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The organoleptic and nutritional characteristics of innovative high-fiber khalas date-based bar

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PAPER

Abstract

Making functional and nutritionally balanced date bars is of innovative concern. The current study intends to create a novel high-fiber and nutritious Khalas date-based bar (KDBB). The proximate composition, mineral contents, sugar profile, amino and fatty acids profile, volatiles and phytochemicals, antioxidant activity, and an *in vitro* digestion of protein and carbohydrates for bar formula containing 50% Khalas dates (KD) were investigated. Results indicated that protein, fat, ash, fiber, available carbohydrates, and vitamin C were 9.34, 4.93, 2.05, 8.01, 54.04 g 100 g^{-1}, and 16.67 mg, respectively. Potassium, magnesium, phosphorus, and calcium were present in abundance. Sucrose had the highest sugar concentration at 246.35 mg g^{-1}. Total phenolic content (TPC) was 547.19 mg gallic acid equivalent 100 g^{-1}, giving 719.39 and 815.98 µmol of *Trolox equivalent* (TE) 100 g^{-1} for 2,2-diphenylpicrylhy-drazyl radical scavenging activity (DPPH-RSA) and 2,2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS)-RSA, respectively. Total carotenoids, flavonoids, and flavonols were 327.19 mg 100 g^{-1}, 998.25 mg quercetin equivalent 100 g^{-1}, and 749.57 mg QE 100 g^{-1}, respectively. The highest discovered phenolics, flavonoids, and isoflavone were pyrocatechol (10249.73 µg g^{-1}), catechin (193.50 µg g^{-1}), and daidzein (18.77 µg g^{-1}), respectively. Lysine was the highest among the essential amino acids. Saturated and unsaturated fatty acids were 43.73% and 56.27%, respectively. The omega-6 fatty acid, *cis*-8,11,14-eicosatrienoic, was predominant with a 31.08% valuation. The gas chromatography–mass spectrometry analysis identified 17 compounds, with a predominant presence of 9,12-octadecadienoyl chloride (38.13 g 100 g^{-1}). The glycemic index (GI) of KDBB was 39.97, which was lower than KD's score (54.12). In conclusion, prepared KDBB could present a good idea for consuming dates and the based products with high fiber content and lower GI. Scaling up such products could be helpful to health-conscious individuals.

Keywords: food supply; functional foods; glycemic index; healthy snacks; innovative high-fiber; nutrition

Introduction

The date palm tree (*Phoenix dactylifera* L., family Arecaceae) has been recognized for a long as an important contributor to the regional economy and food supply in the Middle East and North Africa (Al-Shahib and Marshall, 2003). Saudi Arabia (SA) supplies almost 16% of the world's date fruit demand, growing 450 date palm cultivars, while Egypt is the first date producer with 18% of world production (Parn *et al.*, 2015). Most of these commodities meet global premium quality standards; 10–15% of low-grade fruits are unmarketable and offered at low prices (National Center for Palm and Dates [NCPD], 2018). Therefore, these are used in numerous food products, such as energy bars, which have gained popularity (Al-Shahib and Marshall, 2003; Barakat and Alfheeaid, 2023; Parn *et al.*, 2015). Dates are essential for date pastes and date syrup in the confectionery and alcoholic

beverage industries (Samarawira, 1983). It's also a good source of vitamins A and C as well as vitamins B such as thiamine and riboflavin (Al-Farsi *et al.*, 2005; Al-Shahib and Marshall, 2003), boost antioxidants (Benmeddour *et al.*, 2013; Suresh *et al.*, 2013), and anticancer (Ishurd and Kennedy, 2005) and antiviral (Vayalil, 2002) activities. Date fruits have a relatively high carbohydrate and ash contents (71.2–81.4% and 1.68–3.94%, respectively) and low fat and protein contents (0.12–0.72% and 1.72–4.73%, respectively) on dry weight (DW) base (Amira *et al.*, 2011; Assirey, 2015). Date flesh is a rich source of fructose, glucose, sucrose, dietary fiber (5–8.5%), and polyphenols (Al-Farsi *et al.*, 2007; Elleuch *et al.*, 2008). The most common date fruits produced in Saudi Arabia are Sukkari, Barhi, Khalas varieties, and various date varieties depending on regions (NCPD, 2018). Al-Harrasi *et al.* (2014) revealed 78–86 g 100 g^{-1} dry matter (DM), 1.0–2.0 g 100 g^{-1} ash, 1.0–2.5 g 100 g^{-1} fiber, 0.1–0.7 g 100 g^{-1} fat, 1.8–3.8 g 100 g^{-1} proteins, 74.5–82.4 g 100 g^{-1} carbohydrates, and 307–345.5 kcal 100 g^{-1} of energy. In addition, Ali *et al.* (2009) demonstrated that Khalas date contains 70.99–75.37% carbohydrates, 1.85–2.07% fiber, 1.31–1.39% total fats, 1.28–1.87% proteins, 1.12–1.31% ash, and 18.77–22.74% moisture, providing 302–319 kcal 100 g^{-1} of energy. The authors also found 54.98–59.96 g 100 g^{-1} sugars consisting of 30.67–33.97 g 100 g^{-1} glucose, 22.00–23.65 g 100 g^{-1} fructose, and 1.92–2.34 g 100 g^{-1} sucrose. The glycemic index (GI) of Khalas dates ranged from 49.9–55.6 (Ali *et al.*, 2009). Moreover, dates contain phytochemicals (Al-Harrasi *et al.*, 2014; Ali *et al.*, 2009; Vayalil, 2012), possessing beneficial nutritional and therapeutic characteristics (Barakat and Alfheeaid, 2023).

Date-based bars (DBBs) are a convenient alternative for consuming dates, mainly when the latter are out of season. Demand for DBB can be met both domestically and internationally, even in locations where the fruit is not grown (Sawaya *et al.*, 1982). Recently, there has been a rise in the consumption of healthy snack bars produced from various fruits (Parn *et al.*, 2015; Vijayanand *et al.*, 2000). The available fruit-based bars have great macro-, micro-, dietary fiber, and phytonutrient contents and seem an ideal rapid food option (Sun-Waterhouse *et al.*, 2010). A few studies showed that making distinct DBBs could be valuable and practical (Barakat and Alfheeaid, 2023; Ibrahim *et al.*, 2021; Shaheen *et al.*, 2013). Data analysis indicated that DBB might be required to satisfy the needs of health-conscious consumers (Al-Shahib and Marshall, 2003; Ayad *et al.*, 2020). This DBB is anticipated to achieve greater international marketability (Ayad *et al.*, 2020; Parn *et al.*, 2015). Indeed, researchers worldwide have tried countless varieties of DBBs. Kamel and Kramer (1977) have formulated date bars using skimmed milk powder, single-cell protein, and walnuts. Innovative bars were also prepared using yeast protein, soy protein isolate, and skimmed milk powder (Khalil *et al.*, 1984). Owing to its promising results in the food sector, milk powder was frequently utilized in the following investigation (Hoppe *et al.*, 2008). In contrast, skimmed milk powder has been combined with oat flakes, sesame seeds, and almonds (Al-Hooti *et al.*, 1997). Interestingly, Al-Hooti *et al.* (1997) tested four distinct types of dates (Bushibal, Gash Gaafar, Lulu, and Shahla) and found that they varied in mineral content, as the proximate composition was shown to be considerably different in a separate investigation conducted by Nabtat Ali and Sukkari (Parn *et al.*, 2015). Nut flour, almond flour, and almond milk powder were used to manufacture date bars (Brufau *et al.*, 2006). Ingredients such as chickpeas, oats, and soy flour were added (Rehman *et al.*, 2020). In a similar formulation of date bars, Munir *et al.* (2018) utilized roasted oatmeal flour, chickpea flour, skimmed milk powder, almonds, pistachios, cardamom, and carboxymethyl cellulose (CBC). Recently, cheddar cheese and whey protein isolate were tried with roasted chickpea flour, rice flour, and dried apricots (Jabeen *et al.*, 2020, 2022). Adding healthful components improves date bars. Recently, researchers have tested Sukkari date bars with varied amounts of germinated flax seed powder (Alhomaid *et al.*, 2022).

Based on the above-mentioned formulations, making functional and nutritionally balanced date bars appears challenging. Because dates are protein-poor, traditional formulations with enriched protein are used to create nutritionally complete and protein-rich bars. To maximize date consumption by both healthy and sick individuals, consider making a low-carb, high-fiber bar with antioxidants and β-glucans. Therefore, this study aimed to develop a unique Khalas date-based high-fiber nutritious bar. This innovative high-fiber Khalas date-based bar (KDBB) was studied for its proximate composition, mineral content, sugar profile, amino and fatty acid (FA) profiles, volatiles and phytochemicals, and antioxidant activity (AOA); an *in vitro* digestion model was used for proteins and carbohydrates.

Materials and Methods

Ingredients

Ingredients, such as Khalas dates paste (80 g carbohydrates, 2.8 g fiber, and 2.8 g protein), whole oat flour (10.5 g protein, 70.5 g total carbohydrates, 10.8 g dietary fiber, and 9.3 g total fat per 100 g), Khalas dates syrup (75 g carbohydrates, 1.4 g fiber, and 2.5 g protein), skimmed milk powder (1.25% fat, 33% protein, 54% lactose, 4% moisture, and 8% ash), sesame seeds, roasted cashew, ground walnuts, coconut powder, cow's ghee, peanut butter (total fat 14 g, total carbohydrates 6.5 g, 1.5 g fiber, and 8 g protein per 30 g), soy lecithin, baking powder, and edible salt, were obtained from Al-Tamimi Market

(https://www.tamimimarkets.com) in the Al Qassim region of Saudi Arabia. Oat fiber (NuNaturals, OR, USA) was ordered online from iHerb (https://sa.iherb.com).

Manufacturing of KDBB

The procedure of Ibrahim *et al.* (2021) was modified depending on the raw ingredients given in Table 1. First, roasted cashews, walnuts, and whole oats were crunched lightly using Severin, type Km 3871 (Mecklenburg, Germany) at speed 3 for 30 s. Second, dried ingredients, such as sesame seeds, ground walnuts, roasted cashew, whole oat powder, oat fiber, skimmed milk powder, and salt, were roasted with continuous stirring in an air-heated oven at 200°C for 5 min; then coconut powder was added. The whole mix was stirred for 2 min to prepare mix 1. Third, other ingredients, such as date paste, cow's ghee, and peanut butter, were warmed for 5 min in an air-heated oven at 120°C for 5 min to prepare mix 2. Fourth, Khalas dates syrup and lecithin were vigorously mixed with continuous heating till a completely homogeneous solution was formed. The heating supply was stopped, baking powder was added, and the mix was gently homogenized to prepare mix 3. For KDBB formulation, mix 2 was added to combine three and homogenated, then mix 1 was added till a dough-like texture was obtained. After 10 min, the mixture was shaped similarly using a straight-holed frame (Figure 1) and cooled down at 4±1°C for further analysis or utilization.

Sensory evaluation

The freshly prepared bars were evaluated organoleptically using a 9-point hedonic scale for consumer acceptance testing, from 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Twelve trained panelists received KDBB prepared from various formulations. Appearance, taste, color, odor, texture, mouthfeel, and overall acceptability were examined. The sensory evaluations were carried out in a specially equipped laboratory at the Department of Food Sciences and Human Nutrition, College of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia, at 20±1°C temperature; potable water was provided for each panelist as a taste purifier between samples tasting (Gámbaro and McSweeney, 2020).

Table 1. Raw ingredients of high-fiber KDBB formula (g 100 g^{-1})

Ingredients	KDBB1	KDBB2	KDBB3
Khalas date paste	40.0	50.0	60.0
Whole oat flour	15.0	10.0	5.0
Khalas date syrup	7.0	6.0	5.0
Skimmed milk powder	6.0	4.0	2.0
Oat fiber	6.0	4.0	2.0
Sesame seeds	5.0	5.0	5.0
Cow's ghee	5.0	5.0	5.0
Roasted cashew	4.0	4.0	4.0
Peanut butter	3.0	3.0	3.0
Ground walnuts	3.0	3.0	3.0
Coconut powder	3.0	3.0	3.0
Baking powder	1.5	1.5	1.5
Soylecithin	1.0	1.0	1.0
Edible salt (NaCl)	0.5	0.5	0.5

Figure 1. Formulated high-fiber KDBB2 containing 50% Khalas date (KD).

Proximate chemical composition and minerals content in KDBB

The formulated KDBB was subjected to chemical analysis, such as moisture (method No. 934.01), crude protein (method No. 990.03), crude lipids (method No. 920.39), ash (method No. 923.03), dietary fiber (method No. 978.10), available carbohydrates (by difference), and energy value, according to the methods reported by the Association of Official Analytical Chemists (AOAC, 2012). According to Nielsen (2017), the ascorbic acid content of extracts was determined using the 2,6-dichlorophenolindophenol (DCPIP) dye by titration method. The content of minerals, such as sodium (Na) and potassium (K), was discovered using flame photometry (PFP 7 model Jenway 8515, Ferry Street, London, E14 3BS UK) applying the AOAC (2012) method No. 956.01. In contrast, calcium (Ca), magnesium (Mg), iron Fe), copper (Cu), manganese (Mn), and zinc (Zn) contents were analyzed using atomic absorption spectroscopy (Perkin-ELMER, 2380, UK) using the AOAC (2012) method No. 968.08. In addition, a standard colorimetric method was employed for phosphorus (Ph), as mentioned by Borah *et al.* (2009).

Sugars profile of KDBB

The formulated KDBB was subjected to sugar profile analysis, such as fucose, fructose, sucrose, arabinose, rafinose, zylose, galactose, lactose, cellobiose, and glucose contents according to the method described in AOAC (2012).

Phytochemicals analysis of KDBB

Total phenolic compounds (TPC) in KDBB were determined using the Folin–Ciocalteau method, and TPC was expressed as milligram gallic acid equivalents (mg gallic acid equivalent [GAE] 100 g^{-1} DW) according to the method described by Bettaieb *et al.* (2010). Content of total carotenoids (TCs) was determined colorimetrically according to the modified method described by Khalifa *et al.* (2016). The antioxidant activity as 2,2-diphenylpicrylhy-drazyl radical scavenging activity (DPPH-RSA) was determined colorimetrically using DPPH radicals. The DPPH-free radical inhibition percentage was calculated; the results were interpreted by plotting the Trolox standard and presented as μmol TE g^{-1} DW (Zhang and Hamauzu, 2004). Contents of total flavonoid (TFs) and total flavonols (TFLs) were determined, and the results were presented as mg quercetin equivalent (QE) g^{-1} using the methods described by Barakat and Almundarij (2020) and Kumaran and Karunakaran (2007), respectively.

Quantification of Phenolic Compounds in KDBB by high-performance liquid chromatography with diode-array detection (HPLC-DAD)

Phenolic compounds in KDBB were determined by the HPLC system HP1100 (Agilent Technologies, Palo Alto, CA, USA) equipped with an autosampler, quaternary pump, and diode array detector (DAD; Hewlett Packard 1050), using a column (Altima C18, 5x 150 mm, 4.6-mm ID) and a guard column Altima C18, 5 mm (Alltech) as described by Kim *et al.*(2006). The solvent system contained a gradient of 95% (A) 2.5% acetic acid in water, 5% (B) 8% acetic acid in water, and (C) acetonitrile was applied. The 10 μL of prepared sample extract was automatically injected, the flow rate was adjusted to 1 mL min^{-1}, and separation was performed at 25°C. Chromatograms were recorded at 280, 320, and 360 nm. The peaks of identified phenolic compounds were quantified as μg g^{-1} by comparing the results with a built-in library.

Quantification of Volatile Components in KDBB by Gas chromatography–Mass Spectrometry (GC-MS)

For this GC-MS study, we used a Thermo Scientific Trace GC Ultra/ISQ Single Quadrupole MS equipped with a TG-5MS fused silica capillary column (30-m, 0.251-mm, 0.1-mm film thickness). The electron ionization system used for GC-MS detection had an ionization energy of 70 eV. The carrier gas was helium (He), flowing at a rate of 1 mL min^{-1}. The injector and MS transfer line temperature was set at 280°C. Starting with 50°C, the temperature of the oven was set to rise to 150°C at a rate of 7°C min^{-1} (hold for 2 min), then to 270°C at a rate of 5°C min^{-1} (hold for 2 min), and finally to 310°C at a rate of 3.5°C min^{-1} as the final temperature (hold for 10 min). Calculating the relative peak area as a percentage allowed us to probe the indicated components' quantification. According to Odeh and Allaf (2017) the tentative identification of compounds was accomplished by comparing their relative retention periods and mass spectra with the GC-MS system's NIST and WILLY library data.

Determination of amino acid profile in KDBB

The amino acids profiles of DBB and FBB were determined using HPLC-PICO-TAY upon hydrolysis under acidic conditions in evacuated ampoules at 110°C for 24 h. Quantitative determination of amino acids was carried out according to Cohen *et al.* (1989). According to Blouth *et al.* (1962), tryptophan was colorimetrically measured in alkaline hydrolysate. The predicted biological value (BV) and amino acids score, according to the World Health Organization (WHO, 2007), were calculated as described by Chavan *et al.* (2001) using the following equations:

$$BV = 10^{2.15} \times q_{Lys}^{0.41} \times q_{Phe+Tys}^{0.60} \times q_{Met+Cys}^{0.77} \times q_{Thr}^{2.4} \times q_{Trp}^{0.21}$$

Where,

$$q = \frac{a_i \text{Sample}}{a_i \text{Reference}} \text{ for } ai \text{ samples} \leq ai \text{ reference}$$

$$q = \frac{a_i \text{Reference}}{a_i \text{Sample}} \text{ for } ai \text{ samples} \geq ai \text{ reference}$$

ai = milligram of the amino acid per gram of total essential amino acid (EAA)

$$\frac{\text{Amino acid}}{\text{score}} = \frac{\text{mg of the amino acid per test protein}}{\frac{\text{mg of amino acid per g of FAO}}{\text{WHO standard pattern}}} \times 100 \quad (2)$$

Determination of fatty acids profile in KDBB

Total fatty acid fractions were methylated, according to Petrović *et al.* (2010). The methyl esters of fatty acids obtained from KDBB were determined using gas–liquid chromatography (GLC) equipped with a deep flow inspection (DFI) detector. GLC conditions were updated using an incremental elevated temperature program from 100°C to 200°C at different periods followed by 10 min, from 2°C min^{-1} to 230°C min^{-1}, then held for 10 min; injection temperature was 250°C, and the detector temperature was 300°C. GC method for determining fatty acid methyl esters was subjected to a validation process. Results were evaluated with a conventional integrator program (Saturn

GC Workstation Software ver. 5.51). Quantifying of individual fatty acids was based on the obtained peak area normalized results, and no correction factor was used.

Analysis of *in vitro* glycemic index and hydrolysis index (HI)

In vitro GI determination in Khalas date fruits and KDBB was applied using the method described by Aribas *et al.* (2020) with some modifications. Briefly, 0.1 g of each sample was weighed in a 50 mL falcon tube. Then, 2 mL of HCl (0.05 M) containing pepsin (0.117 g/mL; Sigma, P3000) was added to the tubes, which were incubated at 37°C in a shaking water bath for 30 min. Sodium acetate buffer (4 mL, 0.5 M, pH 5.2), 1 mL of enzyme solution containing 0.243 g pancreatin (Sigma, P3000), and 14.45 U (56 µL) amyloglucosidase from *Aspergillus niger* (260 U mL^{-1}; Sigma) were added to each tube. The tubes were incubated horizontally at 37°C in a shaking water bath. Aliquots (100 µL) from the prepared tubes were taken into Eppendorf tubes at 20 min intervals for 180 min before mixing with 1 mL of absolute ethanol. These solutions were centrifuged at 800×g for 10 min, and glucose content was measured using a glucose determination kit, GOD-PAP (Fortress Diagnostics Limited, Antrim, N Ireland, and unit 2C Antrim Technology Park, Antrim, UK). The absorbance was observed using a spectrophotometer (Shimadzu UV-1800, Japan) at 500 nm wavelength. The absorbance values were plotted against time to draw a hydrolysis curve.

To calculate GI, the HI of each sample was calculated by using the following equation:

$$HI = \frac{\text{The area under the hydrolysis curve of the sample}}{\text{The area under the hydrolysis curve of white bread}} \quad (3)$$

Then, the *in vitro* GI was determined by using the following equation

$$GI = 39.71 + 0.549\ HI. \quad (4)$$

Organoleptic properties

According to Gámbaro and McSweeney(2020), a 9-point hedonic scale, ranging from 1 = dislike extremely to 9 = like extremely, was used to evaluate the formulated bars organoleptically. Freshly manufactured bars of DBB and FBB were examined by 12 trained panelists. Attributes, such as appearance, taste, color, odor, texture, mouthfeel, and overall acceptability, were examined. Sensory tests were conducted at the Department of Food Sciences and Human Nutrition, College of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia, in a prepared laboratory under 21±1°C temperature; potable water was provided for each panelist as a taste purifier before tasting each bar.

Results

Sensory evaluation of prepared KDBB

Table 2 shows the sensory evaluation of different formulated KDBBs. Results indicated that panelists preferred KDBB2 significantly, as shown with high scores for all sensory attributes. In contrast, prepared KDBB1 and KDBB2 were given low sensory scores, showing that panelists did not prefer these samples. The overall acceptability score was between 5 and 6, indicating either like or dislike and slightly like. Thus, KDBB2 was selected as a highly favored formula by panelists and further subjected to complete nutritional and functional characterization.

Proximate composition of formulated high-fiber KDBB

Depending on the organoleptic evaluation (Table 2), KDBB2 was selected and favored by the panelists. Thus, a complete description of the selected bar formula was done. Results of the proximate chemical composition of formulated KDBB are shown in Table 3. Using the ingredients provided in Table 1, moisture and contents of protein, total fat, ash, dietary fiber, and total carbohydrate were 21.63, 9.34, 4.93, 2.05, 8.01, and 54.04 g 100 g^{-1} fresh weight (FW), respectively. This formulated bar presented

Table 2. Sensory evaluation of KDBB.

Treatments	Organoleptical characteristics						
	Appearance	Color	Taste	Odor	Texture	Mouthfeel	Overall acceptability
KDBB1	5.17 ± 0.21^{b}	5.25 ±0.18^{b}	4.75 ± 0.18^{c}	6.00 ± 0.12^{b}	4.67 ± 0.19^{b}	5.33 ± 0.14^{c}	5.19 ±0.08^{c}
KDBB2	8.17 ± 0.24^{a}	7.83 ± 0.21^{a}	7.58 ± 0.15^{a}	7.00 ± 0.28^{a}	8.42 ± 0.19^{a}	7.83 ± 0.21^{a}	7.81 ± 0.09^{a}
KDBB3	5.58 ± 0.23^{b}	5.58 ± 0.23^{b}	5.67 ± 0.26^{b}	6.17 ± 0.21^{b}	4.92 ± 0.19^{b}	5.83 ± 0.24^{b}	5.63 ± 0.12^{b}

Mean±SE; n = 12.
^{a,b,c}Mean values with the same superscripted letters within the same column are not statistically significant ($p > 0.05$).

Table 3. Proximate composition of high-fiber KDBB formula.

Composition*	KDBB (g 100 g^{-1})
Moisture	21.63±0.98
Protein	9.34±1.47
Total fat	4.93±1.35
Ash	2.05±0.02
Dietary fiber	8.01±0.28
Total carbohydrates	54.04±0.78
Calories	297.90±6.28
Vitamin C (mg 100 g^{-1})	16.67±0.79
Minerals (mg 100g^{-1})	
Sodium	42.19±2.19
Calcium	125.24±4.59
Magnesium	245.19±6.59
Phosphorus	238.67±8.99
Manganese	27.45±3.98
Potassium	511.29±9.87
Copper	1.24±0.45
Zinc	2.97±0.35
Iron	4.59±1.32
Selenium	3.99±0.87

Values: Mean±SE, n = 3.
*Presented as fresh weight (FW).

Table 4. Sugar content (mg g^{-1}) in high-fiber KDBB.

Sugar profile	Chemical formula	KDBB (mg g^{-1} FW)
Fucose	$C_6H_{12}O_5$	0.723
Fructose	$C_6H_{12}O_6$	0.025
Sucrose	$C_{12}H_{22}O_{11}$	246.346
Arabinose	$C_5H_{10}O_5$	69.782
Rafinose*	$C_{18}H_{32}O_{16}$	–
Xylose*	$C_5H_{10}O_5$	–
Galactose	$C_6H_{12}O_6$	0.126
Lactose	$C_{12}H_{22}O_{11}$	0.202
Cellobiose	$(C_6H_{10}O_5)_n$	3.856
Glucose	$C_6H_{12}O_6$	–

*Lower than the detection limit, presented data are mean values of duplicate analysis.

Table 5. Composition of amino acids (g g^{-1} protein) of high-fiber KDBB.*

Essential amino acids (EAA)	RT (min)	KDBB (mg g^{-1} protein)
Lysine	39.507	217.88
Threonine	10.248	13.92
Valine	22.131	17.88
Methionine	23.971	27.73
Isoleucine	26.288	13.92
Leucine	27.437	39.61
Phenylalanine	31.419	33.73
Histidine	35.107	15.85
Cystine	21.333	57.49
Nonessential amino acids (NEAA)		
Arginine	43.597	17.88
Aspartic	8.088	83.19
Serine	11.077	43.58
Glutamic	12.600	89.19
Proline	14.283	138.65
Glycine	18.723	93.15
Alanine	19.971	51.50
Tyrosine	30.280	11.88
EAA		438.01
NEAA		529.01
EAA:TAA ratio		0.45
TAA		967.02

*Mean of duplicate analysis.

high fiber and carbohydrate contents with moderate protein and fat contents, which could be a good profile to provide 297.90 kcal 100 g^{-1} of energy. Vitamin C content was 16.67 g 100 g^{-1} FW. Regarding mineral content, 10 minerals were determined and presented in valuable amounts. Among macro-elements, magnesium was the highest, followed by calcium, manganese, sodium, and potassium, while phosphorus was the lowest present element. In comparison, among micro-elements, iron presented the highest content, followed by selenium, zinc, and copper.

Sugar profiles of formulated high-fiber KDBB

High-performance liquid chromatography was used to determine sugar profiles of the formulated KDBB; the results are presented in Table 4. It was observed that KDBB had higher sucrose, followed by arabinose, cellobiose, fucose, lactose, and galactose. However, fructose had the lowest content among fractionated sugars in formulated KDBB, and no rafionse or xylose was discovered.

Amino acids composition in formulated high-fiber KDBB

The high-fiber KDBB was analyzed for their amino acids content as shown in Table 5. It was observed that KDBB had a good profile of all amino acids, reflecting their nutritional quality. Most EAA and nonessential amino acids (NEAA) were present in KDBB. KDBB scored valuable individual EAAs to give 438.01 g EAA g^{-1} protein. Regarding NEAA), KDBB showed considerable content

Table 6. Percentage of amino acids and calculated biological efficiency, essential amino acid index, estimated protein efficiency ratio, and requirement index for different age groups.

Parameters	FBB
Total BCAAs (mg g^{-1} protein)	71.41
Total aromatic amino acids (mg g^{-1} protein)	45.61
Total conditional amino acids (mg g^{-1} protein)	358.67
Total basic amino acids (mg g^{-1} protein)	251.61
Total acidic amino acids (mg g^{-1} protein)	172.38
Total hydrophobic amino acids (mg g^{-1} protein)	416.17
Total polar amino acids (mg g^{-1} protein)	216.06
BV	14.79
EAAI	41.74
Requirement index (infants)	89.42
Requirement index (preschool children)	97.12
Requirement index (school children)	106.27
Requirement index (adults)	111.77

BCAAs: branch-chain amino acids; BAAs: basic amino acids; BV: calculated biological value; EAAI: essential amino acid index.

with 529.01 g NEAA g^{-1} protein. Clearly, the EAA:total amino acid (TAA) ratio was 0.45.

The percentage of amino acids and calculated biological efficiency, essential amino acid index (EAAI), and requirement index of different age groups are presented in Table 6. Total branch-chain amino acids (BCAAs) had 71.41 mg g^{-1} protein, while total aromatic amino acids had 45.61 mg g^{-1} protein. The conditional amino acids recorded 358.67 mg g^{-1} protein; total basic amino acids (BAAs) contents, such as lysine, arginine, and histidine, were 251.61 mg g^{-1} protein; total acidic amino acids contained 172.38 mg g^{-1} protein; total hydrophobic amino acids recorded 416.17 mg g^{-1} protein, and total polar amino acids recorded 216.06 mg g^{-1} protein. The calculated BV and EAAI values were 14.79 and 41.74, respectively. However, the prepared bar is preferred and served to various age groups. The requirement index was calculated according to WHO (2007), and the results are presented in Table 6.

Fatty acid composition of formulated high-fiber KDBB

The composition of fatty acids in KDBB is shown in Table 7. As presented, 15 saturated fatty acids were identified in formulated KDBB, with stearic acid (C18:0) as the predominant fatty acid, followed by undecanoic acid (C12:0) and pentadecanoic acid (C15:0). The total saturated fatty acids presented 43.73 g 100 g^{-1} fat. Seven fatty acids were identified and quantified as monounsaturated fatty acids, giving 11.48 g 100 g^{-1} fat whereas eliadic acid (C18:1n9) was present predominately with 8.89 g 100 g^{-1} fat. The analyzed fatty acids exhibited as having 44.74 g 100 g^{-1} as polyunsaturated fatty acids. Among the nine polyunsaturated fatty acids, *cis*-8,11,14-eicosatrienoic acid (C20:3n6) recorded the highest fatty acid content with 31.08 g 100 g^{-1} fat, followed by arachidonic acid (20:4n6) with 10.40 g 100 g^{-1} fat and *cis*-4,7,10,13,16,19-hexaenoic acid (C22:6n3) with 1.45 g 100 g^{-1} fat. The total of monounsaturated and polyunsaturated fatty acids was 56.72 g 100 g^{-1}, with 43.73 g 100 g^{-1} of saturated fatty acids, which indicated that unsaturated fatty acids were more than saturated fatty acids.

Antioxidant activities

Total phenolic content, TFs, TFLs, and AOA using DPPH-RSA, and 2,2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) ABTS-RSA were determined in formulated KDBB, and the results are presented in Table 8. Formulated bar for indicated ingredients given in Table 1 showed 547.19 mg GAE 100 g^{-1}, 719.39 μmol of TE 100 g^{-1}, 815.98 μmol of TE 100 g^{-1}, 327.19 mg 100 g^{-1}, 998.25 mg 100 g^{-1}, and 749 mg 100 g^{-1} for TPC, DPPH-RAS, ABTS-RAS, TC, TFs, and TFLs, respectively.

Quantification of phenolic compounds in KDBB by HPLC

The quantitative analysis of phenolics in KDBB was carried out, and the data are presented in Table 9. Eight separated phenolic acids and four flavonoids were identified in detectable amounts in KDBB. The most abundant phenolic acid and their derivatives were pyrocatechol (10249.73 μg g^{-1}), followed by chlorogenic acid (224.56 μg g^{-1}), gallic acid (220.89 μg g^{-1}), ellagic acid (69.72 μg g^{-1}), caffeic acid (28.49 μg g^{-1}), ferulic acid (22.47μg g^{-1}), vanillic acid (17.62 μg g^{-1}), and coumaric acid (14.36 μg g^{-1}). The KDBB was rich in flavonoids, as shown in Table 8. Flavonoids, such as catechin (193.50 mg 100 g^{-1}), were detected in higher amounts, followed by hesperetin (37.37 mg 100 g^{-1}) and naringenin (22.68 mg 100 g^{-1}). Low content of daidzein was discovered. It was shown that flavonoids exhibited a superior range in KDBB.

Identification and quantification of volatiles in KDBB

Table 10 and Figure 2 show the identification and concentration (%) of volatile components in KDBB extracts; 17 components were identified in KDBB. The GC-MS analysis of KDBB exhibited 13 components at a concentration higher than 1 g 100 g^{-1}. However, the predominant component was 9,12-Octadecadienoyl chloride (38.56 g 100 g^{-1}), followed by *n*-hexadecanoic acid (24.13 g 100 g^{-1}) and 17-octadecynoic acid (8.43 g 100 g^{-1}). GC-MS

Table 7. Composition of fatty acid (g 100 g^{-1}) in formulated high-fiber KDBB.

Fatty acids categories	RT (min)	Fatty acids	KDBB*
Saturated fatty acids			
	3.21	Butyric acid (C4:0)	0.06
	4.84	Caproic acid (C6:0)	0.42
	4.96	Caprylic acid (C8:0)	1.21
	5.68	Capric acid (C10:0)	0.24
	6.75	Undecanoic acid (C12:0)	6.83
	7.18	Lauric acid (C12:0)	0.54
	8.25	Tridecanoic acid (C13:0)	0.12
	9.80	Myristoleic acid (C14:0)	0.42
	9.99	Pentadecanoic acid (C15:0)	3.69
	11.56	Palmetic acid (C16:0)	0.18
	12.13	Heptadecanoic acid (C17:0)	0.30
	13.63	Stearic acid (C18:0)	27.39
	16.11	Arachidic acid (20:0)	0.12
	17.40	Heneicosanoic acid (21:0)	2.06
	19.09	Behenic acid (C22:0)	0.12
	Total of saturated fatty acids		43.73
Monounsaturated fatty acids			
	11.41	cis-10-pentadecanoic acid (15:1n5c)	0.18
	13.12	*cis*-10-heptadecanoic acid (17:1)	0.36
	14.47	Eliadic acid (C18:1n9)	8.89
	16.18	*cis*-11-Eicosenoic acid (C20:1n9)	0.48
	16.25	*cis*-11,14-Eicosadienoic acid (C20:2)	0.12
	19.37	Erucic acid (22:1 n-9)	1.09
	19.45	*cis*-13,16-Docosadienoic acid (C22:2)	0.36
	Total of monounsaturated fatty acids		11.48
Polyunsaturated fatty acids			
	15.16	Linoleic acid (C18:2n6c)	0.18
	15.37	Linoleliadic acid (C18:2n6t)	0.12
	15.69	α-Linolenic acid (C18:3n3)	0.48
	15.95	γ-Linolenic acid (C18:3n6)	0.24
	16.96	Arachidonic acid (20:4n6)	10.40
	16.40	*cis*-11,14,17-Eicosatrienoic acid (C20:3n3)	0.12
	16.60	*cis*-8,11,14-Eicosatrienoic acid (C20:3n6)	31.08
	17.01	*cis*-5,8,11,14,17-Eicosapentaenoic acid (C22:3n)	0.67
	19.77	*cis*-4,7,10,13,16,19-Hexaenoic acid (C22:6n3)	1.45
	Total of polyunsaturated fatty acid		44.74
	Total of fatty acids		99.92

RT: retention time of fatty acids; *mean values of duplicate analysis.

analysis of KDBB exhibited four compounds of more than 2 g 100 g^{-1}, such as (E)-1-(4-hydroxy-3-methoxyphenyl) dec-3-en-5-one, 9-octadecenoic acid, 1-(4-hydroxy-3-methoxyphenyl)dec-4-YN-3-one, and 4-hexenal, 6-hydroxy-4-methyl-,dimethyl acetal, acetate, (Z) given as 6.14, 4.98, 3.51, and 2.26 g 100 g^{-1}, respectively. In contrast, nine different components were present in concentrations lower than 2 g 100 g^{-1} (Table 10).

In vitro digestion of formulated high-fiber KDBB

The *in vitro* digestion of KDBB was conducted to investigate the HI of KBDB before and after *in vitro* digestion and the GI for Khalas date and KDBB; data are presented in Figure 3. Determination of free ammonia in the form of tyrosine equivalent showed 227.74-µg tyrosine equivalent g^{-1}. The *in vitro* digestion of KDBB

using pepsin and pancreatin enzymes demonstrated 848.62-µg tyrosine equivalent g^{-1}. On the other hand, the results of the present study indicated that Khalas date with 54.12 GI was classified on the higher edge of low glycemic foods or lower edge of medium glycemic foods. Interestingly, formulated KDBB had lower GI, scoring 39.97 GI to be integrated into low glycemic foods. Foods are classified as low (GI ≤ 55), medium (GI: 56–69), and high (GI ≥ 70) GI foods (Kumar *et al.*, 2018).

Discussion

Health-conscious people favor energy and nutritional bars. Normal athletes and busy individuals like energy bars because they include several balanced macro- and micro-nutrients (Ayad *et al.*, 2020). The bar market has increased significantly in the previous decade, from US$15 billion in 2019 to $19 billion by 2025 (Research and Markets, 2020). Despite this, a plethora of healthy and protein-packed cereal alternatives for breakfast as well as energy-boosting snack bars are readily accessible. Dates often found in snack bars have yet to achieve widespread distribution and mass production (Barakat and

Table 8. Total phenolic content, flavonoids, flavonols, and antioxidant activity of KDBB.

Bars	KDBB
TPC (mg GAE 100 g^{-1})	547.19±7.28
DPPH-RSA (µmol of TE 100 g^{-1})	719.39±6.97
ABTS-RSA (µmol of TE 100 g^{-1})	815.98±7.12
Carotenoid (mg 100 g^{-1})	327.19±3.15
TF (mg QE g^{-1})	998.25±2.48
TFL (mg QE g^{-1})	749.57±3.27

Values are mean±SE, n = 3.

Table 9. Quantitative analysis of phenolic compounds in KDBB.

Item	RT (min)	Compound	Concentration (µg g^{-1})
Phenolic acids	3.39	Gallic acid	220.89
	4.07	Chlorogenic acid	224.56
	6.09	Caffeic acid	28.49
	6.93	Pyrocatechol	10,249.73
	8.49	Ellagic acid	69.72
	9.18	Coumaric acid	14.36
	10.10	Vanillic acid	17.62
	10.26	Ferulic acid	22.47
Flavonoids	4.73	Catechin	193.50
	10.73	Naringenin	22.68
	12.47	Daidzein	18.77
	15.41	Hesperetin	37.37

Phenolic acids and their derivatives were identified at 280- and 320-nm wavelength, and flavonoids at 360-nm wavelength.

Table 10. GC-MS identification and quantification of volatile compounds in KDBB.

No.	RT (min)	Compound	Concentration (g 100 g^{-1})
1.	5.20	17-Octadecynoic acid	8.43
2.	7.85	10-Methyl-E-11-tridecen-1-ol-propionate	1.97
3.	13.11	9,12-Octadecadienal, dimethyl acetal	1.2
4.	13.35	4-Hexenal, 6-hydroxy-4-methyl-,dimethyl acetal, acetate (Z)	2.26
5.	13.47	10-Methyl-8-tetradecen-1-ol acetate	1.64
6.	13.82	4-(2,2-dimethyl-6-methyle necyclohexyl)butanal	1.64
7.	24.64	17-Octadecynoic acid	0.81
8.	26.45	Cyclopentane tridecanoic acid, methyl ester	1.27
9.	28.11	N-hexadecanoic acid	24.13
10.	29.67	Trans-13-octadecenoic acid	0.73
11.	30.16	Cyclopropane dodecanoic acid, 2-octyl-, methyl ester	0.67
12.	31.26	9,12-Octadecadienoyl chloride	38.56
13.	31.53	9-Octadecenoic acid	4.98
14.	32.16	(E)-1-(4-Hydroxy-3-methoxyphenyl)dec-3-en-5-one	6.14
15.	33.44	1-(4-Hydroxy-3-methoxyphenyl)dec-4-YN-3-one	3.51
16.	37.01	Phen-1,4-Diol, 2,3-dimethyl-5-trifluoromethyl-	0.67
17.	44.20	Stigmast-5-en-3-ol, (3beta) [β-Sitosterol]	1.4
	-	Unknown	–

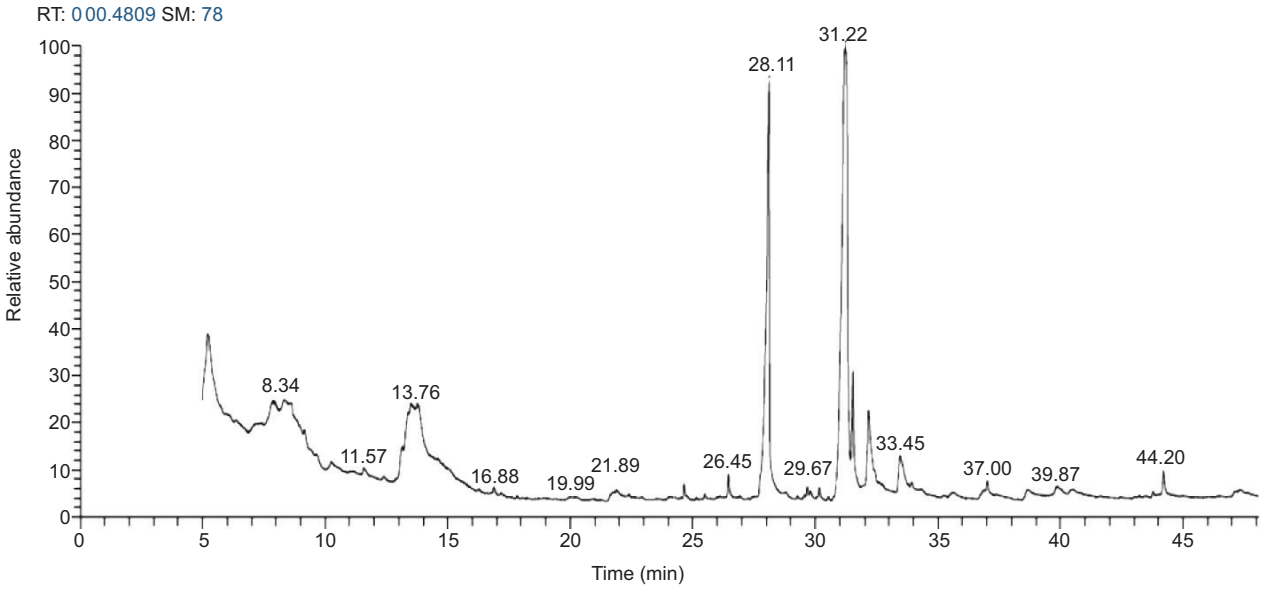

Figure 2. GC-MS chromatogram of formulated high-fiber KDBB.

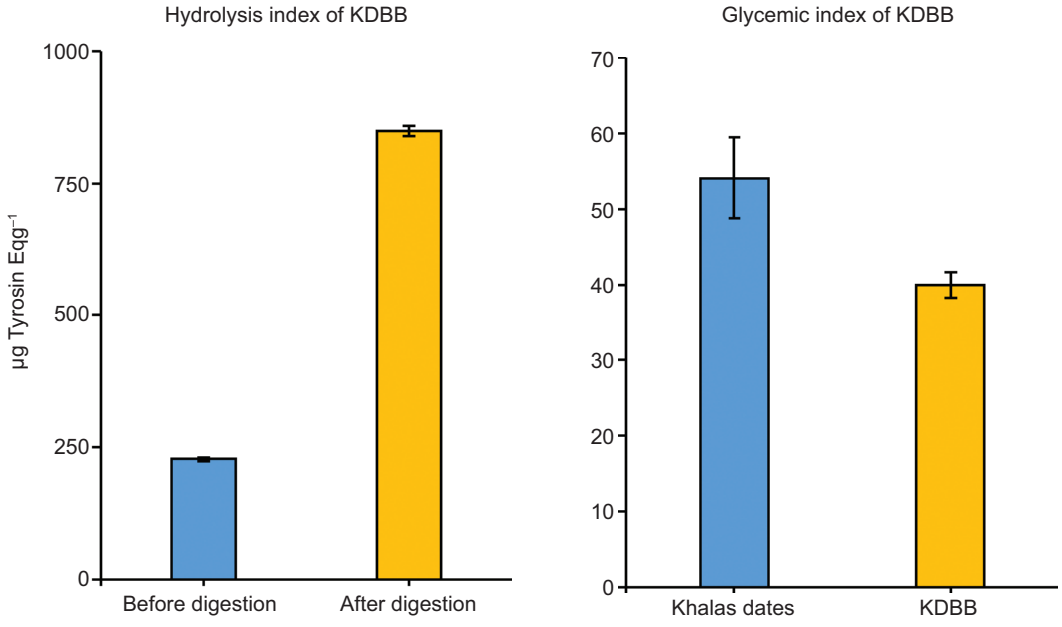

Figure 3. The *in vitro* digestion of formulated high-fiber KDBB. Left: protein hydrolysis index as µg tyrosine equivalent g^{-1}; right: GI of KDBB.

Alfheeaid, 2023; Jabeen *et al.*, 2020). Among available bars, fruit-based snack bars are the healthiest, providing consumers with natural sugars, vitamins, minerals, and other bio-nutrients (Alfheeaid *et al.*, 2023; Ayad *et al.*, 2020). Fruit-based snacks may increase added sugars with high GI (Sun-Waterhouse *et al.*, 2010; Vijayanand *et al.*, 2000).

Interestingly, the date palm fruit's high nutrient density makes it a great ingredient in date bars. Dates are a good source of carbohydrates, vitamins, minerals, and bioactive substances. Dates are a great source of dietary fiber, unsaturated fatty acids, and minerals. Dates are unique among fruits containing EAAs lysine and histidine. Dates were high in antioxidants polyphenols, phenolic acids, and carotenoids (Amadou, 2016; Assirey, 2015; Hussain *et al.*, 2020). According to recent *in vivo* and *in vitro* studies, consumption of dates has been linked to several functional and pharmacological health advantages. Dates help with inflammation, cancer, high blood pressure,

high cholesterol, and infections (Al-Dashti *et al.*, 2021; Al-Sayyed *et al.*, 2021; Al-Zeiny *et al.*, 2022; Arshad *et al.*, 2019; Daoud *et al.*, 2019; Dardjito *et al.*, 2019; Obode *et al.*, 2020). Supplying well-balanced, healthy, and valuable DBBs in markets worldwide is anticipated to be received substantially, as the snack bar business has expanded dramatically over the past decade. Our current research analyzed and extensively characterized the created KDBB2, which contains 50% Khalas date and other indicated ingredients based on organoleptic assessment selection.

Proximate chemical analytical data concluded that KDBB2 (containing 50% Khalas date), as manufactured according to the formula presented in Table 1, exhibited lower moisture content while showing higher fiber content. In contrast, protein, fat, and ash occurred in moderate contents. The prepared bar is nutrient-dense, high-energy, and high-fiber preparations, providing around 298 kcal 100 g^{-1} FW. Date fruits have a relatively high carbohydrate and ash contents (71.2–81.4% and 1.68–3.94%, respectively) and low fat and protein contents (0.12–0.72% and 1.72–4.73%, respectively) on DW base (Amira *et al.*, 2011; Assirey, 2015). Date flesh is a rich source of fructose, glucose, sucrose, dietary fiber (5–8.5%), and polyphenols (Al-Farsi *et al.*, 2007; Elleuch *et al.*, 2008). The most common date fruits produced in Saudi Arabia are Sukkari, Barhi, Khalas, and various date cultivars depending on region (NCPD, 2018). Al-Harrasi *et al.* (2014) revealed 78–86 g 100 g^{-1} DM, 1.0–2.0 g 100 g^{-1} ash, 1.0–2.5 g 100 g^{-1} fiber, 0.1–0.7g 100 g^{-1} fat, 1.8–3.8 g 100 g^{-1} protein, 74.5–82.4 g 100 g^{-1} carbohydrates, and 307–345.5-kcal 100 g^{-1} of energy. In addition, Ali *et al.* (2009) demonstrated that Khalas date contains 70.99–75.37% total carbohydrates, 1.85–2.07% crude fiber, 1.31–1.39% total fats, 1.28–1.87 crude proteins, 1.12–1.31% ash, and 18.77–22.74% moisture, providing 302–319-kcal 100 g^{-1} of energy. Khalas dates contain 8.83–9.43 g 100 g^{-1} dietary fiber. Date fruit is considered a rich source of dietary fiber, ranging from 2% to 8%. Median amount of fiber, 4.35%, are found in Sukkari dates cultivated in Saudi Arabia (Aljutaily *et al.*, 2021). Dates, being a good source of dietary fiber, consist of good quality fiber fractions, such as β-glucans, arabinoxylans, and cellulose, even better than cereals or fruits (Hussain *et al.*, 2020). Formulated KDBB showed considerable content of macro- and microelements with lower Na content, as reported (Assirey, 2015; Siddeeg *et al.*, 2019). The highest element found in dates is mostly K, followed by P and Mg. Ismail *et al.* (2006) reported that K was the most abundant element and Na the lowest-detected element in Khalas dates, which agreed with our findings. Some date varieties, such as Sukkari, contained higher mineral amounts than other fruits, such as pomegranate or mango (Siddeeg *et al.*, 2019). Siddiq and Greiby (2013) reported that some date varieties contained K higher by 2.5 times than that found in bananas. Interestingly, the formulated bar was rich in macro- and microelements and could cover most human requirements (Barakat and Alfheeaid, 2023). High K and low Na content in the presented bar was an excellent product for hypertensive individuals (Ralston *et al.*, 2012).

Sugar profile analysis of formulated KDBB showed high sucrose content, followed by arabinose and moderate amounts of cellobiose. Fucose, fructose, galactose, and lactose were present in lower amount. However, assessed sugars in dates, including glucose, fructose, and sucrose, ranged from 2% to 95%, with the Khalas variety having the highest glucose concentration at 49.6–95.4%. Glucose was higher than fructose, but sucrose ranged from 17% to 31% (Hamad *et al.*, 2015). In another study, Ali *et al.* (2009) found 54.98–59.96 g 100 g^{-1} sugars consisting of 30.67–33.97 g 100 g^{-1} glucose, 22.00–23.65 g 100 g^{-1} fructose, and 1.92–2.34 g 100 g^{-1} sucrose. The remarked higher glucose content did not agree with our formula's content. However, the sugar profile of our KDBB depended on its ingredients. Sugar consumption is crucial to tackle global obesity and diabetes pandemics and related cardiometabolic conditions (Ponzo *et al.*, 2021). It is essential to note that KDBB sugar profiles have lower fructose and glucose levels and higher sucrose content. Fructose is a particularly toxic sugar that promotes metabolic syndrome (Taskinen *et al.*, 2019). Fructose consumption increases insulin resistance, hepatic lipid buildup, and TAG-rich lipoprotein metabolism, causing hypertriglyceridemia (Fisher and Ginsberg, 2002). Thus, KDBB may be "healthier" than other commercial bars because of its reduced fructose level. Owing to its decreased glucose content, KDBB may also have a less negative influence on cardiometabolic risk factors and insulin resistance. This sugar causes the fastest increase in postprandial blood glucose (Hardy *et al.*, 2020). These findings show that dates vary by variety and location (Hussain *et al.*, 2020). Dates are high in sugar, yet El Abed *et al.* (2017) showed that dates' aqueous extract lowered postprandial glycemia in animal models at 200 mg kg^{-1} body weight. Inhibiting type 2 diabetes-related enzymes, including α-glucosidase, which controls the absorption of intestinal glucose, caused these outcomes (Bedekar *et al.*, 2010).

Essential and nonessential amino acids in KDBB demonstrate their nutritional importance. KDBB had a higher concentration of EAA, especially lysine, and NEAA, especially proline. Our results were strongly confirmed by Amadou (2016), who reported that the amino acid composition of dates includes proline, lysine, histidine, tyrosine, isoleucine, and tryptophan. Lysin, an essential amino acid lacking in most cereals, has been found to be 0.025–0.073% in dates, with Ajwa dates having maximum content. Common fruits, such as oranges,

bananas, and apples, may also lack certain amino acids. Dates have 2,000–5,000 times more lysine than apples, bananas, and oranges and 800 times more isoleucine than apples (Amadou, 2016). We formulated KDBB using Khalas dates with marginally increased EAA content and EAA:NEAA ratio. Interestingly, the BV, EAAI, and requirement index of KDBB demonstrated considerable values. For instance, basic amino acids increase protein bioactivity significantly (Saito *et al.*, 2003) along with antioxidant and antibacterial properties (Song *et al.*, 2020). In contrast, total uncharged polar amino acids (glycine, serine, threonine, tyrosine, and cystine) increase protein solubility (Singh and Sogi, 2018). Utilizing Khalas dates increased the calculated BV and EAAI. According to amino acid requirements (WHO, 2007), incorporating Sukkari date in place of fruits mix improved the nutritious value of bars. It gradually increased the efficacy of prepared DBB bars to cover the protein requirements of different age groups.

In KDBB, 15 saturated fatty acids were found, with stearic acid (C18:0) being the most abundant one, followed by undecanoic acid (C12:0) and pentadecanoic acid (C15:0). Eliadic acid (C18:1n9) was the most prevalent among the seven identified monounsaturated fatty acids. Polyunsaturated fatty acid prevailed, with *cis*-8,11,14-eicosatrienoic acid (C20:3n6) presented sensibly among the nine identified fatty acids, and arachidonic acid (20:4n6) was discovered in a considerable amount. Associatively, high-oleic acid oils are considered to be of high quality (Mrabet *et al.*, 2020), and are beneficial against cardiovascular disease by decreasing total and low-density lipoprotein cholesterol (Riley *et al.*, 2022). The presented formula exhibited high monounsaturated and polyunsaturated fatty acids, which benefit the nutritional value of these bars. Numerous studies have used them to make functional foods or replace conventional oils (Maqsood *et al.*, 2020). In our formula, cow's ghee, walnuts, and sesame seeds were added to bars to increase healthier fat content, mainly unsaturated fatty acids, and for taste and satisfaction as recommended (Brufau *et al.*, 2006).

Khalas date-based bar had sustainable TPC, TF, and TFL contents and DPPH and ABTS free RSAs. Khalas date may boost phytochemicals and bioactive substances because of its high phenolic content (Kaushik *et al.*, 2021); the bioactive components of dates correlate with antioxidant activity in several experiments (Fernández-López *et al.*, 2022; Yeh *et al.*, 2009). Al Harthi *et al.* (2015) recorded lower TPC content in four varieties of dates ranging from 32.24 mg to 35.84 mg caffeic acid equivalent to 100 g^{-1} FW. In contrast, Farag *et al.* (2014) indicated that date cultivars had 233–1897 mg 100 g^{-1} phenolic content, which agreed with or was higher than our results. A free RSA ranged from 28.78% to 70.62% in all variants (Al Harthi *et al.*, 2015), which differed from our results. In different studies, date varieties exhibited 55–75% antioxidant capability correlated to phytochemicals, thereby boosting the functionality of food products (Al Harthi *et al.*, 2015; Razali *et al.*, 2019). For instance, polyphenols were abundantly found in various date varieties but dropped following the ripening of dates (Hussain *et al.*, 2020). Such a wide variety of phenolic compounds can play a significant role in elevating antioxidant potential (Razali *et al.*, 2019; Singh *et al.*, 2012). The HPLC analysis of KDBB resulted in eight phenolic acids and four flavonoids. As our formulated bar was innovative and no similar data are available yet, it is difficult to discuss this result. However, a preliminary HPLC examination of date fruits revealed phenolic acids, such as gallic acid, vanillic acid, caffeic acid, *p*-coumaric, and syringic acid in various concentrations, which confirmed and supported our analysis (Al Harthi *et al.*, 2015). Farag *et al.* (2014) elucidated the primary and secondary metabolite profiles of 21 date varieties using *ultra-performance liquid chromatography/*photo diode array/electrospray ionization–Quadrupole time-of-flight–mass spectrometry (UPLC/PDA/ESI–qTOF-MS)-based metabolomics study. A total of 49 fruit skin metabolites were examined. Primary flavones and flavonols were glycosides of luteolin and apigenin, quercetin conjugates, and caffeoyl shikimic acid. A group of sphingo lipids, fatty acids, and other organic acids joined the principal phenolic classes. This difference in phenolic profile could be due to mixed ingredients or affected by processing (Al-Shahib and Marshall, 2003; Kamal *et al.*, 2023).

The GC-MS analysis of KDBB resulted in 17 compounds, with 9,12-octadecadienoyl chloride being the predominant compound. As our formulated bar was innovative and no similar data is available yet, it is too difficult to discuss this result. However, as the highest ingredient of the formulated bar is Khalas date, most extracted volatiles could be related to Khalas dates. Farag *et al.* (2014) elucidated the primary and secondary metabolite profiles of 21 date varieties using UPLC/PDA/ESI–qTOF-MS-based metabolomics study. However, representative UPLC–MS traces in negative and positive ionization modes of *P. dactylifera* fruit skin methanol extract are characterized by two central regions: flavonoids and fatty acids. The assigned peaks included O-caffeoylshikimic acid, luteolin rhamnosyl dihexoside, isoquercetrin, isorhamnetin rhamnosyl hexoside, isorhamnetin-3-O-glucoside, chrysoeriolhexosyl sulfate, quercetin, chrysoeriol, linolenic acid, linoleic acid, palmitic acid, and stearic acid, which supported our results. Interestingly, our study provided a basis for future investigations of DBBs regarding GC-MS analysis.

Hydrolysis index and the calculated GI of KDBB indicated the digestibility rate of carbohydrates, as HI is the ratio of the sample's area under the hydrolysis curve

to a reference sample, such as white bread. Therefore, KDBB was digested *in vitro* to analyze its HI and glycemic response throughout an *in vitro* digestion experiment using pepsin and pancreatin enzymes. By measuring free ammonia as the tyrosin equivalent, the digestibility index exuded a 3.72-fold increase in released ammonia after the *in vitro* digestion of KDBB. The result indicates higher bio-digestibility of KDBB. On the other hand, this bio-digestability could increase the availability of bioactive compounds, such as phenolics, as massively discussed in eight date varieties, including their flesh and seeds (Djaoudene *et al.*, 2021). According to their findings, the effect of digestion varied with date cultivar and sample type. In addition, the digestion of date samples effectively released accessible phenolics, increased antioxidant capacities, and greatly affected enzyme inhibitory activity (Djaoudene *et al.*, 2021). As shown in the *in vitro* experiment, prepared KDBB could be a healthy and nutrient-dense product with high digestibility. However, metabolites' metabolism, tissue, and organ distribution, excretion, and reducing characteristics determine the human body's phenolic bioaccessibility and antioxidant effects (Velderrain-Rodríguez *et al.*, 2014). However, the current study found that Khalas dates, with a GI of 54.12, settled somewhere between the extremes of low and medium glycemic foods. The prepared KDBB had a lower GI than the original one, at 39.97, making it suitable for use in typical glycemic dishes. Depending on their GI, foods are categorized as either low (GI ≤ 55), medium (GI: 56–69), or high (GI ≥ 70) (Kumar *et al.*, 2018). Consuming various dates with a high content of carbohydrates could increase the postprandial glycemic response and accelerate the risk for dysglycemia (Toh *et al.*, 2020). Interestingly, our produced KDBB could offer a concept for consuming dates and their associated products with a lower GI to achieve clinically relevant reduction in acute glycemic response, with benefits to those who lead healthy lifestyles. In addition, a high fiber content of KDBB could be used as a bulking agent and it lowers the GI of prepared date-based bars (Giuntini *et al.*, 2022; Toh *et al.*, 2020).

Conclusions

The application of Khalas dates to formulate high-fiber KDBBs was aimed in this investigation. Complete characterization indicated that chemical examination showed a considerable content of macro- and micronutrients with balanced fatty and amino acid profiles. EAAs and unsaturated fatty acids scored valuable and distinguished profiles as presented in BV, EAAI, monounsaturated, and polyunsaturated fatty acids. KDBB possessed beneficial phytochemicals and bioactive substances with superior antioxidant activity. KDBB is a nutrient-dense, convenient, affordable, and better sugar alternative that helps to combat calorie content. Interestingly, our prepared KDBB presented a super idea for consuming dates and dates-based products with lower GI to provide clinically relevant reductions in acute glucose response. Finally, prepared KDBB could be beneficial to suggest scaling up and further preparation of different functional DBBs to meet the nutritional requirements of both healthy individuals and patients of different age groups.

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Author Contributions

Hassan Barakat and Abdulkarim S.M. Almutairi: conceptualization, data curation, and formal analysis. Abdulkarim S.M. Almutairi: methodology and investigation. Hassan Barakat: writing of original draft, reviewing, and editing.

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Conflicts of Interest

The authors declared no conflict of interest.

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