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Review

Date Components as Promising Plant-Based Materials to Be Incorporated into Baked Goods—A Review

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Abstract: Date (*Phoenix dactylifera L. Arecaceae*) fruits and their by-products are rich in nutrients. The health benefits of dates and their incorporation into value-added products have been widely studied. The date-processing industry faces a significant sustainability challenge as more than 10% (*w*/*w*) of the production is discarded as waste or by-products. Currently, food scientists are focusing on bakery product fortification with functional food ingredients due to the high demand for nutritious food with more convenience. Utilizing date components in value-added bakery products is a trending research area with increasing attention. Studies where the researchers tried to improve the quality of bakery goods by incorporating date components have shown positive results, with several drawbacks that need attention and further research. The objective of this review is to present a comprehensive overview of the utilization of date components in bakery products and to identify gaps in the current knowledge. This review will help focus further research in the area of valorization of date by-products and thereby contribute to the generation of novel functional bakery products that meet consumer expectations and industry standards, thus generating income for the relevant industry and considerable alleviation of the environmental burden this waste and by-products contribute to. Only a few studies have been focused on utilizing date by-products and their extracts for baked goods, while a research area still remaining under-explored is the effect of incorporation of date components on the shelf life of bakery products.

Keywords: bakery products; date fruit; date by-products; valorization; food quality; value-added food

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1. Baked Goods

Improved consumer knowledge about the nutritional value of food with regard to a healthier lifestyle lowering the risk of chronic diseases has led to consumer demand toward a healthy day-to-day diet [1–3]. A current global health trend is to prevent and manage the prevalence of diseases, especially chronic diseases such as diabetes, cancer and cardiovascular disease, to decrease mortality levels due to these ailments through the diet. As a result, there is a growing trend to formulate functional foods making them widely available in the market. These functional foods include bakery products, dairy products, breakfast cereals, confectionery items and beverages, among others [4]. Among these, the main focus is on bakery products that are consumed as a main food on a daily basis all over the world [5,6].

There is a variety of functional ingredients used in food formulations including vitamins, minerals, dietary fiber, prebiotics, probiotics and bioactive compounds to enhance the quality and functionality of food [7–12]. Along with improving the nutritional value of food in order to improve personal health and reduce the prevalence of disease amongst the consumers, another important aspect is to maintain the required organoleptic properties of

food products to secure market demand. Additionally, the consumers also look for convenience through, for instance, convenient packaging, shelf-life stability and the freshness of food products. Bakery products are the most widely consumed processed foods in almost all countries [13]. Food fortification plays a significant role in enhancing health-promoting functional components in baked products to improve value in order to meet consumer demand [14]. In this respect, bakery products have become one of the ideal food products to fulfill almost all the requirements of the consumers through fortification. A number of research studies have been conducted utilizing fruits, vegetables and their by-products in baked goods fortification where the researchers observed improved nutritional value. These attempts and observations are explained in Section 2.2 with relevant examples. However, extensive research on date-component-fortified bakery products is limited. Therefore, this review is organized as summarized in Table 1, from Section 2 onward, including research gaps and future prospects.

Table 1. Organization and summary of the review.

Section	Summary	Characteristics/Importance
Section 2	Health perspectives related to bakery products and the utilization of fruits/vegetables and their by-products to improve the nutritional value are discussed with relevant examples.	Rationale behind the incorporation of fruits/vegetables and their by-products into baked goods.
Section 3	The nutritional value of date components that have been used in baked goods is explained with relevant examples.	Importance of incorporating date components in value-added food products due to their significant nutritional value.
Section 4	The ways that researchers have tried to incorporate date components into baked goods are described in this section, including the nature of the added compound (powder, paste, extract). Furthermore, the effect of addition/substitution on physical, chemical, nutritional and sensory quality of baked goods is elaborated in this section.	The reader will get an overview of research carried out so far utilizing date components in bakery products. The effects of addition/substitution on physical, chemical, nutritional and sensory quality of baked goods are explored. More importantly, research gaps and future directions are identified in this section. **Research gaps identified:** • Lack of studies with alteration of the characteristics of date components/extracted components through different techniques/methods before the substitution to increase the substitution levels and improve the quality of final product. • Lack of studies incorporating date fruit into baked goods. • Lack of studies incorporating date by-products into bakery products. • Lack of shelf-life studies of fortified baked goods. • Lack of clinical trials on fortified baked goods. Future research direction should focus on these areas which remain unexplored.

2. Baked Goods and Health

2.1. Baked Goods and Health Perspectives

Since ancient times, bakery products including bread are part of the human diet and have become one of the most consumed and most popular foods all over the world [13,15]. Bakery products include bread, biscuits, cookies, cakes, muffins, waffles, buns, crumpets, etc. Among other bakery items, biscuits and cookies possess various attractive characteristics such as relatively long shelf life, high convenience and organoleptic quality [16]. The

main ingredient in bakery products is wheat flour which provides the structure and the bulk to the product [17] followed by water, yeast, salt and other ingredients.

Sudha and colleagues [18] pointed out that bakery products are varied with the incorporation of value-adding ingredients. With regard to composite flours, wheat is an essential ingredient as it helps to maintain the required physiochemical and functional properties which are specifically dependent on wheat gluten [19]. Though wheat is a promising source of calories, it is nutritionally poor with respect to essential amino acids such as lysine and threonine [20] which can be improved by the addition of other cereals and pulses. Bakery products such as cakes, muffins and biscuits are usually high in sugar and fat but low in fiber, antioxidants and minerals [9,21]. Traditional or regular bread products are either prohibited or restricted for people who are suffering from diabetes or are overweight or obese due to their high quantity of digestible carbohydrates, which raise blood glucose levels.

The steady growth of the baking industry has been driven by consumer demand. As bakery products are consumed on a daily basis, they play an important role in human nutrition. Currently, there is a growing trend of consumers buying value-added food products. Most of the research has been conducted to improve the quality of bakery products by incorporating functional ingredients including antioxidants and dietary fiber [9,22–28]. The important fact is that the impact of baking on antioxidant capacity is positive [29,30], whereas Rupasinghe et al. [24] claimed that there is no effect on total antioxidant capacity after baking. Apart from the basic nutritional functions, addition of functional ingredients has shown the ability to contribute to the reduction of chronic diseases [31].

Consumers are more attracted to foods that have additional health benefits other than the usual nutritional properties. Hence functional foods are in more demand in the current market. The prevailing busy lifestyle of people keeps them away from healthier food habits making them more prone to diseases such as diabetes, obesity, cardiovascular diseases and high blood pressure. Therefore, including ingredients high in dietary fiber and antioxidants in a regular diet will help to minimize these health issues. There are several studies that focused on the lowering of the glycemic index and slow glucose hydrolysis [32–34]. Regular consumption of dietary fiber, as well as components such as resistant starch (RS), would help to lower the digestion of glucose and its absorption into the bloodstream. Dietary fiber, which affects various kinds of physiological parameters, is mainly responsible for gut health [35]. As refined wheat flour is used as a basic ingredient in bakery products, they are known to be deficient in dietary fiber [6]. Therefore, regular bread or other bakery products are not ideal for people who are suffering from diabetes or obesity as they increase the glucose levels in the blood due to digestible carbohydrates. Incorporation of functional ingredients such as dietary fiber or RS is an excellent way to overcome this issue. Natural ingredients are often added to increase the fiber content of bakery products [6,9]. Nowadays most of the research is focused on the fortification of bakery products with health-promoting ingredients. This leads not only to lowering the glycemic index of food products but can also help to minimize the risk of chronic diseases such as cancer. Specifically, antioxidants play an important role in preventing auto-oxidation in baked goods [36], and they help to minimize the risk of various diseases including cancer, gastrointestinal disorders and coronary heart diseases [37–41].

2.2. Attempts to Improve Quality by Addition of Plant-Based Components

A variety of bakery products are prepared incorporating natural ingredients as well as their by-products. Several developing countries where wheat is not grown much due to climatic reasons, such as Nigeria, have tried to replace wheat flour with unconventional or locally available flours in order to lower the cost of imported wheat [42]. For example, flour from fruits such as banana, mango and dates can be incorporated into bakery items [43–46]. When it comes to by-products, fruit peels, seeds, bagasse and sometimes over-ripe fruits can be used for fortification [47–49]. Fruits and vegetables that do not have the required size or shape can also be used as they are considered as waste in several instances since

they are rejected by the consumers [50,51]. Apart from the above, functional ingredient concentrates extracted from fruits, vegetables and their by-products have also been incorporated in different food products [52–56]. Interestingly, there is a possibility to produce bakery products with high nutritional value by incorporating biologically active marine compounds such as macroalgae, microalgae, seaweeds and bioactive peptides [10].

Wheat flour can be partially substituted with around 20% finger millet flour to prepare nutritionally improved biscuits [57,58]. Addition of 10% sweet potato flour did not adversely affect the texture and flavor of cookies while significantly increasing the dietary fiber and mineral contents [59]. Akubor and Obiegbuna [60] incorporated African bread fruit kernel flour into bread. They investigated that roasting resulted in increased levels of protein, ash and crude fiber contents. Additionally, fermentation improved the protein content, but boiling decreased the bread-making quality.

Fruits and legumes are rich in bioactive compounds such as polyphenols that have antioxidant properties and dietary fiber that can act as a prebiotic as well as resistant starch (RS) which slows down digestion [4]. Dietary fiber and RS help to maintain colon health by decreasing cholesterol levels and acting as an energy source for colonocytes [61–63]. Usually, the protein content will decrease when substituting wheat flour with fruit flours. This was observed in several studies [43,46,64]. However, legumes/pulses are a rich source of proteins [65–67]. Incorporation of chickpea flour and mung bean flour into wheat flour enhanced the protein and resistant starch contents along with the acceptance while not affecting the functional properties of cookies [67]. Biscuits and bars with incorporated soy bean flour, granola and red bean flour showed improved levels of protein [68,69] together with increased levels of minerals and ash. Composite cookies with blends of cocoyam and pigeon pea flour exhibited increasing contents of ash with increasing addition levels [70]. Fruit and legume incorporation into baked products also exhibited significant levels of fat in most of the studies [46,64,68].

Notably, dietary fiber is not consumed in sufficient amounts by the consumers [71]. Fruits and vegetables are an important source of dietary fiber [72]. Recently, diverse studies have focused on increasing the dietary fiber content of bakery products by fortification of unconventional flour. Increased dietary fiber levels were observed when wheat flour was substituted by fruit, vegetable and legume flour adding nutritive value to the cookies and breads. For example, this was evident in several studies where they used pumpkin powder [73], green banana flour [43], apple skin [24], chickpea flour [74] and mango fruit flour [53]. Higher amounts of RS were noticed in bread fortified with chickpea flour [74]. Unconventional flour is used to formulate baked products with lower starch digestibility along with decreased amounts of total starch [4]. This reduction was evident in formulations using unripe fruit [43]. Therefore, there is a positive impact for people suffering from diabetes since it helps to reduce the glycemic index.

A number of studies have focused on improving the antioxidant capacity of bakery products by fortification of plant-derived polyphenols which can act as antioxidants. For example, biscuits with incorporated tea catechins and breads showed higher amounts of catechins even after the baking process allowing them to be used as a good source of antioxidants [75,76]. Polyphenols can also improve the shelf life of the products by reducing the auto-oxidation process and microbial growth and thus preserve the food products for longer periods [36]. The antioxidant capacity was increased with the addition of fruit flour. For example, defatted strawberry and blackcurrant flour increased the antioxidant capacity with a higher effect from defatted blackcurrant flour [77]. The same observation was noticed when muffins were fortified with dates [78]. Not only fruits but also pulses and legumes have also shown increased antioxidant capacities when used to fortify bakery products. Cookies made with bean flour had greater antioxidant activity compared to controls having higher activity with pinto bean flour than navy bean flour [79]. Aligning with these results, legume-fortified cookies also exhibited enhanced antioxidant capacities [80]. Herbs and spices, which are frequently added to bakery items to add flavor [81], contain high amounts of antioxidants [36]. They have improved the nutritional value of bakery products [14].

A composite flour mixture including refined wheat, sprouted mung bean flour, mango kernel flour and soy flour was able to maintain the physical and organoleptic properties of conventional wheat breads [82]. Replacing wheat flour with rice flour was shown to affect the chemical, physical and functional properties as well as sensory scores of the final product [83].

The fruit and vegetable manufacturing processes generate almost 50% by-product waste such as peels, pomace, cores, unripe and damaged forms [84]. Furthermore, seeds are discarded in most of the fruit-processing units. Overall, food industrial by-products are excellent sources of functional ingredients such as antioxidants, fiber and minerals [26,27,56,85–89]. Nowadays the main focus is on valorizing food industry by-products by reincorporating them into the food chain. This sustainable approach can contribute to a more circular economy. Along with manufacturing healthier baked goods, this will lower the impact of disposed waste on the environment. Bakery products exhibit a high glycemic index [90]. It is evident that there is a positive impact on the digestion of glycemic index carbohydrates such as starch by reducing the glycemic index when fruit and vegetable by-products are used [27,47,55,88,89,91]. The reason behind this may be the incorporation of soluble fibers which enhance the thickening properties as well [55,92]. At the same time, phenolic compounds may be responsible for the inhibition of glucose trans-epithelial transporters or inhibition of digestion enzymes [93,94]. Therefore, several studies have focused on utilizing fruit and vegetable by-products from the food industry into composite bakery products such as biscuits, cookies, muffins and bread. Studies have been conducted incorporating by-products from strawberry, raspberry, goji berry, sour cherry, kimchi, blackcurrant, coffee silverskin and pecan nut [21,26,28,88,95–97], and results indicate they can be good sources of fiber, antioxidants and minerals.

Usually, in bread, by-products do not exceed a level of 10% when replacing the wheat flour [9,87]. When incorporating fiber-rich by-products, a harder texture of the final product can be observed along with changes in color [9,87]. In addition, incorporation of by-products reduced the volume of bakery items such as in the case of muffins. In some instances, the reduction of the physical quality of bread was overcome by using additives such as emulsifiers, gluten, enzymes or oxidants [98,99], which were able to minimize the negative impact by adding fiber into breads [100]. Composite bread, biscuits and cake formulations with by-products ended up with increased levels of proteins, total dietary fiber and minerals [47,101–112], while Bhol et al., Ameh et al. and Eshak [103–105] showed that addition of banana peel, pomegranate bagasse and rice bran decreased the levels of different minerals in the final product including P, Mg, K, Zn and Na. Orange bagasse flour at 10 and 15% addition levels enhanced the dietary fiber content by around 40–60% [55]. Cakes with incorporated mango, banana and orange peel resulted in lower levels of protein content than in controls [47,101,110], and the same observation was reported by Ismail and the team's experiment [113] where cookies were made. Hence, the impact of fruit and vegetable by-products on bakery items can be different depending on the by-product used. Therefore, one should be mindful of the amounts and varieties of by-products that are added to the products. In most of the studies, fat content was increased with the addition of by-products. For example, cakes incorporated with pumpkin seed, mango peel and passion fruit peel [47,101] and composite breads with rice bran and cupuassu peel [102–106,108,109,111] resulted in increased fat contents. However, increasing the fat level cannot be considered as good if it is beyond the required level for our health. Moreover, the shortening used in most formulations will affect the overall fat content as well [47,101,110]. Overall, the nutritional value of bakery products increased when they were formulated by partial substitution of flour by fruit and vegetable by-products. This positive effect was higher on breads as compared to cakes and biscuits [87]. In most of the studies, a negative impact was observed with regard to the sensory characteristics [55,111,114], whereas in some, those negative impacts were increased with addition levels [115]. There are, therefore, optimal (for each baked good and for each by-product utilized) addition/incorporation levels that maintain the sensory acceptability. Therefore,

fortification should be done only up to a certain level without affecting the organoleptic quality of the product. Since organoleptic quality plays an important role in overall quality and consumer acceptability and demand, it should also be considered apart from improving the nutritional quality of the bakery product.

Some of the bakery products supplemented with plant-based ingredients and nutritional improvements due to those incorporations are summarized in Table 2 below.

Table 2. Nutritional improvement in bakery products with the addition of plant-based components and their by-products.

Bakery Product	Incorporated Fruit/Vegetable/By-Product	Improved Nutritional Value	References
Cookies	Date fruit powder	• Increased total carbohydrates, crude fibers, ash, crude fat and protein contents	[46]
	Mango dietary fiber from unripe fruit	• Increased dietary fiber • Decreased predicted glycemic index • Maintained significant antioxidant capacity	[53]
	Legume flour (mung bean and chickpea flour)	• Increased protein and resistant starch	[67]
	Pumpkin powder	• Increased fiber content	[73]
	Watermelon seed protein concentrates	• Increased protein content	[56]
	Legume flour (chickpea flour, pigeon pea, mung bean flour and cowpea flour)	• Increased protein, fat and energy contents • Increased phenolic compounds and antioxidant capacity	[80]
	Watermelon rind powder	• Increased dietary fiber • Decreased predicted glycemic index • Increased phenolic content and the antioxidant activity	[89]
	Pomegranate peel powder	• Improved dietary fiber, total phenols and minerals • Improved antioxidant activity	[113]
Muffins	Orange bagasse	• Increased dietary fiber • Decreased predicted glycemic index	[55]
	Apple skin powder	• Increased total dietary fiber content, total phenolic content and total antioxidant capacity	[24]
	Date fruit fiber concentrates	• Increased antioxidant capacity	[78]
	Chinese cabbage outer-leaf powder	• Increased dietary fiber and antioxidant capacity	[21]
	Mango-processing by-product	• Increased indigestible fraction content, total soluble phenolic level and antioxidant capacity	[27]
	Strawberry, blackcurrant, raspberry and sour cherry pomace	• Increased phenolic content	[96]
	Sour cherry pomace	• Induced a lower energy intake (manage glucose levels)	[88]
Muffins and cookies	Goji berry byproduct	• Increased protein, free phenolic compounds, dietary fibers and minerals	[26]
Biscuits	Finger millet seed coat matter	• Increased protein, dietary fiber and calcium contents	[57]
Bread	Dried pomegranate peel powder	• Increased protein, dietary fiber, minerals, antioxidant activity and β-carotene contents	[107]
	Mango peel powder	• Increased dietary fiber and carotenoid contents • Increased polyphenol contents and antioxidant properties	[114]
	Dehulled pigeon pea flour and pigeon pea byproduct flour	• Increased protein and fiber contents	[112]
	Chickpea flour	• Increased protein, resistant starch and dietary fiber contents	[74]
	Green banana flour	• Increased resistant starch and dietary fiber contents	[43]
	Brewer's spent grain	• Increased fiber, protein, fat and mineral contents	[106]
	Defatted rice bran	• Increased dietary fiber content and total antioxidative activity	[108]
	Rice bran	• Increased crude protein, crude fat, crude fiber, vitamins and minerals	[104]

Table 2. *Cont.*

Bakery Product	Incorporated Fruit/Vegetable/By-Product	Improved Nutritional Value	References
	Pomegranate whole fruit bagasse	• Increased protein, dietary fiber, mineral content and carbohydrates • Improved antioxidant properties	[103]
	Green coffee	• Increased phenolic compounds and antioxidant activity	[14]
	Black rice extract powder	• Reduced digestion rates	[36]
	Cupuassu peel	• Increased dietary fiber and phytochemicals	[111]
Bread (toasted)	African bread fruit seed flour	• Increased protein, ash and crude fiber contents	[60]
Flat bread	Banana peels	• Increased protein, fiber and mineral contents	[105]
Indian unleavened vegetable flat bread (*Thepla*)	Apple pomaces, papaya peels and watermelon rinds	• Reduced glycemic index values	[91]
Gluten-free bread	Defatted blackcurrant and defatted strawberry seeds	• Increased protein, dietary fiber and polyphenols	[77]
Cake	Potato peel powder	• Increased protein and dietary fiber contents	[85]
	Passion fruit and orange residues	• Increased dietary fiber content	[101]
	Banana peel	• Increased fiber content	[110]
	Coffee silverskin	• Increased ash content and antioxidant activity	[97]
	Watermelon inner skin	• Increased fiber content • Reduced energetic value	[115]
	Mango pulp and peel flour	• Increased dietary fiber • Low fat, calories and predicted glycemic index	[47]
Snack bar	Date fruit paste	• Increased protein, dietary fiber • Rich in thiamin, calcium, magnesium and zinc	[45]

On the whole, bakery products, which usually consist of high amounts of digestible carbohydrates, lead to a number of health issues including diabetes and obesity. Incorporation of unconventional flour helps to overcome these issues due to higher amounts of dietary fiber and RS, mainly by lowering the glycemic index and reducing the glucose level released into the bloodstream. In addition, higher phenolic content will increase antioxidant, anti-inflammatory and anticancer activities which are, again, an important health benefit. Apart from that, antioxidants help to improve the shelf life. Therefore, bakery product fortification with functional food ingredients would be an excellent way to win the market through consumer demand, while maintaining the physical, chemical and organoleptic quality of products along with the enhanced nutritional value.

3. Date Components Used in Baked Goods

3.1. Date Fruit Components

Date palm (*Phoenix dactylifera L. Arecaceae*) is an ancient plant cultivated mainly in desert regions including the Middle East and North Africa [116,117]. Nowadays, around 2000 cultivars are grown all over the world [118]. However, not every cultivar has high market demand. There are a few cultivars including Deglet Nour, Medjool and Khalas that have high economical value based on the market demand [119]. The main producers of date palm in the world are the UAE, Oman, Iraq, Egypt, Saudi Arabia, Sudan, Tunisia, Algeria, Libya and Pakistan [120]. The fruit from the date palm consists of date pulp (which we often call date fruit) and date seed. Date fruit, which is consumed fresh, has a dense and tacky texture facilitating mixing and binding with other ingredients such as cereals [121]. Therefore it has been used as a functional food ingredient in a number of food items such as bread, cookies, cakes, jam, jelly, juice, candy bars, syrups, cereals, vinegar and ice cream [122].

There are several stages that date fruits pass through until full ripeness including Hababouk, Kimri, Khalal or Bisser, Rutab and Tamer. In the fully ripe stage of Tamer, date fruit has a high sugar content and low moisture content, and it is brown to black in

color [123]. The moisture content decreases throughout the ripeness stages, and hence the total solid content increases when it comes to the fully ripe stage [121]. Moreover, the moisture content of dates can be varied between 7% (dried) to 79% (fresh), depending on the variety [124].

Date fruit is a good source of carbohydrates, dietary fiber, antioxidants, minerals and vitamin B complexes [45]. However, the chemical composition of dates can be varied depending on different cultivars, agronomic practices, soil conditions and ripening stages [125,126]. Carbohydrates are the major chemical constituents of date, including mainly glucose, fructose and small amounts of polysaccharides such as cellulose and starch [127,128]. It contains approximately 80% of glucose making it easy to digest and a good source of rapid energy [125,129]. As evaluated, around 100 g of date fruits will provide energy of 308.52 kCa [130]. The level of sugar changes through the ripening stages, and the sucrose is hydrolyzed into simple sugars, glucose and fructose [131]. Dates contain small amounts of protein (1–7%), which contains essential amino acids needed by the human body [121,132]. Twenty-three different amino acids are identified in dates that are not commonly found in other fruits [133]. Though there is a low amount of protein, there is a high amount of essential amino acids such as histidine, proline, glutamate, arginine, glycine, alanine, asparagine, cysteine, lysine and tryptophan [134–136]. Lipids in date fruits are concentrated in the skin, and their main function is to provide protection to the fruit. Therefore, a small amount of fat is present in dates at the levels of approximately 0.14 g per 100 g in fresh dates and 0.38 g per 100 g of dried dates [121]. Date fruits contain minerals such as iron, potassium, calcium, selenium, magnesium, selenium, copper, phosphorus, zinc, cobalt, sulfur, manganese and fluorene [44,137,138]. It is evident that high potassium and low sodium contents in dates are good for people with hypertension problems [139,140].

Dates are also a promising source of dietary fiber, phenolic compounds and vitamins [124,135,141]. They contain a low proportion of soluble and high proportion of insoluble polysaccharides, cellulose, hemicellulose and lignin compounds [141]. Several studies have investigated that date products are a better source of dietary fiber compared to cereals [7,142]. Hence dietary fiber content in dates adds nutritional quality, and it can be used as a dietary supplement and in preparation of fiber-enriched food products [143,144]. For example, Nwanekezi's team [145] showed that date fruit composite bread increased the dietary fiber content without affecting the nutritional quality of bread when dates were used to replace sucrose. Dates are a rich source of a number of phytochemicals including simple phenolic acids, carotenoids, flavonoids and their derivatives, phytosterols, phenylpropanoids and anthocyanins [116,127,146,147]. Several studies have observed higher amounts of phenolic compounds in dates compared to other fruits such as apple, orange, blueberry, banana, papaya, pineapple, apricot and pomegranate [148,149]. Variations in the total phenolic content of dates have been identified in several studies. Numerous factors such as cultivar type, climate, maturity, harvest time, irrigation, sunlight, geographic location, agronomic practices, harvesting methods and experimental conditions (storage, extraction and analytical procedures) have been verified to be responsible for these variances [119,150]. Dates are also rich in vitamins including vitamins A, B1, B2, B3, B5 and C where vitamin A supports the antioxidant properties of dates and is also responsible for eye health [151]. Fresh dates contain a higher number of vitamins compared to dried dates because of the depletion of vitamins when drying. Dried dates contain folic acid, niacin, riboflavin and pyridoxine in average amounts and vitamin A, C and thiamine in low amounts [121,139].

However, the higher amounts of phytochemicals such as polyphenols and carotenoids and vitamins such as ascorbic acid and tocopherol make dates a promising source of antioxidants [123,152,153]. In ripe dates, antioxidant activity is derived mainly from total phenolic content [154,155], and there is a strong association between date antioxidant activity and the total phenolic content of date fruits [156,157]. The darker color of dates is also mainly because of antioxidants [158] as date fruits are a good source of anthocyanins [127],

and anthocyanins are known to provide reddish-blue colors [159] to the dates. Hence, dates could be suitable for application in the pharmaceutical field and food manufacturing industry as a functional food ingredient [160]. These natural compounds obtained from dates can be used as a healthy substitute for synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) so that the toxicity levels and process cost can be lowered [161]. Though there is an increasing trend for research attempts to study the phenolic content of dates, the impact is quite limited due to the high variability in analytical procedures that have been used in different studies [162]. In some studies, it was reported that the phenolic content was increased once stored under low temperatures for several weeks [163,164]. The action of specific oxidoreductase enzymes involved in phenolic biosynthesis might be the reason behind this [165]. As Al-Najada and Mohamed [164] reported that during storage for 6 and 12 months at 4 °C the antioxidant activity was decreased, these variations cannot be considered conclusive because of the limited number of studies that have been conducted on this aspect. Moreover, detailed characteristics of the dates used should be indicated to allow for a critical comparison. Furthermore, use of different techniques and different solvents makes the comparison of the results difficult.

Apart from the rich nutritional value, date fruits exhibit a wide range of beneficial health effects, including antimutagenic, anti-inflammatory, antihyperlipidemic, hepatoprotective, gastroprotective and nephroprotective activities [160,166,167]. Furthermore, a number of antibacterial properties have been observed in dates including the inhibition of *Escherichia coli*, *Staphylococcus aureus*, *Serratia marcescens* and *Bacillus cereus* [168,169]. This can be due to the high dietary fiber content of dates and its lignin and tannin [170]. Dates provide protection against chronic diseases such as cancer and heart diseases [171]. As dates have adequate amounts of polyphenols and are also rich in functional dietary fiber, dates help to enhance the digestive process [131,172]. Additionally, dates have been used as good substrates for the production of fermentation products including organic acids and polysaccharides as they have nutritive components for microbial growth [173–177].

Several studies have focused on the use of different solvents to extract phenolic and flavonoid and assess antioxidant content [178–181]. From the results of those studies, it is evident that the extracted phenolic content and antioxidant activity depend on the extraction solvent. Based on the previous studies, 70% acetone was more effective than 100% ethanol in extracting phenolic compounds, and both 70% acetone and 50% methanol showed good results for antioxidant assays depending on the technique used. However, 100% ethanol and water were poor solvents for this purpose [179]. Further investigations are needed to find out the efficacy of each solvent in extracting phenolic and antioxidant components in dates.

3.2. Date By-Product Components

3.2.1. Date Seed Components

Date seeds are a secondary product derived after utilizing date pulp, and they represent around 10–15% of the date fruit's weight, which generates a huge quantity of waste as seeds in food-processing units [128,182,183]. For centuries in the Arab world, date seeds have been used to make caffeine-free drinks similar to coffee [167,184]. They have also been used as animal feed [8,184,185] which demonstrated enhanced growth as well as estrogen and testosterone levels [186,187].

Date seeds are brown in color and odorless, with a slightly bitter taste [184]. Several studies have been carried out to study the nutritional value of date seeds from different geographical origins [125,184,188]. They contain considerable amounts of protein (5–6%) [138,189,190] including albumin, globulin, prolamin and glutelin as soluble proteins [190]. The fat content is around 8–10%, and when compared to date fruit, fat and protein content is higher in seeds [138,191–193]. Moreover, high amounts of carbohydrates (80–90%) were also reported in some varieties including Allig and Deglet Nour [125,189], mainly in the form of insoluble fibers [194]. The ash and moisture contents ranged from 1 to

1.3% and 9 to 11%, respectively [184,189,195]. Additionally, date seeds contain significant amounts of minerals including potassium, calcium, magnesium, manganese, sodium, phosphorous, zinc, iron, fluorine, aluminum, chloride, cadmium, lead and sulfur with a higher amount of potassium [124,182,184,189]. Variations were reported in the amounts that can be due to the variations of geographic conditions, different agronomic practices, quality of irrigation water, fertilizers and differences in soil mineral availability [125,182,184,189].

The nutritional value of date seeds is mainly due to the high phenolic content and significant dietary fiber levels [184,196]. Dietary fiber content was found to be 73.1% enabling date seeds to serve as an important source of dietary fiber and be used as an excellent food ingredient [138,190,197,198]. It was also investigated that there can be possibly resistant starch as well present in the date seeds [190]. Not only dietary fiber but also the higher amounts of phytochemicals found in date seeds make it a good potential functional food ingredient. Carotenoids are major phytochemicals in date seeds; β-carotene, lutein, β-cryptoxanthin, lycopene and zeaxanthin were found to be the major carotenoids [196,199]. Compared to date fruit, seeds contain higher amounts of carotenoids [138]. Recent studies have identified date seeds as a rich source of flavonoids, phenolic acids, tocopherols and phytosterols as well [138,199–202]. Because of the high phenolic and flavonoid content, date seeds show excellent antioxidant activity which is even higher than date fruits and other antioxidant-rich food products such as tea extracts and by-products such as grape seeds [133,138,203–205]. Apart from phenolic compounds, oleic acid present in date seeds in higher amounts is also a major antioxidant component [128]. Other fatty acids that date seeds contain are lauric acid, linolenic acid, palmitic acid and myristic acid [189,193]. Hence they are a valuable source of edible and pharmaceutical oils [193].

The structure of the phenolic compounds in date seeds will affect their solubility and hence the extraction yields [182]. Therefore, the phenolic content and antioxidant capacities of date seeds are highly dependent on the extraction solvent. Extraction solvents of phenolic compounds in date seeds exhibited different efficiencies where, in some studies, the highest capacities were found to be in acetone (50%) and butanone purification which was greater than ethanol and methanol extractions [203]. Results of Thouri et al. [206] showed the highest extraction efficiency with water, whereas the lowest one was with absolute acetone. In Ardekani et al. [207], the total phenolic content and antioxidant capacities were higher when using the polar aprotic solvent dimethyl sulfoxide (DMSO) compared to water and methanol/aqueous methanol. They suggested that a mixture of different solvent ratios would give better extraction efficiencies. Maqsood and colleagues [208] demonstrated higher phenolic content and antioxidant capacities when using 60% ethanol and 80% acetone. Hence the extraction solvent plays an important role in determining the phenolic compounds in date seeds as well. In several studies, total phenolic content of date seeds seemed to have variations [125,202,209]. These differences may be attributed to variety, geographic origin, maturity and the extraction method used [160,207]. There is a number of health benefits that can be gained through consumption of date seeds, most of which are related to antioxidant activity. These include anti-inflammatory activity, anti-genotoxic activity, management of diabetes, liver diseases and gastrointestinal disorders and reduction of plasma triglycerides and total cholesterol levels [37–41].

When considering the above-mentioned observations, date seed, which is considered as a waste, can be utilized as a functional food ingredient as it has a number of health benefits. Utilization will enhance the nutritional value of several food products, for instance, fiber content in bakery items [194,198]. Importantly, utilization will not just enable the development of food with enhanced nutritional properties but will also contribute to income increase for the date-processing industries and contribute to the alleviation of the environmental burden that seeds pose as waste.

3.2.2. Other By-Product Components

Wastes generated in date-processing units can be categorized into three main categories. Firstly, fruits that are low-grade, spoiled, etc., are thrown away during sorting.

The second kind of waste is the date seeds already discussed, while the third type of waste generated during processing is date press cake (DPC) [210]. Other than date seeds, DPC leads to a greater loss of raw materials, as well as to the creation of environmental issues [124]. In date syrup or juice industries, DPC results as the primary by-product after extraction that is a fiber- and moisture-rich material [211,212]. DPC is rich in many minerals, including K, Ca, Mg, Mn and Fe [213,214]. DPC also contains a considerable amount of dietary fiber, phenolic compounds and antioxidants which could be used as a natural antioxidant source [125]. In addition, DPC also contains fatty acids including oleic, myristic, lauric, capric and behenic [214].

Date fruit is used in the manufacturing of value-added food products including syrup, paste, jam, jelly and vinegar. As a result, every year about 1.5 million tons of date fruit waste are disposed of by the food-processing industry [215]. Even though it is discarded, date fruit syrup waste contains considerable amounts of active phytochemicals such as phenolics, flavonoids, carotenoids, etc. [211]. In several studies, date fruit waste material has been used to produce antioxidant-enriched active edible films for food packaging applications [215]. Moreover, as date by-products have nutritive components for microbial growth, they act as good substrates for the production of fermentation products including organic acids and polysaccharides [173,176,216–220].

As per Abd-Alla and El-Enany [221], though spoiled dates are not suitable for human consumption, they consist of several components that are responsible for the growth of microorganisms. Therefore, they can be used as substrates to produce ethanol, acetone and butanol, instead of being discarded as wastes. If the quality of date fruits is low, they are also rejected by the consumers and hence go to the category of waste. However, they are also a good source of dry matter, sugar and phenolic compounds allowing them to be used in formulating the value-added products [124].

However, when considering the beneficial characteristics of date waste/by-products, there is a great potential for the production of value-added products using date waste. This can be beneficial not only economically but also environmentally providing solutions to the waste management problems in the date-processing industry. In 2020, a review article was published by Najjar et al. [222] on utilization of date by-products in the food industry. The review was based only on the by-products and provided an overall view of all the areas of date by-product utilization, not only for bakery items.

4. Addition of Date Components into Bakery Items

4.1. Attempts to Formulate Baked Products Fortified with Date Components

Along with an increasing number of health issues worldwide, consumers increasingly tend to eat more healthy food. Nowadays, organoleptic properties of food products are not an adequate reason for a food choice if the food is not also nutritious. Consumer awareness of the constituents that affect our health both positively and negatively keeps on growing due to improved education and increased availability of a range of different sources of information. Hence, functional foods with enhanced nutritional quality are an emerging trend in the food industry. Rather than attempting to formulate completely new food items, it is easier and more effective to add value to existing food products by incorporating beneficial ingredients. When it comes to baked products, most of the baking processes such as formulation, baking conditions, mixing, fermentation, etc., are optimized for almost all bakery items; however, food scientists are now focusing on trying to improve the functional and nutritional qualities of the products by fortification with beneficial ingredients. As dates are rich in a number of nutritional components, there is an evolving trend to use dates and date by-products in bakery products.

Recently there were several studies conducted formulating bakery products by incorporating dates and their by-products [8,45,46,52,54,64,145,194,198,223–228]. The fortification of bakery products has been done either by adding date components such as powder and paste or by adding extracted compounds, for instance, extracted dietary fiber, water-soluble polysaccharides and hemicellulose [52,54,198]. Bakery products that are for-

tified by defatted date components, specifically the seeds, have also been studied [194,228]. Some of the bakery products that have been formulated incorporating date components are summarized in Figure 1.

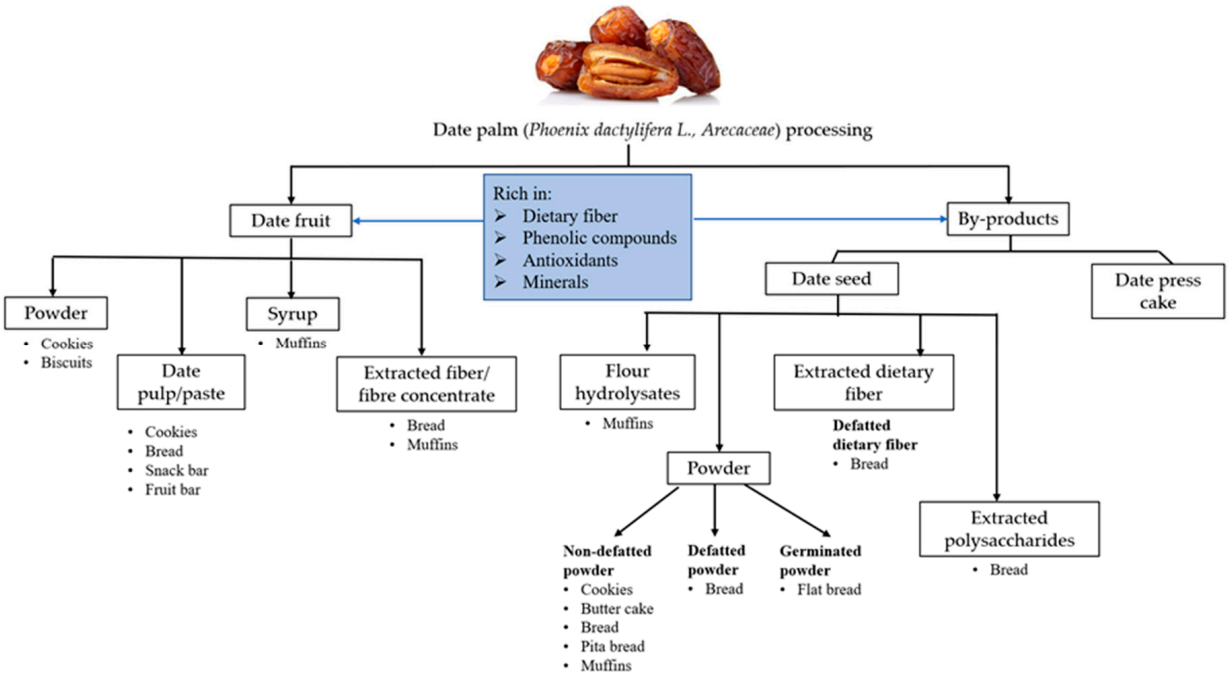

Figure 1. Date components incorporated into bakery products.

Dates can be used in several products as a sugar replacer. Snack bars have become popular due to their convenience, especially energy bars as an excellent replacement for breakfast. They include natural sweeteners such as honey, dried fruits and fruit pastes in order to enhance the energy value as well as to improve technological characteristics [229,230]. In the market, bars are typically made with sugar, honey or glucose syrup. There are some issues related to these ingredients; for instance, honey is a food allergen, and producers are looking for alternatives. Date is a good replacer for honey in bars. Energy bars provide strength while helping to maintain physical and mental health; they are usually high in carbohydrates while their protein content is moderate [44]. Date-based energy bars can provide the required daily nutritional intake as dates are an excellent source of nutritive and bioactive compounds [231]. When date paste was used to substitute sucrose, it improved the nutritional value of bread and cookies by increasing phenolic antioxidants, minerals and vitamins [232]. Date pastes, which have the desired moisture content, are widely used in the bakery industry as a filling in pastries and biscuits. Moreover, invert sugars in dates help to improve the sweetness and softness of bread and cookies [232].

Formulating fiber-enriched staple foods will be a significant contribution to a broader range of health-promoting foods. Daily consumption of fiber is important for a balanced diet as well as to prevent several diseases [233]. Date components can play a significant role in this direction. Addition of date fruit, which is rich in dietary fiber and phenols, improved the nutritional quality of muffins with increased sensory qualities [78]. Mrabet et al. [78] tried to formulate muffins enriched with date fruit fiber concentrate of varying levels (2.5% and 5%). The results are promising and demonstrate the enhanced possibility to use date and date fiber as a good addition in formulating functional foods. Due to the higher amounts of dietary fiber along with the good flavor they give, date seeds could be used as a potential functional food ingredient in bakery foods [234]. Defatted date seed incorporation has also shown improved quality in baked products [194,228]. Shokrollahi and Taghizadeh [228] showed that date seed fiber is an excellent source of dietary fiber and can be added to bakery products while maintaining the appropriate physical and baking

properties providing a better effect than commercially available fiber. Several other studies observed that incorporation of date seeds enhanced the dietary fiber content of baked products [48,194]. Hence it is evident that improvement of nutritional value is mainly due to the improvement of dietary fiber content being contributed by the date seed fortification.

On the other hand, there can be a negative impact on the sensory characteristics as well as the rheological properties of baked goods by adding dietary fiber in baked items which are discussed further in this section with examples. To overcome these issues, the incorporation levels and formulation procedures should be altered accordingly. The quality improvement of bakery products with the incorporation of date components is also discussed further in this section.

4.2. Effect of Addition on Product Quality and Nutritional Value

When formulating new bakery products, it is important to study the physical and chemical properties in aiding the development process. In bakery items, the most important factors are the physical and textural qualities as they consist of a particular set of characteristics that consumers demand. Apart from those, one of the biggest challenges is to secure consumer acceptance for a new fortified product. The physiochemical changes may affect consumer acceptance especially with the improved nutritional quality of a new product [235,236]. As these physiochemical changes would affect the sensory properties, it is important to assess those characteristics during processing. Most importantly, color attribute plays a special role that can change the consumers' impression of a new food product even before tasting [237]. The raw materials and the processing methods used have a significant impact on the physiochemical properties of the final product. Therefore, it is very important to study these changes in newly formulated bakery products fortified with date components. Shelf life is another important factor because if a product can be stored for a longer period of time, the profits and efficiencies are also improved [238]. Storage conditions and hence shelf life of a product depend on the chemical composition, processing conditions, packaging and distribution of it [239]. Thus, it is quite helpful to have an idea of physical, chemical, nutritional and organoleptic properties and the shelf life of date-component-fortified bakery products.

However, incorporation of dates and their by-products in bakery products has improved the overall quality of the product as concluded by many of the studies. The following sections discuss how the fortification of date components into bakery products affects the quality parameters including physical, chemical, nutritional and organoleptic properties and shelf life of the final product.

4.2.1. Physical Quality

Formulation of snack bars with date paste improved the technological qualities along with textural properties when the addition level was 50% date paste. It was also noticed that the free-water level was lower than in control samples illustrating that addition of date paste improved the hardness by maintaining the water balance [45]. The reason behind this may be that when the amount of sugar increases, sugar molecules can draw water molecules lowering water activity. This is expected to lead to an increase in the shelf life of snack bars. In contrast, biscuits fortified with date powder showed decreasing hardness with increasing addition levels proving the effect of sucrose on the texture of biscuits [240]. Here, the researcher used date powder as the required texture of biscuits is different from snack bars. However, increased levels of water activity were also observed which might be due to the replacement of sucrose.

In a study where muffins were formulated incorporating date seed flour and date seed flour hydrolysates, the height of the muffins was not changed either with seed powder or hydrolysates indicating that they do not affect the rising properties of the dough [8]. In agreement with this is the result from [224] where they incorporated date seed flour in muffins and observed no significant effect for physical properties as there was no difference in volume with the incorporation. As Mrabet et al. [78] found, muffins enriched with date

fiber concentrates resulted in a higher dough yield compared to the control. Though the muffin volume decreased, there was not much effect on texture, resulting in softer products compared to the controls. It was suggested that addition of fiber into baked goods led to a partial dilution of gluten and hence a decrease in the volume [241]. When the gluten content is decreased, it will reduce the ability to retain gas during the rising of dough and hence result in lower volume [242]. There are several studies where the volume of muffins decreased with addition of plant-based food ingredients [22,25,243]. An addition level of 2.5% date seed hydrolysates improved the textural quality of muffins without influencing their bakery characteristics [8]. Addition levels of 2.5% and 5% date seed flour also did not affect the bakery characteristics of muffins [8]. These results suggest that date seed can be a better food ingredient to maintain dough properties.

When wheat flour is partially substituted by other flour, such as cassava, dough weakening occurs which might be due to the reduced water absorption with the incorporation [244]. In contrast, as date seeds are rich in fiber, the higher water absorption capacities in fiber-rich dough positively affect dough performances. They increase the dough resistance, extensibility and proving even though addition of higher levels of fiber may negatively affect dough properties [226]. The moisture content of breads is also a major factor that affects the volume where increased water levels result in higher loaf volumes [245]. In certain studies, researchers have studied incorporation of date flesh fiber concentrates (DFFCs) into bread [52,54]. Dough water absorption was significantly increased with the addition of DFFC into the formulation. This might be due to the hydroxyl groups located in fiber structures allowing them to form more hydrogen bonds [246,247]. The stability of dough increased significantly compared to control samples suggesting that there could be higher interactions between DFFC, water and gluten. Quality Index and tenacity increased with increasing levels of DFFC having the most significant value at a 3% addition level along with improved proofing ability. Dough yield was increased significantly with increasing levels of DFFC [52]. However, during storage, DFFC-incorporated bread had significantly increased firmness and was consistent with a large decrease in water activity [54]. There is a negative correlation between moisture content and firmness as studied previously [248]. Water can act as a plasticizer and hence can contribute to the softening of the texture. With time, when the water content decreases, it will allow the formation of cross links between starch and gluten protein molecules and hence increase the firmness. Though the moisture content decreased with time, the staling rate was not significantly decreased as flat bread with incorporated germinated date seeds in the formulations showed reduced bread staling during storage of 5 days [249]. When fiber-rich sources (which are able to interact with water molecules) are added, it will limit starch gelatinization/recrystallization, and hence it may reduce staling mainly due to modifications of starch gelatinization and amylopectin retrogradation [250,251]. Defatted date seed fiber concentrate (DSFC)-enriched bread (1% and 3%) showed increased dietary fiber contents and dough performance in bread but slightly adverse effects on bread quality [194]. Fine-size DSFC decreased the bread volume while increasing the crumb firmness. Coarse-size DSFC decreased the specific volume and crumb firmness while affecting the mixing characteristics. Both DSFCs produced darker crumb colors compared to the controls. In this study, it was concluded that addition of fibers in bread reduces volume in contrast to [52] where they observed no significant difference between DFFC-incorporated samples and control samples. The reason might be that the fiber content is higher in date seeds than date flesh. In addition, the difference in addition levels may be responsible for different observations.

Bouaziz et al. [198] focused on improving bread quality by incorporating the extracted date seed water-soluble polysaccharides and hemicellulose; they demonstrated higher emulsifying abilities of date seed derivatives. Higher water and oil holding capacities were observed with hemicellulose compared to water-soluble polysaccharides. Moreover, date seed hemicellulose improved foam generation while increasing the liquid retention in foam. All these results are related to the higher fiber content of date seeds suggesting that the date seed components can be used to enhance the functional properties of food

formulations. Overall, incorporation of date seed water-soluble polysaccharides and hemicellulose improved the rheological and textural properties of the dough having higher results with hemicellulose. Therefore, it is evident that date seed derivatives are also an excellent source for food product valorization.

In another study, date-powder-incorporated cookies resulted in decreased thickness, diameter and spread ratio lessening the ability to withstand stress [46]. However, in this study, a 10% incorporation level was the most desirable level compared to others with the least adverse effect on the quality of the cookies. The spread ratio of date-pulp-incorporated cookies was higher than the whole-wheat cookies adding quality to composite cookies. In contrast, when considering the break strength, composite cookies were not as strong as the control samples. Other physical characteristics such as weight, diameter and thickness were comparable to control samples with slight effects overall [64]. Stathopoulos and colleagues [252] formulated composite cookies with date seed powder. The samples were prepared using whole-wheat flour and white flour. Color and hardness were significantly affected by the incorporation of date seed powder into cookies, resulting in crispier and darker cookies at higher levels of substitution with the highest level of 7.5% [252].

Rheological properties of butter cakes were negatively affected by the fortification of date seed powder [253]. Batter stability as well as the dough mixing time during which the batter would maintain its consistency also decreased with the addition of date seed powder, and this may be due to the increase in fiber content. Apart from these effects, glass transition temperature (beginning of gelatinization), gelatinization temperature and gelatinization maximum were also decreased compared to the control samples [253].

4.2.2. Chemical Quality

Incorporation of dates and their by-products affects the chemical quality of the bakery products as evident by several research studies elaborated below. Regardless of the bakery product formulated, the change in chemical composition was significant in most of the studies. Snack bars prepared incorporating date paste exhibited lower water activity compared to control samples. Protein content of date-paste-fortified samples was higher than that of the snack bars in local markets [45]. As the sugar content is higher in date paste, it may lead to a decrease in water content. It is noteworthy that the water activity and moisture levels are highly proportional [254]. In contrast, in biscuits with incorporated date powder, the water activity increased with increasing levels of date powder, although the replacement did not affect the moisture content profiles [240]. The reason behind this might be the ability of fiber to interact with water molecules because of the structure [246,247]. Similarly, the cookies that were fortified with date powder showed an increase in moisture content and a decrease in protein content compared with the controls [46,64]. Also evident is the increment of energy values of baked products incorporated with date fruit [45,64] wherein some samples were closer to the bars from local markets proving that dates can be used as a nutritionally rich food ingredient in bars [45]. These results emphasize the fact that date fruit can be used as an excellent sugar replacer in bakery products along with the comparative increment of carbohydrate contents with the addition of date powder into formulations [46,64].

In most of the cases, the mineral content of baked products increased with the incorporation of date fruit [46,64]. The fat content of the fortified cookies was also found to be increased in most of the cases [46,64] where it was over a wide range in some studies such as date-powder- and hydrolysate-incorporated snack bars [45]. Increase in the fat content can be considered as nutritious only if it is not exceeding the required level; therefore, it is important to monitor the fat content depending on the bakery product that is going to be formulated. Moreover, the ingredients used in formulating baked goods have a significant contribution to the total fat content of the final product.

Incorporation of date seed flour in muffins increased the moisture content at a 5% incorporation level, whereas with the hydrolysates, the highest moisture content compared to control samples was observed at a 2.5% substitution level [8]. This could be mainly due

to the hygroscopic nature of hydrolysates because of the hydrophilic parts in their structure. Similarly, the moisture content of composite muffins and shaboura/rusks showed enhanced levels of moisture [227], and the results are in agreement with Platat et al. [223] who worked with date-seed-incorporated pita bread.

According to Ambigaipalan and Shahidi [8], date seed flour and hydrolysate incorporation did not affect the crude fat content of muffins, whereas, in Salem et al. [227], incorporation led to a decrease in fat and carbohydrate contents both in muffins and rusks, though in some studies, it was concluded that seeds contain higher amounts of carbohydrates [125,133]. Nevertheless, the predominant component was carbohydrates in all the samples. In addition, protein, fiber and ash contents also improved with increasing levels of date seed powder [227]. Incorporation of date seed powder into cookies had no or slight influence on moisture, protein, fat and ash [252]. Similarly, [223] observed no statistical difference in fat and protein levels in date seed composite pita breads and control samples.

4.2.3. Nutritional Quality

As dates and date by-products are rich in nutritious compounds, the nutritional value of bakery products can be improved by incorporating dates and date by-products. Not only are they rich in nutritious compounds, but they also consist of bioactive compounds that are non-nutrient such as phytochemicals. Thus, they are linked to beneficial effects against a number of chronic diseases such as cancer, cardiovascular diseases, diabetes, etc., proving dates and their by-product's potential as a medicinal food [116]. Halaby and the team [255] observed improved nutritive quality in pan bread along with a hypoglycemic effect that can decrease the risk of diabetes. As discussed in the previous section, the nutritional quality of date seeds is high with higher amounts of polyphenols, antioxidant compounds and dietary fiber. Hence, they can be used as a functional food ingredient. A study conducted using date seed flour and date seed hydrolysates to formulate muffins observed a significant radical scavenging activity in both seed flour and hydrolysates. Using date seed hydrolysates, higher angiotensin I converting enzyme (ACE) inhibition was exhibited proving that they can be used as an effective ACE inhibitor when used to fortify bakery products [8]. Several studies concluded that the baking process decreases the amount of antioxidant compounds such as anthocyanins and phenolics [22,25]. However, in spite of this reduction, date seed flour and hydrolysates manifested improved DPPH radical scavenging activities [8]. Thus, date seeds can be used as a functional ingredient in baked products to enhance antioxidant activity and ACE inhibition.

In another study where date seed powder was used to formulate pita bread, improved antioxidant activities and phenolic contents were observed with higher addition levels of date seed powder (15% and 20%), compared to controls of whole-wheat bread [223]. These formulated composite pita breads had mainly flavan-3-ols as phenolic compounds which was not found in regular and whole-wheat bread. Compared to the phenolic content of date seeds reported in previous studies [131], the amount is less in composite pita bread. This may be due to the modifications taking place in baking and mixing processes [223]. However, all the composite pita bread samples had higher total flavonoid content compared to regular pita breads. Another important nutritional factor observed in those studies in date seed composite pita bread is that irrespective of the addition level of date seed powder, the acrylamide level was lower compared to the whole-wheat bread. In addition, comparable dietary fiber levels were identified with the daily dietary fiber requirement fulfilled at a 10% addition level of date seed powder. Therefore, this pita bread containing date seed powder with higher levels of dietary fiber, flavonoids, phenolics and antioxidant capacity proved date seed as a reliable functional food ingredient to be used in bakery products.

According to Mrabet et al. [78], muffins enriched with date fiber concentrates showed improved antioxidant capacities and dietary fiber contents. Yaseen's team [225] investigated that incorporation of date syrup and date seeds in muffins increased the protein and fiber levels. Muffins enriched with date fruit fiber concentrates demonstrated improved

antiradical activity and secondary oxidation inhibition along with higher dietary fiber contents specifically at a 5% addition level at 165 °C baking temperature [78]. Likewise, muffins and rusks with incorporated date seed powder exhibited higher phenolic content and antioxidant activity along with increasing levels of date seed powder [227]. A number of health benefits are related to antioxidant, anticancer and anti-inflammatory properties. Furthermore, it helps to manage diabetes, gastrointestinal disorders, liver diseases and reduce blood cholesterol levels [37–41]. Therefore, date component fortification in bakery products will lead the path to control many of the health concerns for consumers.

Incorporation of date paste enhanced the nutritional quality of snack bars by increasing the nutrient density of the bars [45]. Aljaloud and colleagues [44] formulated a probiotic nutritional bar for athletes fortified with dates. As dates contain high amounts of sugar, the bars were capable of providing energy associated with increased performance for athletes. Snack bars and cookies formulated incorporating date fruit demonstrated higher amounts of dietary fiber, vitamins and minerals showing that dates can be used as a food ingredient to improve the nutritional value of bakery products [45,240].

4.2.4. Shelf Life

In comparison to studies assessing the effect of date and date by-product incorporation into baked goods, very limited information is currently available on the effect of this incorporation on the shelf life of the resulting products.

Ibrahim et al. [45] found that replacing honey with date paste enhanced the time of storage of snack bars at a 50% addition level without any development of pathogenic bacteria for a period of 12 days. The low moisture content in date paste might be the major reason for this observation because this will reduce the free-water content available for microbial growth. A study conducted by Peter-Ikechukwu et al. [64] on date-fortified cookies showed that the microbial growth was at a very low level of 2.50×10^3 and 4.10×10^3 cfu/g which is lower than the highest level accepted in a product ($10 - 10 \times 10^6$) [256].

Date-seed-powder-added beef burgers exhibited improved cooking properties along with improved shelf life during 10 days of storage [257]. The lipid oxidation and microbial growth were stabilized because of the phytochemical content and antioxidant activity of the date seeds. Antioxidants play an important role in improving the shelf life of products by minimizing the auto-oxidation process and hence preserving the food product [36]. Lower moisture content allows the extended storage of the burgers, and hence it can be inferred that date seeds contain preservative properties that will enhance the stability of bakery items during storage [257]. This is an area where further attention should be afforded in order to clearly elucidate the effect of date and date by-products on the shelf life of composite baked goods.

4.2.5. Organoleptic Properties

Apart from the nutritional, physical and chemical qualities of bakery products, sensory quality plays a major role as consumer acceptance decides the market value. When analyzing the results obtained through several studies, there are pros and cons in using date components in bakery items. Snack bars incorporated with date paste exhibited improvement in appearance, sweetness, flavor and texture compared to control samples, proving that date paste enhanced the organoleptic properties of snack bars where a 50% addition level showed the highest overall acceptability. There is clear evidence that incorporation of dates makes the baked product darker in color [45,46,64,240]. With regard to color, while the control samples showed a light yellow color, snack bars with date paste had a darker surface [45]. Similarly, cookies fortified with date powder had darker colors with increasing addition levels receiving lower scores for the composite cookies above 10% addition levels. As dates contain more sugar content, this darkness can be due to the baking process with high temperature [64]. Addition at 5% and 10% levels resulted in higher scores while a 40% addition level was least accepted by the panelists. Color holds an important place in deciding the acceptance of baked products. The surface color, which appears during the

later stages of baking, depends on the physiochemical characteristics of raw dough such as pH, moisture content, reducing sugar and amino acid contents [258].

Muffins incorporated with date seed flour showed increased color intensity with increasing addition levels while muffins incorporated with date seed hydrolysate did not show significant differences compared to the control. However, muffins incorporated with date seed flour hydrolysate had higher acceptance levels with regard to texture and flavor as well. These muffins were soft and moist while the seed-flour-incorporated muffins were perceived as hard and dry. It is noteworthy that some panelists preferred the muffins with seed hydrolysates compared to the control ones [8]. Muffins enriched with date fiber concentrates (2.5%) exhibited good acceptability, similar to the control samples with a limitation at the 5% addition level [78].

Several studies have focused on incorporating date seed powder into bread formulations [259]. According to Najafi [260], Saudi Mafrood flat breads containing fine date seed powder exhibited lower sensory scores, whereas those with 10% coarse seed powder had similar sensory properties as flat breads with wheat bran. Pan bread with a 15% addition level of date seed powder had the highest overall acceptability compared to control samples [255]. Pita breads fortified with 10% and 15% date seed powder received the highest overall acceptability with regard to texture, odor, taste and color, though the color intensity increased with increasing addition levels [224]. The panelists liked the appearance and texture of prepared muffins, though they had observed differences in taste. According to this study, incorporation of date seed flour at 10% and 15% levels did not affect the consumer acceptance and baking quality of bakery products. DFFC-enriched breads with an addition level of 1% did not show significant differences compared to control samples in odor or taste [52]. Crumb color was darker than control samples, having the darkest one at a 3% addition level where it was less acceptable. The highest sensory score was observed in the 1% addition level while the overall acceptability was not significantly different from control samples [52].

Cookies fortified with date palm pulp had a darker color which was similar to most of the date-fortified products and was moderately liked by the panelists. Aroma, crispiness, taste and texture also received lower rates from the panelists where most of the samples were either liked or disliked by them. However, a 30% addition level of date fruit pulp into cookies was acceptable compared to other composite samples [64]. As the hardness, crispiness and texture of cookies were not adversely affected by fortification, Amin's team [46] concluded that 10% substitution can be used in cookie formulation without affecting their overall quality. Sensory analysis of date seed composite cookies (2.5%, 5% and 7.5% addition levels) indicated that they are acceptable in terms of taste, smell, texture and overall acceptability [252].

Scores for the sensory attributes including color, taste, odor, appearance, tenderness, porous distribution and palatability for date seed composite muffins and rusks decreased significantly with increasing levels of date seed powder, having the lowest score at a 10% addition level [227]. In line with this observation, butter cakes fortified with date seeds showed decreased scores for sensory attributes including color, taste, texture, odor, appearance and overall acceptability, where it was not significantly different from the control sample only at the addition level of 2.5% [253]. This may be due to the chemical composition of date seeds, especially the fiber content. For instance, the competition between fiber content of date seeds and the ingredients such as flour and sugar to bind with water can affect the cake flavor [261].

However, there is a limited number of studies related to incorporating date components into bakery products and analysis of their physical, chemical, nutritional and sensory properties. These research gaps were identified through this review.

5. Conclusions and Future Research Directions

Dates are a very important crop, particularly for several countries in the MENA region, where they are mainly grown. They have been associated with numerous potential health

benefits due to the diverse and rich composition of various bioactive compounds present in different date by-products. The large volumes of production lead to very significant amounts of waste generated annually, and that poses an unsustainable environmental burden. As this waste is also rich in nutrients, recent work has focused on enhancing the sustainability of the date-processing industry through utilization of this waste. Advances in this field can alleviate the environmental stress created by this waste and at the same time provide opportunities for the relevant industries to generate additional income through the development of new products.

Bakery products are among the most popular and widely consumed food products worldwide. At the same time, there is a growing demand for value-added and functional foods among consumers. Hence, the opportunity to formulate new value-added products with baked foods is very timely. The busy lifestyle of the consumers today makes them more prone to diseases such as diabetes, obesity and cardiovascular diseases. Therefore, consumers demand food that can impart additional health benefits apart from the usual nutritional value. Most of the researchers are now focusing on formulating bakery products with incorporated fruits, vegetables or their by-products. Dates and their by-products are proven to be rich in several functional ingredients such as dietary fiber and antioxidants. Several studies have been conducted to formulate bakery products incorporated with date and date by-products. Most of the studies were able to maintain the required physical and chemical quality of the final product, but sensory properties were maintained only up to a certain addition level, specifically with the incorporation of date seeds. Most of the studies focused on just adding/substituting the date components or extracted compounds into bakery products. No studies tried to improve the characteristics of date components by different methods or techniques before incorporating them into baked goods. Thus, more research should be planned to try different methods and techniques to increase the addition levels of date seeds without affecting the quality of the final product. Apart from seeds, it will be useful to try incorporating other by-products of dates in order to maximize the impact of this practice on sustainability. Furthermore, there is a lack of studies on the shelf life of bakery products with incorporated dates/date by-products. Shelf life is an important criterion for a product to be commercialized, but the effect on it remains largely undetermined. Composite bakery products with incorporated date components should be introduced to the consumers with accompanying health information, and thus more clinical trials would be beneficial. This very extensive research area is still largely unexplored. The potential for generating impact at several levels, environmental, societal and economic, should be the driving force for further research in this field, and it is anticipated to come to the fore in the coming years.

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