Egyptian Journal of Food Science
http://ejfs.journals.ekb.eg/

Influence of Roasting and Microwave Heating on Nutritional Value and Bioactive Compounds of Siwi Date Seed

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THE aim of this study was to investigate the influence of roasting by hot air (HA) and microwave (MIW) heating on the proximate chemical composition, fatty acid and amino acid constituents, total phenolic content, polyphenol profile, and antioxidant activity (IC_{50}%) of Siwi date seeds. There are significant variances ($P< 0.05$) were observed among unroasted and roasted Siwi date seed samples, roasting process slightly affected on moisture and dry matter contents of dried date seed, while crude protein, lipids, fibre and ash contents were increased. Oil content of the roasted and unroasted date seed samples ranged between 11.87 and 14.81%. GC-MS analysis of fatty acids showed that monounsaturated fatty acids; oleic acid was the most abundant fatty acids about 42.67% in unroasted date seed, followed by saturated fatty acids such as lauric acid, palmitic acid, and myristic acid, high oleic and lauric acid. Roasting process resulted in a decreasing of unsaturated fatty acids percentage and an increasing of saturated fatty percentage. Glutamic acid (Glu) was the most predominant amino acid, its content in unroasted sample was about 21.00 mg/g, increased to 28.34 mg/ g after MIW heating and decreased to 17.46 mg/g after HA roasting. The major phenolics compounds of unroasted date seed extracts were catechin, chlorogenic, syringic and gallic acid, its content was 172.98, 100.90, 89.35 and 63.21µg/g, respectively. Significant differences were observed among phenolic compounds of date seed extracts after roasting process where some compounds were increased others decreased after roasting in MIW oven. The L* and b*values of date seed powder and oils were significantly decreased after roasting, however a* value was significantly increased. Siwi date seed has phenolic compounds are thought to have powerful radical scavengers and might be regarded an excellent source of natural antioxidants for medicinal, functional food.The dark hue of the roasted seed hascolorant capabilities.

Keywords: Date seeds, Hot air roasting, Microwave heating, Phenolic compounds, Antioxidants activity, Amino acid compounds and Fatty acid compounds

Introduction

Date palm *(Phoenix dactylifera* L.) is an important food and agricultural crop in most Middle Eastern nations, as well as Egypt in North Africa, and its fruit, known as dates, are consumed by millions of people. According to the statistics of Food and Agriculture Organization (FAO), the production of dates globally is growing. Egypt is the biggest producer, followed by Saudi Arabia, Iran, Algeria, and Iraq (Flowers et al., 2019). In the two past decades, Egypt's annual date production has grown from 1.38 million metric tons to 1.733 million metric tons (FAOSTAT, 2024). As well as, the worldwide production of dates rose from 7.53

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Received :22/8/2024; Accepted :3/10/2024
DOI: 10.21608/EJFS.2024.223982.1190

million metric tons to 9.75 million tons. This rise in production and consumption is exactly related to the date when fruit waste occurs. Date seed (also known as pits, kernels, stones, or pips) are part of the integral date fruit, which is formed of a fleshy pericarp and seed that contributes between 10% and 15% of the mature date fruit's weight, depending on the variety and grade quality (Nehdi et al., 2010). Thus, about 0.975 to 1.643 million tons of date seeds are produced yearly (FAOSTAT, 2024). Considering that it is also recognized date seeds are waste products of date fruit industry (date syrup, date confectionery, pitted dates) which are normally being discarded or used for animal feed.

The chemical composition of date seeds were drastically varied based on varieties and maturity stage of date, presented high content of fibre (75-80%), fats (10-13%) and protein (5-6%) (Al-Farsi and Lee, 2008; Al-Farsi et al., 2007; Besbes et al., 2004). Date seeds are also known to contain significant bioactive components, therefore using this by-product is particularly attractive for the date industry. It is rich in phenolic compounds (21.0-62.0 mg GAE/100 g of date seeds) and antioxidants (580-929 mL Trolox equivalents/g) (Al-Farsi et al., 2007; Suresh et al., 2013). These bioactive molecules, polyphenols, are health-promoting substances, such as antibacterial, antioxidant, anti-inflationary, and anticancer activity, and have protective effects against the onset or delay of cardiovascular alterations, inflammation, and aging. They frequently provide valuable biological activities to plants and animals to regulate their functions and homeostasis as well as preventing diseases (Lancon et al., 2013; Al-Farsi and Lee, 2008).

Date seeds have a pleasant odor when roasted that is similar to coffee, and they are rich source of dietary fiber, phytosterols, and polyphenols. However, despite containing ten times more polyphenols than the fruit of the same branches, they are considered waste (Babiker et al., 2020). To improve the functional and healthful qualities of food items, concentrated forms of the extracted phenolic components might be added. Efforts should be made to use pulp and date seeds economically for the benefit of world food security.

Date seeds contain healthful oils, rich of oleic acids which can be utilized to produce therapeutic compounds (Al-Shahib and Marshall, 2003). Date seed's nutritional value is dependent on its dietary fiber content, making it valuable to produce fibre-based food items such as bread, cookies, and cakes, as well as dietary additives (Almana and Mahmud, 1994; Larrauri et al., 1995). Mrabet et al. (2020) established that eating a diet rich in unsaturated fatty acids lowers the chance of developing inflammatory and cardiovascular disorders. In addition to being healthier than trans-fatty acids and possessing antibacterial properties that inhibit the growth of microorganisms and the production of toxins, lauric acid has been demonstrated to avert the development of prostatic hyperplasia Ramadan et al., 2005; Babu et al., 2009; De Roos et al., 2001; Desbois, 2012).

The roasting process is recognized as the most essential step in the manufacturing of many types of foods and beverages. It has a variety of benefits, including enhancing post-operation performance and enhancing the aroma and flavor of food and drinks. It may also deactivate enzymes that can speed up nutrient loss, destroy undesired bacteria and food pollutants, and extend the product's shelf life. The most important factors of the roasting process are temperature and time (Fikry et al.,2019).

Roasting conditions must be optimized to provide a good product in terms of color, taste, and odor caused by changes in the chemical structure, which are indications of roasting degree (Pittia et al., 2001). During the roasting process, foods' physicochemical properties and sensory attributes undergo considerable changes. Several research have revealed that roasting processing maintains the health benefit effects by boosting antioxidant activity of samples, as well as investigated how roasting settings alter the quality of diverse food products. Furthermore, Areeb et al. (2023) studied the influence of roasting temperatures and times on antioxidants, phenolic compounds, browning index, and several quality and sensory aspects of various beverages. Accordingly; this research were designed to evaluate the effect of two different roasting processs on the proximate chemical and nutrient compositions of Siwi date seeds (*Phoenix dactylifera* L.) varieties, including (moisture, ash, crude fiber, protein and fat) content, the composition of fatty acids and amino acids was also studied the components of phenolic content and the antioxidant activities as they were impacted by roasting process also examined.

Materials and Methods

Date seed material

Siwi date seeds were obtained from Kharja Date Packing Factory during the 2022 season. The

seeds were soaked in water, cleaned to remove any remaining date flesh, and then air-dried for one week. The untreated samples were dried at 50℃. Date seeds were ground in a heavy-duty grinder to pass 1-2 mm screens, and then stored at -20℃ until analysis.

Methods

Roasting process

Rosting of date seed powder by hot air oven

The untreated date seeds were roasted for 12 to 15 min at 200± ١℃ in a hot air oven, then sealed in polyethylene bags and stored in a deep freezer at -20℃ until they were examined.

Roasting by date seed powder by microwave oven

A domestic-size microwave oven (Model NGM-34M2, JAC Co., A.R.E) at 2450 MHz with a power output of 1000 W was utilized. The seed powder was distributed in a proparate layer in a Pyrex petri dish (12 cm diameter) and heated at a medium power setting before being roasted for 120 seconds at 1000 W after covering the dish based on testing findings. Microwave (MIW) roasting was extensively adjusted to produce seed powder without burning. After microwave roasting, the seeds were allowed to cool to normal room temperature. The roasted seed powder was then kept in polyethylene bags in a deep freezer at -20℃ for chemical analysis.

Proximate chemical composition

The moisture contents of date seed samples were determined by using hot air oven about 2 g of sample at 105°C to constant weight according to (AOAC, 2005). Using the Soxhlet method, the crude lipid content was determined by extracting a 3 g date seed sample with petroleum ether. Three grams of the sample were burned in an ash furnace at 600°C till the (AOAC, 2005) white, this served as the ash determination. The (AOAC, 2005) method, which is based on the solubilization of non-cellulosic components by sulfuric acid and hydroxide solutions, was used to evaluate crude fiber content. The Kjeldahl technique was used to calculate the crude protein contents (AOAC, 2005). To determine the protein contents, the nitrogen quantity was multiplied by 6.25 (the protein conversion factor).

Date seed samples energy values were calculated following the method described by Crisan and Sands (1978). Energy value (kcal/100 g) = (2.62 × % protein× 8.37) +) % fat)+ (4.2 × % carbohydrate). The whole number of the following contents was subtracted from 100 to determine the amount of available carbohydrates: {moisture, crude protein, fat, fiber, and ash}.

Colour attributes

Colour attributes of unroasted (control) and roasted date seed and extracted oils samples were analysed by using a colour meter (Chroma meter CR 400, Konica Minolta, Osaka-Japan). CIELab coordinates (L^*, a^*, and b^* were registered directly for each sample (Pagliarini & Rastelli, 1994). The brightness ranged from 0 (black) to 100 (white) for the L* value, −100 (green) to +100 (red) for a*, and −100 (blue) to +100 (yellow) for b*. Additionally, ΔE was measured. The tristimulus values of the L*, a*, and b* readings were calibrated against a standard white plate. (Y=85.6; x=0.3149; y=0.3213) (Kahyaoglu and Kaya, 2006).

Total phenolic Compounds (TPC):

Total Phenolic Compounds (TPC) was determined using the modified method of Yoo et al., (2004), by using Folin-Ciocalteu (FC) reagent. The sample extract (2.5 ml) was combined with Folin-Ciocalteu reagent (1:10) and sodium carbonate (2 ml, 20%) using a vortex mixer. The sample was held at room temperature for two hours and incubated in the dark, then diluted and measured at 725 nm. The standard curve was created using Gallic acid. TPC was calculated as the mg equivalent of gallic acid (GAE) standard. Gallic acid standards were developed at values ranging from 0.05 to 0.4 mg/mL.

DPPH radical-scavenging assayand IC50:

The DPPH free radical scavenging activity of the date seed sample extracts were determined using the method of Bondet et al. (1997). Using this procedure, a 0.1 mM DPPH solution was produced in methanol and allowed to remain at 4ºC in complete darkness until analysis. In short, 3.5 ml of DPHH solution was combined with 0.5 ml of diluted methanolic extracts or ascorbic acid and BHT at the same level. After being stored in the dark for 30 minutes, the sample absorbance was measured at λ = 515 nm. Radical scavenging activity (%) was calculated as follow:

$$\text{Radical scavenging activity (\%)} = \frac{Ab_{515\ \text{control nm}} - Ab_{515\ \text{sample nm}}}{Ab_{515\ \text{control nm}}} \times 100$$

The IC_{50} value, which was determined by plotting the scavenging activity against the sample concentrations, was the concentration of an antioxidant needed to quench 50 % of the initial DPPH radicals.

Extraction of oil from date seed samples

Using the Soxhlet apparatus, the oil of both roasted and unroasted date seeds was extracted in accordance with the AOCS Ba 3-38 (1998) and the American Oil and Chemical Society Official Method (1998). A dark flask containing 100g of date seed was homogenized using 500 mL of n-hexane. Following four hours of vigorous mixing at 180 revolutions per minute in a shaker, the mixture was centrifuged at 1,000 g for fifteen minutes at room temperature (20℃). Whatman No. ۱ filter paper was used to filter the supernatant. The lipids were weighed and kept at 4 °C in a freezer until analysis (Cheikh Rouhou et al., 2006).

Fatty acid GC fractions of date seed oil

Fatty acid methyl esters (FAME) must be prepared in order to increase volatility and decrease peak tailing in order to evaluate the fatty acids in date seed samples. This allows for accurate and repeatable GC analysis later on (Cert et al., 2000). Gas chromatographs (GCs) with flame-ionization detectors and capillary columns (30 m - 320 lm i.d., 0.25 lm film thickness) were used to measure it. Helium was used as the carrier gas. The FID detector had air flows of 300 ml/min and helium fluxes of 45 ml/min, respectively. At 0 minutes, the oven's temperature was 100 °C. It was then raised to 200 °C at a rate of 6 °C per minute and held there for 50 minutes. The injector and detector were kept at respective temperatures of 260ºC and 280ºC.Using standard fatty acid methyl esters (FAMEs) and procedures for producing the FAME from fats and oils (ES, ISO 5508 (1990), the peaks were identified based on their retention times (RT).

Iodine value

The iodine value (IV) of sample was directly evaluated from fatty acid profile by using ratios (calculated factors) between I_2 (iodine) and any of the bound fatty acids (Ham et al., 1998).

Saponification value

Saponification value (SV) of oil can be estimated from the fatty acid methyl ester compositions of oil using formulae Kalayasiri et al. (1996) SV= (Σ (560×D×Ai))/ M Wi) Where (Ai) is the percentage of each fatty acid, (D) is the number of double bonds, and (Mwi) is each component's molecular mass.

The Cox value

Assessing Oxidizability, the key to ensuring oil stability and shelf life, it was calculated based on the following relation as described byFatemi & Hammond (1980):

Cox Value = [1(18:1%) + 10.3 (18:2%) + 21.6 (18:3%)]/100

Amino acids compounds of date seed

Amino acids were detected using Automatic Amino Acid Analyzer (AAA 400INGOS Ltd). Total amino acids: acid hydrolysis was performed according to the method of Csomos and Simon-Sarkadi (2002).

Phenolic compounds fractionation of date seed

The individual phenolics in date seed samples were evaluated using a Shimadzu HPLC system equipped with an Inertsil ODS-3 (5 µm; 4.6 × 250 mm) column linked to a PDA detector. Acetonitrile and 0.05% acetic acid were combined to create the mobile phases, which had a 1 ml/min flow rate set at 30°C. A total of 60 min was spent on each sample, with a 20 µl injected volume yielding peaks at 280 and 330 nm. Additionally, standard solutions for the following phenolic compounds were made by (Gallic, catechin, Chlorogenic acid, Coffeic acid,Methyl gallate, syringic acid, Ellagic acid, Vanillic acid, Ferulic acid, *p*-coumaric acid, Rutin, quercetin, Naringenin, Apigenin, Hesperetin, Pyro catechol, Daidzein, Cinnamic acid and Kaempferol). These solutions were then injected into an HPLC for comparison with the extract samples peaks and retention times. Individual component concentrations were given as mg per 100 g date seed sample. HPLC was used to isolate and quantify phenolic chemicals in accordance with Goupy et al. (1999).

Statistical analysis

The results were presented as mean ± SD (n = 3). All date seed samples were analyzed for variance, with significant differences at $P < 0.05$. Multiple comparisons were then performed using LSDSteel et al. (1997).

Results and Discussion

Chemical composition of unroasted and roasted date seed samples:

Proximate chemical composition (moisture, ash, crude protein, lipid and fiber), available carbohydrate, energy value, in addition to total phenols and IC_{50} were evaluated in unroasted and roasted date seed samples, the obtained results were illustrated in Table 1. Roasting process slightly affected on moisture and dry matter contents of dried date seed. However; the contents of crude protein, lipids, fiber and ash were increased, crude protein was considerably increased from 8.68% in unroasted date seeds to 13.06% and 15.46% in HA and MIW roasted

samples, respectively while oil content increased from 11.87% in unroasted date seeds to 12.45% and 14.81% in HA and MIW roasted samples, respectively. As well as ash and crude fiber were slightly increased, ash content was changed from 1.68% in unroasted date seeds to1.759% and 1.757% in HA and MIW roasted samples; respectively, crude fiber content was changed from 10.79% in unroasted date seeds to12.53%, and 11.66% in HA and MIW roasted samples, respectively. The crude fat content of two kinds produced in the Tunisian region (*Deglet Nour* and *Allig*), was evaluated and determined to be 12.67% and 10.19% fat, respectively. Conversely, Reddy et al. (2017) found that the process of roasting dates enhances the yield of lipids because it increases the surface area of the seed and creates a larger surface-to-solvent contact. As a result, the samples oil yield rises with the amount of roasting that is applied to the seed.

As indicated in Table 1, the available carbohydrate content was estimated by deducting the total of the following contents: moisture, crude protein, fat, fiber, and ash from 100. The average carbohydrate content was highest in unroasted date seed (66.95%) compared to HA roasted seed (60.19%). Even though MIW Roasted Seed recorded a second value of 56.30%, these findings were lower than those reported by Ibourki et al. (2021) they studied the available carbohydrate of seven date seed cultivars and found significant differences ($P < 0.05$) among the total carbohydrate contents of the samples, that ranged between76.69 to 90.18%, There were indicated 54.9 and 80.6 g/100 g for fresh and dried dates, respectively. These results agree with that found by Besbes et al. (2004).

As stated in Table 1, the energy values of the analyzed date seeds ranged from 403.28 to 391.22 kcal/100 g DW. These findings agreed with those published by Al juhaimi et al. (2012) who realized that the analyzed seven date seeds' energy values ranged from 434 kcal/100 g to 479.5 kcal/100 g. However, these findings differed with those of Ahfaiter et al. (2018). They reported that the seven date seeds that were studied had energy levels that ranged from 326.14 to 347.02 kcal/100g. The technique used to calculate the energy value could be the cause of the discrepancy. That indicates that in addition to the energy produced by protein, fat, and digestible carbohydrates, the calorimeter also measured the raw energy, which includes the energy created by fibers.

Table 1 shows significant differences ($P < 0.05$) in total phenolic contents and antioxidant activity (IC_{50}) between roasted and unroasted date seeds. The collected data demonstrated that the maximum concentration of phenolic component (18869.32 mg GAE/100 g) was found in date seed roasted by MIW oven, followed by (17237.02 mg GAE/100 g) for date seed roasted by HA oven, and the lowest value recorded by unroasted date seed (16283.4 mg GAE/100 g). This increase in total phenolic content could be due to the denaturation of the proteins associated with these phenolic chemicals, making them easier to remove (Aksoz et al., 2020). Furthermore, roasting enables the release of polyphenols incorporated to various cellular components, resulting in an increase

TABLE 1. Effect of roasting processe on chemical composition, total phenolic content, and antioxidant activity of the Siwi date seed.

Date seed Constituents	Unroasted	Roasted		LSD
		(HA) oven	(MIW) oven	
Moisture (%)	7.95±0.07	8.27±0.015	7.46±0.15	0.195
Dry matter (%)	92.05±0.07	91.73±0.015	92.54±0.15	0.195
Crude protein	8.68±0.27	13.06±0.55	15.46±0.09	0.7173
Crude lipids	11.87±0.06	12.45±0.31	14.81±0.75	0.9411
Ash	1.68±0.01	1.759±0.08	1.757±0.05	0.1061
Crude fiber	10.79±0.05	12.53±0.18	11.66±0.05	0.2309
Available Carbohydrate Energy values	66.95±0.25	60.19±0.89	56.30±0.80	1.4161
(Kcal \ 100g)	403.28	391.22	400.92	___
Total phenols (mg GAE \100g)	16283.4± 47	17237.02±95	18869.32±66	273.07
IC50 (g/L)	1.94±0.041	1.59±0.012	1.84±0.033	0.06610

HA: Hot air oven; MIW: Microwave oven

in the amount of polyphenol. Results of total phenol concentration were higher than those reported by Babiker et al. (2020) This variance in total phenol in date seed could be due to various factors, including variety, maturity, geographical origin, growth status, fertilizer, season, illnesses, soil type, processing, extraction, and storage conditions (Alem et al., 2017; Al Harthi et al., 2015).

The antioxidant factor IC_{50} (half maximal inhibitory) is the concentration of extract (g/L) required to scavenge 50% of the DPPH radical, and is computed from their concentration-response curves. Data in Table 1 presented antioxidant activity(IC_{50}) which studied the effects of MIW roasting and HA oven roasting on antioxidant activity of date seed. Results indicated that the (IC_{50}) values after MIW roasting process and after the HA oven roasting process were significantly increased compare with unroasted samples, the maximum antioxidant activity was 1.59 (g/L) after HA oven roasted process,this value slightly decreased after MIW roasted process was 1.84 (g/L) compared with unroasted date seed sample it was 1.94 (g/L). These findings are higher than those published by Bouhlali et al. (2017), who investigated the antioxidant activity of three date seed cultivars and discovered that IC_{50} values ranged from 0.166 to 0.112 (g/L).

Color characteristics of unroasted and roasted date seeds and oils

Table 2 illustrates the data color L*, a*, and b* for roasted and unroasted date seed samples and their derived oils. Color characteristics of various samples showed significant differences ($p < 0.05$). After being roasted in a MIW oven or in a HA oven, the L* and b*values of date seed powder and the oils that were extracted from it were considerably reduced. However, following roasting, the derived oils from date seeds and their powder had a much higher a* value. When comparing the L* values of the roasted and unroasted samples, it was found that the roasted date seed by MIW oven produced a value of 53.90, while the unroasted date seed produced a* value of 58.79. While recorded L* value for date seed oil was decreased from 39.91 in unroasted date seed oil to 33.06 and 27.09 in oil extracted samples from roasted date seed by HA oven or by MIW oven, respectively. The a* value for oil sample extracted from date seed roasted by HA oven had the highest value (13.18), the oil sample extracted from unroasted date seed powder had the lowest value (4.59). The b* was varied from 11.59 for unroasted date seed to 11.00 and 10.69 in roasted date seed by HA oven or by MIW oven, respectively, and from 20.19 (oils unroasted) to 18.26 and 15.56 in oil extracted samples from roasted date seed by HA oven or by MIW oven, respectively.

Somporn et al. (2011) examined how roasting affected the color and phenolic components of coffee (*Coffea Arabica* L. cv. Catimor) beans. As the temperature of roasting increased along with a* values were increased. The Maillard reaction and sugar caramelization, two non-enzymatic browning processes and phospholipid degradation that may have produced the seed's dark color, may have produced compounds with functional attributes, specific aromas, and antioxidant activity.

TABLE 2. Effects of roasting in HA oven and in MIW oven on color scale of date seed and its extracted oil.

Date seed samples	Color		
	b^*	a^*	L^*
Date seed powder			
Untroasted seed	11.59±2.35	10.67±0.97	58.79±4.86
Roasted in (HA) oven	11.00±3.04	11.19±1.62	46.11±4.97
Roasted in (MIW) oven	10.69±2.41	9.43±1.08	53.90±5.06
Date seed oil			
Untroasted seed oil	20.19±1.26	4.59±0.93	39.91±4.78
Roasted in (HA) seed oil	18.26±5.02	12.53±2.56	33.06±4.45
Roasted in (MIW) seed oil	15.65±3.91	13.18±3.39	27.09±3.52

HA: Hot air oven, MIW: Microwave oven

The formation of browning substances in oil extracted from roasted seed probably due to interaction of unsaturated fatty acids with tocopherol components to produce toco-red compounds similar to that reported in soybean oil, or caused by the passage of maillard reaction products formed during roasting and crossed during extraction process of oil (Megahad 2001; Kim et al., 2002; Taha and Matthäus., 2018). In order to monitor the formation of maillard reaction products in oil as influenced by roasting. Durmaz and Gökmen (2011) examined the hydroxyl methyl furfural (HMF) level and color intensity of Pistacia terebinthus oil. They discovered that these levels increased with longer roasting times.

Fatty acid composition of unroasted and roasted date seed extracted oil samples:

The results of the fatty acids (FA) composition are summarized in Table 3. The roasted and unroasted date seed samples have oil contents ranging from 11.87 to 12.45%. Analysis of fatty acid composition using GC-MS revealed that monounsaturated fatty acid; oleic acids (C18:1 n-9)were the most abundant fatty acids in all roasted and unroasted date seed oil sample and ranged between (41.66-43.42), Lauric acid (C12:0) came next percentages of saturated fatty acids in all roasted and unroasted date seed oils. Then fatty acid followed this order as follows: linoleic acid (C18:2n6c), which made up about (7.36%- 9.03%) of the polyunsaturated fatty acids; stearic acid (C18:0) was found to be the lowest proportion, at (2.96% -3.55%); while, palmitic acid (C16:0), and myristic acid (C14:0), with their percentages being about (10.95% -11.18%), and (10.99% -11.71%), respectively.While linolenic acid (C18:3n3) was found in traces (0.32%) in unroasted date seed and (0.12 %) for HA sample.

After roasting, there were notable variations ($P < 0.05$) in the fatty acid content of date seed oil. Certain compounds showed an increase after roasting in a HA oven, while others showed a decrease after roasting in a MIW oven. Overall, the roasting process resulted in a decrease in the percentage of unsaturated fatty acids and an increase in the percentage of saturated fatty acids. Because of the oil's unsaturated fatty acid breakdown at higher roasting temperatures, there may be a little decrease in this. The decrease in linoleic acid content could be attributed to the deactivation of the omega-6fatty acid desaturase (FAD2-1) enzyme during the roasting process (Taha & Matthäus., 2018). Hassanien et al. (2003) also demonstrated that microwave heating significantly reduced unsaturated fatty acids (UFA) and polyunsaturated fatty acids (PUFA) in oils compared to conventional heating methods while having no effect on saturated fatty acid concentration.

TABLE 3. Effects of HA and MIW roasting on fatty acids composition of date seed extracted oil.

Date seed Faty acids (%)	Unroasted	Roasted		LSD
		HA* Oven	MIW* Oven	
Caprylic acid (C8:0)	0.36 ^{b}	0.37 ^{b}	0.51^{a}	0.0145
Capric acid (C10:0)	0.43^{c}	0.45 ^{b}	0.51 ^{a}	0.0016
Lauric acid (C12:0)	20.16 ^{c}	21.45 ^{b}	22.19 ^{a}	0.0145
Myristic acid (C14:0)	10.99 ^{c}	11.71 ^{a}	11.26 ^{b}	0.131
Palmitic acid (C16:0)	11.18 ^{a}	10.97 ^{b}	10.95 ^{c}	0.0145
Stearic acid (C18:0)	3.55 ^{a}	2.96 ^{b}	3.54 ^{a}	0.114
Oleic acid (C18:1n9c)	42.67 ^{b}	43.42 ^{a}	41.66 ^{c}	0.780
Linoleic acid (C18:2n6c)	9.03 ^{a}	7.36 ^{c}	8.48 ^{b}	0.726
α- Linolenic acid (C18:3n3)	0.32 ^{a}	0.12 ^{b}	nd	0.0118
Arachidic acid (C20:0)	0.68 ^{a}	0.4 ^{b}	0.41 ^{b}	0.025
Gadoleic acid (C20:1)	0.61 ^{a}	0.49 ^{b}	0.48 ^{b}	0.0145
Behenic acid (C22:0)	nd	0.29 ^{a}	nd	-

a, b and cmeans: No significant difference ($p > 0.05$) exists between any two means that are in the same row and have the same superscripts.

*HA: Hot air oven, MIW: Microwave oven; nd: not detected

The oxidative stability of the oils has a negative correlation with the concentrations of linoleic and linolenic acids and a positive correlation with the level of oleic acid (Nederal et al., 2012). Date seed oil has a high level of oxidative stability, similar to olive oil. The largest amount of oleic acid was found in the date seeds that were examined. Given that date seed oil and edible vegetable oil share many qualities, it is safe for ingestion by humans (Niazmand, 2022; Besbes et al., 2004). High oleic acid oils are among the most significant unsaturated fatty acids in human food because of their numerous health benefits, including the ability to lower blood cholesterol. As a result of their high oxidative stability and nutritional significance, their use in food formulations has increased (Mrabet et al., 2020).

There are several parameters that define the quality characteristics of unroasted and roasted as showed in Table 4. The saponification value (SV) is attributed to the nature of the fatty acid which composes up the fat, and is determined by their average molecular weight. The high saponification value indicates that the fatty acids they contained have a lot of carbon atoms. This suggests that some standard oils utilized in the soap and shampoo sectors could substitute date seed oils after hydrogenation (Akintayo and Bayer, 2002; Falade et al., 2008). The saponification value of roasted and unroasted date seeds oil ranges between 240.49, 239.14 and 241.63 mg KOH/g of oil for unroasted and roasted by HA and MIW date seeds oils, respectively.

The average degree of unsaturation of a lipid is indicated by the iodine value (IV), which varied substantially between 72.45, 66.38, and 68.57 g Iodine/100 g for unroasted and roasted date seed oils (HA and MIW), respectively. According to the iodine readings (67.22 - 74.8 g Iodine /100g), this oil is extremely non-drying. These results are in parallel with the results reported by Boukouada and Yousfi (2009) iodine values are between (67.22 g Iodine /100g for Tamdjouhert seeds oil and 74.8 g Iodine /100g for Ghars seeds oil). But (IV) was higher than those reported by Besbes et al., (2004) it was about 45.5 and 44.1*Deglet Nour* and *Allig* seed oil, respectively. Bouhlali et al. (2017) revealed that iodine values were 45.40, 58.02 and 50.34 for *Boufgous, Bousthammi* and *Majhoul* seedoil, respectively.The tested date seed oil's degree of unsaturation varied between 50.62% and 52.63% for the roasted and unroasted MIW dates, respectively. These results are extremely similar to those were reported by (Bouhlali et al., 2017; Al juhaimi et al., 2012; Besbes et al., 2004).The concentration of unsaturated fatty acid (52.63%) in extracted oil from unroasted date seeds is greater than that of saturated fatty acid (47.35%), making it more susceptible to oxidation. Date seed oil that has been roasted in MIW has the highest

TABLE 4. Quality characteristics of unroasted and roasted date seed oil.

Date seed oil		Roasted	
Quality Attributes	Unroasted	Hot Air	Microwave
SV	240.495	239.145	241.634
IV	72.451	66.384	68.573
SFA	47.35	48.6	49.36
UFA	52.63	51.39	50.62
MUFA	43.28	43.91	42.14
PUFA	9.35	7.48	8.48
UFA/ SFA	1.111	1.057	1.0255
PUFA/ SFA	0.197	0.1539	0.1717
Cox Value	1.393	1.218	1.2818

SFA refers to saturated fatty acids, UFA for unsaturated fatty acids, MUFA for monosaturated fatty acids, and PUFA for polysaturated fatty acids.

Cox Value = [1(18:1%) + 10.3(18:2%) + 21.6(18:3%)]./ 100 SV (Saponification Value) = ((560 × Ai)/M Wi) Ai is the proportion of each fatty acid, and M Wi is each component's molecular mass. IV (Iodine value)= (245 × D×Ai) / M Wi. Where Ai is the fraction of each fatty acid, D is the number of double bonds, and M Wi is each component's molecular mass.

percentage of saturated fatty acids (49.36%) and the lowest percentage of unsaturated fatty acids (50.62%). Compared to other vegetable oils, date seed oil had a significantly lower level of unsaturated fatty acid concentration. Usingthree test diets with different UFA/ SFA, PUFA/SFA ratios and P/S ratios1.025, 0.171 and 1.28 for date seed oil roasted in MIW, the study by Bouhlali et al. (2017) demonstrates that this ratio was significantly associated with a higher prandial HDL-C trend (P/S = 0.27). Additionally, as shown by the results of, the high lauric acid content of these date seed oils may drastically decrease the TC/HDL-C ratio when compared to carbohydrate ingestion Micha & Mozaffarian (2010).Based on the amount of unsaturated fatty acids in the oil of both roasted and unroasted date seeds, the cox value is computed and shown in Table 4. A lower value indicates that more stable oil. This value is frequently used as a measure of the oxidation stability of oil (Herchi et al., 2016).

Amino acid composition of unroasted and roasted date seed proteins

The value of protein in the human diet is determined by its amino acid content or composition, especially when it comes to ensuring sufficient consumption of essential amino acids. It was possible to find and identify seventeen different kinds of amino acids. The most common amino acid was glutamic acid (Glu), which is also one of the most abundant non-essential amino acids in nature. Glutamate is present in almost every diet, including meat, veggies, poultry, fish, and their byproducts (Lourenço et al., 2002).The obtained results of the amino acids composition (AAC) are presented in Table 5. The amount of glutamic acid in unroasted date seed was 21.00 mg/g, its content was increased to 28.34 mg/ g after MIW roasting and decreased to 17.46 mg/g after HA roasting. Amino acids came next in descending order are; Arginine (Arg), Aspartic acid (Asp), Proline (Pro), leucine (Leu), Cystine (Cys), Threonine (Thr), Serine (Ser), glycine (Gly), Phenylalanine (Phe), Alanine (Ala), lysine (Lys), valin (Val), Isoleucine (Ilu), Histidine (His), Tyrosine (Tyr), and Methionine (Mth). All date seed samples contained modest concentrations of the essential amino acids (leucine, threonine,

TABLE 5. Effects of HA and MIW roasting on amino acids composition of date seed proteins.

Amino acids	Unroasred (mg/g)	Roasted	
		HA*Oven (mg/g)	MIW** Oven (mg/g)
ASP	8.12^{b}	6.52^{c}	8.57^{a}
GLU	21.00^{ab}	17.46^{b}	28.34^{a}
Serine	4.42^{a}	3.21^{b}	4.25^{a}
Histidine	2.08^{a}	1.02^{b}	1.35^{b}
Glycine	4.00^{a}	3.02^{b}	3.53^{ab}
Threonine	4.59^{a}	2.87^{c}	3.43^{b}
Arginine	8.98^{b}	6.92^{c}	9.11^{a}
Alanine	3.76^{b}	4.68^{ab}	5.87^{a}
Tyrosine	2.06^{a}	1.17^{b}	1.75^{ab}
Cystine	5.78^{a}	0.99^{b}	1.03^{b}
Valine	2.90^{a}	1.93^{b}	2.32^{b}
Methionine	1.30^{a}	0.78^{b}	1.29^{ab}
Phenylalanine	3.94^{a}	3.27^{b}	4.34^{a}
Isoleucine	2.51^{ab}	2.03^{b}	2.81^{a}
Leucine	5.78^{b}	4.96^{c}	6.36^{a}
Lysine	2.90^{b}	2.20^{c}	3.39^{a}
Proline	6.24^{a}	5.42^{b}	5.81^{ab}

a, b and cmeans: No significant difference ($p > 0.05$) exists between any two means that are in the same row and have the same superscripts.

*HA: Hot air oven, MIW: Microwave oven

methionine, valin, isoleucine, and phenylalanine), these findings aligned with those provided by Bouaziz et al.(2008). According to research on the amino acid composition of date palm fruit seeds from the Tunisian *Deglet Nour* and *Allig* varieties, glutamic acid was found to be the most abundant amino acid, ranging from 17.83% to 16.77% for *Deglet Nour* and *Allig*, respectively, and found all other essential amino acids with the exception of tryptophan. Reported that acid hydrolysis could be caused a decreasing in tryptophan and lossing of cysteine. Because date seed proteins have a higher concentration of essential amino acids than standard egg proteins, they have a relatively high biological value (Salim and Ahmed, 1992), and in agreement with those found by Salem and Hegazi (1971) studies on Egyptian date seeds. Red seaweeds' free amino acid fraction was found to contain high levels of aspartic acid, glutamic acid, and alanine that give foods its umami flavor, which suggests that these amino acids could be isolated and utilized as flavor enhancers. These findings demonstrate the potential of seaweeds as a sustainable and alternate source of protein and amino acids for industrial food processing as well as human nutrition (Machado et al., 2020).

Burger and Walters (1973) identified three main types of reactions that cause the nutritional alterations that take place in processed foods. Among these are the following: cross-linkage reactions, or protein-protein interactions; an example of this is the formation of =CH–N= links (instead of normal peptide bonds) that are resistant to enzymatic hydrolysis in the gut; damage to sulphur amino acids by oxidation or desulphydration; and the Maillard reaction, in which amino groups (particularly the e-amino group of lysine) react with aldehyde groups of reducing sugars or carbonyls from oxidized fat, thereby rendering those amino acids metabolically unavailable (Oluwaniyi et al., 2010). The amino acids composition changes depending on the reactions that occurred and their thermal stability. The changes in glutamic acid content, for example, are not as noticeable as those in cysteine and arginine. Because they are involved in Maillard browning reactions, the later amino acids have a tendency to rapidly deplete during roasting (Illy and Viani 2005).

*Phenolic compounds in roasted and unroasted date seed extract***.**

Fruit seed phenolic components, particularly phenolic acids, have been demonstrated to have anti-inflammatory, anti-carcinogenic, antibacterial, antioxidant, and anti-mutagenic properties. They also appear to reduce the risk of cardiovascular disorders (Peterson and Dwyer, 1998). Therefore, it is thought to be crucial to enhance the amount of antioxidants consumed by humans through diet, and one method of doing so is by adding phenolics to food.

A plant's ability to survive depends on its seeds, and the high antioxidant content of those seeds may be related to their high level of protection (Sirisena et al., 2015).The date seed extracts' phenolic components are listed in Table 6. It was found to contain fifteen distinct phenolic compounds, which include Gallic, catechin, chlorogenic acid, coffeic acid,methyl gallate, syringic acid, ellagic acid, vanillic acid, ferulic acid, *p*-coumaric acid, rutin, quercetin, naringenin, apigenin, hesperetin. The major phenolics of date seed extracts were catechin, chlorogenic, syringic and gallic acid, its content was 172.98, 100.90, 89.35 and 63.21(µg/g), respectively. After roasting, phenolic components in date seed extracts showed significant changes ($P < 0.05$), where some compounds were increased after roasting in HA oven, others decreased after roasting in MIW oven, but in general roasting improve its percentage.

The results presented here confirmed the study results of Jrad et al. (2022) who concluded that the most predominant polyphenols in date seed extract were epicatechin and catechin. A flavanol called epicatechin has been shown to have great anti-inflammatory and antioxidant properties, as well as to protect the nervous system and lessen the symptoms of cardiovascular and cerebrovascular illnesses. Habib et al. (2014) discovered that the most prevalent phenolic compounds in date seed samples were protocatechuic, *p*-hydroxybenzoic, and *o*-coumaric acids. Other phenolic acids were also detected in the date seed extract. While Al-Farsi and Lee (2008) revealed that the most numerous phenolic acids were protocatechuic, caffeic, and ferrulic acids, but *o*-coumaric acid was not found. The process of extraction, purification, and roasting, which enhances the release of phenolic acids, could account for the variation. Phenolic content is influenced by several production-specific variables, such as cultivar, fruit age, growing conditions, season, and soil type. Furthermore, the selection of extraction conditions may introduce influence into the final measured results (Al juhaimi et al., 2018).

TABLE 6. Effects of roasting process by HA and MIW oven on phenolic compounds of date seed extracts.

Date seed samples	Unroasted (µg/g)	Roasted		LSD
Phenolic compound		(HA)* (µg/g)	(MIW)** (µg/g)	
Gallic acid	63.21 [b]	130.14 [a]	60.25 [c]	0.0824
Chlorogenic acid	100.90 [c]	264.06 [a]	106.35 [b]	0.0704
Catechin	172.98 [a]	90.31 [c]	149.28 [b]	0.0724
Methyl gallate	23.44 [c]	97.43 [a]	25.89 [b]	0.0733
Coffeic acid	7.63 [b]	17.71 [a]	5.38 [c]	0.0724
Syringic acid	89.35 [a]	49.81 [c]	54.94 [b]	0.0236
Pyro catechol	nd	nd	nd	
Rutin	0.75 [c]	6.83 [a]	0.99 [b]	0.0704
Ellagic acid	4.52 [b]	7.56 [a]	2.57 [c]	0.0724
Coumaric acid	0.25 [b]	0.43 [a]	0.13 [c]	0.0236
Vanillin	nd	5.38 [a]	nd	0.0653
Ferulic acid	5.92 [b]	11.90 [a]	5.73 [c]	0.0714
Naringenin	25.26 [a]	5.36 [c]	9.49 [b]	0.0714
Daidzein	nd	nd	nd	
Querectin	17.20 [c]	26.63 [b]	38.21 [a]	0.0724
Cinnamic acid	nd	nd	nd	
Apigenin	nd	nd	2.58 [a]	0.0301
Kaempferol	nd	nd	nd	
Hesperetin	1.39 [a]	nd	nd	

a, b and c means: No significant difference ($p > 0.05$) exists between any two means that are in the same row and have the same superscripts.

*HA: Hot air oven, MIW**: Microwave oven, nd: not detected

Conclusion

Egypt is the world's largest and top producer of dates, which generates about 175 to 260 thousand tons of seeds as by-product. Date seeds, whether unroasted or roasted, are rich in antioxidants and have a good approximate composition. The roasting process results in a dark color of seed may be used as colorants. Products obtained during Maillard reactions may have functional properties, unique aromas and enhance seed antioxidant activity. Due to the high content of essential amino acids in date seed proteins, they have a comparatively high biological value compared with egg proteins, and Date seed oils have a good oxidative stability, which makes them easy to preserve, high value-adding of this by-product through its use as a component in functional foods that raises the nutritious content of human or animal diets. In particular, date seed-based coffee powders without caffeine can be made as more healthful substitutes for conventional drinks. Roasted date seeds are valuable resource recovery strategies that support both economic and environmental sustainability. Although the use of date seeds in the food and cosmetics industries may be justified, their safety must first be established.

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