Saudi Journal of Biological Sciences 28 (2021) 3566–3577

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Review

Total phenolic content in ripe date fruits (*Phoenix dactylifera* L.): A systematic review and meta-analysis

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A R T I C L E I N F O

Article history:
Received 22 January 2021
Revised 19 February 2021
Accepted 8 March 2021
Available online 17 March 2021

Keywords:
Antioxidants
Date fruits
Ripe
Total phenolic content

A B S T R A C T

Ripe date fruits contain phenolic compounds which possess a high antioxidant activity. The current review was carried out to evaluate total phenolic content in ripe date fruits. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) was followed during the review process. Relevant studies published from inception up to March 2019 were retrieved from three databases. Study selection was performed based on specific inclusion criteria. A total of twenty-two articles were selected and included in the present review. Data collected from these studies were organized, pooled, and analyzed using descriptive statistics. Total phenolic content means and medians have been reported for the collected ripe date fruit samples for each included study and pooled data. The results suggested that ripe date fruits contain a potent total phenolic content that can contribute mainly to their antioxidant properties.

Contents

Abbreviations: GAE, gallic acid equivalents; DW, dry weight; FW, fresh weight.

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Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2021.03.033
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1. Introduction

Date fruits (*Phoenix dactylifera L.*) play an essential role in the economic and social welfare of populations inhabitant in arid and semi-arid regions of the world (Mrabet et al., 2019). They are an important staple food in many countries around the world, especially in the Middle East and North Africa. (Chao and Krueger, 2007). Ripening of date fruits go through several stages include Hababouk (unripe and inedible), Kimri (unripe, green color and inedible), Khalal (complete-size, and edible), Rutab (soft, brown to a black color and edible), and Tamer (fully ripe, reduced moisture and edible). Tamer is defined as the final stage of date fruits ripeness once their color converted to brown or black, and their composition changed toward relatively lower moisture (about 20%) content and higher sugar content (Hussain et al., 2020). Ripe date fruits at the Tamer stage have considerable economic value compared with date fruits at other ripening stages. This could be referred to their good storability due to lower moisture content which makes them available for consumption in all seasons of the year. Moreover, Ripe date fruits are used in the food industry as processed products such as paste for confectionery manufacturing (Ashraf and Hamidi-Esfahani, 2011; Al-Shahib and Marshall, 2003).

Ripe date fruits are considered as a nutrient-dense food and known as a rich source for carbohydrates, including simple sugars (fructose, glucose, and sucrose) and dietary fiber, vitamins such as ascorbic acid, thiamine, niacin, pyridoxine, and riboflavin, and minerals such as iron, potassium, calcium, selenium, magnesium, and phosphorus (Al-Farsi and Lee, 2008). Date fruits possess numerous health benefits, including antimutagenic, anticarcinogenic, antihyperlipidemic, antiatherogenic, hepatoprotective, nephroprotective, and gastroprotective activities (Echegaray et al., 2020; Al-Alawi et al., 2017; Baliga et al., 2011). All of this makes date fruits an attractive fruit from a medicinal and pharmaceutical point of view (Tang et al., 2013).

Antioxidants act to lower oxidative damage that happened in biological structures by neutralizing unstable free radicals, and thus prevent or slow down body cell damage (Liu et al., 2018). Part of our need for antioxidants should be met from dietary sources, especially with high exposure to free radicals (Halliwell, 2006). Dietary antioxidants include several micronutrients such as tocopherols and ascorbic acid and phytochemicals such as polyphenols. Consequently, antioxidants have an essential role in maintaining human health by lowering the risk of many illnesses such as cancers, and coronary heart disease (Neeraj et al., 2013; Barros, 2020). Ripe date fruits have high antioxidant activity as a result of a relatively high vitamin and phytochemicals content such as polyphenols (Al-Farsi et al., 2018; Al-Shwyeh, 2019). They contain different types of polyphenols, such as phenolic acids, flavonoid glycosides, hydroxycinnamates, and proanthocyanidin oligomers (Hong et al., 2006; Al-Farsi et al., 2005). Polyphenols show a high antioxidant activity and contribute significantly to the antioxidant activity of date fruits (Benmeziane-Derradji, 2019; Hamad et al., 2015; Aldhafiri, 2017). A strong association was indicated between date fruits' antioxidant activity and their content of total phenols (Kchaou et al., 2014; Chaira et al., 2009).

Because of the beneficial health effects of date fruits, increasing research attempts to study their total phenolic content has been shown. Unfortunately, the high variability in the analytical procedures reported in studies that were investigated total phenolic content in date fruits limits the impact and implications of results produced in these studies (AlFaris et al., 2021). There is a great need to generate comprehensive information about the total phenolic content of ripe date fruits to help rationalize their health benefits. The current systematic review and *meta*-analysis were conducted to provide answers about total phenolic content in ripe date fruits. The importance of this systematic review and *meta*-analysis appears clearly in providing a comprehensive overview of available evidence related to total phenolic content in ripe date fruits. Moreover, research gaps and methodological concerns are highlighted which can help to improve future research in this field. The main objective of this study is to systematically summarize the characteristics of collected ripe date fruit samples and their total phenolic content for each included study and pooled data. The present study is based on several hypotheses. First, a growing number of studies were investigated total phenolic content in ripe date fruits. Second, most of these studies were conducted in the Middle East and South Africa. Third, the cultivar types of used date fruits were highly variable. Finally, ripe date fruits contain relatively high total phenolic content.

2. Methods

In this review, ripe date fruits refer to date fruits at the Tamer stage when become with full ripeness, brown to black color, and relatively contain less moisture and more sugars. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) was followed during the review process (Moher et al., 2009).

2.1. Research questions identifying

The present systematic review and *meta*-analysis were performed to seek answers to several questions. First, what are the characteristics of collected ripe date fruit samples reported in the included studies? Second, what is the total phenolic content in collected ripe date fruit samples reported in each of the included studies? Finally, what is the total phenolic content in collected ripe date fruit samples from pooled data for all available data and data stratified based on extraction solvents, production countries, and ripe date fruit cultivars?

2.2. Literature search

The literature search was conducted by experienced researchers to find relevant studies published from inception up to March 2019 in three academic databases: Scopus, PubMed, and Web of Science.

Keywords used for searching literature in this study include antioxidants, antioxidants content, antioxidant components, antioxidant profile, antioxidant composition, total phenolic content, total phenols content, phenolic profile, phenolic composition, date fruits, date palm fruits, ripe date fruits, date cultivars, date varieties, and Phoenix dactylifera. During the search process, various combinations of Boolean operators (OR, AND, NOT) were used to combine the search keywords to find relevant studies in the academic databases.

2.3. Study selection

Study selection from relevant studies found in the academic databases was done based on specific inclusion criteria. The inclusion criteria include: 1) primary research studies published in scientific journals in the English language, 2) the date fruit samples should be collected at full ripeness (Tamer stage), 3) the cultivar types of collected date fruits should be specified clearly, 4) the solvents used to extract total phenolic content should be specified clearly, 5) measurement of total phenolic content should be done by colorimetric Folin–Ciocalteu assay (Singleton and Rossi, 1965), and 6) values of total phenolic content should be reported clearly by using milligrams of gallic acid equivalents (GAE) per 100 g of dry weight (DW) or fresh weight (FW) as a measurement unit. Study selection was accomplished in two phases. Firstly, the titles and abstracts of collected studies were screened for relevance by two independent researchers based on the inclusion criteria, and inappropriate studies were excluded. EndNote software was used for screening titles and abstracts. Secondly, the full text of relevant studies was collected and screened by independent researchers to assess their eligibility to be included in the qualitative and quantitative analyses. A comparison for data collected by each researcher was carried out after each phase and inconsistencies were discussed and polished. The final list of relevant studies was determined and used for data extraction.

2.4. Data extraction

Required data were collected from the selected studies then organized in a charting table by using the Microsoft Excel spreadsheet. The name of several date cultivars was reported in different studies with different spellings. For example, Deglet Nour cultivar was also reported as Deglet Noor. Another example is the Khalas cultivar which is also reported as Khalasa. In some selected studies, bar graphs were used to present data related to moisture content, and total phenolic content, and the actual values were not reported numerically in the text. In this case, the numerical values were extracted from bar graphs automatically by using an online tool called Web Plot Digitizer (Rohatgi, 2019). Furthermore, when moisture content and total phenolic content values were given for two different harvest seasons, an average value was calculated and used. Finally, when dry matter content is reported, the moisture content was calculated by subtracting from one hundred and used. The final charting table was reviewed by researchers to ensure stability in the process of data extraction.

2.5. Qualitative data reporting

The qualitative data extracted from all selected studies were organized in tables that summarized the characteristics of collected ripe date fruit samples. These characteristics include production country and local geographical location, sample source, harvest season, date fruits quality, and types and numbers of selected cultivars. Furthermore, information about storage conditions (periods and temperatures) before analysis and solvents used to extract total phenolic content was reported.

2.6. Quantitative data reporting and meta-analysis

Quantitative data in this systematic review and *meta*-analysis include moisture content whenever reported and total phenolic content from all selected studies. The total phenolic content values were used when reported by using a dry weight basis (mg GAE/100 g DW) in selected studies. However, the values for each ripe date fruit cultivar were recalculated and converted to a dry weight basis before used when reported by using a fresh weight basis (mg GAE/100 g FW). To do this, the conversion to dry weight basis was carried out based on the reported moisture content for each ripe date fruit cultivar when the moisture content is reported in the selected studies. Otherwise, the moisture content was assumed 20% and used. For studies that reported total phenolic content values for collected ripe date fruit cultivars in different conditions (different extraction solvents or different storage periods before analysis), an average value was calculated for each ripe date fruit cultivar and used when appropriate to generate pooled data. Meta-analysis was carried out to evaluate total phenolic content in ripe date fruits from all pooled data and for pooled data stratified based on used extraction solvent, production country, and type of ripe date fruit cultivar (only when data were reported in at least three selected studies).

2.7. Statistical analysis

SPSS version 23 was used for data analysis. Quantitative data (moisture content and total phenolic content) were reported by using descriptive statistics and expressed as means ± standard deviations (SD) and medians ± ranges (minimum value - maximum value). In the current study, the random-effects model was used for *meta*-analysis.

3. Results

3.1. Literature search results

Two hundred and forty records were identified during the literature search; 28 of them were duplicates and excluded (see Fig. 1). We screened titles and abstracts for the remaining 212 articles and excluded 87 of them because they were found irrelevant. Then, full texts of the remaining 125 articles were retrieved and screened; 103 of them were excluded based on our inclusion criteria. Lastly, twenty-two articles were selected and included in this review. (Mansouri et al., 2005; Benmeddour et al., 2013; Ghiaba et al., 2014; Haimoud et al., 2016; Hachani et al., 2018; Allaith, 2008; Abbas et al., 2008; Biglari et al., 2008; Shahdadi et al., 2015; Hemmateenejad et al., 2015; Lemine et al., 2014; Bouhlali et al., 2017; Singh et al., 2012; Haider et al., 2018; Al-Turki et al., 2010; Al-Najada and Mohamed, 2014; Saafi et al., 2009; Mrabet et al., 2012; El Arem et al., 2012; Kchaou et al., 2013; Hamza et al., 2016; Souli et al., 2018).

3.2. Characteristics of the collected ripe date fruit samples

Table 1 presented various characteristics of collected ripe date fruit samples reported in the selected studies (n = 22). The collected ripe date fruit samples in each selected study were produced in one or more of ten countries; namely Algeria, Bahrain, Iran, Mauritania, Morocco, Oman, Pakistan, Saudi Arabia, Tunisia, and the United States. Moreover, information about local geographic location, sample source, harvest season, quality, and types for collected date fruit samples were reported in 20, 12, 17, 10, and 22 studies, respectively. The source of collected ripe date fruit samples was either local retail markets, dates distribution centers, research

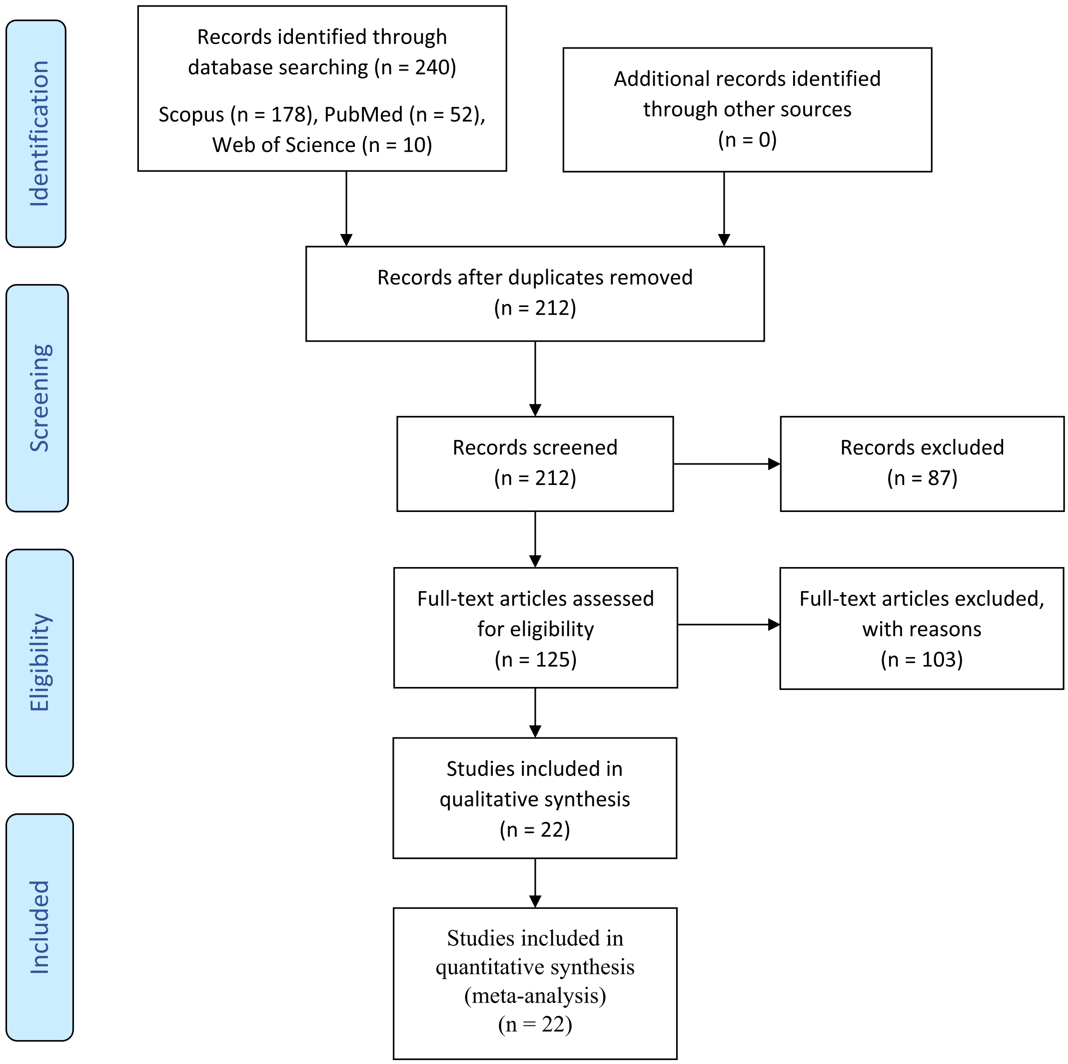

Fig. 1. Flowchart illustrating selection process for studies included in this systematic review and *meta*-analysis which conducted to determine total phenolic content (TPC) in ripe date fruits.

stations, or private farms. The harvest season for collected ripe date fruit samples was either one specific year or two consecutive years. The collected ripe date fruit samples were free of physical damage in nine selected studies and second-grade with texture defect (relatively hard) in only one included study. Types and number of collected ripe date fruit cultivars vary in different studies. The most common collected ripe date fruit cultivars were Deglet Nour (n = 11), Zahedi (n = 6) and Khalas (n = 5). The total number of collected ripe date fruit cultivars in different selected studies ranged from one to fifteen cultivars.

3.3. Storage conditions, extraction solvents, and moisture content

Information about storage periods, storage temperature, and extraction solvents for collected date fruit samples was reported in 3, 19, and 22 selected studies, respectively (see Table 2). Before analysis, collected ripe date fruit samples were stored for one day in one included study, and one to two months in another included study. A third selected study used three different storage periods (one day, six months, and twelve months) for collected date fruit samples. Moreover, the collected samples were stored before analysis at refrigerator temperature (4 °C) in ten selected studies, freezer temperature (−20 to −18 °C) in seven selected studies, and at temperature −40 °C in two selected studies.

In the vast majority of selected studies (n = 20), one solvent was used to extract total phenolic content. However, one included study used five different solvents, while another included study used two different solvents to extract total phenolic content. In all selected studies, total phenolic content was extracted at a single stage except one study where total phenolic content was extracted at two stages with two different solvents (methanol 80% then ethyl acetate 50%). The most commonly used extraction solvent in the selected studies was methanol 80% (n = 11). Other used extraction solvents include methanol (100%, 95%, 88% and 50%), ethanol (100% and 80%), acetone (80%, 70% and 60%) and distilled water. The moisture content of collected ripe date fruit samples was found in six selected studies; two of them reported only dry matter content. The moisture content for all date fruit cultivars reported in these six studies (n = 45) was ranged from 10.5% to 34.7% (see Fig. 2A). The mean for pooled moisture content data was 20.9%, and the median was 21.2%.

3.4. Total phenolic content reported in selected studies

Total phenolic content values were reported in selected studies by using gallic acid equivalents as a reference standard. Moreover, total phenolic content values were expressed as dry weight in half of the selected studies. However, the values were reported as fresh

Table 1
Characteristics of collected ripe date fruit samples reported in the studies included in this systematic review and *meta*-analysis (n = 22).

No.	Studies	Production country/local geographic location	Samples source	Harvest season	Date fruits quality	Types of selected cultivars
1	Mansouri et al., 2005	Algeria/Ghardaia	NA*	2002	NA	Tazizaout, Ougherouss, Akerbouche, Tazerzait, Tafizioune, Deglet-Nour, Tantbouchte
2	Allaith, 2008	Bahrain/NA, Saudi Arabia/NA & Tunisia/NA	Retail local markets or private farms	2003 & 2004	NA	Hallaw, Khalas, Ruzaiz Khudhairy, Mabroom, Suffry Deglet nour
3	Abbas et al., 2008	Iran/Tehran	Dates distribution center	2006	Date fruits identical in terms of size, colour, ripening stage, without damaged and calamity	Honey, Kabkab, Bam, Jiroft, Piarom, Sahroon, Zahedi, Kharak
4	Biglari et al., 2008	Iran/Tehran	Dates distribution center	2006	Date fruits identical in terms of size, colour, ripening stage, without damaged and calamity	Jiroft, Bam, Kabkab, Honey, Sahroon, Piarom, Zahedi, Kharak
5	Saafi et al., 2009	Tunisia/Southern region	NA	2006	Date fruits of uniform size, free of physical damage and injury from insects and fungal infection	Khouet Kenta, Kentichi, Deglet Nour, Allig
6	Al-Turki et al., 2010	Saudi Arabia/NA & United States/ Riverside, California	Private farms/USDA-ARS National Clonal Germplasm Repository for Citrus & Dates	2006 & 2007	NA	Khalasa, Shaishi, Sukari, Gur, Khunizi Amir Hajj, Barhee, Deglet Noor, Halawy, Hayany, Hilali, Khadrawy, Khalasa, Medjool, Zahidi
7	Singh et al., 2012	Oman/NA	Retail local markets	2010	NA	Fardh, Khasab, Khalas
8	Mrabet et al., 2012	Tunisia/Gabès oasis	NA	2010	NA	Rochdi, Matteta, Korkobbi, Eguwa, Bouhattam, Mermella, Limsi, Kenta, Deglé Nour, Garen Gaze, Smeti
9	El Arem et al., 2012	Tunisia/Kébili	NA	2008	Date fruits free from defects and color uniformity	Gondi, Gasbi, Khalt Dhabi, Rtob Ahmar
10	Benmeddour et al., 2013	Algeria/Biskra	Station of Tolga	2009	Date fruits with uniform size, free of physical damage, insect's injury and fungal infection	Mech Degla, Deglet Ziane, Deglet Nour, Thouri, Sebt Mira, Ghazi, Degla Beida, Arechti, Halwa, Itima
11	Kchaou et al., 2013	Tunisia/Tozeur	NA	NA	Second-grade date fruits, with texture defect (relatively hard)	Allig, Deglet Nour, Kentichi, Zehdi, Bejo, Baydh El-Hamam
12	Ghiaba et al., 2014	Algeria/Ouargla	NA	2010	NA	Degla Baidha, Deglet Nour, Ghars, Tamjhourt, Tafezauine
13	Lemine et al., 2014	Mauritania/Atar and Tijigja	NA	2013	NA	Ahmar dli, Ahmar denga, Bou seker, Tenterguel, Lemdina, Tijib
14	Al-Najada and Mohamed, 2014	Saudi Arabia/ Jeddah	Retail local markets	NA	NA	Khalas, Shishi
15	Shahdadi et al., 2015	Iran/Jiroft	Dates distribution center	NA	Date fruits identical in term of ripening stages	Bam Mazfati, Jiroft Kalute
16	Hemmateenejad et al., 2015	Iran/Bushehr	Bushehr date research center	2010	Date fruits without damaging	Berehi, Mordasang, Shahabi, Mazafati, Kabkab, Khanizi, Medjool, Piarom, Halavi, Zahedi, Karoot, Rabbi
17	Haimoud et al., 2016	Algeria/El-Oued	NA	2012	Date dates with homogeneous size and without damage	Tantebouchte, Biraya, Degla Baidha, Deglet-Nour, Ali Ourached, Ghars, Tansine
18	Hamza et al., 2016	Tunisia/Jemna" oases	NA	2013	NA	Deglet Nour
19	Bouhlali et al., 2017	Morocco/ Errachidia	Errachidia national institute for agricultural research	NA	NA	Boufgous, Bouskri, Bousrdon, Bousthammi, Bouzgagh, Jihl, Majhoul, Najda
20	Hachani et al., 2018**	Algeria/Ain Salah	NA	2015	Date fruits of uniform size, and free of physical damage	Clean Tinnaser, Agaz, Tamazouchete, Takarboucht, Takarmoust
21	Haider et al., 2018	Pakistan/Jhang	Date palm research station	NA	NA	Zehdi, Be-Rehmi, Neelum, Ko-Herba, Kozan Abad, Karblian, Jan-Sohar, Khadrawy I, Khadrawy II, Angoor
22	Souli et al., 2018	Tunisia/Tozeur	Private farms	2015	NA	Alig, Akwatte Alig, Ammarri, Beyd Hamem, Bejou, Besser Helou, Deglet Nour, Horra, Kenta, Kentichi

* NA: Data is not available in the study.
** Infected date caltivar (called Infected Tinnaser) was excluded.

weight in the rest of the selected studies (n = 11). Therefore, they were recalculated and reported based on dry weight (see Table 2). The mean total phenolic content reported in all included studies ranged from 4.36 mg GAE/100 g DW (Haimoud et al., 2016) to 753.30 mg GAE/100 g DW (Shahdadi et al., 2015). The total phenolic contents were less than 200, 201-400, and 401–600 mg GAE/100 g DW in 10, 6, and 5 selected studies, respectively. Only one included study was reported that mean total phenolic content was higher than 600 mg GAE/100 g DW (see Fig. 3A). In the same way, the median total phenolic content reported in selected studies ranged from 1.67 mg GAE/100 g DW (Abbas et al., 2008) to 753.30 mg GAE/100 g DW (Shahdadi et al., 2015). The total phenolic content medians were less than 200, 201-400, and 401–600 mg GAE/100 g DW in 10, 8, and 3 selected studies, respectively. Similarly, only one included study was found that median total phenolic content was higher than 600 mg GAE/100 g DW (see Fig. 3B).

Table 2
Total phenolic content in collected ripe date fruit samples that reported in the studies included in this systematic review and *meta*-analysis (n = 22).

No.	Studies	Number of cultivars	Storage period/ temperature before analysis	Extraction solvents	Moisture	Total Phenolic Content		
					mean ± SD (median ± range) %	mean ± SD (median ± range) mg GAE/100 g FW	mean ± SD (median ± range) mg GAE/100 g DW	Min. (cultivar) * Max. (cultivar) Max.:Min. ratio mg GAE/100 g DW
1	Mansouri et al., 2005	7	NA*/−18 °C	Methanol (80%)	NA	4.64 ± 2.15 (3.91 ± 5.87)	5.8 ± 2.69 (4.89 ± 7.34)	3.11 (Tazizaout) 10.45 (Tantbouchte) 3.36
2	Allaith, 2008	7	1 day/4 °C	Distilled water	NA	304.0 ± 44.44 (301.0 ± 126.0)	380.0 ± 55.55 (376.25 ± 157.5)	312.5 (Suffry) 470.0 (Mabroom) 1.5
3	Abbas et al., 2008	8	NA/4 °C	Methanol (80%)	NA		10.41 ± 23.81 (1.76 ± 68.36)	0.93 (Jiroft) 69.29 (Kharak) 74.51
4	Biglari et al., 2008	8	NA/4 °C	Methanol (80%)	NA		21.61 ± 48.40 (4.60 ± 138.46)	2.89 (Jiroft) 141.35 (Kharak) 48.91
5	Saafi et al., 2009	4	NA/−20 °C	Methanol (50%)	NA	281.08 ± 111.70 (233.59 ± 238.31)	351.35 ± 139.63 (291.99 ± 297.88)	261.78 (Kentichi) 559.66 (Allig) 2.14
6	Al-Turki et al., 2010	15	NA/−20 °C	Acetone (80%)	17.4 ± 3.4 (16.1 ± 10.0)	352.47 ± 63.37 (335.0 ± 217.0)	426.05 ± 72.15 (392.27 ± 219.11)	328.98 (Khalasa (USA)) 548.09 (Gur) 1.67
7	Singh et al., 2012	3	NA/−40 °C	Methanol (80%)	NA		220.0 ± 22.61 (231.0 ± 41.0)	194.0 (Khasab) 235.0 (Fardh) 1.21
8	Mrabet et al., 2012	11	1–2 months/4 °C	Acetone (70%)	NA	106.28 ± 57.44 (94.48 ± 192.36)	132.85 ± 71.8 (118.1 ± 240.45)	36.2 (Rochdi) 276.65 (Deglé Nour) 7.64
9	El Arem et al., 2012	4	NA/−20 °C	Methanol (50%)	NA	240.23 ± 62.42 (230.80 ± 129.5)	300.28 ± 78.03 (288.5 ± 161.87)	231.13 (Gasbi) 393.0 (Khalt Dhabi) 1.7
10	Benmeddour et al., 2013	10	NA/−40 °C	Acetone (60%)	NA		493.15 ± 310.85 (309.97 ± 729.02)	225.57 (Deglet Nour) 954.59 (Ghazi) 4.23
11	Kchaou et al., 2013**	6	NA/−20 °C	Distilled water	26.4 ± 3.2 (25.8 ± 9.0)	169.58 ± 42.32 (165.45 ± 122.5)	230.74 ± 58.17 (236.17 ± 168.86)	133.17 (Zehdi) 302.03 (Bejo) 2.27
			NA/−20 °C	Methanol (88%)		175.30 ± 62.71 (154.42 ± 178.41)	238.53 ± 85.99 (208.85 ± 245.25)	156.35 (Zehdi) 401.6 (Bejo) 2.57
			NA/−20 °C	Methanol (50%)		207.87 ± 57.07 (202.24 ± 146.07)	281.44 ± 73.34 (273.79 ± 201.44)	199.44 (Baydh El Hamam) 400.88 (Bejo) 2.01
			NA/−20 °C	Acetone (70%)		317.61 ± 137.12 (302.77 ± 377.05)	430.22 ± 183.85 (405.43 ± 507.36)	276.11 (Baydh El Hamam) 783.47 (Bejo) 2.84
			NA/−20 °C	Ethanol (100%)		72.19 ± 14.78 (72.82 ± 39.09)	98.51 ± 22.36 (97.64 ± 55.3)	72.21 (Kentichi) 127.51 (Bejo) 1.77
	Average					188.51 ± 58.63 (183.99 ± 170.58)	255.89 ± 78.66 (246.44 ± 234.82)	168.28 (Baydh El Hamam) 403.1 (Bejo) 2.4
12	Ghiaba et al., 2014	5	NA/4 °C	Methanol (80%) then Ethyl acetate (50%)	NA		14.55 ± 5.14 (13.42 ± 13.55)	9.50 (Tafezauine) 23.05 (Tamjhourt) 2.43
13	Lemine et al., 2014	6	NA/4 °C	Methanol (80%)	NA		548.92 ± 99.33 (568.50 ± 255.6)	405.5 (Tenterguel) 661.1 (Tijib) 1.63
14	Al-Najada and Mohamed,	2	1 day/4 °C	Methanol (80%)	NA	182.5 ± 38.89 (182.5 ± 55.0)	228.13 ± 48.61 (228.13 ± 68.75)	193.75 (Khalas) 262.5 (Shishi)

(*continued on next page*)

Table 2 (*continued*)

No.	Studies	Number of cultivars	Storage period/ temperature before analysis	Extraction solvents	Moisture	Total Phenolic Content		
					mean ± SD (median ± range) %	mean ± SD (median ± range) mg GAE/100 g FW	mean ± SD (median ± range) mg GAE/100 g DW	Min. (cultivar) * Max. (cultivar) Max.:Min. ratio mg GAE/100 g DW
	2014***							1.35
			6 months/4 °C	Methanol (80%)		244.0 ± 62.2 (244.0 ± 88.0)	305.0 ± 77.78 (305.0 ± 110.0)	250.0 (Khalas) 360.0 (Shishi) 1.44
			12 months/4 °C	Methanol (80%)		292.5 ± 17.7 (292.5 ± 25.0)	365.63 ± 22.1 (365.63 ± 31.25)	350.0 (Khalas) 381.25 (Shishi) 1.09
	Average					239.67 ± 39.59 (239.67 ± 56.0)	299.58 ± 49.5 (299.58 ± 70.0)	264.58 (Khalas) 334.58 (Shishi) 1.26
15	Shahdadi et al., 2015	2	NA/NA	Methanol (80%)	NA		753.30 ± 41.72 (753.30 ± 59.0)	723.80 (Jiroft Kalute) 782.80 (Bam Mazfati) 1.08
16	Hemmateenejad et al., 2015	12	NA/4 °C	Methanol (80%)	NA	328.89 ± 39.57 (324.54 ± 147.48)	411.11 ± 49.46 (405.67 ± 184.35)	313.44 (Khanizi) 497.79 (Karoot) 1.59
17	Haimoud et al., 2016	7	NA/4 °C	Methanol (80%)	NA		4.36 ± 1.45 (4.51 ± 4.47)	2.06 (Biraya) 6.53 (Ali Ourached) 3.17
18	Hamza et al., 2016	1	NA/4 °C	Ethanol (80%)	10.5	142.51	159.28	159.28 (Deglet Nour)
19	Bouhlali et al., 2017	8	NA/−20 °C	Methanol (80%)	25.1 ± 5.4 (23.2 ± 14.5)		466.26 ± 70.78 (494.15 ± 205.21)	331.86 (Bouskri) 537.07 (Bousrdon) 1.62
20	Hachani et al., 2018**	5	NA/NA	Methanol (80%)	18.6 ± 9.2 (14.6 ± 22.3)		36.67 ± 19.80 (32.18 ± 49.47)	20.38 (Tamazouchete) 69.85 (Takarboucht) 3.43
			NA/NA	Acetone (70%)			14.53 ± 2.45 (14.48 ± 6.66)	11.13 (Tamazouchete) 17.79 (Agaz) 1.60
	Average						25.6 ± 10.28 (22.93 ± 26.96)	15.76 (Tamazouchete) 42.72 (Takarboucht) 2.71
21	Haider et al., 2018	10	NA/NA	Methanol (95%)	21.7 ± 3.6 (22.9 ± 11.7)		87.0 ± 44.26 (85.22 ± 124.7)	26.93 (Ko-Herba) 151.63 (Karblian) 5.63
22	Souli et al., 2018	10	NA/−20 °C	Methanol (100%)	NA	110.62 ± 8.87 (111.05 ± 25.50)	138.28 ± 11.09 (138.82 ± 31.88)	123.25 (Horra) 155.13 (Deglet Nour) 1.26

* Min.: minimum value; Max. maximum value, NA: Data is not available in the study, GAE: Gallic acid equivalents, FW: Fresh weight, DW: Dry weight.
** Total phenolic content was reported for the same date fruit cultivars that extracted by using more than one solvent.
*** Total phenolic content was reported for the same date fruit cultivars that exposed for three different storage periods.

3.5. Total phenolic content for pooled data

The number of total phenolic content values reported in all selected studies (n = 22) was 151 (see Table 3). The mean and median for all pooled data were 246.68 and 229.92 mg GAE/100 g DW, respectively (see Figs. 2B and 3). When pooled data were stratified based on commonly used extraction solvents, variations in total phenolic content have been observed. The mean was 224.02, 306.8, and 187.06 mg GAE/100 g DW when methanol 80%, methanol 50%, and acetone 70% were used as an extraction solvent, respectively. In the same way, the median was 105.6, 283.99, and 119.44 mg GAE/100 g DW when methanol 80%, methanol 50%, and acetone 70% were used as an extraction solvent, respectively. Stratifying pooled data based on production countries exhibited high variability in total phenolic content. A relatively high total phenolic content was reported in ripe date fruits produced in Saudi Arabia (mean and median were 423.75 and 449.29 mg GAE/100 g DW, in order) when compared with that produced in Algeria (mean

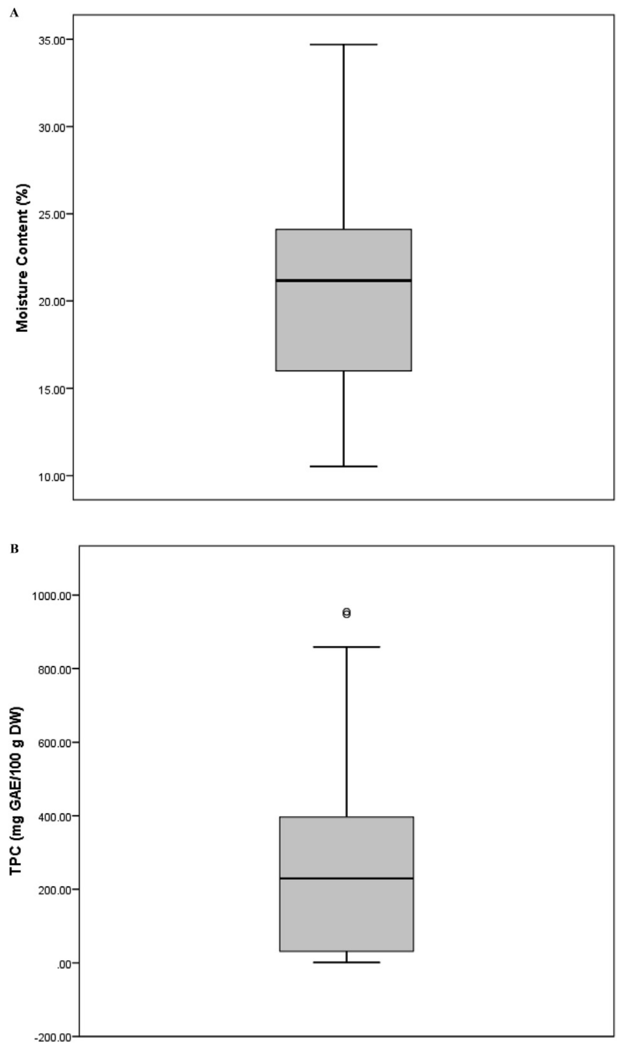

Fig. 2. Boxplot graph illustrating (A) moisture content (%) for pooled moisture data (n = 45) that reported in six selected studies and (B) total phenolic content (TPC) for all pooled data (n = 151) reported in all selected studies (n = 22).

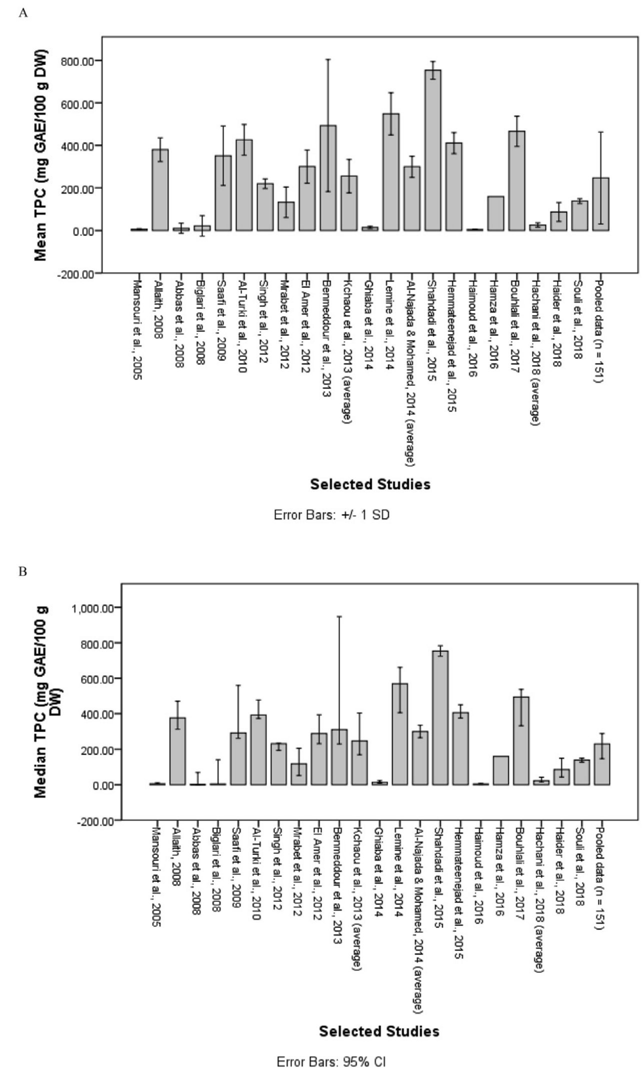

Fig. 3. Bar graph illustrating (A) means (±SD), and (B) medians (±95% CI) for total phenolic content (TPC) values that reported in studies included in this systematic review and *meta*-analysis (n = 22) and for all pooled data (n = 151).

and median were 153.04 and 14.12 mg GAE/100 g DW, in order), Tunisia (mean and median were 202.14 and 168.28 mg GAE/100 g DW, respectively) and Iran (mean and median were 223.2 and 105.32 mg GAE/100 g DW, in order). We also reported pooled data for selected common ripe date fruit cultivars. A relatively high total phenolic content was reported in two ripe date fruit cultivars: Medjool (mean and median were 363.72 and 379.49 mg GAE/100 g DW, respectively) and Khalas (mean and median were 323.07 and 328.98 mg GAE/100 g DW, respectively). On the other hand, a relatively low total phenolic content was reported in two ripe date fruit cultivars: Kabkab (mean and median were 134.99 and 3.25 mg GAE/100 g DW, respectively) and Piarom (mean and median were 320.91 and 252.58 mg GAE/100 g DW, respectively).

4. Discussion

In recent years, there are considerable interests in natural antioxidants found in date fruits to understand their medicinal and pharmaceutical effects. Polyphenols are among important natural antioxidants commonly found in date fruits, and they have growing attention as potential agents with preventive capability for many chronic diseases (Elmi et al., 2020; Vayalil, 2012). Antioxidant activity of ripe dates was derived mainly from total phenolic content (Farag et al., 2016; Benmeziane-Derradji, 2019). The results of this review demonstrated that ripe date fruits have a high phenolic content compared with many other fruits, such as red apple (73.96 mg GAE/100 g FW), banana (57.13 mg GAE/100 g FW), blueberry (46.24 mg GAE/100 g FW), red grape (80.28 g GAE/100 g FW), lemon (61.47 mg GAE/100 g FW), orange (77.23 mg GAE/100 g FW), peach (27.58 mg GAE/100 g FW), honey pear (11.88 mg GAE/100 g FW), pineapple (94.04 mg GAE/100 g FW) and watermelons (24.66 mg GAE/100 g FW) (Fu et al., 2011).

Our findings showed that the total phenolic content values reported in different selected studies were highly variable (mean total phenolic content ranged from 4.36 to 753.30 mg GAE/100 g DW). These variations in the total phenolic contents are caused by numerous factors such as cultivar type, climate, maturity, harvest time, irrigation, sunlight, geographic location, post-harvest treatments, and experimental conditions (storage, extraction, and analytical procedures). These factors may affect the chemical composition of ripe date fruits and play an important role in determining their total phenolic content (Lemine et al., 2014; Al-Farsi et al., 2007).

Table 3
Total phenolic content in collected ripe date fruit samples from pooled data for all available data and data stratified based on extraction solvents, production countries, and ripe date fruit cultivars.

Pooled data	Number of values	Number of studies	Total Phenolic Content mean ± SD (median ± range (min.-max.)) * mg GAE/100 g DW
All pooled data	151	22	246.68 ± 216.51 (229.92 ± 953.66 (0.93–954.59))
Extraction solvents **			
Methanol 80%	68	11	224.02 ± 237.29 (105.6 ± 781.87 (0.93–782.8))
Methanol 50%	14	3	306.8 ± 94.3 (283.99 ± 360.22 (199.44–559.66))
Acetone 70%	22	3	187.06 ± 189.8 (119.44 ± 772.34 (11.13–783.47))
Production countries **			
Algeria	34	5	153.04 ± 275.82 (14.12 ± 952.53 (2.06–954.59))
Iran	30	4	223.2 ± 243.68 (105.32 ± 781.87 (0.93–782.8))
Saudi Arabia	10	3	423.75 ± 94.92 (449.29 ± 282.68 (264.58–547.26))
Tunisia	37	7	202.14 ± 107.76 (168.28 ± 523.46 (36.2–559.66))
Ripe date fruit cultivars **			
Deglet Nour	11	11	205.55 ± 163.91 (225.57 ± 543.37 (4.72–548.09))
Zahedi	6	6	189.02 ± 190.16 (143.96 ± 3.88–445.69)
Khalas	5	4	323.07 ± 82.87 (328.98 ± 214.77 (231.0–445.77))
Medjool	3	3	363.72 ± 44.54 (379.49 ± 84.79 (313.44–398.23))
Kabkab	3	3	134.99 ± 230.05 (3.25, 399.54 (1.09–400.63))
Allig	3	3	320.91 ± 212.97 (252.58 ± 409.16 (150.5–559.66))
Piarom	3	3	136.28 ± 227.81 (6.09 ± 395.92 (3.41–399.33))
Kentichi	3	3	217.72 ± 62.74 (245.51 ± 115.9 (145.88–261.78))

* Min.: minimum value; Max. maximum value, GAE: Gallic acid equivalents, DW: Dry weight.
** Total phenolic content was reported for pooled data stratified based on used extraction solvent, production country, and type of cultivar only when data were reported in at least three selected studies.

It is evident about selected studies that much information about characteristics of collected ripe date fruit samples such as local geographic location, sample source, harvest season, quality, storage periods, and temperatures before analysis was missing. Furthermore, there was a high variation in these characteristics reported in different selected studies. One noteworthy example is information about storage periods before analysis. They were missing in most selected studies (n = 19) and the storage periods were inconsistent in the three included studies that reported this information. Al-Najada & Mohamed (2014) studied the total phenolic content of two Saudi date fruit cultivars (Khalas and Shishi). It was reported that total phenolic content of fresh date fruit samples (mean was 228.13 mg GAE/100 g DW) had been increased after storing samples at 4 °C for six and twelve months (means were 305.0 and 365.63 mg GAE/100 g DW, in order). Similar results were found for two Iranian date fruit cultivars (Bam and Kharak) stored for six months at 4 °C, followed by one-week at 18 °C (Biglari et al., 2009). The increase in total phenolic content during cold storage could be caused by the action of specific oxidoreductase enzymes involved in phenolic biosynthesis (Hamauzu, 2006). Unfortunately, high variability in the characteristics of collected ripe date fruit samples and the absence of some of them in many selected studies could affect their results impact negatively and make it hard to run results comparison among different included studies. Therefore, more attention to reporting various characteristics of collected ripe date fruit samples in the prospective research is required. Also, trying to minimize variances in these characteristics and follow common characteristics are recommended to improve the research quality and reproducibility in this area of research (AlFaris et al., 2021).

The results of this review revealed that various extraction solvents were used in different selected studies and the total phenolic content varied greatly when different solvents were used. This indicated the possible influence for the solvent used to extract total phenolic content. The chemical nature of different phenolic compounds varies greatly (Zhou and Yu, 2004). Thus, choosing of extraction solvent has a great potential effect on the recovery of phenolic compounds and the measured quantity of total phenolic content (Ali et al., 2016). The recovery of phenolic compounds from different samples is determined by the polarity of extraction solvents and the solubility of these compounds in the solvents (Sulaiman et al., 2011; Rebey et al., 2012). Consequently, it is hard to select a good solvent to extract total phenolic content from various food samples. Usually, a mixed polarity solvent may be suitable to extract more phenolic contents. For example, adding distilled water up to 50% to acetone increased phenolic compounds extraction (Alothman et al., 2009; Liu et al., 2009).

Kchaou et al. (2013) used five different solvents to extract total phenolic content. They stated that acetone 70% was the solvent with the best efficiency to extract total phenolic content (mean was 430.22 mg GAE/100 g DW) followed by methanol 50% (mean was 281.44 mg GAE/100 g DW). Contrarily, ethanol 100% was the least efficient solvent for extracting total phenolic content (mean was 98.51 mg GAE/100 g DW). Similarly, total phenolic content was extracted from five Algerian date fruit cultivars by using two solvents. The results showed that methanol 80% was a more efficient solvent for extraction of total phenolic contents (mean was 36.67 mg GAE/100 g DW) than acetone 70% (mean was 14.53 mg GAE/100 g DW) (Hachani et al., 2018). Our results from pooled data exhibited that methanol 50% was more efficient in extracting total phenolic content (mean was 306.8 mg GAE/100 g DW) compared with methanol 50% and acetone 70%. Unfortunately, it is hard to compare total phenolic content values reported in different selected studies when different extracting solvents were used. Therefore, producing a standard solvent extraction procedure to follow is highly recommended to maximize the impact of the results produced from scientific research.

Our results showed that the total phenolic content varied among ripe date fruit samples produced in different countries. This indicated the possible influence for geographic locations on the total phenolic content of ripe date fruits. Date palm cultivation needs hot climatic conditions to fruit properly. This weather is usually found in arid regions (Chao and Krueger, 2007). Date palm is frequently cultivated in the Middle East and North Africa for a long time. Globally, the top ten producers for date fruits in 2018 were Egypt, Saudi Arabia, Iran, Algeria, Iraq, Pakistan, Sudan, Oman, United Arab Emirates, and Tunisia (FAO Statistics, 2020). However, date palm plantations were newly introduced in new regions such as Southern California in the United States. Al-Turki et al. (2010) compared total phenolic content in five-date fruit cultivars collected from Saudi Arabia with ten date fruit cultivars collected from the United States. They concluded that total phenolic content was higher in samples collected from Saudi Arabia. This was true even for the same cultivar. For instance, total phenolic content was higher in Khalas cultivar that were collected from Saudi Arabia (445.77 mg GAE/100 g DW) compared with that were collected from United States (328.98 mg GAE/100 g DW) (Al-Turki et al., 2010). The effect of geographic location can be linked to the interaction of numerous factors such as cultivar geographic origin (native or introduced), growing conditions, climate, and received sunlight (Al-Farsi et al., 2007).

There are more than two thousand known date fruit cultivars are being planted around the world. However, only a few cultivars are highly important economically based on market demand such as Deglet Nour, Medjool, and Khalas. Cultivars with high commercial quality have been frequently evaluated for their nutritional quality and chemical composition (Lemine et al., 2014; Hamad et al., 2015). Our findings suggested that different cultivars varied greatly in their total phenolic content. This variation could be explained by diverse genotypes and growth conditions for different cultivars (Al Harthi et al., 2015). Biglari et al. (2008) investigated total phenolic content in eight Iranian date fruit cultivars. They found that the kharak cultivar has relatively high total phenolic content (141.35 mg GAE/100 g DW) compared with other collected cultivars (2.89–6.64 mg GAE/100 g DW). The same result was reported by Abbas et al. (2008). In another example, Mrabet et al. (2012) studied the total phenolic content of eleven Tunisian date fruit cultivars. They found that the Deglet Nour cultivar has about eight folds higher total phenolic content (276.65 mg GAE/100 g DW) compared with the Rochdi cultivar (36.2 mg GAE/100 g DW).

Ripe date fruits are one promising food source of natural antioxidants. They serve as a rich source of polyphenols which could be suitable for application in the pharmaceutical field and healthy foods manufacturing as a functional food ingredient (Maqsood et al., 2020). These natural compounds can be used as a healthy substitute for synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) that may have toxicity and need high manufacturing costs (Idowu et al., 2020). The future trends in the food industry that were affected by customer-driven pressure move toward more depend on natural antioxidants instead of synthetic additives to have their protective effects against many chronic diseases (Al-Mssallem, 2020).

The current study had a few limitations. The literature searching was limited to studies available in three trustworthy databases (Scopus, PubMed, and Web of Science) to guarantee choosing papers with good quality. The second limitation was excluding many studies during the study selection stage as they were not met our inclusion criteria either because not reporting needed information (ex. maturation stage, cultivar type, and extraction solvent) or not using the colorimetric Folin–Ciocalteu method and gallic acid equivalents as a reference standard to measure total phenolic content. There is no agreement on one standard method to measure total phenolic content in various foods. However, the colorimetric Folin–Ciocalteu method by using gallic acid as a reference standard is still the most popular method commonly used for a total phenolic content determination as being a simple, rapid, reproducible, and low-cost assay (AlFaris et al., 2021). These factors could affect our selected studies and thus, our results. However, this review is the first one carried out to investigate the available data from studies conducted to evaluate total phenolic content in ripe date fruits. Our findings will contribute positively to current knowledge about the antioxidants and total phenolic content of date fruits for nutritionists and the general public.

In conclusion, the findings of this review signify that ripe date fruits are considered a rich source of polyphenols; the potent natural antioxidants. Overall, ripe date fruits have the potential to be used as a nutraceutical or functional food ingredient to produce food products rich in natural antioxidants. Further studies with standard and rigor methodologies are required to evaluate total phenolic content in different cultivars planted in various growth conditions.

CRediT authorship contribution statement

Nora Abdullah AlFaris: Conceptualization, Resources, Writing - review & editing, Project administration, Funding acquisition, Supervision. **Jozaa Zaidan AlTamimi:** Conceptualization, Validation, Data curation. **Fatima Ali AlGhamdi:** Validation. **Najla Abdullah Albaridi:** Formal analysis, Software, Visualization. **Riyadh A. Alzaheb:** Methodology, Investigation. **Dalal Hamad Aljabryn:** Software, Writing - review & editing. **Amani Hamzah Aljahani:** Software. **Lujain Abdulaziz AlMousa:** Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors wish to thank the Deanship of Scientific Research at Princess Nourah bint Abdulrahman University, Kingdom of Saudi Arabia, for the financial assistance provided to conduct this research. This research was supported by the Deanship of Scientific Research at Princess Nourah bint Abdulrahman University through the Fast-track Research Funding Program.

Funding

This research was supported by the Deanship of Scientific Research at Princess Nourah bint Abdulrahman University through the Fast-track Research Funding Program.

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