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Date Palm (Phoenix dactylifera) as food supplement and antimicrobial Agent in the 21st Century – A review

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Abstract: *Date palm (Phoenix dactilifera) is one of the oldest cultivated plants of the tropical and sub-tropical regions with its production, utilization and industrialization increasing ever since mostly in Arabian countries with Saudi Arabia been the world's largest producer. Date palm is also grown in northern Nigeria including Jigawa, Kano, Borno and Katsina states among others, propagated by seed, offshoot and tissue culture with latter been more promising.Date palm has a high nutritional value to humans due to its rich content of essential nutrients including sugar (65-80%), potassium, vitamin B1 and B2,fat (0.2–0.5%), salts and minerals, protein (2.3–5.6%), vitamins, Amino acid and a high percentage of dietary fiber (6.4–11.5%) which give its potential health benefit when consumed. Pharmacologically, Date palm fruit has a variety of phytochemicals including anthocyanin, phenolics, carotenoids, and flavonoids among others thus owing to its antioxidant, anti-inflammatory, antimicrobial, antimutagenic and immunostimulant activities. Industrially, date fruits are processed into a variety of products including date syrup, date-jam, date-vinegar e.t.c. with its by-products been used in making sweets, confectionaries, concentrated beverages, substrate for microbial biomass and a variety of fermented products; other products obtained from date palm fruits include biopolymers, biofuels, biosurfactants as well as variety of organic acids thus makes the date palm fruit one of the most nutritive fruit in terms of health benefit and as ideal substrate for deriving a range of value added products in food and nutraceutical industries.The paper therefore reviews the nutritional as well as antimicrobial benefits of Date Palm in the management of infectious diseases and common nutritional disorders in our society.*

Keywords:*Antimicrobial, pharmacology, antioxidant, flavonoids, immunostimulant, nutrient, biofuels*

I. Introduction

Date palm (*Phoenix dactylifera*), is a tropical and subtropical tree, belonging to the family *Palmae (Arecaceae)*. It is one of mankind's oldest cultivated plants, and in the Arabian Peninsula it has played an important role in the day-to-day life of the people for the last 7000 years (Ahmed *et al.*, 1995). Worldwide production, utilization and industrialization of dates are continuously increasing and as per the production of date fruits are on the increase as recorded for some of the major date producing countries like Egypt, Saudi Arabia, Iran, UAE and Algeria. Date fruit is marketed all over the world as a high value confectionery, and as a fresh fruit it remains an important subsistence crop in most of the desert areas. It is produced largely in the hot arid regions of the world particularly in Gulf Cooperation Council (GCC) countries, and Saudi Arabia is considered as one of the world's major producer of dates. The development of date fruits is divided into three stages, Khalal, Rutab and Tamr, and dates are generally harvested at the fully ripened Tamr stage, that is after the development of Total Soluble Solids (TSS) of 60–70 brix that are edible at this stage. Most dates are consumed at the Rutab (semi-ripe) and Tamr (fully-ripe) stages, with little or no processing. Huge amount of wastes are generated from the Kabkab date and the wastes have potential for use in date syrup production with economic advantages (Al-Hooti *et al*., 1997).Although several investigators have studied date palm cultivation, their utilization and scope for utilizing date fruit in therapeutic applications, reviews available in the literature are rather limited to the chemistry and pharmacology of the date fruits *(P. dactylifera)* and phytochemical composition, nutritional significance and potential health benefits of date fruit consumption (Vayalil, 2012).

Date palm is grown in northern Nigeria including Kaduna, Kano, Katsina, Yobe, Borno, Gombe, Bauchi, Adamawa, and Jigawa State. Other states including Plateau, Taraba, Nasarawa, Southern Kaduna and Niger state could be classified as marginal areas for date palm cultivation in the country both of which has two fruiting season (dry and wet seasons fruits), but only the dry season fruit is economically useful.Date palm is propagated by seed, offshoot and tissue culture. However, tissue culture has been found to be the best method of propagation for commercial planting and true to type of the characteristics of the mother plant. The date palm is dioecious perennial, the females of which normally begin to bear date fruits after four years depending on the agronomic practices. It is a monocotyledonous plant with no tap roots but fibrous root system. The trunk is vertical and columnar of the same girth all the way up. The fruit is single, oblong one seeded berry with terminal stigma, a fresh pericarp and a membranous endocarp (Zaid and Wet, 1999).

II. Nutritional Value And Biochemical Composition

Date fruits assume great importance in human nutrition owing to their rich content of essential nutrients which include carbohydrates, salts and minerals, dietary fibre, vitamins, fatty acids, amino acids and protein. They have enormous scope and potential for use as food for generations to come due to their remarkable nutritional, health and economic value. The nutritional value of dates is due to their high sugar content (around 50–60%), potassium (2.5 times more than bananas), calcium, magnesium and iron as well as vitamins (B1, B2) and Niacin (Lambiote *et al*., 1982).

Furthermore, dates are rich in sugar ranging from 65% to 80% on dry weight basis mostly of inverted form (glucose and fructose). Fresh varieties have a higher content of inverted sugars, the semi dried varieties contain equal amount of inverted sugars and sucrose, while dried varieties contain higher sucrose (Lambiote *et al*., 1982).Water content is between 7% (dried) and 79% (fresh) depending on variety. Dried dates can easily be stored and preserved because of their naturally high sugar content. Thus, date is considered as a nutritious fruit that contributes to human health when consumed with other food constituents and people eat fresh and/or dried dates. Recently, the phytochemical compositions, nutritional significance, and potential health benefits of date fruit consumption was reviewed and discussed its great potential as a medicinal food for a number of diseases inflicting human beings (Vayalil, 2012).

Fruits of the date palm (*P. dactylifera*) were reported to contain a high percentage of carbohydrate (total sugars, 44–88%), fat (0.2–0.5%), 15 salts and minerals, protein (2.3–5.6%), vitamins, and a high percentage of dietary fibre (6.4–11.5%) (Al-Shahib and Marshall, 2003).Unsaturated fatty acids of the fruit include palmitoleic, oleic, linoleic and linolenic acids and the oleic acid content of the seeds varies from 41.1% to 58.8%, indicating that the seeds of date could be used as a source of oleic acid. The protein in dates contains 23 types of amino acids, some of which are not present in the most popular fruits such as oranges, apples and bananas. They contain at least six vitamins including a small amount of vitamin C, and vitamins B1(thiamine), B2 (riboflavin), nicotinic acid (niacin) and vitamin A.Dates contain 0.5–3.9% pectin, which may have important health benefits. Thus dates are considered as an ideal food, providing a wide range of essential nutrients and potential health benefits (Al-Shahib and Marshall, 2003).

Pharmacological Properties and Applications

Date fruits have been ascribed to have many medicinal properties when consumed either alone or in combination with other herbs. In recent years dates have drawn greater attention owing to their numerous health benefits and consequently many in vitro and animal studies besides the identification and quantification of various classes of phytochemicals are being pursued worldwide (Vayalil, 2012).Phytochemical investigations have revealed that the fruits contain anthocyanins, phenolics, sterols, carotenoids, procyanidins and flavonoids, known to possess multiple beneficial effects. Preclinical studies have shown that the date fruits possess free radical scavenging, antioxidant, antimutagenic, antimicrobial, anti-inflammatory, gastro protective, hepatoprotective, nephroprotective, anticancer and immunostimulant activities (Baliga *et al*., 2011).

Date Palm Fruits Processing Products and By-Products

The whole date fruits are traditionally used to prepare a wide range of products such as date juice concentrates (spread, syrup and liquid sugar), fermented date products (wine, alcohol, vinegar, and organic acids) and date pastes for different uses (e.g. bakery and confectionary) besides their direct consumption.

Date processing industries manufacture a variety of date products such as date-paste, date-syrup, date dip, date-honey, date-jam and date-vinegar. Date pectin, dietary fibre and syrup are some of the date substances which find a plethora of applications as a thickener or gelling agent in processed foods, i.e. confectionery products, jams, table jellies, soft cheeses, yoghurts, etc. Date juice extraction and date syrup were extensively studied by several investigators (EI-Shaarawy, 1989; Ramadan *et al*., 1995; Al-Hooti *et al*., 2002). The dates are generally steamed, destoned, macerated, and converted to a semi-solid form known as paste with approximately 20–23% moisture content and a water activity below 0.6 (Ahmed *et al*., 2005). Date paste has been used as filler and as a substitute sugar in many food formulations and confectioneries has been utilizing date paste as one of their major ingredients (Alhamdan & Hassan, 1999).

Date syrup (dibs), the main and general by-product of date, is being used in the preparation of foodstuffs such as jams, marmalades, concentrated beverages, chocolates, ice cream, confectioneries, sweets, snacks, bakery products and health foods (Riedel, 1986). It is produced as an incidental by-product when bagged humid dates are heaped for several months, during which some syrup oozes out by the force of its own weight. In the date syrup industry, the fruits are mixed with water and heated for around 1 hour at 50^0C and the main component, sugars, are then extracted. It is also produced in homes and in villages by extraction and boiling down of juice and on a semi and full industrial scale (FAO, 1992). Mature date fruits are also processed into products such as date bars, date syrup, etc. (El-Mohsen & El-Din, 1995).

Date fruit products and wastes have been considered as potential raw material for deriving value added products employing fermentation. The various products derived from date fruit by-products and wastes employing different microorganisms are presented in Table 1 for instant reference.

Table 1. Products derived from date fruit byproduct & wastes through microbial fermentation

Product	**Substrate**	**Microorganisms**
Biopolymers	Date palm juice	*Xanthomonas campestris*
Xanthangum	Date palm juice Date syrup	*X.campestris* NRRLB-1459
Poly 3-hydroxybutyrate (PHB)		*Bacillus megaterium*
	Date palm juice	
	Date syrup	*Rhizobium radiobacter* ATCC 6466 *Lactobacillus planetarium* Q53
Curdlan		
Carotenoid	Rotten date	*E. Coli* EGY *Clostridium acetobutylicum* ATCC 824
Biofuel		*Rodobacter capsulatus* DSM 1710
Hydrogen		
	Date extract	*Saccharomyces cerevisae* ATCC 36858 *S. cerevisae* STAR brand
	Date waste	
Ethanol		*Saccharomyces cerevisae* SDB
	Spoiled date fruit	
		Clostridium acetobutylicum ATCC 824
	Date molasses	*Bacillus subtilis* DSM 4451
Butanol		
	Date extract/molasses	*Bacillus subtilis* DSM 20B
Biosurfactant	Date wastes	
		Aspergillus niger ATCC 6275 & 9642
Organic acids	Date juice	*Aspergillus niger* ANSS – B5
Citric acid	Date juice	
		Lactobacillus casei
Lactic acid	Date fruit waste	*Lactobacillus delbrucki*
	Date fruit waste	
Amino acids		*Corynebacterium glutamicum* CECT 690 &
Glutamic acid	Date sugars	CECT77 *Corynebacterium glutamicum* CECT 690
Biomass		
Baker's yeast		*Saccharomyces cerevisae* (I) *S.dastorianus* NRRL YI2693 *S.cerevisae* (III) *S.dayanus* NRRL Y-12624
Probiotics	Date powder	*S.cerevisae* NRRL Y-12632
Lactobacilli		*S. lodgwii*
Antibiotics	Date syrup	*Lactobacillus casei* ATCC 334
Bleomycin		*Streptomyces mobaraensis*
Oxytetracycline	Date – Coatsugar extract & date seed hydrolysate	*Streptomyces rimosus*
Enzymes	Date syrup	
Pectinase	Oate pomace	*Bacillus subtilis* EFRL 01
Endopectinase	Date waste	*Aspergillus niger* PC5
Alpha amylase		*Candicla guiliemondii* CGL-A10

Biopolymers

Xanthan gum

Date fruit by-products are known to be useful for the production of high value-added components such as xanthan gum, which has been authorized by the Food and Drug Authority (FDA) in 1969, for use in food products (Besbes *etal*,. 2006).In fact, the cost of the fermentation medium has always been a major concern in the commercial production of xanthan gum and consequently search for cheaper natural alternatives for the currently used substrates, namely glucose or sucrose has drawn the attention of researchers towards the economic production of the final product. Accordingly, the Allig date palm by-products, which are abundantly available in nature as a waste of palm date harvesting, storing and conditioning processes, were tried as a cheap substrate for xanthan gum production by *Xanthomonas campestris* in batch experiments and the process variables were optimized employing response surface methodology (Besbes *etal*., 2006).

Poly (3-hydroxybutyrate)

Polyhydroxyalkanoates (PHAs) are biocompatible, non-toxic and biodegradable materials, which are accumulated to store carbon and energy in various microorganisms with a potential to replace petroleum-based plastics.*Bacillusmegaterium*, isolated from the sludge of a sewage treatment plant in Makkah, Saudi-Arabia, was optimized for growth and **Poly 3-hydroxybutyrate** (PHB) accumulation in medium enriched with 5% (w/v) date syrup or beet molasses supplemented with NH4Cl. It was observed that when date Radiobacter curdlan syrup and beet molasses were used alone without an additional nitrogen source, the bacterium registered a cell density of about 3 g l^{-1} with a PHB content of the cells of 50% (w/w). Further, the addition of NH4NO3 followed by ammonium acetate and then NH4Cl was found to support cell growth up to 4.8 g l^{-1}, while PHB accumulation increased with NH4Cl followed by ammonium acetate, NH4NO3 and then (NH4)2SO4 to a PHB content of nearly 42% (w/w) (Omar et al., 2001).

Curdlan

Curdlan is a high molecular weight polysaccharide consistingof β-(1,3)-linked glucose units, produced by pure-culturefermentation from a non-pathogenic and non-toxicogenicstrain of Agro bacterium biovar 1 or Agro bacterium consists of β-(1,3)-linked glucose residues and has the unusual property of forming an elastic gel upon heating its aqueous suspension. It is a food additive that is used as firming agent, gelling agent, stabilizer, and thickener in the food industry. Rhizobium radiobacter ATCC 6466 was reported to produce curdlan using date palm juice by-products with an yield of 22.83 g l^{-1} when cultivated in a medium with optimal conditions of pH 7; 2 g l^{-1} of ammonium sulphate; 120 g l^{-1} of date glucose juice concentration, 30^0C; inoculum ratio of 5 ml/ 100 ml; 180 rpm agitation, and a fermentation period of 51 h (Salah *et al*., 2011).

Carotenoid

With respect to date fruit by-products as substrates for the fermentation production of carotenoids there are no other reports other than the one on optimization of the medium components by Plackett–Burman design for carotenoid production using date (P. dactylifera) wastes by Lactobacillus plantarum QS3 (Elsanhoty et al., 2012).Results of the study indicated that Date syrup at 5% sugar concentration resulted in 16.21 mg kg^{-1} dry cell of carotenoids when used alone, and there was increase in carotenoids production (54.89 kg^{-1} dry cell) with supplementation of the MRS medium with salts and organic nitrogen after optimization of pH and temperature using date syrup as a carbon source.

Biofuels

Hydrogen Production

Hydrogen production from rotten dates by sequential three stage fermentation was studied using three different bacteria (Abd-Alla *et al*., 2011). A facultative anaerobe, *Escherichia coli* EGY was used in the first stage to consume O_2 and maintain strict anaerobic conditions for a second stage dark fermentative H_2 production by the strictly anaerobic *Clostridiumacetobutylicum* ATCC 824. Subsequently, a third stage photo fermentation using *Rhodobacter capsulatus*DSM 1710 was conducted for the H_2 production. The total H_2 yield of the three stages was observed to be 7.8 mol H_2 per mol of sucrose when 5 g l^{-1} of sucrose was supplemented as rotten date fruits. Results of the study indicated that rotten dates can be efficiently used for commercial H_2 production without the need for addition of a reducing agent or flashing with argon, both of which are expensive.

III. Bioethanol, Acetone And Butanol

The most commonly used metabolically derived liquid bio-energy compounds are ethanol and butanol. The three major classes of feed stocks used for ethanol production are sugars, starches and lignocelluloses. Date palm (*P. dactylifera*) sap which is highly nutritive and has high sugar content (60–70%) is a very good source for microbial fermentation (Gupta & Kushwaha, 2011). Hence, fermentation of date extracts to ethanol and

vinegar in batch and continuous membrane reactors (Mehaia and Cheryan, 1991) and date syrup and wastes were tried for the production of ethanol (Besbes *et al*., 2009). A mutant strain *S. cerevisiae* ATCC 36858 and a commercial *S. cerevisiae* (STAR brand) activated at different periods demonstrated that *S. cerevisiae* ATCC 36858 could selectively convert glucose to ethanol and biomass with minimal fructose conversion (Gupta and Kushwaha, 2011). Butanol, along with small amounts of acetone and ethanol, is produced biologically from renewable biomass by Clostridium spp. Under strictly anaerobic conditions (Jones & Woods, 1986; Qureshi & Ezeji, 2008) using spoiled date palm fruits as substrate.

Antibiotics

Date fruit by-products and wastes were explored as possible substrates for the production of few antibiotics by investigators. From the literature available it was inferred that date fruits could be successfully used in the production medium as substrate for the production of Bleomycin and Oxytetracycline by species of Streptomyces.

Amino Acids

Date waste generated from date processing industry was recognized as a substrate for the glutamic acid production. Two mutants' of *C. glutamicum*CECT690 and CECT77 were found to produce amino acids from date wastes and the amino acids measured by HPLC showed that many amino acids such as alanine, valine, lysine, proline, tyrosine, phenylalanine, leucine and isoleucine apart from glutamic acid and threonine were produced(Davati *etal*., 2007).

Organic Acids

A. niger obtained from soil samples of different locations in Saudi Arabia was screened for its ability to produce citric acid in date syrup medium under free and immobilized cells systems. Date syrup and wastes were experimented for the production of biomass and citric acid (Besbes *et al*., 2009). Citric acid production by *A. niger* ANSS-B5 was found to be influenced by the cumulative effect of temperature (30^0C), sugar concentration of 150.0 g l^{-1}, methanol concentration of 3.0%, initial pH of 3.5, ammonium nitrate concentration of 2.5 g l^{-1}, and potassium phosphate concentration of 2.5 g l^{-1}. Thus under the said conditions during the fermentation process of date wastes syrup the citric acid production was increased to 98.42 ± 1.41 g l^{-1} (Acourene and Ammouche, 2012). Other important organic acids produced are lactic acid, Studies on date juice as nitrogen supplement for the production of lactic acid by *Lactobacilluscaesei* sub *sp. rhamnosus*showed that lactic acid production in date juice supplemented with 20 g l^{-1} yeast extract (0:5) was at same levels of lactic acid produced with the elemental nitrogen ratio of ammonium sulphate to yeast extract at 4:1 ratio (Nancib *et al*., 2001).

IV. Microbes Associated With Date Palm Fruits

Microorganisms capable of fermenting wild date palm (*Phoenix sylvestris*) sap into wine (toddy) were isolated and identified (Shamala and Sreekantiah, 1988). *Saccharomyces cerevisiae, Schizosaccharomyces pombe, Acetobacteraceti, Acetobacter rancens, Acetobacter suboxydans, Leuconostoc dextranicum, Micrococcus sp., Pediococcus sp., Bacillus sp., and Sarcina sp*. were encountered in the freshly tapped sap few by-products are also produced through chemical modifications of date seeds such as polyol and mayonnaise. Polyols were produced from date seeds through oxypropylation and liquefaction techniques using organic solvents in the presence of a catalyst while date pit oil has been shown to be used as non-traditional oil in mayonnaise production (Briones *et al*., 2011).

Antimicrobial Property

Phoenix dactylifera and its constituents play a significant effect in the prevention or treatment of bacterial diseases. An important study showed that the effect of methanol and acetone extracts of leaves and pits *Phoenix dactylifera* inhibited the growth of *Fusarium oxysporum, Fusarium sp., F. solani, A. alternata, Alternaria spp. (*Bokhari *et al.*, 2012).Some other important finding showed that methanol and acetone extracts of the *P. dactylifera* pits reasonably inhibited the growth of Gram positive and Gram negative bacteria (Jassim *et al.*, 2010; Ammar *et al.*, 2009). Another recent study in the support of *P.dactilifera* effect as antimicrobial on *Klebsiella pneumonia* and *Escherichia coli* and also showed a role in reducing the side effects due to the use of drugs as methylprednisolone. (Aamir *et al.,* 2013).Another study also showed that *Phoneix dactylifera* extract has antibacterial effect against *Enterococcus faecalis*, indicating that this extract can be used for treating enteric diseases (Aamir *et al.,* 2013).

Uses as Food/Food Supplements

Dry or soft dates are eaten out-of-hand, or may be pitted and stuffed with fillings such as almonds, walnuts, pecans, candied orange and lemon peel, tahini, marzipan or cream cheese. Date nut bread, a type of cake, is very popular in the United States, especially around holidays. Dates are also processed into cubes, paste called "'ajwa", spread, date syrup or "honey" called "dibs" or "rub" in Libya, powder (date sugar), vinegar or

alcohol. Vinegar made from dates is a traditional product of the Middle East (Das *et al*., 1936). Dates can also be dehydrated, ground and mixed with grain to form a nutritious stock feed. Dried dates are fed to camels, horses and dogs in the Sahara. In Israel date syrup is used while cooking chicken and also for sweet and desserts.

V. Conclusion

Date palm fruit is one of the most nutritive and comprehensive fruit in terms of health benefits is an ideal substrate for deriving a range of value added products in food and nutraceutical industries in the coming future employing bioprocessing technologies which have immense scope for application in the volarization of date fruit by-products and wastes. Date seeds, discarded dates and spoiled waste hold immense potential as raw material for bioprocessing and augmentation of new range of products. The plant has great medicinal value as it has been reported to have versatile phytochemical including phenolics, sterols, carotinoids, anthocyanins, procyanidins, flavonoids, different minerals and vitamins. These phytochemicals have been responsible for the different pharmacological effect like antibacterial activity.

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