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UTILIZATION OF AGRO-INDUSTRIAL WASTE FOR DATE PALM AS LOW-COST BY-PRODUCTS AND HIGH NUTRITIONAL VALUE

Maha M. Tawfik[a], Samah M. I. Shaheen[b], Raafat N. Sandak[a], Soheir N. Abd El-Rahman[a]

[a] Crops Technology Research Department, Food Technology Research Institute, Agricultural Research Center, Giza 12619, Egypt; Bread and Pasta Technology Research Department, Food Technology Research Institute, Agricultural Research Center, Giza 12619, Egypt.

***Corresponding Author: soheirkenawy@yahoo.com**

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ABSTRACT

The goal of the current study was to assess the nutritional value, antioxidant content and antioxidant activity of date kernels and palm fronds and their effect on oil stability. Total phenolic compounds, tannins and α-tocopherol were determined and DPPH radical-scavenging activity was examined. Polyphenolic substances were identified by HPLC. BHT and tannic acid as synthetic antioxidant agents, in addition to aqueous and ethanolic extracts of date kernels and palm fronds, as natural antioxidants were added to edible mixed oil at concentrations of 100, 200 and 500ppm and heated daily at 80°C for 5 hours for 7days, then the stability of oil was assessed by acid value, peroxide value, TBARS and iodine number. The Economics of date palm kernel waste also was evaluated. The findings showed that date kernels had greater total phenol content than those of date palm fronds and palm fronds also had much higher concentrations of tannins and tocopherol. According to HPLC-based polyphenol fractionation, vanilne, resorcinol and syringic acid made up the bulk of palm fronds. The findings suggested that the heat stability of both synthetic and natural antioxidants improved the stability and properties of oil after being heated daily at 80°C, for 5 hours for 7 days.

The present study concluded that adding natural antioxidants obtained from date kernels and palm frond could lengthen the shelf life of oil. They were also risk-free and have numerous dietary applications, as alternative natural antioxidants.

Keyword: Date kernels; Palm fronds; Antioxidants; Total phenols; HPLC.

INTRODUCTION

The amount of agro-industrial waste has significantly increased recently, and the ecosystem is harmed by the disposal of garbage. Due to the date palm's favorable environment and tasty, nutrient-rich fruit, the palm tree is the most common palm in the Middle East. The palm dates also contain low moisture levels and extremely volatile solids. These features make the wastes of palm dates great sources of biomass in countries that grow dates **(Zafar, 2021)**. The date palm, which is the most significant tree in the Middle Eastm, that generates enormous amounts of garbage every year in forms of fibrous materials, dried fruits and seeds. Such wastes are wonderful sources of degradable biomass that can be used in a variety of applications, including the creation of natural fiber composites, active carbon precursors and even nano-featured sheets. Due to a lack of efficient processing methods, date palm plantations annually burn that abundant resource Date palm has a wide range of uses nowadays, as technology advances **(Faiad *et al.*, 2022)**.

Date seeds are regarded as a by-product and typically weigh between 5.6 to 14.2% of the fruit. According to **Shafiei *et al.* (2010) and Tang *et al.* (2013)**, date seeds have high levels of proteins, vitamins, fatty acids and minerals. They are good sources of vital fatty acids and phytochemicals like phenols, sterols, carotenoids, anthocyanins, procyanidins and flavonoids. They have a high percentage of water-insoluble mannan fiber and are also high in dietary fiber (67.5–74.2%). Additionally, **John and Shahidi (2019)** reported that catechin, epicatechin, rutin, ferulic acid and proanthocyanidin were among the phenolic components found in both date palm leaf and date palm seeds (DPL and DPS). The seed is a source of edible oil and can be utilized as a useful food ingredient. Also, over 10% of the total date seeds waste produced every day by industries might be used for producing usable food items. Date fruit and seeds are highly beneficial to human, since they are full of sugar, vitamins, fiber, minerals, and phenolic compounds with anti-inflammatory and antioxidant qualities. Due to their chemical composition, bioactive substances and essential oils that are employed, date seeds are suited for usage in many foods, medications, cosmetic products, dietary supplements, and food product creation **(Alkhoori *et al.*, 2022 and Alharbi *et al.*, 2021)**. Date seeds have a good chance of being used as a useful element in meals for human. Furthermore, items made from date seeds are edible. **(Platat *et al.*, 2019)**.

Leaves of date palm are significant natural sources of fibers, that can be used as component in several industrial applications in virtually every field **(Agoudjil *et al.*, 2011)**. It has been found that 70% ethanol extract of leaves of *Phoenix dactylifera L.* has an anti-hyperglycemic action and controls the absorption of glucose by inhibiting α-amylase and β-glucosidase **(Chakroun *et al.*, 2016)**. In liver and kidney tissues of streptozotocin- and alloxan-induced diabetic rats, the aqueous extract of DPS has been shown to have a possible protective effect against diabetes **(Abdelaziz *et al.*, 2015; Abiola *et al.*, 2018)**.

Thousand tons of date palm seeds and leaves are thrown away each year, despite the fact that both of them contain significant amounts of secondary metabolites, including polyphenolic compounds like flavonoids, antioxidants and phenolic acids that can be used as a good source for functional foods **(Al-Farsi and Lee, 2011)**.

Therefore, the current study aimed to assess the nutritional value of date kernels and palm fronds, as well as their fractionation of the polyphenolic extract by using HPLC, and study effect of their aqueous and ethanolic extracts on oil oxidative stability during heated five hours per day for seven days at 80±2°C. Additionally, evaluate the Economics of date palm kernel waste.

MATERIALS AND METHODS

Materials:

Date palm *(Phoenix dactylifera)*, the Egyptian Sukkari date fruit variety, and its fronds were collected from Siwa Oasis. Sigma-Aldrich (Dorset, UK) supplied the chemicals and reagents Ethanol alcohol was given by El-Nasr Pharmaceutical Chemical, El-Ameriea, Cairo, Egypt. Butylated hydroxyl toluene (BHT), tannic acid, and other synthetic antioxidants, such as flavonoids and phenolic compounds, were purchased from Sigma Chemical Co. in St. Louis, Missouri, in the United States. Tanta Company for Oils and Soaps, located in Tanta, Egypt, sold edible mixed oil-free antioxidants.

Preparation of date kernel powder

Directly separated from the Sukkari date, the kernels were cleaned by hand, rinsed by soaking in distilled water for five minutes, and then allowed to drain for two to three days at room temperature. According to Johnson et al. (2013), the kernels were dried at (40^{o}C), stirred, crushed, and processed using a heavy-duty grinder into a fine powder passing a 1.2 mm screen, then placed in polyethylene bags and kept in a dry location until utilized.

Preparation of date fronds powder

Date palm tree fronds were initially cut into 5 cm-sized parts and washed thoroughly with water for removing any particles of dust or dirt. The samples of fronds were subsequently dried in an oven for 5 h at a temperature of 70 °C till it is completely dried and milling according to **Al-Awa *et al.* (2023).**

Determining the raw materials' chemical analyses

According to **AOAC (2012),** the crude protein, crude lipids, ash, and crude fibers in the raw materials were determined, and the total carbohydrates were computed by deference. Date kernels and palm fronds were estimated as total dietary fiber (TDF), soluble (SDF), and insoluble dietary fiber (ISF) by **Prosky *et al.* (1988).**

Antioxidant extraction

date kernels and palm fronts (10g each) were extracted for 24 hours with 50ml of each water and ethanol. In a rotary evaporator (RE 300/ MS), the antioxidant extracts were filtered and dried at 40 °C.

Determination of total phenolic compounds, tannins, and α-tocopherol

The total phenolic content of raw materials was determined by applying the **Muscolo *et al.* (2019)** technique and the Folin-Ciocalteu reagent. The findings are presented as mg/100g of dry weight of gallic acid equivalents (GAE). To determine the total tannins content, the method of **Çam and Hişil (2010),** was applied. Separately, 10mL of a 3:2 v/v hexane: isopropanol solution was used to extract vitamin E (-tocopherol) from raw materials. The mixture was agitated for 5 hours before being centrifuged at

3000rpm for 10minutes. The amount of vitamin E was measured in the supernatant, according to **Prieto *et al.* (1999).**

DPPH radical-scavenging activity

Date kernels and palm fronds were tested for their ability to scavenge DPPH free radicals using the technique described by **Xu and Chang (2007).** At 517 nm, the absorbance was immediately measured.

HPLC-based antioxidant measurement

Using HPLC (HP 1050), polyphenolic substances were identified in accordance with the procedure outlined by **Waksmundzka – Hajnos*et al.* (2007).**

Addition of antioxidant to oil

Sunflower oil was used as the substrate for oxidation studies. According to **Buford, (1988),** antioxidants were added at concentrations of 100, 20 and 500 ppm on a dry weight basis in order to examine the antioxidant potency of natural antioxidants extracted (aqueous) from date kernels and palm fronds powder as well as synthetic antioxidants (BHT and tannic acid). The preparation of an additive-free control sample followed the same steps. Sunflower oil with and without antioxidants (natural or synthetic) was intermittently heated for five hours each day for seven days at a temperature of 80±2 °C in a 500 mL glass beaker.

Determination of oxidative status in sunflower oil

In oils, thiobarbituric reactive compounds (TBARS) can be used Spectrophotometers to assess according to **Jung *et al.* (2016), and Zeb and Ullah, (2016).**

According to **AOAC (2012),** the peroxide value, acid value, and iodine number were determined.

Statistical evaluation

The statistical analysis was carried out using the SPSS10 program. A one-way analysis of variance and Duncan's tests were used for statistical analysis, and the data were reported as means and standard error of the means (SEM) **(SPSS, 2000).**

RESULTS AND DISCUSSION

Chemical composition in date kernels and palm fronds

Samples of date kernels and palm fronds were subjected to chemical analysis, results are reported in Table (1). It could be observed that the crude protein, oil and hydrolysable carbohydrates in date kernels were higher than those of palm fronds, as they were 3.17, 6.69 and 73.73%, respectively, for the former, while they were 1.99, 1.01 and 31.98%, respectively, for the later. Whereas, ash content and crude fiber were higher in palm fronds than those of date kernels, as they were 12.99 and 52.03%, respectively, for the former, while there were 1.41 and 15.00%, respectively, for the later. According to chemical analysis, date kernel includes, by weight, 60–80% fiber, 4–14% oil and just little amount of protein. These results are confirmed with **Shafiei *et al.* (2010) and Tang *et al.* (2013).**

Concerning the total dietary, insoluble, and soluble dietary fibers, that were determined in date kernels and palm fronds, it was found that the total dietary fiber and insoluble dietary fiber were higher in palm fronds (74.21 and 65.69% respectively), compared with date kernels (70.52 and 50.45%, respectively). Meanwhile, soluble dietary fiber was the highest in date kernels (20.07%) than palm fronds (8.52%). Dietary fibers that are soluble also have a physical mode of action that plays a significant role in controlling how well some macro- and micronutrients are absorbed. For instance, because of their high molecular weight and water solubility, they make the intestinal contents more viscous, which inhibit the absorption of glucose and cholesterol and the reabsorption of bile salts. Preventing intestine absorption and maintaining insulin secretion, which encourages hepatic cholesterol production, stabilizes serum cholesterol levels. Additionally, increasing intestinal capacity encourages fullness and suppresses hunger **(Lattimerand Haub, 2010).**

Date seeds contain between 67 to 74% more dietary fiber than date fruit, with water-insoluble mannan fiber being the most prevalent **(Mrabet *et al.*, 2019).** The findings suggest that date seeds could be exploited as superior dietary fiber source in food preparation (**Sayas-Barberá *et al.*, 2020).**

Table (1): Chemical composition of date kernel and palm fronds (on dry basis %)

Chemical analysis	Date kernel	Palm fronds
Crude Protein	3.17±0.02	1.99±0.84
Crude Oil	6.69±0.05	1.01±0.75
Ash content	1.41±0.08	12.99±1.24
Crude Fiber	15.00±0.95	52.03±3.12
Total Carbohydrates	73.73±4.25	31.98± 2.01
Dietary fiber	70.52±3.76	74.21±4.12
Insoluble dietary fiber	50.45±2.61	65.69±3.58
Soluble dietary fiber	20.07±1.87	8.52±0.93

Values are mean ±SD, n = 3.

Yield extract, antioxidants and its activity in date kernels and palm fronds

By guarding against the oxidative damage caused by dangerous chemicals known as free radicals, antioxidants serve a crucial function in food systems, human body cells, and tissues **(Idowu *et al.*, 2021).** Some well-known disorders, like cancer, heart disease, Parkinson's and Alzheimer's disease are directly linked to those free radicals (**Kim *et al.*, 2015).**

Table (2) shows that each of palm kernels' ethanolic and aqueous extract contained 2.47 and 2.43% of antioxidants, respectively. Meanwhile, Palm frond aqueous extract gave better result, concerning to total antioxidant content (3.51%), compared with that of ethanolic extract (0.40%). These findings agree with those of **Maqsood *et al.* (2015),** who claimed that date seed, which was extracted with ethanol is more effective than that extracted with water, because it is predominately composed of non-polar chemicals.

Total phenolic, total tannins, tocopherol and its antioxidants activity (DPPH) were determined in date kernels and palm fronds and the results are tabulated in the same table. Results indicate that date kernels were characterized by having higher quantities of total phenols, being about 728.97mg gallic acid/100g, compared with palm fronds, which were 442.09mg gallic acid/100g. Moreover, palm fronds contained significantly high amounts of tannins and tocopherol, which were 1699.93mg/100gm and 30.88μg/100g, respectively, as high as that of date kernels, which were 1559.96mg/100g and 0.950μg/100g, respectively. Results demonstrated that palm fronds contain higher amounts of total tannins and tocopherol, as well as lower amounts of total phenols. According to **Yusoff (2006)**, palm oil is the fastest-growing oil in the world and a source of α-tocopherol, α-tocotrienol, γ-tocotrienol and δ-tocotrienol. The antioxidants of tannins, carotenoids, sterols and polyphenols are all abundant in dates **(Idowu *et al.*, 2019)**.

The ethanolic extract of date seed powder (*Phoenix dactylifera*) contained a total of 56.16 to 67.32mg/ml of phenolic compounds, while its methanolic extract contained 56.6 to 65.32mg/ml of phenolic compounds. It was also found that aqueous extract of date seed powder contained 27.88 to 40.06mg/ml of phenolic compounds, **Al Ghezi *et al.* (2020)**. While the total flavonoid content of the aqueous extract varied from 22.12 to 33.32mg/ml, comparing with that of the ethanolic extract, ranged from 40.21 to 52.16mg/ml, and that of the methanol extraction, ranged from 35.11 to 46.16mg/ml. The antioxidant activity of (*Phoenix dactylifera*) date seed power variety is indeed varied from 37.50 to 88.70%. The reduction strength is ranged from 0.895 to 2.63 and the value of ferrous ion bond is ranged from 41.92 to 60.93%.

In the same table, both of date kernels and palm fronds showed significant antioxidant activity, for the DPPH radical-scavenging experiment. Results showed that date kernels, which have significant levels of natural antioxidant activity, had higher inhibition ratio (79.93mg/ml), whereas palm fronds had lower one (59.98mg/ml). Date kernels may have larger total phenolic acid and tocopherol contents compared to palm fronds, which may explain why they have the highest inhibition ratio. While scavenging of the ABTS radical is caused by the scavenging of proton radicals created through the donation of electrons, scavenging of the DPPH assay may be owing to the hydrogen-donating ability **(Chu *et al.*, 2010).** Our findings demonstrate that date seeds and palm fronds can be considered as good sources of natural antioxidants.

Table (2): Total antioxidant contents and its activity, for date kernels and palm fronds

Extracts	Date kernel	Palm fronds
Aqueous extract (mg/ 100g)	2.43±0.009	3.51±0.013
Ethanolic extract (mg/ 100g)	2.47±0.009	0.40±0.002
Total phenols (mg/ 100g)	728.97±3.760	442.09±1.890
Total tannins (mg/ 100g)	1559.96±9.040	1699.93±3.880
Tocopherol (µg/ 100g)	0.950±0.001	30.88±0.240
DPPH (mg/ ml)	79.93 ± 5.310	59.98 ± 2.190

Values are as mean ±SD (n= 3).

Fractionation of polyphenolic compounds, for date kernel and palm fronds using HPLC

According to **Maqsood *et al.* (2017),** using HPLC as a tool to determine the quantitative analysis of phenols and flavonoids makes it simple to move forward with the most efficient and abundant bioactive compounds in the different plant parts' extracts. This also aids in clearly differentiating species.

Fractionation and analysis of polyphenolic in date kernel and palm fronds using HPLC are reported in Table (3). Results show that the main components of date kernels were Syringic acid, kaempferol, salicylic acid, ferulic acid, protocattechuic acid, cinnamic acid and ρ-coumaric acid, as they were 19.987, 14.911, 7.901, 7.723, 6.752, 3.498 and 1.007ppm, respectively. Meanwhile resorcinol, coumarin, caffic acid, benzoic acid and Vanilne were less than 1ppm. Date kernel does not detect for quercetin. The polyphenolic chemicals of gallic, vanillic, caffeic, protocatechuic and ρ-hydroxybenzoic acids were among the functional bioactive molecules that were discovered through a number of phytochemical studies **(Al-Farsi and Lee, 2008).** Date seeds are a great source of natural antioxidants according to the phenolic compounds they contain **(Bouhlali*et al.*, 2017),** making them a possible replacement for synthetic or semi-synthetic antioxidants. Furthermore, growing research suggests that date seeds have anti-inflammatory **(Saryono *et al.*, 2020)** and immunostimulant properties **(Saryono *et al.*, 2019).**

The main components in palm fronds were vanilne, resorcinol, and syringic acid (38.579, 13.001 and 10.497ppm, respectively), as well as, quercetin, coumarin, salicylic acid, kaempferol and cinnamic acid were the minor components, as they were 3.701, 3.677, 2.671, 2.411 and 2.196ppm, respectively. Meanwhile, caffic acid and ρ-coumaric acid was lower than 1ppm in the palm fronds and also, ferulic acid protocattechuic acid and benzoic acid were not detected in the palm fronds. Concerning to date palm seeds and leaves, phenolic substances such as proanthocyanidin dimers, catechin, epicatechin, 5-O-caffeoylshikimic acid isomers, ferulic acid, rutin, and isorhamnetin hexoside were found **(John and Shahidi, 2019).**

Table (3): Analysis of the HPLC polyphenols, for date kernel and palm fronds (ppm)

Polyphenolic analysis	Date kernel	Palm frond
Ferulic acid	7.723	ND
Protocattechuic acid	6.752	ND
Syringic acid	19.987	10.497
Coumarin	0.721	3.677
Caffic acid	0.587	0.600
ρ-Coumaric acid	1.007	0.387
Salicylic acid	7.901	2.671
Resorcinol	0.924	13.001
Vanilne	0.071	38.579
Benzoic acid	0.132	ND
Cinnamic acid	3.498	2.196
Quercetin	ND	3.701
Kaempferol	14.911	2.411

Natural and synthetic antioxidants for oil stability

Highly unstable reactive compounds with one or more free electrons are known as free radicals. These substances have the potential to harm or even destroy the vital organs. One of the earliest cultivated plants is *Phoenix dactylifera L*, also known as the "date palm"(dates), which are said to be a good source of antioxidants (**Al-Farsi *et al.*, 2018)**.

Natural antioxidants for an aqueous and ethanolic extract from date kernels and palm fronds, as well as a synthetic antioxidant as BHT and tannic acid were added to edible mixed oil at 100, 200 and 500ppm and heated to 80ºC, for 5hrs daily, for 7 days and the results were tabulated in Table (4), which express the effect of adding antioxidants on acid value, peroxide value, TBARS and iodine number.

Acid value reflected the degree of oil hydrolysis and the amount of free fatty acids involved in the heated oil samples. The tabulated data revealed that heating of oil caused an increase in the acid value for the control sample after 7 days to 2.385mg KOH/g oil, comparing to zero time, which was 0.008mg KOH/g oil. Such increase could be attributed to the formation of acidic compounds and free fatty acids.

The decrease in acid value after 7 days, after adding antioxidant extracts separately from 100 to 500ppm for aqueous from 0.567 to 0.217mg KOH/g and ethanolic extract from 0.700 to 0.198mg KOH/g in date kernel, as well as, palm fronds decreased from 0.744 to 0.278mg KOH/g in aqueous extract and in ethanolic extract was from 0.641 to 0.249mg KOH/g, respectively. These decreases may have been as a result of fatty acid degradation, which could produce highly volatile, low molecular weight fatty acids or by the decarboxylation reaction, which produces the equivalent alkanes. These results showed that oil samples treated with butylated hydroxytoluene (BHT) and tannic acid, after heating oil at 80°C for 5 hours each day for 7 days, exhibited abet the hydrolysis, as affected by antioxidant addition. These findings agree with those of **Alsharjabi (2005).**

Peroxide formation in oil during heating oil at 80ºC, for 5hrs daily, for 7days. The results show that as heating time increased, peroxide values increased to 11.099ml equl/kg oil in control sample. Meanwhile, aqueous and methanolic extracts from date kernel at 100ppm were 2.8009 and 2.2871mlequl/kg oil, respectively, while for500ppm concentration, the results were 0.899 and 0.7909mlequl/kg oil, respectively. The different extracts from palm fronds the results were parallel to the results from date kernel extracts. Moreover, the effects of aqueous and ethanolic extracts from date kernel were more effective on oil, this was due to the rate difference between peroxide formation and its decomposition. At the beginning of heating, peroxide formation was faster than its decomposition. The effects of added antioxidants, as BHT and tannic acid on the peroxide value of the oil were tested after heating oil at 80ºC, for 5hrs daily, for 7 days. Both of antioxidant agents effectively reduced the oxidation rate in the oil, as detected by decreases in peroxide values compared to those of oil without antioxidants. Tabulated data showed that continuous exposure of oil to air and light-enhanced oxidative cause changes in oil and these changes became very fast by heating.

The same table revealed that TBARS value increased, for control sample gradually in oil samples by heating oil at 80ºC, for 5hrs daily, for 7 days. The increase in TBARS readings is a sign that carbonyl compounds were forming. These compounds were created, because of heating in the presence of air. The type of oil used and the heating techniques used may have an impact on how much of these chemicals are generated. These findings concur with **Lee *et al.* (1994)** findings. The addition of antioxidant agents to oil was very effective, since the TBARS values after 7 days of heating were significantly less than the values of oil without adding antioxidants. The effects of adding antioxidant agents (BHT and tannic acid) on peroxide value of oil were tested after heating oil at 80ºC, for 5hrs daily for7 days. Both of antioxidant agents effectively reduced the oxidation rate in oil, as detected by decrease in TBARS values, compared to oil without them.

Tabulated data showed that heating of oil substantially reduced the iodine numbers. The loss of hydrogen near the double bond and creation of free radicals during oxidation, which was the result of a complicated series of chemical processes, caused a reduction in the amount of total unsaturated oil. As a result, heating is what accelerates oil oxidation resulted in a maximum fall in iodine levels **(Paz and Molero, 2001)**.

By measuring the iodine value during heat treatment, a progressive reduction in unsaturated bonds was found in all examined materials. This decline might be explained by the double bonds being broken down by polymerization, scission and oxidation. After heating oil for 7 days, at 80°C for 5 hours/ day, and the impact of adding antioxidants (BHT and tannic acid) on iodine number of oil was examined. Increases in iodine numbers compared to control samples (oil without antioxidants) were observed, which show that both antioxidants had significant impacts on slowing the rate of oxidation of oil. These findings are consistent with those found by **Naz *et al.* (2005).**

According to **Tena *et al.* (2014),** frying causes oil to degrade by collecting polar molecules, which involves a number of physicochemical events such thermo-oxidation, hydrolysis and polymerization. Triacylglycerols that have been oxidized, dimerized or polymerized, as well as diacylglycerols and free fatty acids are examples of polar molecules. They come from triacylglycerols and speed up the breakdown of oil. These degradation products eventually build up in fried food due to mass transfer processes, which lowers the nutritional value of both oil and meal **(Zhang *et al*., 2012).**

The capacity to maintain its properties throughout heat processing is one of the most crucial requirements for an appropriate antioxidant in oils and fats. It has been demonstrated that most naturally occurring additives in various edible oils have more antioxidant activity and thermal stability than synthetic ones **(Taghvaei andJafari, 2015).** The development of these secondary oxidation products may be postponed by antioxidants. However, the most of natural and synthetic antioxidants were found to be more effective at a prolonged frying temperature **(Marmesat *et al*., 2010).**

In summary, it could be shown that subjecting the tested oil to thermal treatment caused significant changes to its chemical composition. This might be because heat changes unsaturated fatty acids, which therefore changes the characteristics of oil.

Table (4): Effect of natural and synthetic antioxidant agents on oil stability, during heating oil daily, to 80ºC, for 5hrs, for 7days.

Concentration of extracts	Control at Zero time	Control after7 days	Date kernel		Palm fronds		Synthetic antioxidant agents	
Acid value after 7days (mg KOH/g)								
			Aqueous	Ethanolic	Aqueous	Ethanolic	Tannic acid	BHT
100ppm	0.0080 ±0.0001	2.3850 ±0.0100	0.56700 ±0.0020	0.7000 ±0.0030	0.7440 ±0.0050	0.6410 ±0.0019	0.7410 ±0.0020	0.8180 ±0.0012
200ppm			0.5120 ±0.0017	0.6470 ±0.0040	0.6510 ±0.0020	0.6190 ±0.0020	0.7490 ±0.0030	0.7990 ±0.0021
500ppm			0.2170 ±0.0015	0.1980 ±0.0006	0.2780 ±0.0030	0.2490 ±0.0011	0.4580 ±0.0018	0.3220 ±0.0017
Peroxide value after 7 days (mlequl/kg)								
Concentration of extracts	Control at Zero time	Control after7 days	Date kernel		Palm fronds		Synthetic antioxidant agents	
			Aqueous	Ethanolic	Aqueous	Ethanolic	Tannic acid	BHT
100ppm	0.0140 ±0.0006	11.0990 ±0390	2.8009 ±0.0107	2.2871 ±0.01300	2.8928 ±0.0099	2.1008 ±0.0107	2.0699 ±0.0110	2.0786 ±0.0150
200ppm			1.8017 ±0.0070	1.6001 ±0.0068	2.4011 ±0.0097	1.4002 ±0.0080	1.9125 ±0.0099	1.5810 ±0.0070
500ppm			0.8990 ±0.0029	0.7909 ±0.0060	0.9048 ±0.0049	0.8001 ±0.0023	0.9073 ±0.0041	0.1270 ±0.0010
TBARS after 7 days (mg/kg)								
Concentration of extracts	Control at Zero time	Control after7 days	Date kernel		Palm fronds		Synthetic antioxidant agents	
			Aqueous	Ethanolic	Aqueous	Ethanolic	Tannic acid	BHT
100ppm	0.0070 ±0.0010	0.7900 ±0.0020	0.1170 ±0.0009	0.0730 ±0.0007	0.1540 ±0.0009	0.0940 ±0.0003	0.0990 ±0.0006	0.0940 ±0.0002
200ppm			0.0790 ±0.0007	0.0490 ±0.0004	0.1180 ±0.0005	0.0410 ±0.0007	0.0710 ±0.0002	0.0810 ±0.0003
500ppm			0.0150 ±0.0002	0.0090 ±0.0002	0.0140 ±0.0002	0.0110 ±0.0003	0.0190 ±0.0005	0.01200 ±0.0001
Iodine number after 7 days (g I_2/100g)								
Concentration of extracts	Control at Zero time	Control after7 days	Date kernel		Palm fronts		Synthetic antioxidant agents	
			Aqueous	Ethanolic	Aqueous	Ethanolic	Tannic acid	BHT
100ppm	111.69 ±0.5378	97.14 ±0.4897	103.87 ±0.5874	105.93 ±0.5007	106.39 ±0.5701	107.400 ±0.5200	108.190 ±0.6140	108.810 ±0.5412
200ppm			105.59 ±0.4895	107.72 ±0.5070	109.67 ±0.6002	108.830 ±0.5794	109.920 ±0.5311	109.189 ±0.5221
500ppm			110.01 ±0.5991	110.99 ±0.5006	111.66 ±0.5167	110.600 ±0.5394	111.090 ±0.5250	110.910 ±0.5475

Values are mean ±SD, n = 3 control sunflower oil free antioxidants

The feasibility economical of date palm kernel waste

Table (5) shows the development of the quantity and price of date kernel waste from 2014 to 2023. It is clear from the first equation (Table 6) that the quantity of date kernels in Egypt increased by an annual statistically significant amount of about 1.74 kg/ton. The coefficient of determination was about 0.96, meaning that about 96% of the changes in the quantity of date palm kernels are due to some variables whose effect reflects the impact of the element of time.

Table (6) indicates that the equations of the general time trend, the quantity and the price of date kernel waste in Egypt during the period of 2014-2023. It also appears from the second equation that the price of date palm kernels in Egypt increased by an annual statistically significant amount of about 1.5 pounds/ kg. The determination coefficient was about 0.98, meaning that about 98% of the changes in the price of the date palm kernels are due to some variables that reflect their impact on the time factor.

Table (5): Development of the quantity and price of date kernel waste from 2014 to 2023

Year	Quantity (Ton)	Price (LE)/ kg
2014	2.2	1.75
2015	2.3	1.75
2016	2.6	2.00
2017	2.5	2.25
2018	3.4	2.50
2019	3.5	2.60
2020	3.7	2.75
2021	3.8	3.00
2022	4.5	3.25
2023	5.0	3.25

Table (6): Equations of the general time trend, quantity and price of date kernel waste in Egypt, during the period of 2014-2023

No.		Equations	R2	F
1 (Y1)	Quantity (Ton)	Y1 =0 .298 + 1.740 x (15.6) (14.6)	0.96	243.7
2 (Y2)	Price (LE)/ kg	Y2 = 424 + 1. 5x (2.4)** (22)**	0.98	484.5

Where: Y1=amount of date kernel waste, Y2 = Price of date kernel, Xi = time variable where i (1, 2, 3, ..., 10).
The value in parentheses indicates the calculated (T) value, (R2) the coefficient of determination, (F) the significance of the model as a whole. (*) indicates the significance of the regression coeffi cient.

CONCLUSION

Numerous sources of protein, dietary fiber, oil and carbohydrates can be found in date kernels and palm fronds. They also include bioactive phenolic compounds, that may have many biological effects. Date seeds are also excellent for usage in dietary supplements and food product formulation due to their rich chemical content. It may be argued that the aqueous and ethanolic extracts of date kernel and palm frond had antioxidant capabilities and might be used as substitute natural antioxidants with a variety of food applications. There is a need for further research on palm fronds, that date seeds and palm fronds are both worthwhile investments.

Conflicts of Interest

The authors declare no conflict of interest in this review.

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الملخص العربي

الاستفادة من مخلفات الصناعات الزراعية لنخيل التمر كمنتجات ثانوية منخفضة التكلفة وذات قيمة غذائية عالية

مها منير توفيق ١، سماح محمد إبراهيم شاهين٢، رأفت نجيب سندق ١، سهير نظمى عبد الرحمن ١
1قسم بحوث تكنولوجيا المحاصيل، معهد بحوث تكنولوجيا الأغذية، مركز البحوث الزراعية، الجيزة ١٢٦١٩، مصر؛
2قسم بحوث تكنولوجيا الخبز والعجائن، معهد بحوث تكنولوجيا الأغذية، مركز البحوث الزراعية، الجيزة ١٢٦١٩، مصر.

*للمراسلة soheirkenawy@yahoo.com :

الهدف من الدراسة الحالية هو تقييم القيمة الغذائية ومحتوى ونشاط مضادات في نوى التمر وسعف النخيل وتأثيرها على ثبات الزيت. تم تحديد إجمالي المركبات الفينولية والتنينات وألفا توكوفيرول وتم تقدير نشاط الكسح الجذري DPPH تفريد المركبات الفينولية بواسطة HPLC.تم إستخدام BHTوحمض التانيك كعوامل صناعية مضادة للأكسدة، بالإضافة إلى المستخلصات المائية والإيثانولية لنواة التمر وسعف النخيل كمضادات أكسدة طبيعية، حيث أضيفت إلى زيت الطعام الصالح للأكل بتركيزات ١٠٠، ٢٠٠، ٥٠٠ جزء في المليون وتسخينها يومياً عند درجة حرارة ٨٠ درجة مئوية لمدة ٥ ساعات، و ٧ أيام، تم تقييم ثبات الزيت بواسطة تقدير قيمة رقم الحامض، ورقم البيروكسيد، TBARSوالرقم اليودي. كما تم تقييم القيمة الإقتصادية للإستفادة من مخلفات النخيل .وأظهرت النتائج أن نواة التمر تحتوي على محتوى فينولي إجمالي أكبر من تلك الموجودة في سعف نخيل التمر، كما يحتوي سعف النخيل أيضًا على تركيزات أعلى بكثير من التنينات والتوكوفيرول. وفقًا للنتائج المتحصل عليها HPLCتم التعرف على المركبات الفينولية، وهى الفانيلن والريسورسينول وحمض السيرنجيك من سعف النخيل. تشير النتائج إلى أن الثبات الحراري لكل من مضادات الأكسدة الاصطناعية والطبيعية أدى إلى تحسين ثبات خصائص الزيت بعد تسخينه عند ٨٠ درجة مئوية لمدة ٥ ساعات و ٧ أيام .

خلصت الدراسة الحالية إلى أن إضافة مضادات الأكسدة الطبيعية المستخرجة من نوى التمر وسعف النخيل يمكن أن يطيل العمر الافتراضي للزيت. كما أنها خالية من المخاطر ولها العديد من التطبيقات الغذائية، كمضادات الأكسدة الطبيعية البديلة .

الكلمات المفتاحية: نواة التمر، سعف النخيل، مضادات الأكسدة، الفينولات الكلية، HPLC.