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A Review on Date Palm Tree: Properties, Characterization and Its Potential Applications

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Abstract: Date palm (*phoenix dactylifera*), which is mostly found in the middle east countries such as Iran, Iraq, Saudi Arabia, and the United States (California) that play a significant role in the economical and the environmental condition in those areas. The main purpose of planting dates is its fruit, which is consumed as fresh, dried or processed forms. There are approximately 100 million date palm trees in the worldwide that 62 million of these trees located in the Middle East and North Africa. In Saudi Arabia only, 15000 tons of date palm leaves is prepared as waste materials. The leaves of date palm tree are used in several applications such as making ropes, baskets, and mats in many parts of the world. Unfortunately, the huge amount of the non-food products from the date palm remains as landfill materials without any specific usage. By attention to the date palm properties, the literature clearly showed that each part of date palm has great potential to be used for a variety of applications such as: making paper, absorption of heavy and toxic metals, energy production and soil fertilizing. Some of the obstacles and solutions for using palm date in these applications were also explored. Considering these issues and their solutions, the date palm is a favorable alternative. Despite some limited and traditional uses of these palm wastes, this review considered date palm applications and the properties' of the most important part of that tree in recent researches and related issues for future research are also spotted.

Keywords: Date palm; energy production; heavy and toxic metals; date palm leaf

1 Introduction

In the last decades and especially these last years, wood and woody products have played a considerable role as an alternative for other synthetic materials such as carbon and glass. The natural fiber can be in many sectors and their applications are growing day to day [1]. Some of its application which can be called are in furniture, construction, automobiles and so on [2-4]. Wood as engineering material has an important role in developing and developed countries [5]. Recently, the sources of wood have been decreasing while the demands for raw wood materials are increasing [6,7]. On the other hand, the pressure on the environment has been increasing in the last years, which resulted in the wood supplies changing. Several products such as medium density fiberboard (MDF), laminated strand lumber (LSL), parallel strand lumber (PSL) and so on were manufactured from raw wood materials [8]. The environmental concern about raw wood materials leads to find alternative resources instead of wood materials [9]. For years agricultural wastes and residues such as bagasse, wheat straw and so on have been used [10-12]. Another substitute resource, which already allocated a huge amount of agricultural residues is date palm (*phoenix dactylifera*) which can be found in the lands around the Persian Gulf such as Iran, Saudi Arabia [13,14] and other countries like Iraq. Despite the lack of water, date palm trees grow and provide some fresh fruit and have their own residues. In addition, some other countries such as Arabian Peninsula and North Africa, South America, Mexico, and Pakistan are introduced in the list of countries, which have and produce date palm's fruit. According to the food and agriculture organization (FAO) statistics, approximately 105 million date palm trees are existing in the world. Middle East countries climate is an ideal situation for date palm plantation [15]. Every year after date palm harvesting, large quantities of residues (frond and leaves) accumulated in agricultural lands.

Fig. 1 shows a date palm farm and the amount of residues that can produce by each of them.

Figure 1: Date palms and residues on the trees

These waste mostly are left in agricultural lands or they burned, which can be an environmental and health issue [16]. According to evidence, leaving raw materials from date palm waste for a long time are prone to be highly flammable [17]. Fig. 2 shows the burning date palm residues in the land farm.

Figure 2: Burning date palm residues in the land farm

So the wise way is to use this natural resource in bio-applications, which can meet the increasing demand in renewable and biodegradable materials [18]. In addition, these sources can be used in other application, such as absorbing some toxic ions like lead, producing energy that is one of the most problematic issues in the world [19,20].

The aim of this review was to investigate the recent studies, which have been done on the date palm as raw material for energy production, absorption of toxic ions, and bio-composites manufacturing from date palm fibers. To the best of our knowledge, there is no similar review on date palm previously.

1.1 Date Palm Seed

Date palm leaves are the most residues, which are produced by date palm trees annually; other parts of date palm such as seed and trunk are utilizable too. However, a few studies investigated the using of these parts in some applications. The chemical composition and ultimate analysis of date seeds are shown in Tabs. 1 and 2.

Table 1: Chemical composition of date palm seeds

	Carbohydrate	Moisture	Dietary fiber	Protein	Fat	Ash	Ref.
Fresh date seed	2.4-4.7	8.6-12.5	67.6-74.2	4.8-6.9	5.7-8.8	0.8-1.1	[21]
Dry seed	81.0-83.1	-	-	5.2-5.6	10.2-12.7	1.1-1.2	[21]
	81.0-83.1	-	-	5.56-5.17	10.19-12.67	1.15-1.12	[22]
	-	10.50	-	5.56	-	1.35	[23]

Table 2: Ultimate Analysis of date palm seeds

	C	N	O	S	H	Bulk density (Kg/m^3)	Ref.
Seed	45.3	1	47.2	0.8	5.6	560	[24]
	44.1	0.9	48.3	0.6	6.1	-	[25]

These residues are also contain many minerals such as magnesium, potassium, sodium, calcium, iron, phosphorus, zinc, copper, nickel, cobalt, chromium, lead and cadmium [26,27].

The average mass of date palm seeds is about 8-15 wt% of date palm fruit [22,28]. In addition, it is estimated that Saudi Arabia has produced 550000 tons of dates fruits in 2011 which contains about 55000 tons of date seeds [29]. On the other hand, the date fruit production was almost 1084000 tons in Iran in 2013 which can produce 100000 tons of date seeds approximately [21].

Besides, the seeds occupied a huge number, which cannot be collected again and use as an efficiency material. However, investigations [21] showed that the date seeds are prone to be used as fuel production material and it can be converted to gas, high-value liquid (bio-fuel), and solid (bio-char).

1.2 Date Palm Chemical Composition

It is believed that the suitability of different materials for different applications needs knowing their chemical composition; because of the dependency of some of the characteristics such as fungi attack, recyclability, weather resistance, and degradability of the fiber [30,31]. Therefore, it is important to know the chemical composition of materials to use in the right applications

Date palm mostly consists of cellulose embedded in the lignin matrix [32]. By dividing leaf into two separated parts (leaflet and rachis) as it has shown in Fig. 3, the chemical composition of leaflet and rachis are shown in Tab. 3.

Figure 3: Date palm Rachis and Leaflet

Table 3: shows the average weight percentage of chemical composition of the date palm fibers from leaf (leaflet and rachis) [33,34]. Reproduction of table from [30]

Constituents	Cellulose	Lignin	Hemi-cellulose	Extractive	Ash	
Leaflet	40.21	32.2	12.8	4.25	10.54	[33]
	54.75	15.3	20	8.2	1.75	[34]
	47.14	36.73	16.13	32.86		[35]
	34.87	14.03	19.84			
Rachis	38.26	22.53	28.17	5.08	5.96	[33]
	45.16	26.68	28.16	17.45		[35]
	40.40	12.49	33.08			

Table 4: Characteristics of Date Palm Leaf

Source	Part	Moisture (%)	VM (%)	FC (%)	LHV (MJ/kg)	Ash (%)	Ref.
Wood	-	20	82	17	18.6	1	[36]
Bituminous Coal	-	11	35	45	34	9	[36]
Date Palm	Leaflet	5	78.1	5.2	17.9	11.7	[24]
		7.1	68	9.7	19	15.2	[37]
		8.50	72.28	7.64	-	11.58	[38]
	Rachis	17.7	55.3	7.8	10.9	19.2	[24]
		12.1	73.6	8.3	15.2	6	[37]
		7.27	78.11	9.12		5.50	[38]
	Leaf (leaflet and rachis)	17.6	70.59	22.30	-	7.11	[39]
		6.2	69.9	20.9	-	2.9	[40]
		5	78.1	5.2	-	11.7	[41]
		5.3	52.1	6.1	-	20.2	[25]

Taking into account the percentage of cellulose and its role in the cell wall and enhancing cell strength, date palm potential is considerable. Cellulose and lignin percentage of date palm leaf show appropriateness and competitiveness of date palm fibers compare to coir, hemp and sisal [18]. Date palm cellulose amount is lower than hemp and sisal and as the result; its water absorption is less. On the other hand, the cellulose content in date palm fibers is more than that of lignin, which makes it appropriate for using in automotive applications [18]. Considering the chemical composition of date palm can be useful to find different applications and products for remaining waste materials. Tab. 4 shows the date palm leaves LHV in different studies. Most of them are on dry basis. Comparing the date palm leaves LHV to Bituminous coal and wood illustrated that the date palm LHV is about half of the Bituminous coal and approximately adequate to wood.

1.3 Physical Properties of Date Palm

Several studies have been conducted on the physical properties of the date palm because is important in the suitability for the final applications. Different industrial applications need some properties such as density, thermal conductivity, cost, availability, fiber's length, diameter and aspect ratio [18,42,43]. Density, which is one of the most important physical properties, can has a great role in implementing natural fibers. Fig. 4 illustrates a comparison between the date palm and other natural fibers density.

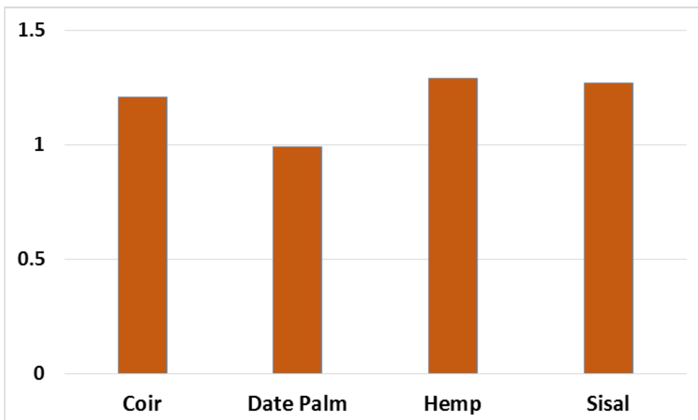

Figure 4: Comparison between date palm and other natural fibers density [18]

As seen from Fig. 4, the date palm fiber has a lower density compared to other natural fibers, so this property can lead to having the low-density composites suitable for automotive and space application [30]. The other physical properties of the date palm compared to other natural fibers are listed in Tab. 5.

Table 5: Comparison between physical properties of date palm and other natural fibers [18]

Fiber type	Coir	Date Palm	Hemp	Sisal
Density (g/cm^3)	1.15-1.46	0.9-1.2	1.4-1.5	1.33
Length (mm)	20-150	20-250	5-55	900
Diameter (µm)	10-460	100-1000	25-500	8-200
Specific modulus (approximate)	4	7	40	17
Thermal conductivity (W/m k)	0.047	0.083	0.115	0.07

As seen from Tab. 5, the density of the date palm is lower but the fibers' length is higher than the other ones. On the other hand, the date palm diameter is larger which can lead the date palm to have an intermediate value of aspect ratio, which at the end it could be a great property for using in different applications [18,44].

1.4 Mechanical Properties of Date Palm

Mechanical properties can be affected and determined by some other factors and variables such as chemical composition, microfibrillar angle, structure, cell dimensions, and defects [31,45-47]. The angle between the micro-fibrils and fiber axis is known as microfibrillar angle, which is responsible for the fibrils mechanical properties. The higher strength and stiffness of the fiber can be attributed to the smaller angle [18]. The natural fibers which shown the higher mechanical strength usually have higher longer cell length, cellulose content, a higher degree of polymerization of cellulose and lower microfibrillar angle. Also, some of the important mechanical properties like Young's modulus and tensile strength usually improve by increasing of the cellulose content and cell wall [48,49]. A comparison between date palm cellulose content and Sisal are shown in Tab. 6.

Table 6: Comparison the relation between cellulose content and some mechanical properties

Constituents	Cellulose (%)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)
Date palm fiber[a]	40.21-54.75	58-203	2-7.5	5-10
Sisal[b]	78	530-630	17-22	3-7

[a] [3]; [b] [50]

Tab. 6 illustrates the contribution of cellulose on the tensile strength and Young modulus and approve by increasing the cellulose content. The two mentioned properties' increase and as a result, the final properties of the composite will go up.

2 Applications of Date Palm

2.1 Paper from Date Palm Rachis Fiber

The amount of consumption of paper has increased from 324 million tons in 2002 to 389 million tons in 2008 [51]. Softwoods are the main source of raw materials for papermaking and about 5-10% provide from non-wood lignocellulosic resources such as cereal straw, canes, etc. Using agricultural residues or marine biomass is a way that some countries have considered. Some countries investigated the possibility of papermaking from date palm fibers such as Malaysia [52], Iran [53], Portugal [54,55], and Tunisia [56,57]. According to the literature, the softwood and hardwood fibers length are about 2-3 mm and 1-2 mm respectively. So, their aspect ratio is approximately 100 and 60 while the date palm aspect ratio is about 40 [58]. This number shows the capability of date palm rachis for pulping [58]. The main characteristics of date palm rachis pulp are shown in Tab. 7.

Table 7: The Main Properties of Date Palm Rachis Pulp. Reproduction of [58]

Fiber length[a] (mm)	0.89
Fiber width (μm)	22.3
Fine elements (% in length)	30.8
Shopper Riegler degree (^{0}SR)	14
WRV% (w/w on o.d. pulp)	138

[a] weighted mean

The Water Retention Value (WRV) of the date palm is 138 while the softwood and hardwood are 90 and 100% respectively, which show high flexibility, and as the results, good mechanical properties of the ensuing paper [58]. In addition, the date palm rachis paper properties are shown in Tab. 8.

Table 8: The main properties of the paper produced from date palm rachis. Reproduction of the table from [58]

Properties	Values
Shopper Riegler degree (^{0}SR)	14
Basis weight (g/m^2)	63.9 ± 1.9
Permeability (cm^3/s Pa m^2)	450 ± 0.042
Bulk (cm^3/g)	2.21
Thickness (µm)	141 ± 6
Breaking length (km)	3.13 ± .23
Elongation (%)	1.09 ± 0.09
Specific energy (mJ/g)	221 ± 37
Young modulus (GPa)	2.51 ± 0.14
Burst index (kPa m^2/g)	1.32 ± 0.05
Tear index (mN m^2/g)	4.4 ± 0.37
Dry zero-span breaking length (km)	13.4 ± 0.91
Wet zero-span breaking length (km)	10.8 ± 0.66
Internal bond strength (J/m^2)	94 ± 8.8
Short-Span Compression test (kN/m)	1.32 ± 0.13

Tab. 8 revealed that the date palm rachis can be considered as a proper raw material for papermaking applications.

2.2 Date Palm as an Absorbent for Heavy and Toxic Metals

Removal of heavy metals can be affected by several mechanisms involving adsorption on surface and pores, ion exchange, chemisorption, complexation, entrapment in inters and intrafibrillar capillaries and spaces of the structural polysaccharides network [59-61]. The functional groups such as amino, amido, carbonyl, phenolic, sulphydryl, carboxyl, alcohols, and esters groups present in biomass [62,63] like date palm which affinity for metal complexation. The complexation of heavy metal and functional groups has been reported by several researches through spectroscopic techniques [64-66].

According to the chemical composition of different parts of the date palm, it can be used for absorbing heavy metals such as lead. Lead is one of the toxic heavy metals that our environment accumulated of that heavily [67,68]. Most of the industries such as newsprints, battery industries, smelting, petrochemicals and so on release it and contaminate the environment [69]. From the past up to now, various methods have proposed and have been used to remove this ion from industries [70]. Tab. 9 shows the methods which have been used for absorbing lead heavy metals.

Another efficient way is using date palm fibers and petioles for absorption lead in an aqueous solution [77]. Their investigation was contained various parameters such as solution pH, adsorbent dosage, contact time, ionic strength and temperature. According to the result, palm fibers and petioles are the efficient material for removing lead ions.

Alghamdi [78] use a filtration setup by date palm fibers to remove lead ions (Pb(II)) from waste-water and declared that using this material can be a viable alternative to make sustainable and economic waste-water treatment system.

As a result, using date palm waste for absorbing heavy and toxic metals is practical and it can be performed in low costs.

Table 9: The methods for absorbing heavy metals

Methods	**Ref.**
Membrane separation	[71]
Electro dialysis	[72]
Absorption-flotation	[73]
Removal by adsorption on minerals	[74]
Calcined phosphate	[75]
Activated carbon or mineral	[76]

2.3 Date Palm for Producing Wood Composites

Because of the availability of non-wood plant, agricultural, and horticultural residues, several researchers from different parts of the world were considered the potential of using the biomass waste. For example, the rice husks [79], wheat-cereal straw [80-83], tobacco [84], sunflower stalks [85], bagasse [86], kenaf [87,88], oil palm [89], bamboo [90,91], and cotton carpel [92] were investigated. Several studies have considered the different parts of date palm for composite materials [93,94]. Tab. 10 indicates the different uses of date palm in composites production.

Table 10: The different uses of date palm in composites production

Application	Ref.
Date palm propylene composite	[95]
Propylene reinforced with date palm fibers	[96]
Date palm fiber/polyester composite	[97]
Reinforced ethylene terephthalate composite	[98]
Starch-based biodegradable composite	[99]
Natural mortar reinforced with date palm	[100]
Wood-polymer composite with date palm and epoxy matrix	[101]
OSB from date palm	[5]
Date palm MDF	[102]
Particleboard from date palm	[103-106]
Wood-cement composite with date palm	[107]
Gypsum board from date palm (insulation board)	[108]

The following section will discuss the way of using date palm (fibers, particles) in different products according to Tab. 10. Haque et al. [95] considered date palm as reinforcement in polyethylene (PE) matrix. Because of the incompatibility of date palm fibers and poor interface, the date palm fibers were chemically modified with benzene diazonium salt. According to their statement, treated date palm fibers showed better mechanical properties.

Polypropylene (PP) and low-density polyethylene (LDPE) were reinforced with date palm frond fibers and the results revealed the possibility of using date palm as reinforcement for industrial applications [96].

Date palm soda treatment and polyester had higher mechanical properties compared to untreated raw materials and date palm has great potential to be used as reinforcement in the polyester polymer [97].

Dehghani et al. [98] investigated the mechanical and thermal properties of date palm leaf fibers as reinforcement for recycled polyethylene terephthalate (PET) polymer. Surface modification was done by alkaline treatment. Fig. 5 shows the treated and untreated date palm fiber.

As can be seen from Fig. 5, the surface of untreated fiber was not clean and after alkaline treatment, they became gently cleaned. The better mechanical interlocking was as a result of increasing surface roughness and exposing more cellulose on the surface which will increase the number of possible reaction site [109]. The general conclusion of this study showed that the use of the date palm fibers and PET can produce an environmental friendly composite as an alternative for current products [98].

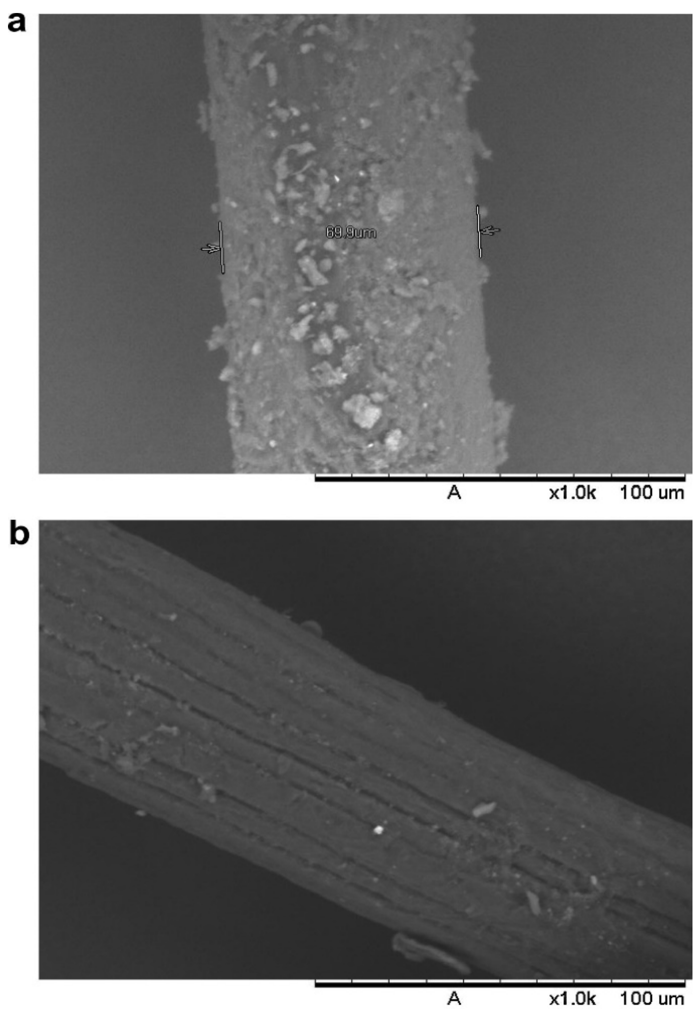

Figure 5: Untreated (a) and treated (alkaline treatment) (b) date palm fiber [98]. Permission obtained through Rights Link®

Completely biodegradable composite with date palm fibers and starch was manufactured by Ibrahim et al. [99]. The use of 50 wt% fibers showed the optimum mechanical properties. Also, mixing flax and date palm fibers (hybrid composite) 25 wt% of each one can be resulted in a satisfactory and eco-friendly composite [99].

The insulation composite, which was produced by Benmansour et al. [100] showed that the date palm fibers can either have good mechanical properties and thermal insulation characteristics. The potential of using date palm fibers as reinforcement for polymeric composites was taken into account by Alsaeed et al. [101]. A range of the NaOH treatment (0-9%) was used to modify the surface of the fibers. The result of this study showed that 6 wt% of NaOH is the optimum solution for treating the date palm fibers.

Investigation on the possibility of making OSB from date palm leaflet has been done by Hegazy et al. [5]. The fibers were prepared by collecting four types of date palm leaves and cutting out the leaflet from the rachis. The obtaining fibers and phenol-formaldehyde adhesive at a rate of 10 wt% were mixed in a rotary drum blender and finally pressed using a hot press. The results showed that the date palm leaflet is an appropriate raw material for making OSB.

Hosseinkhani et al. [102] studies the MDF manufactured from pruning residues of the date palm. The results showed that the MDF manufactured from these materials featured better than the limitation that ASTM and EN standard recommended inspecting of mechanical properties.

Some researcher investigated the possibility of making particleboard from date palm and the results illustrated that the date palm waste materials were suitable for making particleboard and it can be an alternative for solid wood. In addition, they had low price and high potential as raw material compared to wood resources [5,105,106]. The biggest point of using date palm residues for making composites is, producing composite and other products, which need a lot of energy. For example, manufacturing MDF needs to use a lot of water for growing a tree from the first year to the harvesting time. Then cutting and transporting, chipping, drying, making fibers, gluing, pressing and other extra works on that. On the other hand, the date palm residue already exists without any energy for producing which can increasingly decrease energy consumption.

Wood-cement is another type of composite produced by mixing cement and particles or fiber together and the fibers act as reinforcement [107]. Some of the advantages of the wood-cement are listed as follows [110].

- High resistant to water
- Excellent sound insulation
- High resistance to termites
- Fire performance
- High stiffness

By attention to unique properties of wood-cement, it can be used in different applications such as [111]:

- Flat roofing
- Mobile homes
- Prefabricated structure
- Permanent formwork
- Cladding
- Sound barriers
- paving

Manufacturing wood-cement composites have its own drawbacks. The wood or lignocelluloses natural fibers contain cellulose, hemicellulose, starches, phenols, hydroxylated carboxylic acids are known as inhibitory substances in wood-cement crystallization. Therefore, it is necessary to improve the lignocelluloses fibers by washing or using additives such as calcium chloride and sodium silicate [112]. In a study which was carried out by Nasser and Al-Meffarrej [107], they used different pretreatment and chemical additives. The results showed that the suitability of the date palm either hot water or adding 3 wt% $CaCl_2$ as the accelerators. The effect of date palm fibers on the mechanical properties, water absorption and thermal conductivity of Gypsum board were studied by Chikhi et al. [108]. They said that the compressive and flexural strength can be improved and can be a great thermal insulation material. Overall, the date palm fibers have very competitive properties for using as reinforcement to produce composites production. Therefore, it can be strongly suggested that the date palm fibers have high potential to use in composites materials because they are cheaper and sustainable resource compare to wood or other cellulosic materials.

2.4 The Potential of Using Date Palm Biochar

The growth of the population needs more and more food and relative food materials. One of the initial ways for producing more food and agriculture products was bringing more land into agriculture, and some new lands were brought, but competition between agriculture and the other human activities can limit it [113,114]. In addition, a new land means consuming more water that is not favorable. So, the best scenario is that more food must be produced in the same lands with more productivity.

In the past, farmers recognized the nutritional value of the residues and added these to the soil in several ways such as direct incorporation and surface retention. Although according to the studies, burning can cause loss of the nutrient into the atmosphere [115] which can destroy the chemical and biological properties of the soil, too. It seems that biochar is one of the best ways of using this waste and make it more efficient. The situation in which a natural material can change into biochar is heating under limited or no oxygen space [116]. The biochar can increase N retention onto soil and the N reduction rate [117]. The previous studies have shown that this addition is also useful for decreasing net nitrification rate [118], N leaching as ammonium (NH_4^+) and nitrate (NO_3^-) [119,120] ammonia (NH_3) volatilization [121] stimulates N immobilization [122]. In recent years, for reducing greenhouse gas emission, sequestering carbon and improving soil quality, biochar emerged to soil [123-126].

As mentioned before, the huge amount of the date palm waste has no useful products and almost all these wastes were burned. Some studies have been done on using the date palm biochar in different purposes. A study by Bassyouni et al. [41] showed the date palm waste can be converted into wealth. They pyrolyzed the date palm waste in order to produce activated carbon and liquid phenolic products. The existing literature on using the date palm biochar as fertilizer is few but it seems it can be used and improve soil quality.

2.5 Date Palm for Fuel and Energy

The routine daily life of a human is very much dependent on fossil energy, nowadays. By increasing in the industrialization, the fossil energy consumption was enhanced, too. Rising fossil fuel consumption and other gaseous pollutants affected the world climate conditions. The other disadvantage of using fossil fuels is rising the global temperature, which can reduce the agriculture production. In addition, the appearance of new disease and new pests, water shortage, ozone layer depletion because of increase in carbon dioxide and finally increase ultra Violet-B radiation on the earth that can enhance several problems for humans [127]. Furthermore, the climate changing and global warming have been causing significant variations which leading to have 150000 deaths per year [128]. It threatens millions of people all around the world with a growing risk of water shortage, floods, hunger and disease such as malaria [129]. One of the ways of decreasing these risks and have perdurable source of energy is using renewable energy, which is termed as plant-, based energy, bioenergy or green energy [127].

Comparison of the life cycle of two different materials (China reed pallet (CRP) and glass fiber pallet (GFP)) is shown in Tab. 11. By considering this Table, CRP pallet's environmental impacts are lower than GFR pallet, although the nitrates emission to water is not comparable.

Table 11: Comparing the life cycle environmental performance of glass fiber pallet and China reed pallet [130], Reproduction of table from Joshi et al. [131]

Environmental indicator	China reed pallet	Glass fiber pallet
Cumulative nonrenewable energy use MJ	717	1400
Carbon dioxide emission (kg)	42	73.1
Carbon monoxide (g)	54.6	74.3
NO_x air emission (g)	349	513
Sulfur oxides (SO_x) air emission (g)	163	289
Water emission-BOD (mg)	266	414
Water emissions- nitrates (g)	153	1.72
Water emission-phosphates (g)	1.67	0.59
CML- human toxicity (kg 1,4 $dichl_{eq}$)	9.04	21.2
CML-terrestrial Eco toxicity (kg 1,4 $dichl_{eq}$)	4480	5250
CML-Greenhouse effect (kg $CO_{2\ eq}$)	40.4	75.3
Eco-indicator[a] 95-carcinogenicity (10^{-7} kg PAH_{eq})	4.48	7.11
Eco-indicator 95-acidification (kg $SO_{2\ eq}$)	0.41	0.65

[a] Eco-indicator id index of environmental impact with weighting factors covering damage to resources, damage to ecosystem quality, and damage to human health, developed by Pre Consultants.

Table 12: Nonrenewable energy or production glass and flax fiber mat production

Nonrenewable energy requirements (MJ/kg)			
Flax fiber mat		Glass fiber mat	
Seed production	0.05	Raw materials	1.7
Fertilizers	1.0	Mixture	1.0
Transport	0.9	Transport	1.6
Cultivation	2.0	Melting	21.5
Fiber separation	2.7	Spinning	5.9
Mat production	2.9	Mat production	23.0
Total	9.55	Total	54.7

The nonrenewable energy is another of energy, which is more important than others, is because it makes pollution and cannot be recovered. Tab. 12 shows the nonrenewable energy for production of two kinds of materials. Flax (natural) and glass fiber (synthetic) fiber mat.

The main source of energy for natural fiber is solar energy, and for fiber productions while the main energy source for glass fiber production, is fossil fuels. These two Tables are a comparison between synthetic fiber and natural fiber. No literature is on date palm life cycle, but according to the both tables, the required energy for date palm residues is almost nothing. In addition, it can be concluded that date palm fiber production is lower than flax fiber and reed. Biomass waste is suitable for making energy. One of the positive points of using this biomass as energy producer materials is their renewability, which can ensure that their resource will not be depleted [132]. Biomass utilization for energy production and energy resource has several environmental and economic advantages [14].

Brazil and America are the biggest ethanol producers, which produce it from sugarcane (sugarcane ethanol) and corn (corn ethanol), respectively [133]. The US Department of Energy afforded to replace the 30% of gasoline consumption with cellulosic ethanol by 2030 [134]. Therefore, the characteristics that an ideal crop must have to think about as an energy production are listed below [36].

- High yield (maximum production of dry matter per hectare)
- Low cost
- Low energy input to produce
- Composition with the least contamination
- Low nutrient requirements

Taking into account these factors and determinations, it could be said that, the date palm could be planted in dry and semi-dry regions and with a few water it grows. Low-cost limitation for these materials is also passed; because most of the date palm residues are abandoned in the farm's land and in most cases, the farmer only wants them to be taken out or could be bought at low price. In addition, the biomass can be converted to three main types of product as follows [36]:

- Transport fuel
- Electrical/ heating energy
- Chemical feedstock

To be converted to any kind of this energy, the biomass is depending on some factors:

- Cellulose and lignin content
- Calorific value (CV)
- Ash/ residue content
- Properties of fixed carbon and volatile
- Moisture content (intrinsic and extrinsic)
- Alkali metal content

The following section will discuss these factors

3 Chemical Structure of Palm Date

3.1 Cellulose and Lignin Content

In biochemical conversion, the proportion of lignin and cellulose will be important [36]. For biochemical conversion, because of the greater biodegradability of cellulose than lignin, its conversion is easier compared to the lignin [36]. Date palm cellulose/hemicellulose content is approximately 70% of the chemical composition of the date palm leaves (about 54% cellulose and 20% hemicellulose) [34]. Therefore, the potential of making ethanol from date palm as fuel production material is high.

3.2 Calorific Value (CV)

Calorific value can express the heating value or energy content when it burnt in air. Usually, this term (CV) measured as energy content per unit mass. For example, MJ/l for liquid, MJ/kg for solids and MJ/Nm^3 for gases. The way of expressing CV is higher heating value (HHV) and lower heating value (LHV). When a material is burnt in air the total energy content that will be released, which including the latent heating contained in the water vapor, so in a biomass it can be maximum energy that potentially recoverable. However, in practical the latent heat contained in the water vapor cannot be used effectively. So, LHV is used for the energy available for subsequent uses [36].

3.3 Volatile Matter (VM) and Fixed Carbon (FC)

Analyzing solid fuels such as coal consist of two forms which store as chemical energy in that mass [36]:

- Volatiles
- Fixed carbon

The volatiles can be defined as the proportion of that mass which will be driven off as a gas including moisture by heating (to 950ºC for 7 min.). On the other hand, fixed carbon content is something that remains after releasing volatiles, which can be included ash and moisture content. VM and FC are measured in which the biomass can be burnt and subsequently gasified or oxidized.

3.4 Moisture Content

Moisture content can affect the final fuel that can be achieved. The most efficient biomass sources for thermal conversion to liquid fuels such as methanol are those, which have low moisture content. If biochemical conversion (fermentation) were used, the high moisture content is appropriate, which finally gives ethanol. On this basis, the moisture content (typically < 50%) is suitable for thermal conversion, so the date palm leaves which have low moisture content (Tab. 2) can be used for producing methanol but also ethanol was produced, too.

3.5 Ash/residue Content

The residue that will be produced after combustion in air is called ash. On the other hand, a solid mass that after either biochemical or thermos-chemical can be seen is residue [36]. The biomass energy cost will be affected by the ash content [36]. Increasing ash content, the fuel energy is reduced proportionally [36,135]. Comparing the ash content of the date palm is lower than Bituminous coal and show the date palm suitability for energy production.

3.6 Ultimate Analysis of Date Palm Leaf

Tab. 13 shows the ultimate analysis of date palm leaf. The amount of carbon and oxygen play an important role in the amount of heating value. Increasing in the oxygen and reducing carbon lead to having a low heating value and on the other side, the high amount of carbon and the fewer amount of oxygen are favorable for combustion applications [136]. Comparing the amount of the date palm ultimate elements to Bituminous coal showed a higher amount of carbon and lower oxygen in bituminous coal. Although the date palm leaves cannot produce as much energy as coal but the LHV of the date palm is, about half of bituminous coal LHV that make it attractive for using is application of energy production.

Ethanol and biodiesel, which are the most common biofuels and generally used for, or added to, gasoline and diesel, and methane which can be directly used. Materials that used for ethanol production by fermentation are fruit and cellulose biomass in which for photosynthesis need atmospheric carbon dioxide, and the date palm residues are prone to be an excellent choice as biofuel sources [138]. Although the amount of date palm residues is considerable, a few studies have evaluated the using of date palm waste as a renewable energy source. Biogas is one of the products that can be obtained from the date palm by-products which has considered by Jaafar [139], and the results illustrated that the date palm waste are high potential to produce biogas which contain approximately 67% methane of total gas produced. Abd-Alla and El-Enany [140] investigated the possibility of producing acetone-butanol-ethanol from spoilage the date palm and declared that these waste can be used as an inexpensive renewable substrate for acetone-butanol-ethanol production. Therefore, the date palm is a great alternative to be used for producing those.

Table 13: Ultimate analyses of date palm leaf

Source	C	H	N	S	O	Ref.
Leaflet	49.4	5.8	1.2	1.3	42.3	[24]
	46.50	5.69	0.66	-	-	[35]
	43.14	7.49	0.196	-	52.71	[38]
Rachis	36.1	5.2	0.7	0.7	57.2	[24]
	39.8	5.7	0.19	0.26	53	[137]
	45.65	5.95	0.27	-	-	[35]
	39.95	7.19	0.158	-	52.70	[38]
Leaves	45.4	5.6	0	5.5	40.4	[40]
	43.19	5.83	0.70	4.16	39	[39]
	38.1	5.2	0.8	0.3	55.6	[25]
Bituminous coal	73.1	5.5	1.4	1.7	8.7	

4 Conclusions

Date palm is a conventional crop in the Middle East which has the ability to use as alternative resource instead of wood materials for different applications. Although palm fruit, which is the main product of palm trees, is used as a nutrient source in low-water and desert areas, date palm waste is an easy collecting waste which mostly found in the Middle East countries. The amount of this waste is considerable and only in Iran it is more than million tons leaves annually. The properties of different parts of that are in a way, which can be used in different applications. For making paper according to aspect ratio and the other morphological properties, it has great potential this purpose. Producing energy is another application of date palm, which is a renewable energy production material, and it ensures that this source will not be depleted. The date palm also can be used for abruption of heavy and toxic metals, soil fertilizing and the other application, which have been proven by the researchers. Certainly, increasing the beneficial uses of fruits and especially palm waste will increase people's interest in planting this crop and can lead to sustainable industrial and economic growth in different areas. Thus, there is a need to investigate the potential of using date palm in different applications for encouraging the industries to make value-added products from date palm which can be used in future.

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