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Review article
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Chemical Composition of Date–Pits and Its Potential for Developing Value–Added Product – a Review

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Moisture, protein, oil and carbohydrate contents of date–pits varied from 3.1–12.5, 2.3–6.9, 5.0–12.5 and 70.9–86.9 g/100 g date–pits, respectively. BET–monolayer (*i.e.* strongly bound) moisture content, solids–melting peak (at moisture: 6.7 g/100 g date–pits), and melting point of oil were 4.3 g/100 g dry–solids, 106°C, and 1.8°C, respectively. The major fatty acids were lauric, myristic, palmitic, stearic, oleic, and linoleic acids and polyphenol content varied from 21.0–62.0 mg/g date–pits depending on the varieties, types of solvent and temperature used for extraction. Date–pits showed effectives in animal and poultry feeds and it could be used as value added products, such as: dietary fibres, functional polysaccharides, caffeine–free drinks (similar to coffee), oil (biofuel or cooking oil), and other functional or medicinal products. Date–pits powder and activated carbon from date–pits showed effective in purifying water by removing different types of pollutants, such as heavy metals, boron, dyes, phenolic compounds, and pesticides. Date–pits also showed effective to be used as ingredient for composed, biomass, and fermentation processes.

INTRODUCTION

Dates are very popular and staple food in the arid and semiarid regions in the world [Al–Farsi & Lee, 2008a]. They have been a source of main wealth for the earlier generations of Arabian world. Dates are commercially sold as such and processed into various date products [Omezzine *et al.*, 1997]. Dates are consumed in fresh or dried form; dried dates can be stored round the year for their consumption. Pericarp is an edible part and a pit is considered as by–product and waste [Besbes *et al.*, 2004a]. On an average, mass of date–pits varies from 10 to 15% of total date–fruit mass [Hussein *et al*., 1998] and contains about 10% crude oil [Al–Farsi *et al*., 2007]. The date fruits are an excellent source of carbohydrates, dietary fibres, protein, lipids, some vitamins, minerals and bioactive compounds [Barreveld, 1993; Hussein *et al.*, 1998; Hamada *et al*., 2002; Al–Farsi & Lee, 2008b; Besbes *et al.*, 2004b; Nehdi *et al.*, 2010]. Therefore, their utilization is highly desired by the date processing industries in developing their value–added products [Al–Hooti *et al.*, 1997; Nancib *et al.*, 1997, 2009; Waezi–Zadeh *et al.*, 2010]. The growing demand of dates enhanced their production which reached 7.2 million tons in 2010 [FAO, 2011] and approximately 720,000 tons of date–pits could be produced annually (*i.e.* considering 10% of the total fruit mass).

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Each year, 1.3 billion tons of different types food wasted throughout the supply chain could feed as many as two billion people without any additional impact on the environment as identified by FAO [Scott–Thomas, 2013]. Food waste was "one of the great paradoxes of our times", and it is wasting resources to produce food [Scott–Thomas, 2013]. Recent research trends are to explore the use of waste from food industry, and the waste utilization could provide economic gain to the farmers, industry, food security, environmental safety and sustainability. Date–pits are generally used as complementary feed materials for animals and poultry or as a conventional soil fertilizer [Vandepopuliere *et al.*, 1995]. These are also used for extracting oil for cosmetic and pharmaceutical purposes [Devshony *et al.*, 1992]. Limited research has been conducted on the utilization of date–pits for the development of value added products. The aim of this review is to present up–to–date data on the chemical composition and nutritional value of date–pits; and their wide applications for various purposes.

CHEMICAL COMPOSITION AND PHYSICO–CHEMICAL CHARACTERISTICS OF DATE–PITS

Figure 1 shows the freeze–dried date–pits, date–pits oil, and freeze–dried water extract. Table 1 demonstrates the chemical composition of the different date–pits varieties; with moisture content ranging from 3.1 g/100 g date–pits for Mabseeli to 12.5 g/100 g date–pits for Raziz variety. Fat or oil content ranged from 5.0 g/100 g date–pits for Mabseeli to 12.5 g/100 g

FIGURE 1. Photographs of date–pits, extracted date–pits oil and freeze–dried water extract.

date–pits for Allig variety of dates. The protein content varied from 2.3 g/100 g date–pits for Shalal to 6.9 g/100 g date–pits for the Raziz variety of dates. The ash content varied from 0.91 to 1.20 g/100 g date–pits. Date–pits are rich sources of carbohydrates, the content of which varied from 70.9 g/100 g date–pits for Raziz variety to 86.9 g/100 g date–pits for the Mabseeli variety. The average chemical characteristics of four varieties of date–pits oil were: acid value 1.04, iodine value 49.5, saponification value 221.0, and un–saponifiable matter 0.8%. The functional and structural properties of date–pits are presented in the literature, therefore their potential for value added products could be assessed. Figure 2 shows a flow diagram including different unit operations for developing date–pits oil, fibres and bioactive components. Thermal characteristics [Rahman *et al.*, 2007; Suresh *et al.*, 2013], antioxidant activities [Al–Farsi *et al.*, 2007; Chaira *et al.*, 2007; Amany *et al.*, 2012], and antiviral activities [Jassim & Naji, 2010] of date–pits are evaluated and presented in the literature. The un–freezable water content of date–pits was observed as 29.4 g/100 g date–pits [Rahman *et al.*, 2007]. BET–monolayer is considered as an effective method for eval-

TABLE 1. Chemical composition of date–pits (g/100 g date–pits).

Variety	Moisture	Fat	Protein	Ash	Carbohydrate	Reference
Khalas	7.5	10.5	5.7	1.05	78.3	Suresh *et al.* [2013]; Hamada *et al.* [2002]; Habib & Ibrahim [2009]
Fardh	9.5	8.2	5.8	1.20	78.0	Hamada *et al.* [2002]; Habib & Ibrahim [2009]
Lulu	10.9	10.5	5.2	0.91	74.7	Hamada *et al.* [2002]; Habib & Ibrahim [2009]
DegletNour	11.2	10.1	5.6	1.10	83.1	Besbes *et al.* [2004a]; Chaira *et al.* [2007]
Allig	10.3	12.5	5.2	1.10	81.0	Besbes *et al.* [2004a]; Chaira *et al.* [2007]
Mabseeli	3.1	5.0	3.9	1.00	86.9	Al–Farsi *et al.* [2007]
Um–sellah	4.4	5.9	5.4	1.20	83.1	Al–Farsi *et al.* [2007]
Shahal	5.2	5.1	2.3	0.90	86.5	Al–Farsi *et al.* [2007]
Barhe	10.6	7.5	5.7	1.06	75.1	Habib& Ibrahim [2009]
Shikatalkahlas	9.6	7.4	5.3	0.97	76.7	Habib & Ibrahim [2009]
Sokkery	12.1	6.5	6.4	0.96	74.0	Habib & Ibrahim [2009]
Bomaan	9.6	6.4	5.4	1.02	77.6	Habib & Ibrahim [2009]
Sagay	10.8	5.7	5.3	0.99	77.2	Habib & Ibrahim [2009]
Shishi	10.4	6.2	5.7	0.94	76.8	Habib & Ibrahim [2009]
Maghool	9.8	6.5	5.6	1.14	77.0	Habib & Ibrahim [2009]
Sultana	10.0	6.6	5.2	0.91	77.2	Habib & Ibrahim [2009]
Maktoomi	9.8	7.5	5.8	1.07	75.8	Habib & Ibrahim [2009]
NaptitSaif	10.2	6.9	5.7	0.84	76.4	Habib & Ibrahim [2009]
Jabri	9.9	7.1	5.4	0.96	76.7	Habib & Ibrahim [2009]
Khodary	10.2	7.7	5.4	0.87	75.9	Habib & Ibrahim [2009]
Dabbas	12.3	6.9	5.1	0.92	74.8	Habib & Ibrahim [2009]
Raziz	12.5	8.8	6.9	0.99	70.9	Habib & Ibrahim [2009]
Shabebe	11.5	7.7	4.8	1.09	75.0	Habib & Ibrahim [2009]

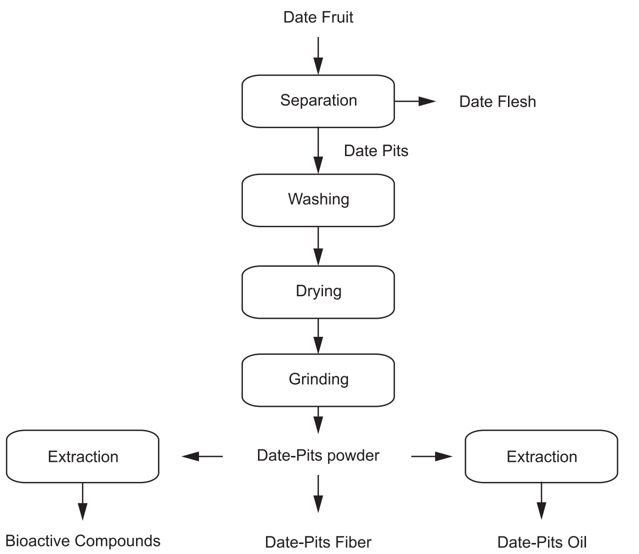

FIGURE 2. Flow diagram showing extraction of date–pits oil and bioactive compounds.

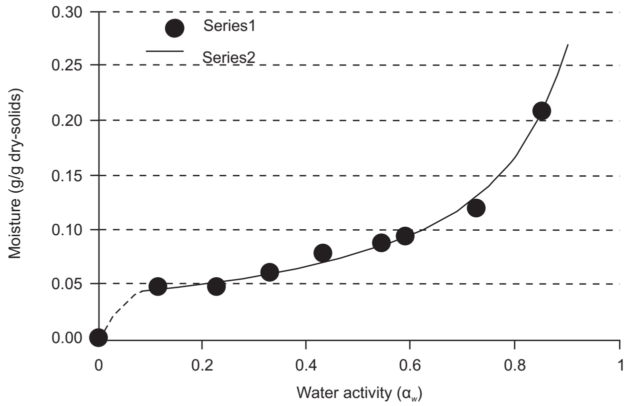

FIGURE 3. Moisture adsorption isotherm of freeze–dried date–pits powder measured by static isopiestic method and best fitted GAB model (series 1: experimental points, series 2: GAB model line) [Suresh *et al*., 2013].

uating the amount of bound water to the specific polar sites in dried foods or biomaterials [Rahman, 2006]. Figure 3 shows the moisture adsorption isotherm of the freeze dried date–pits powder and best fitted GAB model. The moisture sorption isotherm of date–pits powder showed characteristic of type II–sigmoidal sorption isotherm. The BET and GAB monolayer values for date–pits powder were estimated as 4.3 and 4.1 g/100 g dry–solids, respectively. In the case of date–pits (deglet nour), similar values were also observed by Belarbi *et al*. [2000].

Thermal characteristics of date–pits are given in Figure 4. The heating thermogram shows two endothermic peaks (*i.e.* one for melting of oil, marked as A; another one for solids–melting, marked as B), a shift just before melting (*i.e.* marked as G) and an exothermic shift after solids–melting (*i.e.* marked as C)

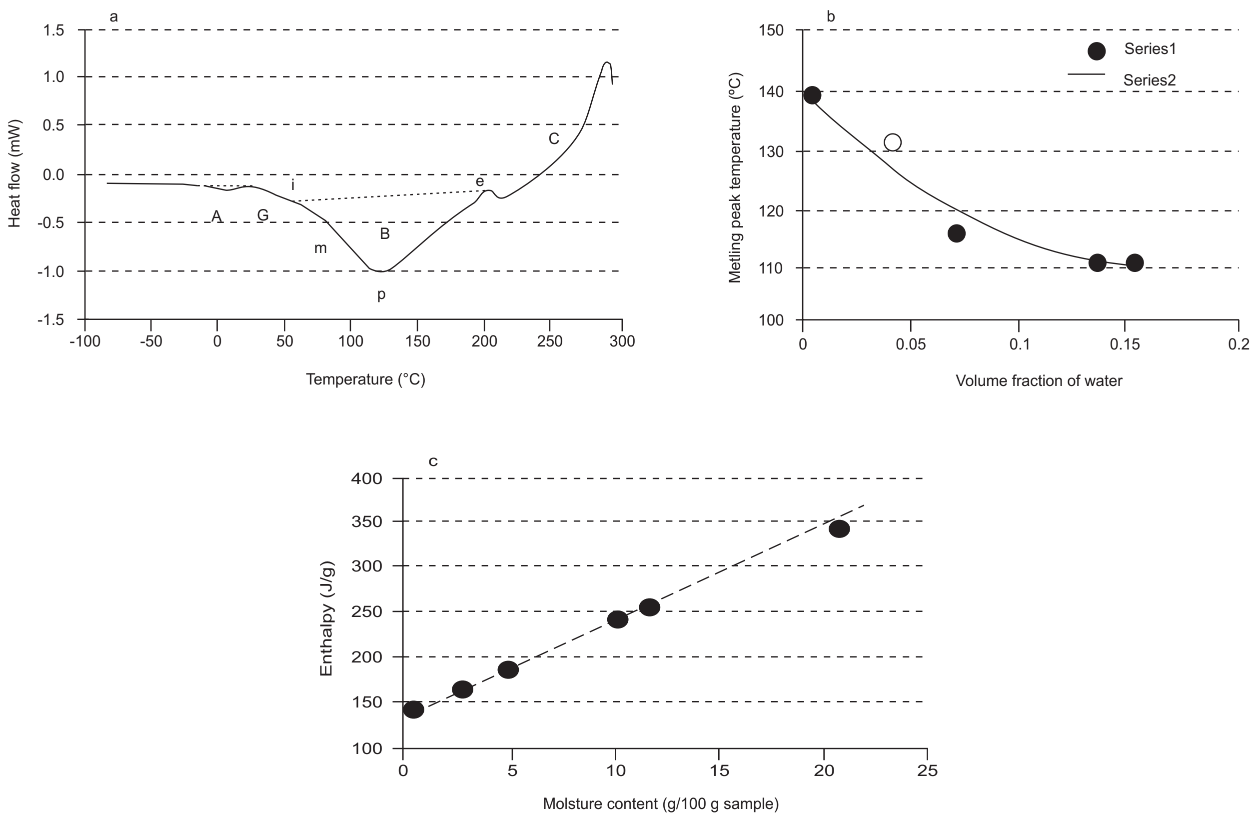

FIGURE 4. Modulated DSC thermogram of date–pits powder containing moisture 6.7 g/100 g sample (cooling and heating rate: 2.5°C/min). a: total heat flow cooling thermogram, b: total heat flow heating thermogram (A: melting of oil, G: glass transition, B: melting of solids, C: exothermic shift, i, m, p, e: onset, maximum–slope, peak, and end of solids melting), c: reversible heat flow heating thermogram (G: glass transition), d: non–reversible heat flow heating thermogram (A: melting of oil, B: melting of solids, i, m, p, e: onset, maximum–slope, peak, and end of solids melting) [Suresh *et al.*, 2013].

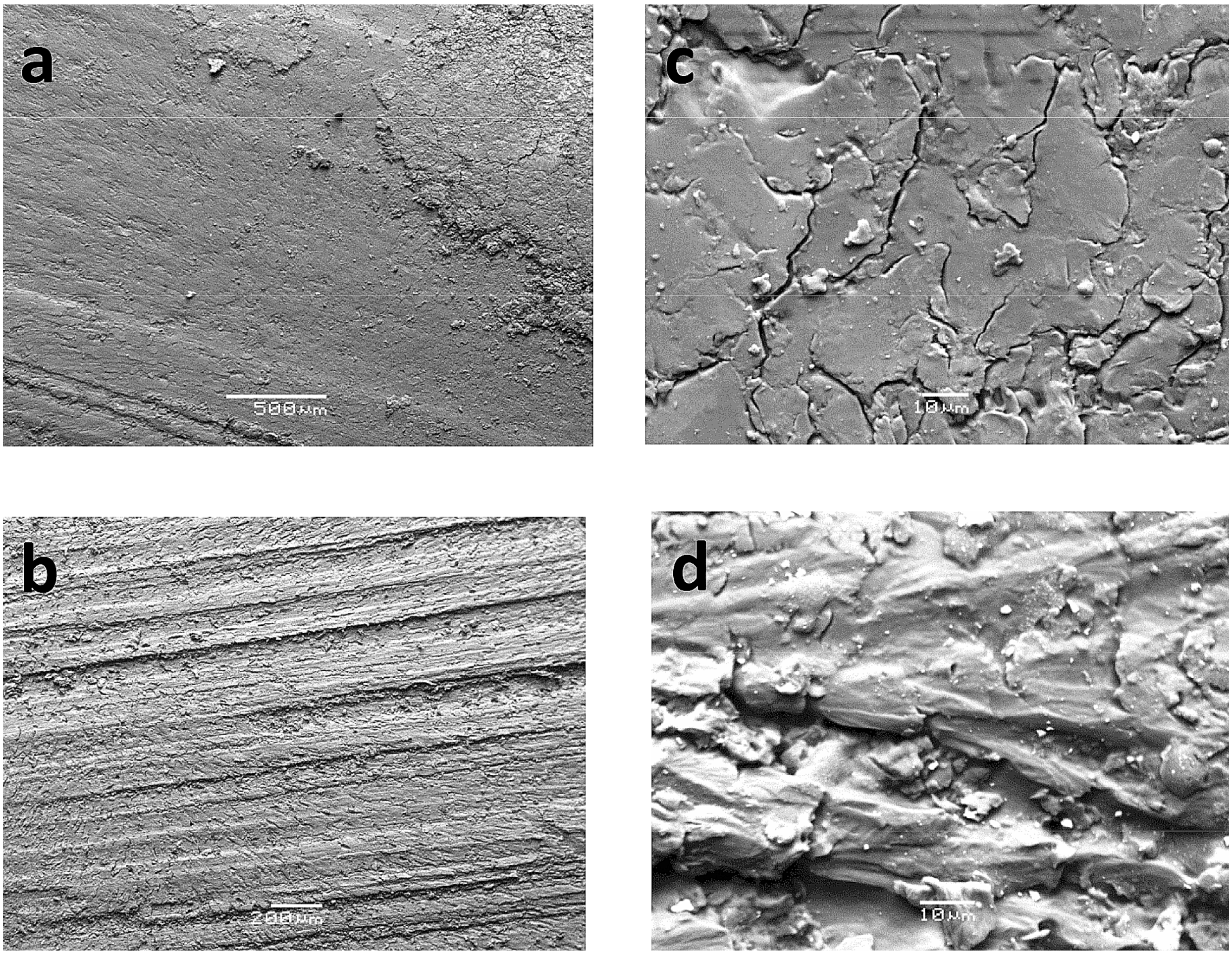

FIGURE 5. SEM micrographs of freeze–dried date–pits at different levels of magnification. a: low magnification, b: medium magnification, c: high magnification (transverse cut), d: low magnification (longitudinal cut) [Suresh *et al*., 2013].

(Figure 4a). The onset, mid and end points of the glass transition of freeze–dried date–pits were 43.0, 44.4 and 51.0°C at 5°C/min, whereas the onset, mid and end points of glass transition were 51.2, 52.3 and 58.3°C at 50°C/min. It was very difficult to observe the plasticization of the date–pits with water [Rahman *et al*., 2007; Suresh *et al*., 2013]. Date–pits contain very tightly packed structure as it was observed in the SEM analysis (Figures 5) [Suresh *et al*., 2013]. SEM images at different magnifications showed that cells are very packed in the case of date–pits with very low pore volume and the pores (*i.e.* cracks) in the date–pits are in the nano–size. Solids–melting peak temperature decreased with the increase of water (Figure 4b), and enthalpy increased with the increase of water content (Figure 4c).

Structural characteristics of date–pits were also studied by measuring solids–melting as a function of moisture content, heating rate and annealing conditions [Suresh *et al*., 2013]. At a heating rate of 5°C/min, onset, maximum slope, peak and end of second endothermic peak (*i.e.* solids–melting) were observed at 59, 64, 106 and 197°C, respectively (Figure 4a). This was due to the heterogeneity of date–pits with multicomponent mixture having amorphous, crystalline and semi–crystalline phases, and varied distribution of crystal lamellae thickness [Pandey *et al*., 2011]. The enthalpy value was observed as 184.0 J/g. The exothermic shift after solids–melting presented in the Figure 4a (marked as C) was observed at 290°C.

FATTY ACIDS COMPOSITION OF DATE–PITS

Using Differential Scanning Calorimetry (DSC), melting point (*i.e.* maximum slope of the melting peak) and enthalpy (*i.e.* latent heat of melting) of date–pits oil were observed as 1.8°C and 68.1 kJ/kg, respectively. The melting started at –32.7°C and ended at 20°C, respectively [Rahman *et al*., 2007]. Thermal characteristics of extracted date–pits oil were also measured by modulated DSC (Figure 6) [Suresh *et al*., 2013]. Figure 6a shows the crystallization of oil during cooling cycle. Similarly total (Figure 6a), reversible (Figure 6b) and non–reversible (Figure 6c) heat flow showed the melting characteristics of oil. Using reversible heat flow, the onset, peak and end of glass transition temperature were observed at –22.0, –19.2, and –17.9°C, respectively and specific heat change at the transition was 436 J/kg K (Figure 5c). The onset of oil melting from total heat flow thermogram was observed at –37.0, peak at –2.3 and end at 20.0°C with an enthalpy 56.0 J/g. Similarly non–reversible heat flow showed an onset at –34.0, peak at –1.6, and end at 19.0°C with an enthalpy 36.0 J/g [Suresh *et al*., 2013].

As presented in Table 2, the major fatty acid composition found in date–pits oil may differ within the varieties, and climate conditions of growing [Al–Shahib & Marshall, 2003]. Major saturated fatty acids present in date–pits are lauric (C12:0) (0.11–38.81 g/100 g fatty acid), myrsitic

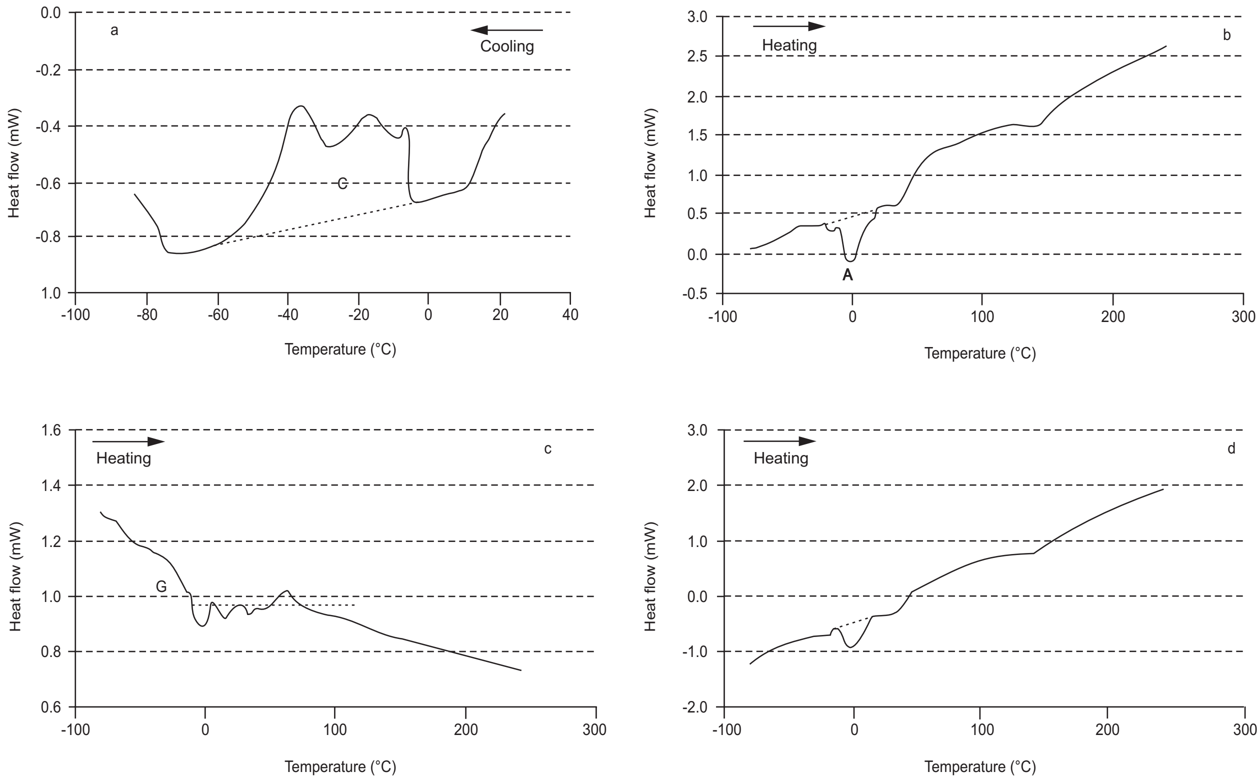

FIGURE 6. Modulated DSC thermogram of date–pits oil (cooling and heating rate: 5°C/min). a: total heat flow cooling thermogram (C: oil crystallization), b: total heat flow heating thermogram (A: melting of oil), c: reversible heat flow heating thermogram (G: glass transition), d: non–reversible heat flow heating thermogram (A: melting of oil) [Suresh *et al*., 2013].

(C14:0) (3.12–18.23 g/100 g fatty acid), palmitic (C16:0) (0.42–15.09 g/100 g fatty acid), and stearic (C18:0) (1.66––6.05 g/100 g fatty acids). Palmitoleic (0.07–1.52 g/100 g fatty acids) and oleic (32.16–55.10 g/100 g fatty acid) acids are the main monounsaturated fatty acids while linoleic (C18:2) (4.33–21.00 g/100 g fatty acids) and linolenic (C18:3) (0.03––1.68 g/100 g fatty acids) are the major polyunsaturated fatty acids [El–Shurafa *et al*., 1982; Fayadh & Al–Showiman, 1990; Al–Showiman, 1990; Besbes *et al.*, 2004a; Nehdi *et al.*, 2010; Habib *et al.*, 2013; Devshony *et al*., 1992; Zubr, 1997]. Generally, oils with high oleic fatty acid contents showed good flavour and frying stability. Date–pits oil showed low content of linoleic acid as compared to the commonly consumed vegetable oils and lower degree of unsaturation [Sawaya *et al*., 1984]. Oleic fatty acid is beneficial to health due to its low saturation level, minimal *trans*–isomer level and its potential to reduce LDL cholesterol in the blood as well as high oxidative stability [Liang & Liao, 1992]. Linolenic acid is vital for the healthy growth of human skin [Bruckert, 2001].

INDUSTRIAL APPLICATIONS OF DATE–PITS

Date–pits as a source of edible oil

Date–pits oil could be considered an edible oil, and could be used in cosmetics and, pharmaceuticals, but it is not competitive with other oil crops due to lower oil content (*i.e.* low yield) as compared to traditional oil crops [Al–Shahib & Marshall, 2003; Besbes *et al.*, 2004ab,c]. It possesses characteristics that distinguish them from other vegetable oils and it has unique fatty acid and tocopherols composition. Date–pits oil could protect UV light (*i.e.* high absorbance of UV), responsible for much cellular damage of skin. Recently, date–pits oil was used for the production of mayonnaise [Basuny & Al–Marzooq, 2011]. Mayonnaise containing date–pits oil was superior in sensory characteristics as compared with control manufactured from corn oil. Hence, the date–pits oil could be used as non–traditional oil in selected food products. The potential functional and economic utility of date––pits oil could be considered as a new source of oil. However, safety of date–pits oil must be tested before its use for human consumption [Nehdi *et al.*, 2010].

Appropriate conditioning and milling procedures of date pits need to be applied in order to prevent oil rancidity [Hamada *et al.*, 2002; Habib *et al.*, 2013]. Generally date–pits oil can be extracted using organic solvents, such as diethyl ether and hexane. The quality characteristics of date–pits oil, particularly its oxidation stability during storage in accelerated conditions (60°C), has been previously reported [Besbes *et al*., 2004c]. The oxidative stability of date–pits oil was much higher than that of most vegetable oils as compared to the olive oil [Besbes *et al.*, 2005]. Using an accelerated Rancimat test, it was reported that date–pits oil could resist thermal treatments (*i.e.* 30–40 h long) during refining and may be used in frying and cooking, and the date–pits oil could have a good shelf–life and could be stored safely for a relatively long period [Besbes *et al.*, 2005].

Date–pits as a source of dietary fibres

High intake of dietary fibres has been known to lower low density lipoprotein, the atherogenic marker, blood pressure,

TABLE 2. Fatty acid profile of date–pits oil (g/100 g fatty acids).

Variety/Fatty acid	Capric (C10:0)	Lauric (C12:0)	Myristic (C14:0)	Palmitic (C16:0)	Stearic (C18:0)	Palmitoleic (C16:1)	Oleic (C18:1)	Linoleic (C18:2)	Linolenic (C18:3)
Deglet Noor	0.80	17.80	9.84	10.90	5.67	0.11	41.30	12.20	1.68
Allig	0.07	5.81	3.12	15.00	3.00	1.52	47.70	21.00	0.81
Phoenix Canariensis	0.11	10.24	7.51	9.83	1.66	0.07	50.00	19.23	0.11
Khalas	–	–	13.72	12.52	3.48	0.13	55.10	8.88	0.09
Barhe	–	–	14.02	11.72	3.05	0.13	48.01	10.3	0.11
Lulu	–	–	14.72	11.41	2.80	0.13	45.60	9.45	0.05
ShikatAlkahlas	–	–	13.33	11.91	3.34	0.15	44.90	9.67	0.17
Sokkery	–	–	15.33	12.95	3.31	0.13	44.60	10.20	0.14
Bomaan	–	–	13.73	13.32	3.83	0.16	46.90	7.90	ND
Sagay	–	–	13.24	12.13	3.08	0.12	42.31	13.90	0.18
Shishi	–	–	14.23	12.92	3.42	0.13	46.20	10.70	0.21
Maghlool	–	–	14.73	12.01	3.52	0.13	47.30	11.50	0.04
Sultana	–	–	10.43	14.20	6.05	0.16	41.40	10.30	0.03
Fardh	–	–	13.54	12.12	3.88	0.16	48.00	9.06	0.04
Fardh and Khasab	0.35	38.81	–	15.09	–	–	36.51	9.21	–
Maktoomi	–	–	12.73	11.31	2.70	0.15	44.40	10.05	0.03
NaptitSaif	–	–	14.70	12.41	3.15	0.15	51.40	11.70	0.17
Jabri	–	–	14.92	12.52	3.42	0.15	48.20	12.80	0.40
Khodary	–	–	17.92	13.34	2.78	1.14	50.30	8.33	0.10
Dabbas	–	–	18.23	12.41	2.87	0.15	48.10	9.02	0.14
Raziz	–	–	14.72	11.51	2.52	0.11	52.30	10.4	0.09
Shabebe	–	–	17.14	12.72	3.28	0.19	49.50	9.93	0.15
ALBarakawi	–	37.10	–	9.24	1.71	–	32.66	4.33	–
Alqundeila	–	0.11	–	0.42	46.93	–	ND	ND	–

Reference: Besbes *et al.* [2004a, 2005]; Nehdi *et al.* [2010]; Habib *et al.* [2013]; Abdalla *et al.* [2012], Rahman *et al.* [2007].

blood glucose, and improve insulin resistance in people with pre–diabetes and type 2 diabetes, and improve bowel regularity and gastrointestinal health [Clemens *et al*., 2012]. Date–pits extract showed reduction in blood glucose level in induced type I diabetics mellitus rats as compared to the group without extracts. It was concluded by measuring C–peptide levels that date–pits stimulated certain endogenous insulin–secreting cells. However, date–pits did not show any effect in the case of normal rats (*i.e.* without induced disease) [El Fouhil *et al*., 2013].

The nutritional value of date–pits is based on their dietary fibre content, which makes them suitable for the preparation of fibre–based foods, such as bread, biscuits, and cakes; and dietary supplements [Almana & Mahmud, 1994; Larrauri *et al*., 1995]. Date–pits fibre could be used as an alternative to wheat bran, and it may provide a valuable contribution to dietary fibre intakes [Almana & Mahmoud, 1994]. Finely milled date pit fibre had a total dietary fibre content of 71% while the coarsely milled fraction contained 80% total dietary fibre. Total dietary fibre contents, rheological characteristics and sensory properties of flat breads containing 0, 5, 10 and 15% date–pit fibres were compared to control flat breads containing wheat bran. Rheological properties were similar for different dough containing coarse date–pits fibre or wheat bran. Bread containing 10% coarse date–pits fibre had higher dietary fibre content and similar sensory properties to the wheat bran control. Breads containing the fine date–pits fibre had higher dietary fibre contents than wheat bran controls, but lower desired colour, flavour, odour, chewiness, uniformity and overall acceptability of sensory scores [Larrauri *et al.*, 1995; Najafi, 2011].

Hamada *et al.* [2002] extracted different high value–added components for the potential use as functional foods. Abou–Zeid *et al*. [1983] conducted a study to develop hydrolysed–pits. Date–pits were dried at 90–95°C and then ground to fine powder in a pulverizing mill. The powder was then passed through a 40 mesh sieve and dried again in an oven to constant mass. A sample of 200 g of the powdered date–pits was placed in a 2 L round bottom flask to which 1 L of 3 N hydrochloric acid was added. The mixture was refluxed for 7 h, then cooled to room temperature and filtered. The filtrate was then dried. They also tested to produce citric acid by utilising low value hydrolysed–pit and cheese whey. The fermentation was performed by *Candida lipolytica* with glucose, ammonium sulphate, ammonium chloride, and sodium nitrate. Date–pits include high amount (14.4%) of crude fibre and sodium hydroxide treatment of date–pits increased the rate of *in–vitro* digestibility by solubilizing some of the cell wall components, such as neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose, and cellulose. However, lignin content was not affected by sodium hydroxide treatment [Al–Yousef *et al*., 1986].

The addition of date–pits in the fermentation medium increased the output of citric acid, indicating the importance of certain elements, such as magnesium, iron, calcium, manganese, zinc and nickel in the formation of citric acid. Al–Ogaidi *et al*. [1985] tested the production of single cell protein by *Aspergillus oryzae* by utilising date–pits. The fungal biomass that contained high amount of protein was produced by growing the fungi on a nutritive media containing 20% date–pits, 0.2% ammonium sulphate at a temperature of 24°C, pH 5.7 and incubation time of 5 days.

Al–Farsi & Lee [2008b] conducted a study to optimise extraction of dietary fibre from date–pits. The effects of solvent to sample ratio, temperature, extraction time, number of extractions and solvent type on phenolic compounds were also studied. They found that the total dietary fibre of date–pits (57.9 g/100 g) was increased after water and acetone extractions to 83.5 and 82.2 g/100 g, respectively. It is evident from Table 1, the total dietary fibre contents in date–pits were 57.9 g/100 g, whereas insoluble fibre was the major fraction (52.7 g/100 g). Al–Farsi *et al*. [2007] reported a higher content of total dietary fibre in three date–pits varieties ranging between 77.8 and 80.2 g/100 g. Considering different types of date–pits, Hamada *et al.* [2002] also reported that total dietary fibre varied within 64.5 to 68.8 g/100 g date–pits.

The total dietary fibre of WDF (dietary fibre after extraction of phenolic compounds with water) and ADF (dietary fibre after extraction of phenolic compounds with acetone) was increased significantly to 83.5 and 82.2 g/100 g, respectively, as well as their insoluble fibre to 82.0 and 81.1 g/100 g, respectively. This is clearly due to extraction of phenolic compounds as well as other components, such as protein, fat and mono– and di–saccharides with water and 50% acetone, which leads to increase in the insoluble dietary fibre (cellulose and hemicellulose). Most soluble fibres (pectin, inulin and gums) were extracted with phenolic extraction. Thus, phenolic extract from date–pits also contained soluble dietary fibre (82–84%). Akasha *et al*. [2012] extracted and characterised plant–based protein fractions from defatted date–pits in order to develop ingredients to be used as emulsifiers, foaming agents, and thickening or gelling agents in formulated foods. They used acid and alkali extraction followed by acetone precipitation. Polysaccharides or other higher molecular weight components affected the separation and quality of protein.

Date–pits as a source of animal feed

The demands of animal feed are increasing globally and date–pits can be used as an alternative feed. Date–pits could be a non–traditional carbohydrate sources in animal feed. The use of date–pits in animal feeds was first carried out by Ali *et al*. [1956] for dairy cows. Studies were conducted to use date–pits as a feed for broiler [Al–Yousef *et al*., 1986], layer [Najib *et al*., 1994], sheep [Aldosari *et al*., 1995] and fish [Yousif *et al*., 1996]. Alwash & De Peters [1982] concluded from their study that date–pits could be used up to 50–75% in ruminant rations. Yousif *et al*. [1996] found positive growth performance in all fish groups fed with diets containing date–pits. Lambs fed with date–pits promoted better growth with higher carcass weight and decreased percentage as compared with alfalfa alone [Al–Kinani & Alwash, 1975].

Date–pits were used in animal feed to enhance growth and increase plasma level of estrogens [Elgasim *et al.,* 1995] or testosterone [Ali *et al*., 1999]. Aldhaheri *et al*. [2004] investigated effects of five isonitrogenous and isocaloric diets with or without date–pits on the reproductive hormonal status of male and female rats. The dietary treatments showed no effect on testosterone level in male rats, while oestradiol concentration in the serum of female rats decreased as the percent of date–pits increased in the diet. This may be due to the esterogenic effect of date–pits, which may cause reduction in the fertility of the female rats. However, Ali *et al*. [1999] observed that extracts of polar components from date–pits significantly reduced plasma oestradiol concentration by about 25 and 36%, respectively. On the other hand, the non–polar fraction increased the hormone level by about 12%. Juma *et al*. [1983] studied the effect of date–pits–based diets (*i.e.* 0, 25 and 50% date–pits) on the rams and observed no significant effects on the volume and concentration in specific ejaculation. However, sperm concentration was affected by frequency of ejaculation, whereas it was observed higher in the first ejaculate.

Date–pits as a source of poultry feed

The poultry industry in Middle Eastern countries has tremendously increased due to their importance and demand, basically this industry relies on costly imported feed. Giving the fact that the in Middle Eastern countries are the largest producer of dates in the globe, thus utilization of date–pits could provide a potential alternative to the conventional feeds used in the poultry industry. This potentially helps to reduce the reliance on the foreign imports of raw materials. Furthermore, it could reduce load on the main cereals and to reduce environmental pollution by decreasing the reduction of agricultural waste [Al–Bowait & Al–Sultan, 2007; Al–Attar & Sial, 1978].

Vandepopuliere *et al.* [1995] evaluated the dietary potential of dates, date–flesh, and date–pits for broilers' growth. The feeds were prepared by incorporating different levels of ingredients, ranging from 8 to 43% dates, 16 to 43% date–flesh, and 5 to 27% date–pits. The quails' feeds contained ingredients ranging of 10 to 30% dates, 8 to 24% date–flesh, and 5 to 15% date–pits. The diets with date fruits supported broiler weights and feed conversions were comparable to or even better than the control diet. The consumption by quail decreased at the 30% date–pits level in the first trial, while in the second trial 24% level of date–pits supported normal intake. Egg production and egg weight were equal to those of the control when date–pits were used as feed. It was also reported that date–pits can contribute positively to the poultry industry in the Arabian Gulf region [Kamel *et al*., 1981].

Date–pits as a coffee drink alternative

Date–pits drink is used in the Middle Eastern region and it could be popular as an alternate to coffee drink. A naturally caffeine–free drink can be produced from roasted date–

–pits, which could provide an alternative to normal coffee, when caffeine is a concern. Traditionally, the drink has been in use in this region for a long time. It was believed that date–pits help in reducing blood pressure, relaxation of the intestinal and uterine musculature and in increasing body protein by decreasing fat. Other traditional claims included lowering effects of body temperature and blood sugar. It could be used as a medicinal food in treating renal stone, bronchial asthma, cough, hyper–activity and weak memory. Ishrud *et al*. [2001] showed that date–pits contain glucomannan, which helped to normalize blood sugar, relieved stress on the pancreas, and discouraged blood sugar abnormalities such as hypoglycemia and prevented many chronic diseases. Date–pits contain amino acids and hormones that could help improve memory [Rahman & Al–Kharusi, 2004]. It is also important to use optimum processing conditions and methods to develop new products. For example, when date–pits are used as a hot drink, white skin should be removed before roasting since it could form foam in the drink. However, the white skin could be used as natural foaming agent in other food products.

Date–pits as a water filter medium

Water absorption of date–pits was modelled by three different approaches [Motahareh *et al*., 2010]. The rate of water diffusion was high during the first 2 h of soaking and then it gradually decreased. The date–pits reached their equilibrium moisture content of 41.5% (wet basis) after 240 h of soaking in distilled water. Date–pits powder could be used to remove 90% phenol and p–nitrophenol (cause unpleasant taste and odour of drinking water) from waste water. The degree of removal depended on the pH, adsorbent dose and contact time [Ahmed & Theydan, 2012]. Date–pits powder was used to remove dyes (*i.e*. methylene blue) from aqueous solution [Belala *et al*., 2011].

Activated carbon is perhaps one of the most widely used adsorbents. It contained distinguished properties to the extensive surface area and internal porosity, as well as their developed surface structure. Low cost activated carbons were developed from date–pits under chemical activation with phosphoric acid, and it was determined the BET–adsorption surface area with nitrogen and adsorption capability [Girgis & El–Hendawy, 2002]. Low porosity activated carbon obtained at 300°C showed good capacity to remove iodine, phenol, and methylene blue. Ahmad *et al.* [2012] reviewed the potential of activated carbon developed from date–pits (prepared by different methods) to remove different types of pollutants (*i.e.* heavy metals, dyes, phenolic compounds, pesticides, and other pollutants). Date–pits ash showed remarkably higher efficiency of boron removal (71%) and phenol from drinking water as compared to power plant ash, pine tree fly ash, and coagulants [Alhamed, 2009; Al–Ithari *et al*., 2011]. Two mechanisms were observed for the adsorption of heavy metals: first one was the hydrogen bonding and electrostatic attraction, while other mechanisms were the binding of two cellulose/lignin units; and by two hydroxyl groups in the cellulose/lignin unit [Al–Ghouti *et al*., 2010].

Date–pits for compost preparation

A composting mixture consisting of 70% date–palm wastes and date–pits, 30% shrimp and crab shell wastes was reported to take about 13 weeks to mature and at the end of maturation the compost was found a good fertilizer. The final compost product was found to contain moisture at 57.1 g/100 compost with a pH of 7.9. The organic matter of 891.0 g/kg dry matter with significant amounts of calcium (2.2 g/kg), phosphorus (0.82 g/kg), potassium (14.3 g/kg), and sodium (1.3 g/kg), respectively [Khiyami *et al*., 2008a,b]. Date–pits could be used to produce biomass using baker's yeast fermentation. It was observed that date–pit's oil increased the efficiency of biomass production and its ash could substitute the required salts [Nancib *et al*., 1997].

Date–pits as an antimicrobial agent

Water and alcoholic extracts of date–pits showed anti–microbial activity against *Klebsiella pneumonia, Escherichia coli* [Mossa *et al*., 1986], *Staphylocaccus aurus, Proteus vulgaris,* and *Bacillus subtilis* [Saddiq & Bawazir, 2010]. Date–pits are most effective in inhibiting the growth of bacteria as compared to antibiotics, mainly due to two reasons: i) differences in resistance of bacteria to anti–tested materials, and ii) the change in membrane permeability of cells, thereby hindering the entry of enzymes or excreted by the change in the chemical composition of the constituent chemical [Mossa *et al*., 1986; Saddiq & Bawazir, 2010].

HEALTH APPLICATIONS OF DATE–PITS

Date–pits as a source of antioxidants

Plants produce different types of secondary metabolites (*i.e.* polyphenols, flavonoids, phytochemicals) and protect them from infections and harsh environments. These polyphenols often provide valuable bioactive properties to the plants and animals for maintaining their functions and homeostasis as well as preventing diseases [Lancon *et al*., 2013]. It is now documented that regular consumption of green vegetables, fruits and fibres has protective effects against the onset or delay of cardiovascular alterations, cancer, inflammation, and aging.

Date–pits have the potential to be used as a supplement for antioxidants in nutraceutical, pharmaceutical, and medicinal products [Al–Farsi & Lee, 2008a]. It was observed that date–pits contained high levels of phenolic compounds (21.0––62.0 mg gallic acid equivalents, GAE/100 g date–pits) and antioxidants (580–929 mL Trolox equivalents/g) [Al–Farsi *et al.* 2007; Suresh *et al*., 2013]. Date–pits extract showed to impair the cytotoxicity of azoxymethane–induced cancer in colonic tissue in rats [Waly *et al*., 2013].

It is important to explore the extraction of health–promoting bioactive compounds, such as antimicrobial, antioxidant, anti–inflation, and anticancer activities. Al–Farsi & Lee [2008b] optimised the extraction of phenolic compounds from date–pits. The optimum conditions were observed as: ground powder, extraction temperature at 45°C, solvent to solid ratio of 6:1, and two–stage extraction each stage for 1 h. Types of solvents affected total phenolic compounds and antioxidant properties of the extracts. It was observed that acetone (50%) was the most efficient solvent for phenolic extraction and butanone was the most efficient solvent for purifying phenolic extract. The polyphenol contents of acetone extracts were 54, 55 and 62 mg GAE/g date–pits powder at 22, 45 and 60°C respectively [Suresh *et al*., 2013]. Temperature and solvent had a significant effect on the extraction of total polyphenols. Al–Farsi *et al*. [2007] reported that the total polyphenols for three date–pits varieties (Mabseeli, Um–sellah and Shahal) varied from 31.0 to 44.3 mg GAE/g sample. The solubility of polyphenols depends on the type of solvents with varied polarity [Cheung *et al*., 2003; Al–Rawahi *et al*., 2013]. Different types of polyphenols present in the date–pits could exhibit different polarities, thus affected the polyphenols in the extracts. Aqueous acetone showed capability of dissolving many hydrophilic compounds and high molecular weight bioactive compounds as compared to only aqueous solvent [Dai & Mumper, 2010]. The mixing of different solvents with varied degree of polarity can increase the extraction of polyphenols by dissolving compounds with varied degrees of polarity [Naidu *et al*., 2012]. In addition, higher temperature may soften the tissues which allow the migration of polyphenols into the solvents, enhancing the extraction efficiency [Shi *et al*., 2003]. However, volatility of the organic solvents and un–stability of polyphenols could restrict the use of very high temperature (for example, boiling point of acetone is 56.2°C). The extracted phenolic components could be concentrated and used as natural additives in food products to enhance their functional and health properties. It is important to point out safety concerns associated with organic solvents for extractions. The most important ones are: solvent residues in the final dried extract; and their handling and recovery. Therefore, safer and cost–effective techniques need to be developed to extract specific phenolic compounds from crude extracts.

Date–pits combat induced toxicity in animals

Date–pits extract showed an ability to restore the normal functional status of the poisoned liver, and to protect against subsequent carbon tetrachloride hepatotoxicity in the liver in rats [Al–Qarawi *et al*., 2004]. There was no acute toxicity of date–pits extract in rat model, as reported in a recent animal model, in which no death in rats was observed when they were given up to 42 mg date–pits/g body weight (BW) [Hussein *et al*.,1983]. All animals had good appetite and activity when given doses up to 21; but the dose of 42 mg/g BW showed photophobia and greater sensitivity to cold, even after 14 days of the acute toxicity. This transformed to 1.3 and 2.5 kg date–pits per 60 kg recipient BW (daily dose), which was very high to be consumed normally. They suggested the necessity of conducting further chronic toxicity experiments.

Date–pits effects on reproductivity in animal models

Lim [2012] reviewed the effects of date–pits on animal reproductivity. Sperm count in guinea pigs was increased with the feeds added with date–pits extracts. Similarly, spermatogenesis was enhanced and concentration of testosterone, follicle stimulating hormone, and luteinizing hormone was increased in rats [El–Mougy *et al.,* 1991]. Egyptians used pollen grains of date palm to improve fertility in women [Amin *et al.,* 1969]. The chronic oral administration of date–pits caused a recovery effect on testicles of male albino rats exposed to methylprednisolone and a significant increase in the serum levels of testosterone was observed [El–Mougy *et al.,* 1991].

Date–pits reduce side effects of certain therapeutic drugs

Methylprednisolone is used to treat conditions such as allergies, arthritis, lupus and ulcerative colitis. Chronic oral administration of methylprednisolone drug has adverse side effects including decrease in neurotransmitters (norepinephrine, NE; dopamine, DA, and gama amino butyric acid, GABA), however concomitant daily oral administration of date–pits caused the maximal increase in NE, DA and GABA content in the brain stem after 2 weeks of exposure. Therefore, it was suggested that date–pits might acts as a preventive measure to reduce the side effects resulting from the use of a drug methylprednisolone on some neurotransmitter content in the brain.

CONCLUSION

Date–pits are rich sources for nutritive substances (proteins, fats and oil), dietary fibre, bioactive compounds, and polyphenols. Date–pits are considered as waste and have shown high potential to be used as a source of ingredients for food products, for the extraction of bioactive compounds with health functionality, water purification, and biomass production. In order to valorize this waste, it would be interesting to extend the research in the three major themes: date–pits oil for cooking and biofuel; extraction of functional fibres, and health functional bioactive components. Applications in water purification and biomass production need to be given low priority due to their minimal economic gain. The future research needs to be focused on the development of technology for commercial production and biomaterials characterisations for their functionality and safety. At present, the scientific evidence of health claims is at its early stages and there is a need for further investigation using cell lines tests, animal trial and finally clinical trials for establishing their efficacy and safety. All studies were conducted using crude extracts with different solvents, however it is important to develop the technology for extracting pure specific bioactive compounds to be used for pharmaceuticals.

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