فرنگی بود. پیش‌تیمار دانه‌ها با امواج مایکرویو (۰، ۲۰۰ و ۵۰۰ وات) طی زمان‌های مختلف (۰، ۱، ۳ و ۵ دقیقه) انجام و روغن دانه‌ها با روش سوکسله و پرس استخراج گردید. ترکیب اسیدهای چرب روغن با دستگاه کروماتوگرافی گازی تعیین گردید. ویژگی‌های اسیدهای چرب با استفاده از شاخص اسیدهای چرب اشباع (SFA)، اسیدهای چرب تک غیراشباع (MUFA)، اسیدهای چرب چند غیراشباع (PUFA) و پایداری اکسیداتیو (Se Index) ارزیابی گردید. تجزیه و تحلیل داده‌ها بر اساس آزمایش فاکتوریل در قالب طرح آماری کاملاً تصادفی در سه تکرار انجام شد. اسیدهای چرب لینولئیک (۵۱/۷۳ درصد)، اولئیک (۲۵/۸۵ درصد) و پالمیتیک (۱۲/۸۴ درصد) به عنوان بیشترین اسیدهای چرب روغن دانه گوجه‌فرنگی تعیین شدند (p<۰/۰۵). روغن استخراج شده با دو روش پرس و سوکسله به ترتیب دارای متوسط عدد پراکسید ۰/۵۸ و ۲/۲ میلی‌اکی والان اکسیژن در هر کیلوگرم روغن و عدد اسیدی ۰/۱ و ۰/۱۴ میلی‌گرم هیدروکسید پتاسیم در هرگرم روغن بود. افزایش توان (۵۰۰ وات) و زمان (۵ دقیقه) پیش‌تیمار دانه ها با مایکروویو در هر دو روش استخراج با سوکسله و پرس، عدد پراکسید، عدد اسیدی و مقادیر اسیدهای چرب تک غیراشباع را افزایش و اسیدهای چرب چند غیراشباع و شاخص پایداری اکسیداتیو روغن استحصالی را کاهش داد (p<۰/۰۵). کیفیت روغن دانه گوجه‌فرنگی بدون پیش تیمار و استخراج شده با دو روش پرس وسوکسله و پس از پیش‌تیمار دانه‌ها با امواج مایکروویو (توان ۵۰۰ وات طی ۵ دقیقه) از نظر عدد پراکسید و اسیدی در محدوده مصرف مجاز استاندارد قرار داشت.