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RESEARCH ARTICLE

Utilization of date by-products in the food industry

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ABSTRACT

The fruit of date palm tree *Phoenix dactylifera* is among the most abundant fruits, and it is rich in essential nutrients. Quality-wise, not all cultivated date fruits meet the commercial standards, and tons of date fruit that are immature, or of poor appearance but with no reduced nutritive value are treated as date by-product and are being used for animal feed or are discarded during processing by the relevant industries. Together with the rejected fruit, date seed which is the inedible part, and the trimmed fronds of the date palm, they are all discarded, resulting in an environmental problem, and an economical loss. The objective of this review is to identify current practices on the uses of low-grade date, seed, and frond in the industry. The literature shows date fruit of low quality is typically processed to make date paste and date syrup, and both are well utilized in the food sector. The chemical composition of date seed, and increasingly of other parts are well known, and fully exploited in many industrial applications.

Keywords: Date palm tree; Date by-products; Date paste; Date syrup; Date seed

INTRODUCTION

Date palm tree, *Phoenix dactylifera,* is one of the oldest cultivated plants, and the main staple and ancient crops are grown in many regions; in southwest Asia, North Africa, Australia, Mexico, South America, and in southern Africa (Chao and Krueger 2007; Al-Harrasi et al. 2014; Hazzouri et al. 2015). Due to its high tolerance of aridity and very harsh climatic conditions, date palm tree invaluably provides the people in those regions a nutritious food source and environmental protection (Daoud et al. 2019; Kalbouneh 2011). The date fruit is known to be nutrient-rich (Chao and Krueger 2007). It is a good source of carbohydrates (approximately 70%, in the forms of fructose and glucose), dietary fibers (predominantly insoluble fibers), proteins, and minerals (Al-Harrasi et al. 2014; Siddiq 2014; Eoin 2016). It is also rich in phenolic acids, flavonoids, procyanidins, carotenoids, and sterols (Baliga et al. 2011; Gheisari, Heydari, and Basiri 2020).

On average of 5 years after propagation, date fruit can be obtained from a female tree, yielding 400-600 kg/tree annually (Al-Alawi et al. 2017). Date fruit is being harvested and marketed depending on the cultivar at three developmental stages (Fig. 1), which include Khalal (mature firm), Rutab (soft brown), and Tamr (hard raisin-like) (Awad 2007; Glasner et al. 1999).

During cultivation, different ripening stages are found within the same cluster, including immature dates (Lobo, Yahia, and Kader 2013). Thus, date production generates substantial fruit losses (approximately 30%) during picking, storing, or conditioning the fruits. Due to the large quantity of second-grade date, together with other inedible parts combined at harvesting, it would be beneficial for farmers and the food industry to valorize this by-product by utilizing its nutritional value into value-added products, which at the same time is beneficial to the environment.

This review provides an overview of the potential applications of date by-products (fruit, seed, and leave), and summarizes their incorporation in the industry.

DATE BY-PRODUCTS

Low-grade date

Studies on health benefits of date fruit, such as chemoprevention of cancer, prevention of diabetes, and cardiovascular diseases have been investigated (Chao and Krueger 2007; Al-Alawi et al. 2017). Date fruit contains phytochemicals which have cholesterol-lowering properties and antioxidant activity (Tiwari, Brunton, and Brennan 2013). It is involved in traditional medicine as a stimulator

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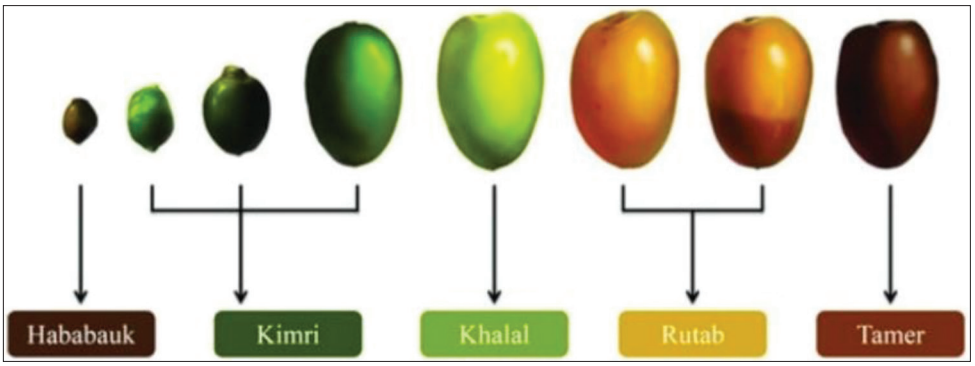

Fig 1. Growth stages of date fruit (Siddiq 2014).

of immune, and it shows antifungal, antiviral, antibacterial, antiparasitic, hepatoprotective, anti-inflammatory, and anticoccidial activities (Puri et al. 2000; Mohamed, Awad, and Adel 2014).

The lost date at harvest (or second-grade date) is a low-grade date, either hard in texture or contaminated with fungi or infested by insects; such date fruit is not marketed for human consumption, but discarded, and often used in animal feeding (Chandrasekaran and Bahkali 2013; Siddiq 2014).

The second-grade date that is safe for consumption can be used to prepare many products, such as date paste, date juice concentrates (spread, syrup, and liquid sugar, which are being used mainly in bakery and confectionary), and in the production of fermented products like wine, alcohol, vinegar and organic acids (Chandrasekaran and Bahkali 2013). For non-food applications, second-grade date fruit can be used as a substrate for biogas production like methane (Lattieff 2016; Abd-Alla and Elsadek El-Enany 2012). Table 1 lists the possible uses of date by-products.

Date syrup

Low-quality date fruit serves as a good source of dry matter, sugars, and phenolic compounds, and can be used to make high value-added products like syrup (Fig. 2; (Chandrasekaran and Bahkali 2013). According to the 2013 Iran National Standard Organization, date syrup must have the following standards: a minimum Brix of 70, a pH in the range of 4.2 to 6, a maximum ash content of 2%, and a minimum reducing sugars of 58% (Farahnaky et al. 2016).

Date syrup can be used as an ingredient in some food formulations like ice cream, beverages, bakery products, jam, and butter (Barreveld 1993; Jridi et al. 2015; Razavi, Habibi Najafi, and Alaee 2007). Due to its high fiber and sugar contents, the incorporation of date syrup and date powder in desserts creates a sweetening effect, enhances viscosity, and spontaneous exudation (Ashraf and Hamidi-Esfahani 2011; Tang, Shi, and Aleid 2013; Elleuch et al.

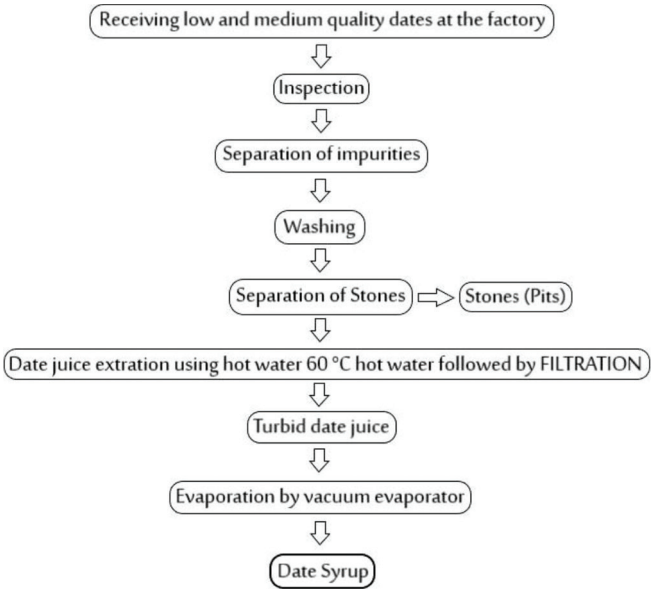

Fig 2. Large scale process chart of production of date syrup [adapted from (Farahnaky et al. 2016).

2008). It is also used as a natural coloring and flavoring agent. A study on the effects of date syrup and date powder in a dairy dessert showed the physicochemical, phytochemical, microbiological, rheological, and microstructural properties of the date-added products differed from those of the commercial sample tested (Djaoud et al. 2020). Date syrup was reported to be suitable for replacing sugar in some traditional Indian and Iranian desserts (Manickvasagan, Chandini, and Al Attabi 2018; Ardali and Akbarian 2014). Improvement of organoleptic properties and chemical composition in products such as prebiotic chocolate milk and yogurt after addition of date syrup was observed (Kazemalilou and Alizadeh 2017; El-Nagga and Abd ElTawab 2012; Sayed, Kholif, and S. 2010).

Date syrup contains several components that are crucial for microbial growth, e.g. simple sugars (glucose, fructose, sucrose), vitamins (B1, B2, nicotinic acid), potassium, and chloride (Al Eid 2006). Thus, it has been used in biomass production and microbial fermentation process. Reports on

Table 1: The main uses of date by-products

Date by-product		Possible use
Low-grade date	Date syrup	Ice cream, beverages, baked products, jam, butter (Barreveld 1993; Jridi et al. 2015; Razavi, Habibi Najafi, and Alaee 2007; Gheisari, Heydari, and Basiri 2020; Tammam, Salman, and Abd-El-Rahim 2014) Dairy desserts (Djaoud et al. 2020), traditional desserts (Manickvasagan, Chandini, and Al Attabi 2018; Ardali and Akbarian 2014) Prebiotic Milk (Kazemalilou and Alizadeh 2017) Yogurt (El-Nagga and Abd ElTawab 2012; Tammam et al. 2013) Carbon source for bacterial fermentation (Ben Salah et al. 2011; Elsanhoty, Al-Turki, and Ramadan 2012; Khiyami, Alfadul, and Bahkali 2011) Source of biogas (Jaafar 2010; Lattieff 2016)
	Date paste	Enhancing cooked meat (Sánchez-Zapata et al. 2011) Date jam (Besbes et al. 2009)
	Date fiber	Ice cream industry (Yangılar 2015) Baked goods (Mrabet et al. 2016)
	Spoiled date	Acetone, butanol, and ethanol production (Abd-Alla and Elsadek El-Enany 2012)
Date seed	Date seed components	Animal and poultry feed (Vandepopuliere, Al-Yousef, and Lyons 1995) Yeast growth (Bkary et al. 2018) Pita bread (Platat et al. 2015) Polyols production (Briones et al. 2011) Pollutants treatment (Alhamed 2009; Ahmed 2016; Al-Ghouti et al. 2017)
	Date seed oil	Cooking and frying (Nehdi et al. 2018) Producing margarine (Nehdi et al. 2010) Replaces oil in Mayonnaise (Basuny and Al-Marzooq 2011) Cosmetics (Lecheb and Benamara 2015) Biodegradable polyester (Al-Muhtaseb et al. 2018)

microbial fermentation using date by-products as substrates can be found, for example, curdlan gum production by *Rhizobium radiobacter* ATCC 6466™ using date juice (Ben Salah et al. 2011), carotenoid production by *Lactobacillus plantarum* using lost date at Tamr stage (Elsanhoty, Al-Turki, and Ramadan 2012), bleomycin production by *Streptomyces mobaraensis* ATCC 15003 using date syrup (Radwan et al. 2010), xanthan gum production by *Xanthomonas campestris* NRRL B-1459 using date juice by-products (Ben Salah et al. 2010), polyhydroxyalkanoates production by *Bacillus* spp. using date syrup (Khiyami, Alfadul, and Bahkali 2011). Those studies indicated that the date fruit by-products exhibit promising potentials to be used as cost-effective substrates.

Apart from being a suitable substrate for the growth of some microorganisms, date syrup has also been reported for exhibiting antimicrobial activity. A study demonstrated date syrup sterilized by acetone and the polyphenolic components extracted from that sterile date syrup were able to inhibit the growth of *Escherichia coli* and *Staphylococcus aureus* by inducing oxidative stress in bacteria through hydrogen peroxide generation (Taleb et al. 2016).

Date paste

Low-quality date can be processed into date paste, which is, similar to date fruit, high in sugar content, total and insoluble dietary fiber, and natural antioxidants. Due to its dietary fiber content, date paste exhibits functional properties, e.g. water holding capacity, oil holding capacity, emulsifying activity, gel formation, and pseudoplastic behavior of its suspension, which are necessary for the formulation of certain food products (Elleuch et al. 2008; Hussein and Ali 2017). Applications of date paste into various food products, such as meat, bakery, and confectionery, have been explored. The incorporation of date paste in cooked meat decreases fat content and increases total dietary fibers resulting in more adhesive, less hard, chewy, and cohesive product (Sánchez-Zapata et al. 2011). The addition of fresh date paste into certain meat products may suppress lipid and pigment oxidation during storage (Martín-Sánchez et al. 2013). Due to its high sugar content, date paste can also be used in manufacturing value-added products like date jam (Besbes et al. 2009), and date candy (Shi, Shahidi, and Ho 2005). In baked goods, the addition of date paste helps improving dough rheological properties, retarding retrogradation, and prolonging shelf life (Shi, Shahidi, and Ho 2005; Ahmed and Ramaswamy 2006).

Date fiber

Date fruits contain high total dietary fiber, of which 80-90% is an insoluble fraction. Depending on the variety, stage of maturation, extraction methods, and the total dietary fiber content of date fruit varies from 6 to 11% (Al-Shahib and Marshall 2003; Al-Farsi and Lee 2008; Tang, Shi, and Aleid 2013; Al-Farsi et al. 2007).

Applications of date fibers in food products have been investigated, for example, in ice cream (Yangılar 2015), and baked goods (Mrabet et al. 2016). Improvement in rheological property and texture in such products was noted.

Spoiled date fruit

Spoilt date fruit, albeit unsuitable for human consumption, still contains several essential components for the growth of microorganisms and can be efficiently used as a substrate to produce acetone, butanol, and ethanol (Abd-Alla and Elsadek El-Enany 2012).

Date seed

Date seed is considered as waste (Besbes et al. 2004). It accounts for 10-15 % of total date fruit mass on average, depending on maturity, variety, and grade (Besbes et al. 2004; Al-Shahib and Marshall 2003). Date seed represents a significant amount of waste, considering global date fruit production was more than 8 million tons in 2018 (FAOSTAT 2018). Therefore, over 800,000 tons of date seed could be produced. Conventionally, date seed is generally used either as animal and poultry feed or soil fertilizer (Vandepopuliere, Al-Yousef, and Lyons 1995).

Chemical composition analysis showed that, by weight, date seed contains 60-80% fiber, 4-14% oil, and a low proportion of protein. A wide range of phytochemicals such as alkaloids, flavonoids, anthraquinone, saponin, terpenoids, and tannin are present in date seed, in addition to the essential minerals like potassium and calcium (Hamada, Hashim, and Sharif 2002; Al-Farsi and Lee 2008; Al-Farsi et al. 2007). These findings present a new opportunity to reconsider the use of date seed in higher value-added products.

There is a wide range for date seed utilization, in the food and non-food industry. A study on the use of date seed components and flesh to cultivate bakers' yeast biomass reported date components served as good carbon and nitrogen source for the fermentation process and gave promising yield (Nancib, Nancib, and Boudrant 1997). Date seed can be processed into powder form and can be used as a cost-effective ingredient to increase crude fiber and minerals in cereal snacks and baked products (Hussein and Ali 2017; Platat et al. 2015). Besides food applications, date seed can be chemically modified to produce polyols, which can be applied to many other industries, e.g. furniture, packing, and transportation (Briones et al. 2011). In water treatment applications, date seed can be converted into activated carbon, exhibiting good adsorbent properties for removal of pollutants (synthetic dyes, heavy metals) from wastewater (Alhamed 2009; Ahmed 2016), and brominated toxic by-products from drinking water (Al-Ghouti et al. 2017).

Date seed oil

Date seed oil can be extracted with different methods, e.g. soxhlet extraction (Ali, Al-Hattab, and Al-Hydary 2015; Al-Sumri et al. 2017), supercritical fluid extraction (King 2014), green ecological method (Ben-Youssef et al. 2017; Jadhav et al. 2016), and ultrasonic-assisted extraction (Vinatoru 2001).

There are several applications for date seed oil. In food applications, it can be used for cooking, frying, and seasoning, and as an alternative to palm olein (Nehdi et al. 2018), margarine production (Nehdi et al. 2010), and corn oil replacement in mayonnaise production (Basuny and Al-Marzooq 2011). In cosmetic applications, it is feasible to incorporate date seed oil in the formulation of cosmetic creams [80]. In petrochemical applications, it has been used in biodiesel production and studies indicated the quality of the biodiesels produced to meet the limits of the regulatory standards (Azeem et al. 2016; Al-Zuhair et al. 2017; Al-Muhtaseb et al. 2018). In another study, date seed oil was successfully used as a sole carbon source for the growth of *Cupriavidus necator* for the production of Poly (3)-hydroxybutyrate, which is a biodegradable polymer (Yousuf and Winterburn 2017).

Date palm frond

The date palm tree is known to produce large quantities of agricultural waste; around 20 kg of dry leaves every tree produces per year that is usually burned in farms resulting in a serious threat for the environment (Tang, Shi, and Aleid 2013), but it was reported that date palm frond has good potential for ruminants (El Hag and Al Shargi 1998), it can be successfully used to feed local sheep (Mahgoub et al. 2005; Mahgoub et al. 2004). It is used as a supplement to traditional feed (soya and maize) for lamb without affecting the flavor of the meat (Myhara et al. 2000).

The date palm frond composes of cellulose, hemicellulose, and lignin (Saadaoui et al. 2013). Recently it is of interest as a renewable source for cost-effective and green lignocellulosic fibers and composites, which opens a new avenue for waste valorization (Agoudjil et al. 2011). Under certain treatment conditions, the midrib of date palm frond (Fig. 3) is suitable for making wood-cement boards (Nasser and Al-Mefarrej 2011). Different parts of the frond (leaflet, rachis, and leaf sheath) and tree surface fiber (fibrillum) can be transformed into particleboard composites with satisfactory mechanical properties, especially those made from the fibrillum and rachis due to their high amount of lignin (Saadaoui et al. 2013).

Date palm tree fibers have the potential for water treatment applications. Rachis can be structurally modified into sodium carboxymethylcellulose (CMCNa), which acts as an eco-friendly flocculant to remove turbidity in drinking water treatment (Khiari et al. 2010). Satisfactory performance of date palm fiber on the reduction of turbidity and chemical

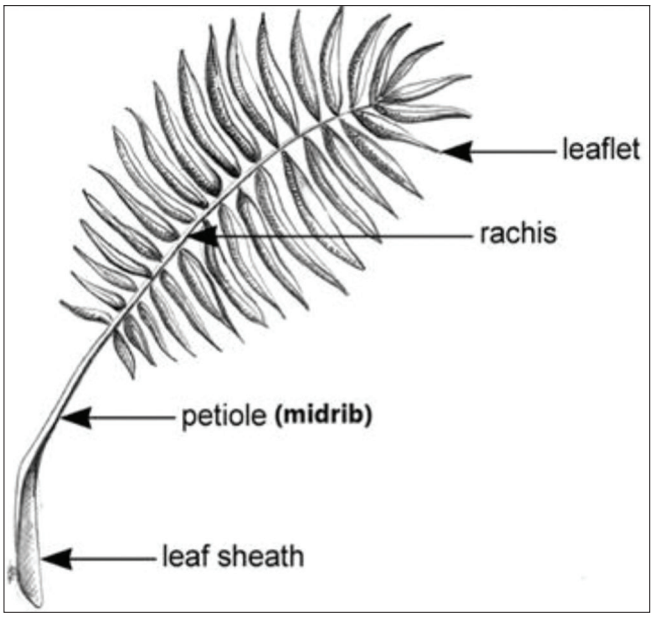

Fig 3. Diagram of date palm frond structure (Anderson 2010).

oxygen demand (COD) in wastewater was observed (Riahi, Mammou, and Thayer 2009). In the automotive industry, date palm fiber shows competitive mechanical properties in comparison to other natural fibers (coir, hemp, and sisal) (Al-Oqla and Sapuan 2014). Petiole and bunch exhibit good insulating properties and have potential for the construction industry (Agoudjil et al. 2011).

CONCLUSIONS

Date palm cultivation is of high importance in the Middle East, Africa, South America, and recently, Australia. In some regions, apart from being a staple food, the tree serves the people in many other aspects. Harvesting date palm fruit generates a significant amount of waste, which is a burden to the environment. At present, fruit that does not meet the market value, as well as other inedible parts, are relatively well exploited in many industrial applications. The literature shows creativity in date waste valorization. Nevertheless, more opportunities to exploit date waste fora novel and high-market-value products are still available.

SUPPLEMENTARY MATERIALS

None

AUTHOR CONTRIBUTIONS

All authors contributed in writing and editing the manuscript.

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CONFLICTS OF INTEREST

None.

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