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Evaluation of Caffeine-Free and Low-Caffeine Coffee Alternatives Prepared from Saidi Date Seeds

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ABSTRACT

Date seeds are a significant source of numerous nutritional components, particularly bioactive compounds such as phenols, flavonoids and other beneficial compounds. They are also naturally caffeine-free. This research aimed to produce a caffeine-free beverage using roasted Saidi date seed powder (DSP), as well as low-caffeine alternatives by blending them with coffee at substitution ratios ranging from 10% to 50%. The obtained results indicated that as the substitution ratio increased, the content of phenolic compounds and the caffeine level also increased, although both remained lower than in pure coffee samples. The statistical analysis of the sample's cupping evaluation revealed that roasted date seeds alone received a score of 61.1% and were classified as Exchange Grade, which could adequately satisfy caffeine-sensitive coffee consumers. Samples T7 (50% coffee blend) and T6 (40% coffee blend), with scores of 78.8% and 75.4%, respectively, were categorized as usual good quality and demonstrated the best fragrance, aftertaste, acidity and cleanup. Therefore, date seed powder can be effectively combined with coffee to produce palatable low-caffeine or caffeine-free alternatives that meet market demands.

1. Introduction

The annual production of dates in Egypt has increased from 1.38 million tons to 1.733 million tons. Said dates are a semi-dry variety that represents, 13% of Egypt's total date production (Shahbandeh, 2022; Kiesler et al., 2024 and FAOSTAT, 2024). In addition, the global production increased from 7.53 million tons to 9.75 million tons. Depending on the variety and grade quality, date seeds, also referred to as pits, kernels, stones, or pips, make up 10% to 15% of the mature date fruit weight (Nehdi et al., 2010). Accordingly, the annual production of date seeds ranges from 0.975 to 1.643 million tons (FAOSTAT, 2024), Additionally, date seeds are considered waste products of the date fruit manufactured (date syrup, date confectionary, and pitted dates), which are frequently discarded or utilized as animal feed. The date (*Phoenix dactylifera L.)* is a staple food for millions of people in the Middle Eastern countries and a significant agricultural crop. Date packing and processing enterprises produce date seeds. As a result, even though date seeds are rich in vital nutrients like protein, dietary fiber, carbohydrates, oil, bioactive polyphenols, and natural antioxidants, they have caused issues for the date industry (Tafti et al., 2017). However, there are many applications for date seeds, such as the production of food products, cosmetics, and functional and medicinal supplements. Date seeds are a great source of dietary fiber, phytosterols, and polyphenols, and when roasted, they have a pleasant aroma that is comparable to coffee. The polyphenol content of date seeds is many times higher than that of the flesh of the date fruit, which is often considered waste (Djaoudene et al., 2019 and Babiker et al., 2020). The high nutritional value of date seeds makes them suitable for a variety of uses. Additionally, they contain an enormous quantity of minerals, dietary fiber, carbohydrates, protein, and polyphenols. They are also a source of bioactive substances such as tocopherols, flavonoids, carotenoids, and polyphenols (Sultan, 2019).

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The active components in date palm seeds can help pancreatic beta cells that are under oxidative stress, thereby restoring insulin production. Date seed consumption does not affect the glycemic index in healthy people; however, it may lower blood glucose levels in hyperglycemic patients. This indicates that dates are beneficial for those with diabetes (Saryono, 2019). Date seed coffee is a sustainable food system innovation rooted in the traditions of high date-producing regions. Production world coffee increased by 0.1% representing 168.2 million packages in year 2022/2023. Due to the effects of rising living expenses, declining disposable incomes, and a long stock drawdown, coffee consumption in 2022–2023 shifted to continuously follow the prior trend. the challenging global economic would have had a negative impact on its consumption (ICO, 2023). Caffeine could improve physical performance by raising dopamine levels in the brain, which alleviates depression and reduces the risk of heart and brain vascular disorders. However, excessive caffeine consumption has negative health effects; it can cause lightheadedness, nausea, increased urination, gastrointestinal issues (diarrhea), elevated blood pressure, restlessness, insomnia, and palpitations. There is also evidence that caffeine has negative effects on older women who are postmenopausal, it speeds up the loss of bone tissue (Vuletić et al., 2021). Coffee alternatives offer several benefits, including being caffeine -free and rich in beneficial phytochemicals. The potential negative effects of excessive coffee drinking are a concern, especially in the context of the stimulant and addictive properties of the alkaloid caffeine. It is recognized that there is an elevated risk of hypertension and heart rate among those predisposed, which can have detrimental effects on the nervous system (Tahmouzi et al., 2024). Alternatives to coffee may be viewed as advantageous both from an economic perspective and in terms of health benefits compared to traditional coffee beverages. Alternative coffee materials are roasted before use, just like conventional coffee, to improve the product's flavor and chemical characteristics; the roasting process is dependent on temperature and time (Samsonowicz et al., 2019).

2. Material and Methods

Materials

Saidi date seeds (*Phoenix dactylifera*) were obtained from the drying unit of fruit and vegetables, Food Technology Research Institute (FTRI), Agricultural Research Center (ARC), Giza, Egypt Also, Commercial coffee medium colored grade was purchased from Shaheen coffee co., Dokki, Giza, Egypt.

Technological methods

Preparation of saidi date seeds powder

Saidi date seeds were visually inspected and washed with tap water to remove any adhering date flesh or dust, thereafter, the date seeds were dried in a hot air oven for 8 hours at 80°C, then crushed using a seed grinder. The dried date seeds granules were roasted at 220°C for 6 hours (Ghnimi et al., 2015). Then the roasted date seed were milled into fine powder, that passed through a 105 mesh sieve (fine particle size powder) and stored at 15°C for further analysis and formulation of coffee alternatives. Roasted Saidi date seeds powder and commercial coffee powder were used to prepare a caffeine-free and low-caffeine healthy coffee alternative as follows:

- Date seeds powder (DSP)100% (T1).
- Commercial coffee powder medium colored grade 100% without any additives as control (T2).
- Saidi date seeds powder 90% +commercial coffee 10% (T3).
- Saidi date seeds powder 80% +commercial coffee 20% (T4).
- Saidi date seeds powder 70% + commercial coffee 30% (T5).
- Saidi date seeds powder 60% + commercial coffee 40% (T6).
- Saidi date seeds powder 50% + commercial coffee 50% (T7).

The aforementioned for formulated samples (T1-T7) 100g each were packed in foil laminated bags and stored until analysis. Then, the samples of the powder (100g) were packed in foil laminate

materials for coffee bag packages and stored until analysis.

Analytical Methods

Physiochemical analyses

Moisture, pH value, total acidity, ash, crude fiber, fat, and protein were determined according to AOAC (2019). Total carbohydrates were calculated by difference as follows:

Total carbohydrates = 100 - (moisture + protein + lipids + ash + fiber) per 100g. Heavy metals content such as cadmium (Cd), lead (Pb), cobalt (Co), and arsenic (As) were determined in date seed powder according to AOAC (2019).

Determination of caffeine

Calibration solutions preparation

A calibration curve was established using standard caffeine solutions at concentrations of 1, 5, 10, 15, 20, and 25 ppm. The absorbance of each standard solution was measured at 274 nm using a UV-Vis spectrophotometer (model Jenway, 6705, UK). A linear calibration equation ($y = 0.0685x – 0.0067$) was generated by plotting absorbance versus concentration, and the correlation coefficient ($R^2 > 0.99$) confirmed the accuracy of the curve.

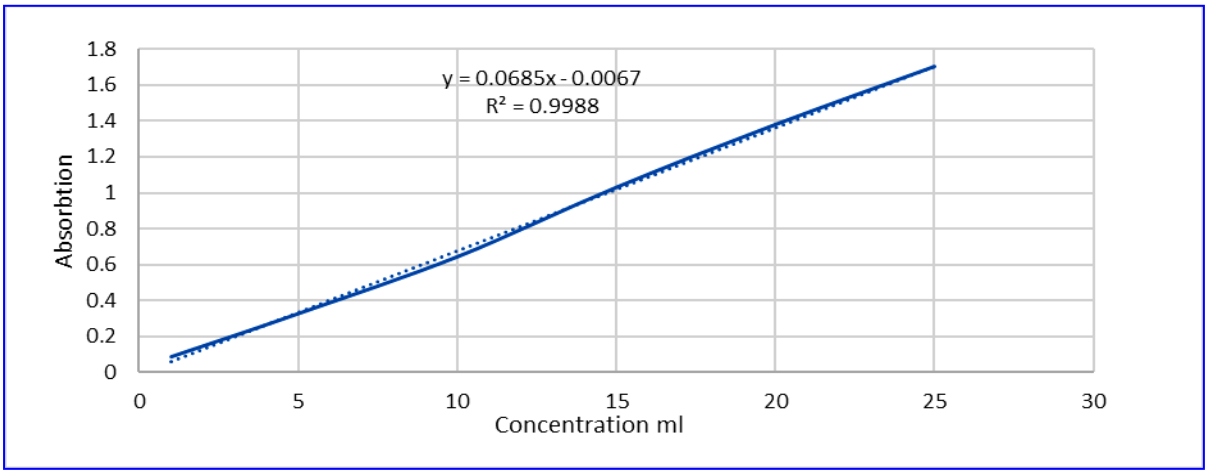

Figure 1. Caffeine standard curve mg/ml

Extraction of caffeine

Caffeine extraction was performed using a liquid-liquid extraction method. Exactly 2g of each powdered sample was mixed with 20mL of distilled water, heated, and boiled for 10 minutes. To precipitate tannins, 2g of sodium carbonate was added, followed by filtration. The filtrates were concentrated to 5mL by heating. For caffeine extraction chloroform was used as a solvent. A total of 5mL of chloroform was added to the filtrate in a separatory funnel, mixed thoroughly, and allowed to separate into two layers (Kwame et al., 2017). The lower caffeine-containing layer was separated and analyzed for caffeine content using a UV/Vis spectrophotometer. Next, 0.1mL of extract was mixed with 10mL of chloroform and placed in a quartz cuvette. Absorbance was measured at 274nm. Three samples were analyzed for caffeine content (Vuletić et al., 2021).

Determination of bioactive compounds

Total phenols were determined using the Folin-Ciocalteu reagent method as described by Ghosh et al. (2021). Total flavonoid content was measured as described by Matic et al. (2017). DPPH radical scavenging activity was assessed according to Rojas -Ocampo et al. (2021). Total tannin content was estimated using the Folin-Ciocalteu method, according to Mesfin and Won (2019). The percent inhibition of free radical DPPH (I%) was calculated as follows:

$I\% = (A \text{ control} - A \text{ sample} / A \text{ control}) \times 100$

Physical properties

Solubility index

One gram of coffee sample was added to 100mL of distilled water and was agitated in a magnetic stirrer at 700rpm for 5min. The mixture was centrifuged for 5min at 3000g centrifugal force. One aliquot (25mL) of the supernatant was

transferred to a petri dish and dried in an oven for 5h. at 103ºC. After drying, the solubility percentage (g of coffee sample per 100g of water) was calculated by the difference in weights (Cano-Chauca et al., 2005 and Sarabandi et al., 2014).

Hygroscopicity Degree

Hygroscopy is the phenomenon of attracting and holding water molecules via either absorption or adsorption from the surrounding environment. Approximately 1g of sample was put into a container with a saturated NaCl solution (75.29% RH) at 25°C for determining the hygroscopicity of samples. The samples were weighed after one week, and the hygroscopicity was expressed as grams of adsorbed moisture per 100g of solid (g/100g) (Fernandes et al., 2013).

Evaluation of Bulk Density and Tapped Density

The bulk density (P^{bulk}) of coffee samples was determined by measuring the weight of the sample in a volume of 10 mL, while the tapped density (P^{tapped}) was quantified by measuring the volume of the sample for a weight of 3.0 g (USP, 2015). For P^{tapped}, the cylinder used was tapped firmly and continuously on the surface until the volume did not change. They were expressed as g/cm³ of coffee sample. Each sample was analyzed three times, and the average value was calculated with ± standard deviation (St. Dev.).

Evaluation of Flow Property by Measuring Hausner Index and Compressibility Index (Carr's Index)

Cohesiveness and flowability of coffee samples were evaluated with the Hausner ratio (HR) (Hausner, 1967) and Carr index (CI) (Carr, 1965), respectively. CI and HR were calculated from the P^{bulk} and P^{tapped} values of the sample as given below.

$$HR=(P^{tapped}/ P^{bulk}) \quad CI=[P^{tapped}- P^{bulk}]/ P^{tapped}$$

The values of the Carr index and Hausner ratio are based on the flow property that defines the quality of the coffee samples. While the range from excellent to passable is acceptable, values outside this range indicate lower quality of the powder (Clayton, 2019).

Sensory evaluation

The sensory quality was assessed according to the Specialty Coffee Association of America's guidelines and cupping protocol (Specialty Coffee Association of America, SCAA, 2015). The sensory attributes included flavor, fragrance, aftertaste, acidity, body, clean cup, uniformity, and overall palatability. The cup score and taste notation were divided into four groups: 6.00–6.75 = good; 7.00–7.75 = very good; 8.00–8.75 = excellent; and 9.00–9.75 = outstanding. Sensory properties were evaluated by 10 panelists who were coffee lovers and members of the Food Technology Research Institute, Agricultural Research Center, Giza, Egypt.

Statistical Analysis

Data were analyzed using SPSS 20.0 (Statistical Package for the Social Sciences). Mean values, standard deviation (SD), and least significant difference (LSD) were calculated. A one-way analysis of variance (ANOVA) was performed, and Duncan's multiple range test was applied to compare means. Statistical significance was set at $p \leq 0.05$.

3. Result and Discussion

Proximate composition of date seed powder, coffee and alternative coffee. Dates are a well-known source of biologically active compounds and have significant nutritional value. The seed of dates, one of their primary by-products, was once primarily utilized for animal feed, but an increasing number of studies are demonstrating its potential value (El-Rahman and Al-Mulhem, 2017; Bijami et al., 2020). The chemical constituents of date seed powder, coffee, and alternative coffee were shown in Table 1. The moisture contents were 2.26 and 5.30% in coffee and DSP respectively; meanwhile, alternative coffee products made from date seed and partially replacing DSP with coffee in proportions ranging from 10 to 50% had moisture contents ranging from 5.41 to 3.37%. Previous studies have reported that the moisture content of date seed is 3.10–12.5%. This indicates that our findings are similar to those of previous studies (Suresh

et al., 2013). In the same table it could be seen that alternative coffee contains relatively high levels of protein, crude fiber, crude fat, and ash, which are considered key factors in determining quality compared with DSP. This is to be expected since coffee powder had a higher protein content than date seeds, with values of 11.53% and 5.55%, respectively. Alternative coffee's fat content ranged from 8.39% to 11.59%, following the same pattern as the seed's protein content. This is because coffee powder has a higher fat content (13.54%) than DSP (8.52%).

Table 1. Proximate composition of date seed powder, coffee and alternative coffee (g/100g DW)

Samples	Characteristics							
	Moisture %	pH	Total Acidity	Protein %	Crude fiber %	Ether extract %	Ash %	Total Carbohydrates%
T1 (DSP)	5.30^{a} ±0.172	6.12^{a}±0.026	0.205^{d}±0.136	5.55^{e}±0.079	4.24^{g}±0.123	8.52^{e}±0.403	1.14^{e}±0.131	75.25^{a}±0.242
T2 (Coffee)	2.26^{c} ±0.303	4.37^{d}±0.015	0.376^{a}±0.133	11.53^{a}±0.335	13.89^{a}±0.434	13.54^{a}±0.345	3.55^{a}±0.369	55.23^{f}±0.314
T3	5.41^{a} ±0.282	6.02^{ab}±0.021	0.188^{e}±0.171	6.51^{d}±0.252	5.01^{f}±0.659	8.39^{e}±0.229	1.34^{de}±0.084	73.34^{b}±0.369
T4	5.04^{a} ±0.083	5.65^{bc}±0.031	0.205^{de}±0.143	6.69^{d}±0.376	6.25^{e}±0.117	9.84^{d}±0.182	1.60^{cd}±0.219	70.58^{c}±0.620
T5	4.92^{a} ±0.202	5.58^{c}±0.021	0.271^{c}±0.153	7.60^{c}±0.351	7.39^{d}±0.281	10.53^{cd}±0.236	1.86^{c}±0.200	67.71^{d}±0.352
T6	4.11^{ab}±0.456	5.43^{c}±0.595	0.280^{bc}±0.213	8.02^{c}±0.203	8.44^{c}±0.233	10.59^{c}0.572	2.25^{b}±0.107	66.59^{d}±0.848
T7	3.37^{bc}±0.264	5.35^{c}±0.021	0.296^{b}±0.118	8.66^{b}±0.390	9.19^{b}±0.214	11.59^{b}±0.344	2.48^{b}±0.196	64.71^{e}±0.430

There is no significant difference (P>0.05) between any two means, within the same column have the same superscript a, b and c letter.

These results are in accordance with Algarni (2020), who found that date seeds mainly reduce agro-waste and they contain protein (7.73%) and fat (7.90%). Meanwhile, Warnasih et al. (2019) found that date seed coffee contained 8.55% protein, 7.34% fat, 1.17% ash, and 78.52% total carbohydrates. They stated that the difference may occur due to variations in date varieties, origins, harvesting times, and the use of fertilizers, which could affect the nutrient content of the date (Shalaby et al., 2017). From the results, it can be indicated that DSP contained the highest amount of total carbohydrates (75.25%), while coffee had 55.23%. However, it decreased in the alternative coffee due to the increased addition of coffee powder. Coffee's pH changes have a significant impact on the product's acceptability by consumers. It could be observed that there was a gradual decrease in pH value from T3 to T7 (6.02 to 5.35). The pH of coffee powder and DSP was 4.73 and 6.12, respectively, which is consistent with the findings reported by Yaiche et al. (2022), who found that date seeds have an acidic pH ranging from 5.7 to 6.21. In contrast, there was an increase in acidity from 0.188 to 0.296 in T3 to T7. Acidity is a crucial characteristic in coffee sensory analysis, and its degree varies based on the species, fruit maturation stage, harvest type, location, processing method, drying conditions, and climate during harvest and drying Lower-grade coffees may have more acidity and lower quality, whereas higher acidity may be linked to lower coffee quality. Additionally, coffee's pH value ranges from 5.25 to 5.32 (Lima Filho et al., 2015). The coffee flavor may be affected by the type and concentration of acids. For example, the acidity caused by citric and malic acids has a positive impact, whereas the acidity caused by acetic, lactic, propionic, and butyric acids has a negative influence on coffee quality (Pinheiro et al., 2021). Date seed powder has the potential to be a nutrient-dense ingredient for enhancing food products due to its substantial levels of fiber, proteins, lipids, and carbohydrates.

Caffeine content of date seeds powder, coffee and alternative coffee

Caffeine (1,3,7-trimethylxanthine) concentration was determined calorimetrically using spectrophotometry in an aqueous solution of all samples. The advantages of this method were that it is safe, rapid, and ecologically benign and can facilitate experimentation without the harmful and negative effects of certain chemical solvents. The process to produce decaffeinated coffee is more expensive than producing regular coffee, so it

usually requires additional equipment and specific procedures and frequently leaves a residual amount of caffeine in the seeds (Farah, 2012). The caffeine content of all samples is shown in Figure 2. It appeared that date seed powder is free of caffeine; that is the benefit of using DSP to produce non-caffeinated and low-caffeine drinks. Meanwhile, the caffeine content of coffee powder was 1.240mg/mL. Pinheiro et al. (2021) reported that the caffeine content ranged from 1.2 to 2.2% in *C. arabica and C. canephora*, respectively. The concentration of caffeine in alternative coffee increased gradually in all samples due to an increase in the coffee powder replacement ratio from 10 to 50% instead of DSP (0.253 to 0.733mg/mL) in T3 to T7. Alternative coffee powder is low in caffeine compared to coffee powder, which may achieve satisfaction for special consumers, making it healthy to consume. According to Santos and Rangel (2012), decaffeinated ground roasted coffees have been shown to contain roughly 0.3–0.5mg of caffeine per 100g. Meanwhile, Fujioka and Shibamoto (2008) reported that instant decaffeinated coffees have been found to contain 0.7–0.9 mg/100g. Additionally, caffeine levels in decaffeinated coffee beverages range from 0.1 to 2.6mg/100mL. Regarding the possible risk factor for falls and bone fractures, most of the research found no correlation between caffeine consumption and an elevated risk of fracture when taking into account daily intakes below 400mg (Lee et al., 2014).

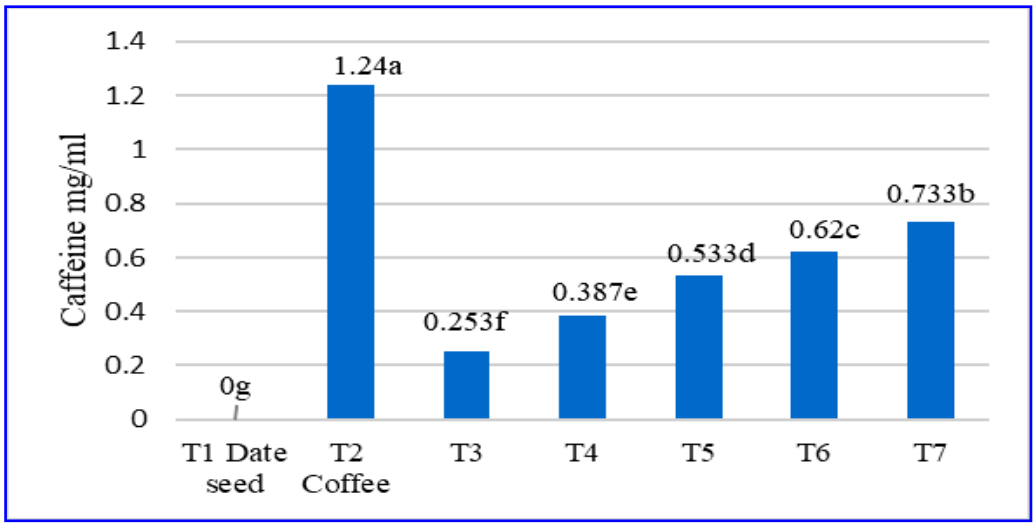

Figure 2. Caffeine content mg/ml of date seeds powder, coffee and alternative coffee

Compared to people who "almost never" drank coffee, individuals who consumed more than 544 mg of caffeine per day were at a greater risk of bone fracture. Additionally, Hallstrom et al. (2006) found that consuming more than 330mg of caffeine per day may be linked to a slightly elevated risk of osteoporotic fractures, particularly in women who consume inadequate calcium. However, the increased risk was only significant when the calcium intake was low (less than 700mg/day). The maximum recommended daily intake (RDI) of caffeine, according to the European Food Safety Authority (2015), is 400mg for adults, 300mg for pregnant and lactating women, and for children and adolescents up to 18 years, 2.5mg/kg of body weight.

Residual heavy metals of date seeds powder, coffee and alternative coffee. Food may naturally contain metals and other elements or may contain them due to human activities like manufacturing and agricultural practices. Lead, cadmium, tin, arsenic, and mercury are the metals that are most concerning in terms of their detrimental effects on health, often referred to as "heavy metals". These metals accumulate in biological tissues, a process known as bioaccumulation, which contributes to their toxicity. The amount and types of heavy metals present, soil physicochemical properties, plant species, and other factors all affect how quickly heavy metals are transferred to and accumulated by plants at different rates (Fonge et al., 2021).

Some heavy metals, such as lead, cadmium, and mercury, pose significant health risks even at low concentrations (Engwa et al., 2019). Table 2 shows the analysis of heavy metal contents in the tested samples. Cadmium, lead, and cobalt in DSP were below the maximum permissible limits. Lead content ranged from 0.1 to 0.33ppm., but it was the highest in coffee. The increase in lead concentration might be due to environmental contamination of the date palm. However, cadmium and lead contaminants were only detected in trace amounts, making it unlikely to pose a risk to human health. These results are similar to those of AL-Tunsi et al. (2019), who found that date seeds may be better for health as they have a low concentration of heavy metals. Cobalt was found below the maximum permissible limits (0.32–0.41ppm.).

Table 2. Heavy metals of date seed powder, coffee and alternative coffee (ppm.)

Minerals	Samples						
	T1 (Date seed)	T2 (Coffee)	T3	T4	T5	T6	T7
Cadmium	<0.025	<0.025	-	-	-	-	-
Lead	0.10	0.10	0.35	0.33	0.33	0.32	0.29
Cobalt	0.41	0.41	0.38	0.40	0.40	0.35	0.32
Arsenic	-	-	-	-	-	-	-

Cadmium and arsenic contents in the coffee and alternative coffee were not detected. The proximate analysis values of date seeds powder found in the present work are within the range of values presented earlier in the literature (Al-Khalili et al., 2022). Heavy metals, like cadmium, lead, tin, arsenic, and mercury, can be easily taken up by plants during the growth phase. The lead and cadmium concentrations were lower in the examined DSP than in coffee, so the mixing of date seeds and coffee led to a decrease in lead levels in different samples. In the present study, coffee and DSP had the highest content of cobalt compared with other heavy metals in the samples, which may be attributed to cobalt pollution from mining, manufacturing, fertilizers, pesticides, and rock weathering (Zhou et al., 2020). In addition, the negligent application of fertilizers, burning of coal and motor fuels, wastewater discharge, and increased mining of cobalt have all contributed to an increase in the concentration of naturally occurring cobalt (Saaltink et al., 2014). Cobalt in DSP (0.41ppm.) was higher than cobalt in coffee (0.38ppm.), so the mixing of DSP and coffee in the other samples led to a decrease in cobalt levels. However, date seeds had the lowest content of lead compared to coffee, so the mixing of coffee and DSP in other samples led to a decrease in lead content in those samples. Lead concentration may be attributed to various causes, with automobiles contributing to a greater extent, followed by the use of lead-based pesticides in crop protection. Additionally, traces of heavy metals in date seeds may be due to contamination of date palms with heavy metals, which can occur through the uptake of these metals from contaminated soils or irrigation water (Salama et al., 2019).

Phenolic compounds content of date seed powder, coffee and alternative coffee

Enhancing our diet by substituting synthetic ingredients with natural ones and encouraging better use of byproducts are the two main pillars of the growing significance of natural products with biological qualities that enhance our health. The byproducts are derived from low-quality varieties of dates and seeds that have been studied to offer alternatives and improve their properties, such as obtaining pastes, antioxidants, fibers, or phenolic extracts (Bijami et al., 2020). Furthermore, DSP is a good ingredient for pharmaceuticals and nutraceuticals due to its greater phenolic content, antioxidant properties, and odorless stability. 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 and Ajlouni, 2015).

Flavonoids and phenolic compounds are abundant in date seeds. Numerous investigations have verified that date seeds are caffeine-free. They are a valuable ingredient for food manufacturing because of their high content of nutrients, chemicals, and antioxidant effects (Kiesler et al., 2024). Data on the total phenolic compounds in DSP, coffee, and alternative coffee are shown in Table 3. The statistical analysis of our findings showed significant differences ($p < 0.05$) in phenolic compound content by type of extract. Aqueous extracts exhibited the lowest content of phenolic compounds compared with ethanolic extracts. These findings were comparable to those of Al Ghezi et al. (2020), who showed that the phenolic compound concentration in the methanolic and ethanolic extracts of date seeds was substantially greater than that of the aqueous extract (60.11, 62.33, and 33.34mg/mL, respectively). Phenolic compounds are the most abundant compounds with natural antioxidant characteristics and antimicrobial activity. Both alcoholic and aqueous extract phenolic compound contents of date seeds are higher than those of coffee. Moreover, the phenolic compound content of alternative coffee samples increased significantly compared to that of original coffee powder as a result of the use of DSP. Free phenols extracted in ethanol ranged from 28.78 to 37.45mg/g gallic acid equivalent, while bound phenols ranged from 1.88 to 5.74mg/g gallic acid equivalent. Meanwhile, aqueous phenolic compounds ranged from 16.09 to 28.93mg/g gallic acid equivalent. Swaidan et al. (2024) reported that Kabkab seed had the greatest TPC value (271.2mg GAE/g), and Majdool seed had the lowest value (63.2mg GAE/g), suggesting that the phenolic content of the date seed was strongly dependent on the variety. Additionally, Selim et al. (2022) reported that the total phenolic content of date pits was 24.84mg GA/g. The total phenolic content extracted using methanol and ethyl acetate extracts of seven Algerian date pits ranged from 27.2 to 38.5mg CAE/100g and 27.2 to 38.5mg CAE/100g, respectively (Messaoudi et al., 2013). The findings indicate that DSP are favorable when added to produce alternative coffee. Even when comparing studies that looked at the same variety, it was found that the total phenolic content varied significantly. This can be due to the fact that most prior research used solvents other than distilled water to extract polyphenols from date seeds. Additionally, due to variations in variety and origin, the overall composition and total phenolic content can vary, just like with many other plants and fruit seeds. Furthermore, a number of variables, such as geographical location, irrigation, harvest time, post-harvest treatment, extraction techniques, maturity, climate, and experimental conditions, can influence these results (Selim et al., 2022). Regarding flavonoids, the data in Table 3 show that the flavonoid content followed the same pattern as phenolic compounds.

Table 3. Total phenolics, total flavonoids and tannins content of date seed powder, coffee and alternative coffee (mg/g) (mean±SD).

Samples	Phenolic compounds (as gallic acid)			Flavonoid compounds (as quercetin)			Tannins
	Free Ethanol extract	Bound Ethanol extract	Water extract	Free Ethanol extract	Bound Ethanol extract	Water Extract	
T1 (DSP)	37.45^{Aa}±0.183	5.74^{Ca}±0.036	28.93^{Ba}±0.554	23.37^{Aa}±0.319	2.47^{Ba}±0.715	20.62^{Ba}±0.087	1.71^{a}±0.056
T2 (Coffee)	20.53^{Ag}±0.218	1.88^{Cg}±0.069	16.09^{Be}±0.299	12.59^{Ag}±0.037	0.49^{Cc}±0.080	12.10^{Bc}±0.055	0.71^{f}±0.021
T3	34.42^{Ab}±0.171	4.64^{Cb}±0.038	26.16^{Bb}±0.064	20.97^{Ab}±0.196	2.16^{Ba}±0.146	17.13^{Bb}±0.022	1.58^{b}±0.107
T4	33.06^{Ac}±0.264	4.49^{Cc}±0.115	25.97^{Bb}±0.033	17.15^{Ac}±0.131	1.99^{Ca}±0.125	16.62^{Bb}±0.010	1.42^{c}±0.011
T5	31.85^{Ad}±0.085	3.80^{Cd}±0.023	23.03^{Bc}±0.022	16.41^{Ad}±0.107	1.77^{Bab}±0.123	16.51^{Ab}±0.006	1.34^{c}±0.046
T6	29.81^{Ae}±0.118	3.35^{Ce}±0.021	22.92^{Bc}±0.058	15.58^{Ae}±0.011	1.73^{Cab}±0.245	15.26^{Bbc}±0.012	1.22^{d}±0.028
T7	28.78^{Af}±0.057	3.21^{Cf}±0.052	21.11^{Bd}±0.027	13.44^{Af}±0.141	1.10^{Bb}±0.412	14.29^{Abc}±0.015	1.06^{e}±0.014

There is no significant difference (P>0.05) between any two means, within the same raw have the same superscript A, B and C letter.

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The results showed that there are significant differences between aqueous and alcoholic extracts ($p < 0.05$). The ethanol extract of date seed powder reached 23.37mg/g, and the ethanolic extract of coffee was 12.59mg/g, while flavonoid in alternative coffee ranged from 13.44 to 20.97mg/g. The water extract varied from 14.29 to 17.13mg/g compared to DSP and coffee powder (20.62 and 12.10 mg/g, respectively). Al Ghezi et al. (2020) showed that the aqueous extract of the flavonoid content of DSP ranged from 22.12 to 33.32mg/mL, and the methanolic extracts ranged from 35.11 to 46.16mg/mL. From the results shown, the aqueous extract from DSP has the highest total phenolics and flavonoids compared to coffee powder. According to the data presented above, employing DSP increased the amount of phenolic compounds in alternative coffee when compared to coffee powder. In general, as the concentration of DSP decreased, the phenolic and flavonoid content also decreased. Date seed powder had the highest value of phenolic and flavonoid content. Moreover, El Sheikh et al. (2014) mentioned that DSP has shown some bioactive properties, including the treatment of neurodegenerative diseases and colon cancer, because they contain high amounts of phenols and antioxidants. It can be concluded that DSP represent a good source of bioactive compounds. Algarni (2020) reported that the total phenol content and total flavonoid compounds were 13.20mg/g gallic acid equivalent and 5.15mg/g quercetin equivalent, respectively. The processes of extraction, purification, and roasting, which enhance the release of phenolic acids, could account for the variation. The difference between results was due to the phenolic content, which can be affected by several production-specific factors, such as the cultivar, fruit maturity, growing conditions, season, and soil type. Additionally, the final measured results may be skewed by the choice of extraction conditions (Al Juhaimi et al., 2018). Approximately 1–2% of the total phenolic content (TPC) is flavonoids, and they contribute proportionally to the antioxidant activity (Kiesler et al., 2024). Tannin content was the highest in DSP (1.71mg/g) compared to coffee (0.71mg/g). It dectreased from T3 to T7 due to a decrease in the substitution of DSP by different concentrations of coffee. According to Hossain et al. (2014), date seeds may be used as a dietary supplement to treat several types of chronic conditions, including renal stones, bronchial asthma, coughing, hyperactivity, and memory loss. They may also help lower blood pressure, relax the uterine and intestinal muscles, build body protein by reducing body fat, normalize blood sugar, and soothe the pancreas.

Antioxidant activity% (DPPH) of date seed powder, coffee and alternative coffee

Date seed drink could potentially be beneficial for scavenging free radicals due to its phytochemical components (Abdelaziz and Ali, 2014; Bouhlali et al., 2017). According to Al Juhaimi et al. (2018), date seeds' powder highly potent antioxidant activity is associated with their high phenolic content. Additionally, Zarie et al. (2023) reported that the ethanolic extract of DSP showed the highest phenolic compound content and antioxidant activity. The primary cause of polyphenols' antioxidant activity is their redox characteristics, which enable them to function as hydrogen donors and reducing agents. However, according to a study by Gawron-Gzella et al. (2012), the presence of additional antioxidant secondary metabolites, such as carotenoids and vitamins, may also contribute to the antioxidant activity in extracts. Figure 3 shows that date seed powder and alternative coffee had the highest values of radical scavenging activity compared to coffee, which is due to their high content of phenolic and flavonoid compounds. These compounds possess hydroxyl groups and can donate electrons to free radicals. The concentration of phenolic compounds and phenolic acids, as well as the strongest antiradical activity, were obtained using hot water extraction, producing a product with high antioxidant activity. Using water as an extraction solvent is ideal for making herbal infusions and teas at home (Gawron-Gzella et al., 2012).

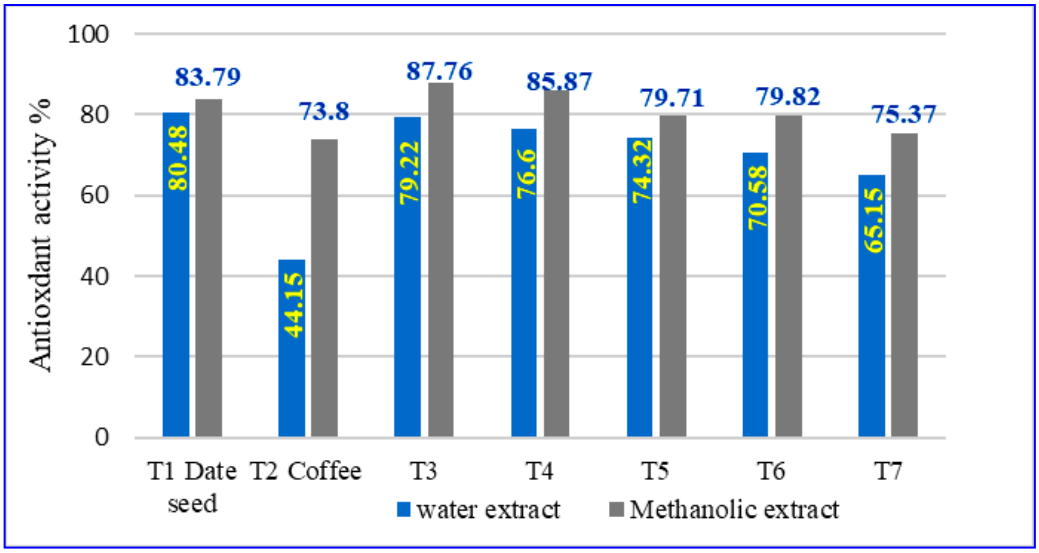

Figure 3. DPPH radical scavenging activity % of the date seed, coffee and alternative coffee

Conversely, the activity to scavenge decreased in alternative coffee as the concentration of DSP decreased. The antioxidant effects of date seeds could be exploited either through the use of date seeds or through their use in powdered form. In both cases, the use of date seed would have a positive impact on food by delaying oxidation processes and improving the stain of color and flavors (Aminzare et al., 2019). In addition, the use of date seed has potential health benefits, such as lowering plasma triglyceride and total cholesterol levels, protecting against diabetes, liver disease, and gastrointestinal problems, and having antigenotoxic and anti-inflammatory properties (Al-Alawi et al., 2017).

Physical properties of date seed powder, coffee and alternative coffee

The physical properties of DSP, coffee, and alternative coffee focus on bulk density, tapped density, solubility, hygroscopicity, cohesiveness, compressibility, and flowability. Understanding these characteristics is essential for evaluating the quality and usability of coffee products. Bulk density is a critical characteristic of substances such as powders, granules, and other particles like solid substances. It refers to the mass of the coffee sample per unit volume. The bulk and tapped density values of DSP, coffee, and alternative coffee powders are shown in Table 4. The bulk and tapped densities of date seed powder (0.557–0.652g/mL) were found to be significantly higher than those of coffee powder (0.497–0.533g/mL). For alternative coffee powders, bulk and tapped densities decreased significantly with an increase in coffee substitution. Thus, it can be said that coffee particles are finer than the particles of date seed powder. Higher bulk density often indicates a more compact material, which can affect packaging and transport efficiency. Tapped density is a very popular measure for powder characterization because of its simplicity and the rapidity of the measurement. The ability of a powder sample to pack under taps gives a measure of the powder's cohesiveness, which can be linked to its flowability (Mehrabi et al., 2023). According data of the same table, coffee had a higher solubility (25.50%) than DSP (8.21%) in water, and this solubility was influenced by moisture, dry matter, processing, density, and particle size (Rahman, 2007). Additionally, the solubility of alternative coffee increased with the level of substitution of coffee powder from 10 to 50% in samples T3 to T7, respectively. Furthermore, decreasing the moisture content increased the solubility (Nakilcioğlu-Taş and Otleş, 2019). Increased hygroscopicity, which is related to adsorbing water from air humidity, causes varying deterioration in product properties, such as caking formation, and decreases flowability. The hygroscopicity of coffee was 9.38%, higher than that of DSP (7.37%).

Data showed an increase in hygroscopicity with decreasing DSP level and reducing the moisture content of alternative coffee as a result of increasing coffee substitution (Rebolledo-Hernández et al., 2023). Additionally, increasing the roasting process of coffee increases the adsorption of water and porosity properties.

Table 4. Physical properties of date seed powder, coffee and alternative coffee

Samples	Physical characteristics						
	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Solubility %	Hygroscopicity %	Cohesiveness (HR)	Compressibility (CI)	Flowability
T1 (DSP)	$0.557^{a}\pm0.012$	$0.652^{b}\pm0.014$	$8.21^{d}\pm0.176$	$7.37^{e}\pm0.146$	$1.17^{b}\pm0.018$	$14.57^{b}\pm0.420$	Good
T2 (Coffee)	$0.497^{b}\pm0.027$	$0.533^{cd}\pm0.016$	$25.50^{a}\pm0.366$	$9.38^{a}\pm0.062$	$1.07^{d}\pm0.025$	$6.75^{c}\pm0.550$	Excellent
T3	$0.547^{a}\pm0.006$	$0.698^{a}\pm0.040$	$7.90^{d}\pm0.219$	$7.27^{e}\pm0.110$	$1.28^{a}\pm0.079$	$21.63^{a}\pm0.320$	Passable
T4	$0.497^{b}\pm0.012$	$0.632^{b}\pm0.029$	$11.01^{cd}\pm0.602$	$7.68^{d}\pm0.066$	$1.27^{a}\pm0.058$	$21.36^{a}\pm0.329$	Passable
T5	$0.487^{b}\pm0.021$	$0.567^{c}\pm0.015$	$12.42^{bc}\pm0.550$	$7.83^{cd}\pm0.072$	$1.16^{bc}\pm0.056$	$14.11^{b}\pm0.176$	Good
T6	$0.480^{bc}\pm0.017$	$0.541^{c}\pm0.007$	$13.65^{bc}\pm0.394$	$7.97^{c}\pm0.081$	$1.13^{bcd}\pm0.054$	$11.28^{bc}\pm0.181$	Good
T7	$0.457^{c}\pm0.006$	$0.493^{d}\pm0.019$	$16.32^{b}\pm0.358$	$8.56^{b}\pm0.132$	$1.08^{d}\pm0.036$	$7.30^{c}\pm0.212$	Excellent

There is no significant difference (P>0.05) between any two means, within the same column have the same superscript a, b and c letter.

The free-flow properties are used to estimate the flowability. For packing, handling, measurement, shipping, bag filling and emptying, storage, dosing purposes, and selecting parameters for mixing and conditioning, the producer and the final consumer depend on the proper flow of powders (Caliskan and Dirim, 2016). The flowability and cohesiveness properties of all treatments, as measured by the Carr index and Hausner ratio, were determined. The Carr index and Hausner ratio of coffee and DSP are 6.75 and 1.07 (excellent) and 14.75 and 1.17 (good), respectively. The higher Hausner ratio of DSP means that the powder is more cohesive and less able to flow smoothly, compared to coffee, which has excellent flowability.T3 and T4 treatments, with 90% and 80% DSP content mixed with 10% and 20% coffee powder, respectively, showed passable flowability. For T5 and T6, increasing the coffee concentration from 30% to 40% resulted in good flowability behavior. Finally, when the coffee level reached 50% with 50% DSP (T7), the mixture exhibited excellent flowability and cohesiveness. The reduction in moisture content may contribute to increased flowability. According to Iqbal and Fitzpatrick (2008), increased moisture content in powders has been shown to increase particle cohesiveness, which reduces flowability.

Sensory properties of date seed powder, coffee and alternative coffee drink

The main characteristic of coffee is its flavor, which varies from the initial impressions provided by its aroma and acidity to the final aftertaste. Regarding the aroma, it is known for the coffee after it has been infused with hot water, while the fragrance of the ground coffee which sniffing when it is still dry is known as its fragrance. The data from Table 5 clearly shows that the sensory characteristics of the DSP drink are significantly different from those of traditional coffee, as highlighted in the cupping assessment conducted according to the SCAA (2015). The sensory attributes, including flavor, fragrance, aftertaste, acidity, body, clean cup, uniformity, and overall palatability of all samples, were evaluated. The findings showed that there were significant differences due to the addition of coffee to date seed powder compared to premium coffee as a control sample.

Table 5. Sensory evaluation of date seed, coffee and alternative coffee drinks

Samples	Attributes									
	Flavor (10)	Fragrance and Aroma (10)	Aftertaste (10)	Acidity (10)	Body (10)	Clean cup (10)	Uniformity (10)	Overall Palatability (10)	Final score%	Classification
T1 (DSP)	$6.15^{c}\pm0.284$	$5.90^{c}\pm0.575$	$5.95^{b}\pm0.462$	$6.30^{b}\pm0.789$	$6.35^{e}\pm0.860$	$6.25^{c}\pm0.677$	$5.90^{d}\pm0.888$	$6.08^{e}\pm0.336$	61.1	Exchange Grade
T2 (Coffee)	$8.30^{a}\pm0.856$	$8.10^{a}\pm0.738$	$8.00^{a}\pm0.624$	$7.85^{a}\pm0.914$	$8.14^{a}\pm0.524$	$7.90^{a}\pm0.775$	$8.85^{a}\pm0.818$	$8.16^{a}\pm0.292$	81.6	Premium
T3	$5.80^{c}\pm0.753$	$6.70^{b}\pm0.919$	$6.15^{b}\pm0.626$	$5.60^{b}\pm0.738$	$6.47^{de}\pm0.264$	$6.50^{bc}\pm0.471$	$6.50^{cd}\pm0.577$	$6.24^{e}\pm0.319$	62.5	Exchange Grade
T4	$6.05^{c}\pm0.798$	$7.10^{ab}\pm0.775$	$7.75^{a}\pm0.635$	$6.40^{b}\pm0.738$	$6.85^{cde}\pm0.374$	$6.70^{bc}\pm0.919$	$6.47^{cd}\pm0.264$	$6.76^{d}\pm0.271$	67.6	Exchange Grade
T5	$6.15^{c}\pm0.966$	$7.70^{a}\pm0.715$	$7.75^{a}\pm0.425$	$6.20^{b}\pm0.789$	$7.01^{cd}\pm0.582$	$7.2^{abc}\pm0.753$	$7.01^{bc}\pm0.427$	$6.74^{d}\pm0.314$	69.7	Exchange Grade
T6	$7.10^{b}\pm0.775$	$7.80^{a}\pm0.753$	$7.55^{a}\pm0.798$	$7.75^{a}\pm0.677$	$7.20^{bc}\pm0.425$	$7.60^{ab}\pm0.472$	$7.75^{b}\pm0.738$	$7.53^{c}\pm0.323$	75.4	Usual Good Quality
T7	$8.25^{a}\pm0.677$	$8.00^{a}\pm0.615$	$8.00^{a}\pm0.624$	$7.90^{a}\pm0.876$	$7.59^{b}\pm0.383$	$7.65^{ab}\pm0.337$	$7.80^{b}\pm0.715$	$7.85^{b}\pm0.245$	78.8	Usual Good Quality
LSD	0.719	0.784	0.663	0.708	0.468	0.829	0.669	0.357	-	-

There is no significant difference (P>0.05) between any two means, within the same column have the same superscript a, b and c letter.

The cupping attributes revealed that the individual DSP had a low final score (61.1%) from cuppers compared to other samples, so it was classified as Exchange Grade. In contrast, coffee powder had a final score of 81.6% and was classified as Premium. Additionally, the alternative coffee samples T3, T4, and T5 had final scores of 62.5%, 67.6%, and 69.7%, respectively, and were also classified as Exchange Grade. Furthermore, the data showed there were no significant differences in flavor and acidity between T3, T4, and T5 compared to date seed. Regarding fragrance and aftertaste, these findings indicated that the slight increase in all samples was due to the increased levels of substitution from premium coffee powder. Meanwhile, the alternative samples T6 and T7, with up to 40% and 50% substitution with premium coffee, were the most desirable. The data showed that there were no significant differences in fragrance, aftertaste, acidity, and clean cup between T6, T7 and coffee powder. The sensory quality results indicate that an increased addition level of coffee from 10% to 50% could improve the flavor and fragrance, as well as other attributes. The final scores increased for T6 and T7 (75.4% and 78.8%) respectively, with increasing coffee concentration, which confirmed greater acceptability to the cuppers, resulting in their classification as Usual Good Quality. Finally, the results of the sensory evaluation suggest that DSP can achieve a desired success and be used as a natural substitute of coffee to produce decaffeinated and less caffeinated coffee compared to premium coffee drinks. This promotes a reduction in the adverse impacts of caffeine consumption while allowing consumers to enjoy the fragrance and flavor of coffee.

4. Conclusion

In conclusion, date seeds are a valuable byproduct of the date industry, owing to their rich content of polyphenols, flavonoids, antioxidants, dietary fiber, and other beneficial compounds. Utilizing these readily available date seeds also contributes to environmental conservation and pollution reduction. The results demonstrate that roasted date seed powder can be effectively used as a functional caffeine-free beverage or as a substitute for coffee (10-50%) to produce low-caffeine coffee alternatives. These caffeine-free and low-caffeine alternatives significantly enhance the economic aspects of coffee production and mitigate the negative side effects of excessive caffeine consumption, particularly for caffeine-sensitive individuals. Additionally, the heavy metal analysis confirmed that date seed-based coffee formulations remained within safe consumption limits. Date seed coffee alternatives T6 (40% coffee + 60% date seed powder) and T7 (50% coffee + 50% date seed powder) were identified as the best blends through cupping evaluation, achieving scores of 75.4% and 78.8%, respectively, and were categorized as Usual Good Quality. Moreover, date seed powder alone, as a functional caffeine-free coffee alternative, received a score of 61.1% in cupping evaluation and was classified as Exchange Grade, which could adequately satisfy highly sensitive caffeine consumers.

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