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***Prosopis cineraria* as an Unconventional Legumes, Nutrition and Health Benefits**

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Abstract

Prosopis cineraria (L.) Druce is considered as one of the highly valued plants in the native system of medicine for many arid and dry areas in the world. Ancient literature for Arabian Gulf and Indian desert illustrated the important of the plant in treated various ailments like asthma, dysentery, leucoderma, leprosy, dyspepsia, earache, etc. The present chapter review the using of *P. cineraria* as unconventional legumes that not well known as a rich and sustainable source of protein for many people in the world. It emphasis on its broad food and nonfood applications, nutritional values and health benefits. As well as looking at the phytochemical constituent's content that has been identified in the various parts of the plant as alkaloid, steroids, alcohol and alkane. The present paper describes the morphological trait of *P. cineraria* and identifies the environmental conditions required for its natural distribution. Historically, this plant has drag attention for its various uses therefore, it has been considered as the National Tree of the United Arab Emirates in the Arabian Gulf.

Keywords: *Prosopis cineraria*, Leguminosae, nutritional value, pharmacological properties, usage, phytochemicals

1. Introduction

The continuous world population growth, inadequate protein sources, exorbitant cost of animal protein are considered the main reasons for malnutrition and undernourishment among people living in many developing countries around the world. To meet the increasing demand of protein, alternative strategies and unconventional sources of protein for human and animal nutrition have been considered recently.

Trees of *Prosopis* genus, which belongs to the Leguminosae family, are one of the most important source of proteins in arid and semi-arid regions. Its capability to stand heat and tolerate drought, salt, and alkalinity make *Prosopis* cultivated and distributed in many areas around the world especially India, America, GCC, and MENA [1]. According to the recent studies, the species *Prosopis cineraria* has significant contribution in the farm economy and rural area development. Undoubtedly, it shares with other *Prosopis* species numerous characteristics, uses and effects, i.e., chemical composition, types of phytochemical components, and health effects. *Prosopis cineraria* has been valued by different communities and cultures for the versatility of all its parts and named as “the Wonder Tree” or “King of Desert” [2] or “the Golden Tree of Indian deserts” [3]. The tree parts including leaves, pods, seeds and barks has been used in many ways as food, i.e., flour, drink, vegetable, and gum. Leaves and pods are used for ruminant and animal feed. *Prosopis cineraria* extensively used in traditional medicine to cure many diseases such as ailments like leprosy, dysentery, asthma, leucoderma, dyspepsia and earache [4–6]. Barks are used for non-nutritional purposes, i.e., wood, tanning, fuel, firewood and charcoal. The *Prosopis cineraria* has many chemical constituents as alkaloid, steroids, alcohol and alkane.

Despite its fabulous importance in local culture, there is minimal aware by the developed communities about *P. cineraria* as unconventional legumes. Therefore, authors present a comprehensive chapter about this important tree from all aspects including traditional uses, biological and phytochemical investigation.

2. Botany

The genus *Prosopis* L. belongs to Leguminosae family, subfamily Mimosoideae and accommodates 44 species of which 40 are native to North and South Americas, three originate in Asia, and one comes from Africa [7–9]. Trees of *Prosopis* L. are widespread in Western Asia, Africa and arid and semi-arid regions in the Americas and Australia.

The species *P. cineraria* is native to dry and arid regions of Arabia and India [10]. Its main population is center on the Thar Desert of India and Pakistan, with less dense populations occur in the Arabian Peninsula, Iran, and Afghanistan [11]. It is considered the national tree of the United Arab Emirates [12]. *P. cineraria* is known as Ghaf in Arabic, Khejri in Indian, and Jand in Pakistan.

P. cineraria is an evergreen, thorny tree, 10–25 m in high. The stem is commonly straight, unbranched for several meters with a gray roughish, exfoliated bark (**Figure 1**). The branches are slender, drooped giving the canopy a rounded appearance with short triangular spines (3–6 mm long) between leaves nodes. At the time of no grazing the lower branches can reach to the ground. Leaves are gray-green, alternate usually divided into two pinnae, each pinna has 7–14 pairs of oblong, oblique, apex leaflets. The mid-rib nearer the upper edge, is sessile.

Flowers are small, yellow or creamy white, nearly sessile in slender pedunculated axillary spikes 5–13 cm long. Pods are yellow to reddish brown with cylindrical shape and slightly curved; 10–20 cm long and 0.5–0.8 cm thick. Seeds 10–25, oblong or rhomboidal,



Figure 1. The tree of *Prosopis cineraria*, flower, leaf and pods.

brown, smooth, with a moderately hard taste [13, 14]. The tap root of *P. cineraria* penetrates vertically up to 20 m but can reach water at an extraordinary depth of 53 m or more [15]. Flowering and fruiting period is varied between locations and weather condition and generally from February to May after the new flush of leaves. The pods are mature almost after 2 months.

3. Environmental conditions

P. cineraria is a xerophytic plant that is well adapted to dry and arid environment. Under the conditions of drought, the tree produces more flowers and fruits [16]. In areas of its natural distribution, the annual rainfall ranges between 100 up to 500 mm annually, whereas the optimum density is confined to areas receiving 350–400 mm [17]. The climate is characterized by extremes summer temperature varies from about 40–48°C [18]. It can tolerate frost and withstand low temperature less than 10°C in the winter season.

The tree grows on a variety of soils. It is seen at its best on alluvial soils consisting of various mixtures of sand and clay [19]. In arid areas, the growth is better in dune lows than in sandy plains. Good drainage is very essential. *P. cineraria* can grow under highly saline and alkaline soils. However, it is relatively salt tolerant at seed germination whereas seedling emergence was found to be reduced to 50% in soil with a salinity of 7.6 dS m⁻¹ and a further increase in salt concentration was detrimental to seed germination [20].

4. Socio economic and ecological importance

P. cineraria is a multipurpose tree that holds an important role in the rural economy in many arid regions, particularly in the Arabian Gulf and the northwest arid region of Indian

sub-continent. Historically, the Bedouin and Indian uses all its part in their traditional life-style [21–23]. It is used as a folk remedy for various diseases and conditions [24].

The unripe pods are used for making curry and pickle. The green pods are consumed as vegetables. The flour of mature pods is used for cookies preparation and other local dishes. The leaves and dry pods are annually harvested for cattle and sheep feed, where an adult tree produce 2–5 kg/year dry pods. A resin occurring naturally on the tree, known as mesquite gum, is also occasionally eaten by people [25].

P. cineraria as a leguminous tree has importance in improving soil fertility through fixing atmospheric nitrogen. Litter fall production for *P. cineraria* and decomposition rate are considered the highest comparing with other arid trees, and that build up soil organic matter contents under its canopy, increase soluble calcium and available phosphorus and decrease soil pH [26, 27]. Therefore, farmers tend to grow field crops under its canopy to boost the growth and productivity of their crops.

The rounded shape crown provides the shade and shelter for animals and wildlife during hot season. It is widely used for sand dune stabilization program because of it is deep mass root system which enable plant not to compete with others for moisture and nutrients [28]. It provides good quality resources of wood for basic construction and fuel for people in the desert regions.

P. cineraria is one of major bee foraging plant in the Arabian Gulf [29], it supports honey bees with long and abundant flowering and honey produced is of a good quality.

5. Nutritional value

Numerous people around the world, especially in Africa and Asia, are suffering from protein deficiency due to lack of protein-rich food. *P. cineraria* have 16.5–18.25% protein content compared with 25.47% in *Acacia nilotica* and 38.89% in *Acacia senegal* [30]. On other hand, legumes contain 18–35% protein [31], and cereals contain 10–15% protein [32]. Therefore, *Prosopis* seeds are considered a potential and cheap source of protein for industrial use, especially in developing Afro-Asian countries and can be an alternate protein source for solving the protein-energy-malnutrition problem. The protein content, *P. cineraria* contains reasonable amount of ash (5.34%), and fiber (20.93%) [33–35]. Chemical composition of pods is varied between individual trees that it influenced by a wide range of environmental factors. The *P. cineraria* pods have low moisture content (8.55%) that may be advantageous in increasing of the pods shelf-life, 18% protein, 1.89% oil, 5.34% ash and 20.93% fiber [34]. The *P. cineraria* seed contains 10.6% oil, 28.6% of the oil are saturated fatty esters, 68.3% are unsaturated fatty esters, and 3.1% are methyl hydroxy fatty ester. Moreover, the seed oil is rich in oleic acid (31.3%) along with linoleic acid (32.1%). Oil and seeds of *P. cineraria* show an absence of keto, cyclopropenoid, and epoxy fatty acids or any evidence for the presence of trans-unsaturation or the presence of conjugation. In addition, the tree leaves have a good source of macro minerals as calcium (2.43%), phosphorus (0.16%) and potassium (0.41%). So, it can be used as good food during the mineral deficient periods [36].

6. Usage

Besides the ecological value of *P. cineraria* tree, there are significant utilizations centered on its use for human food, animal feeds, medical purposes and many other applications. The multipurpose and added value usages of *P. cineraria* tree; barks, pods, and leaves; will be discussed with regards to its health benefits and nutraceutical effects as follow:

6.1. Human nutrition/food application

P. cineraria tree are extensively used as human food in many area especially arid land region and semi-desert as Arizona, India, California, South America and northwestern Mexico. There are diverse uses of the *P. cineraria* tree parts; dried and undried pods, green and dry leaves, and seeds; in human food. It is interesting to note that studies did not refer to the presence of cyanogenic or toxic compounds in *Prosopis* parts as seeds or pods till now [37–39]. The *P. cineraria* food applications include:

6.1.1. Vegetables

Leguminous *Prosopis* trees play a great role in feeding human in dry area to prevent protein and mineral deficiency especially during famine period. In these area, people used to eat unripe green pods of *P. cineraria* that selling in their market as vegetables and children eat its ripe fruits [2, 33, 40, 41]. In addition, green and unripe pods are also used in the preparation of pickles and curries [3].

6.1.2. Flour

The *Prosopis* pods consist of three parts, mesocarp (56% of the pod) that grind to produce flour, endocarp (35%) that discard as waste alongside seeds (9%). People used the flour to make bread, cake, chapatti by mixing with wheat flour and sweets [40]. The *Prosopis* flour contains a high level of proteins (62%), dietary fiber (25%) and low content of total carbohydrate and fat in addition to dominant amounts of free polyphenol and carotenoids compounds as shown in **Table 1** [42]. *Prosopis* flour is gluten-free, and a premium source of calcium, potassium, magnesium, zinc, and iron, in addition to amino acids such as lysine that is low in other cereals [11, 43]. *Prosopis* flour has a unique combination taste that has been variously described as; sweet or slightly nutty, with a sweet chocolate or coffee flavor, with a pleasant hint of caramel or molasses, with a hint of cinnamon as it contains many volatile components, i.e., γ -nonalactone, 5,6-dihydro-6-propyl-2H-pyran-2-one, 2,6-dimethylpyrazine, and methyl salicylate [44]. Therefore, only 10 to 25% flour is generally used in combination with other flours because above than 25%, the taste becomes too strong for most palate. While, the desirable degree of browning for different bakery products was obtained using different adding concentration, i.e., biscuits (5%), breads (10%), pancakes (15%) and chapatti (50%).

The dried pods are used to make flour after collecting pods directly from the tree or from pods that have recently fallen to the ground. Sometimes they store the dried pods to provide food year round. The flour particle size is varied depending on the grinding processing,

Compounds	<i>Prosopis</i> flour	Plain white wheat flour
Energy (kcal/100 g)	361	338
Carbohydrate (g/100 g)	69.2	72.2
Total sugars (g/100 g)	13.0	1.5
Fiber (g/100 g)	47.8	3.2
Protein (g/100 g)	16.2	9.4
Fat content (g/100 g)	2.12	1.3
Saturated fatty acids (g/100 g)	0.6	0.2

Table 1. Nutritional values of *Prosopis* flour compared with plain white wheat flour.

e.g., pounded using pestle and mortar produces coarse powder, while using stone grinding produces a fine powder.

The *Prosopis* flour assist the diabetic patient through helping maintain a healthy insulin system in those people not affected by blood sugar troubles because of two reasons: firstly, the *Prosopis* flour requires a longer time to be digested compared with other grains, i.e., it needs 4 to 6 hours compared to 1 to 2 hours needs for wheat flour to be digest. This help to sustains constant blood sugar over time and prevents hunger. Secondly, the pods contain fructose, which the body can process without insulin [45].

6.1.3. Syrup and drinks

In many places, the *Prosopis* species are used to make fermented, non-fermented beverages, and syrup [46–50]. Nutritious syrup is produced by boiling the clean green pods in water after breaking them into small pieces. Beans should be simmered for 2 hours with continuous adding a small amount of water to avoid burning. Followed by mashing the pods to release more of the sweet pulp with simmering for further few minutes. The juice then sieved through strain and kept in clean containers to be used directly as a drink. Or more sugar can be added to the juice and boil to produce unique flavor syrup [51].

6.1.4. Gum

In addition to the previous uses, amber colored gum is produced from the *P. cineraria* tree. This gum has similar properties to the gum produced from acacia tree [40]. Its exudate gum is liquid, water soluble and slowly hardening. Moreover, this genus is not the only source of gum. A galactomannan types interesting gum that called vinal gum is produced from *P. rusCIFolia* [52].

6.2. Animal nutrition

P. cineraria is an important feed species under traditional livestock production systems in the arid regions. Leaves and pods are highly palatable, nutritious and eaten readily by camels, cattle, sheep and goats.

The leaves contained 12.1% crude protein, 20.1% crude fiber, 3.2% ether extract and 12.2% ash [53]. The ripened pods contained 91% dry matter, 13.5% crude protein, 14.3% crude fiber, 1.3% ether extract and 5.2% ash [54]. Feeding *P. cineraria* to sheep did not cause overt health problems such as diarrhea or impaction. Though, it is not advisable to use leaves as a sole feed for animal as it contain 8–10% tannins [55]. Increasing *Prosopis* tannin in the diet reduce animal intake, digestibility of nutrients and body weight gain in sheep [54, 56] and goats [57]. In general goat showed superior efficiency in utilizing *P. cineraria* leaves than that in sheep [58]. However, feeding *Prosopis* tannin at 23 and 45 g/kg dry matter in the ration of lambs and kids can achieve maximum microbial protein synthesis under intensive feeding system. Beyond this level, *Prosopis* tannins will have anti-nutritional effects [59].

6.3. Health benefits

Despite the economic importance of *Prosopis* spp. as food, plants have been used in traditional medicine to treat various human ailments since ancient history. *Prosopis* spp. is one of these plants that possess many medicinal properties and used to cure many diseases. Studies showed that leaves and seeds were largely used to treat many diseases such as diarrhea, inflammation, measles, diabetes and prostate disorders [4, 5].

The pods of *P. cineraria* contain alkaloids (good anesthetic and spasmolytic activity), Saponin (boost immunity system of the body, lowering the cholesterol level in the body and reducing the risk of intestinal cancer), and tannins (produce anthelmintic activity). In addition to the mineral content as zinc (relevant to the nutritional aspect as zinc supplementation in diabetes mellitus have antioxidant effect), magnesium (important for proper functioning of every organ like heart, muscle, and kidney), iron (used in anemia, tuberculosis and growth disorder), calcium and phosphorous (useful for the bone, teeth, and ligament related disorder) [17, 60].

Moreover, studies show that the alkaloid mixture of *P. cineraria* in a dose of 1 mg/kg decreased the blood pressure and immediate mortality of dogs. In contrast, extensive damage to the liver, spleen, kidney, lung, and heart was observed on histological examination of mice given the same alkaloid mixture [61].

6.3.1. Antimicrobial activity

Studies show that the methanolic extract of *Prosopis* pods has antimicrobial activity against *Candida albicans* [62]. And the aqueous and methanolic extracts of stem bark have moderate antibacterial activity at a dose of 250 µg/ml. In addition to the previous effects, the methanolic extract shows significant action on all pathogens. This antibacterial activity of *Prosopis* spp. is due to the presence of flavonoids and tannins [63].

6.3.2. Antihyperglycemic (antidiabetic) and antioxidant activities

Many researchers illustrated that the bark extract of the *P. cineraria* have abundant activity in lowering blood sugar level by 27.3%, in addition, to significant decrease in body weight (29.6%) in diabetic rats when a dose of 300 mg/Kg mice body weight are given orally in daily

base for 45 days [6, 64] explained the effect of the *Prosopis* extracts is due to activate the surviving of the β cells of the islets of langerhans and producing an insulinogenic effect.

6.3.3. Antihypercholesterolemic activity

The 70% hydroalcoholic bark extract dose of 500 mg/Kg BW of albino male New Zealand white rabbits reduced significantly the serum total cholesterol by 88%, LDL-C by 95%, triglyceride by 59%, VLDL-C by 60% and ischemic indices compared to hypercholesterolemic control [64–66].

6.3.4. Antitumor activities

A study on *P. cineraria* illustrated that a dose of 200 and 400 mg/Kg BW of hydroalcoholic extract of leaves and bark have a significant antitumor activity against Ehrlich ascites carcinoma tumor model. In addition, the methanolic extract of the *P. cineraria* leaves shows significant radical scavenging activity. This effect is due to the inhibition of cell proliferation even through inducing the cell death and/or extending the time for cell proliferation [67].

6.3.5. Antidepressant effect

Studies show that aqueous extract of the *P. cineraria* leaves have a significant antidepressant effect on mice and a similar effect of the antidepressant drugs. This is due to the presence of some phytochemicals as saponins, flavonoids, glycosides, alkaloids, and phenolic compounds in these extracts [5].

6.3.6. Toxicity studies

Toxicity effect of 50% Hydroalcoholic extracts of *Prosopis* (at dose ranged between 50 and 2000 mg/Kg BW) through oral route of rats did not show any significant effects in breathing, behavior, sensory nervous system responses, cutaneous effects or had any mortality recorded within 24 h after treatments [6]. Further studies are required to determine the toxicity effects of the *Prosopis* extracts that might show adverse effects when consumed because it contains piperidine alkaloids [68].

6.4. Other uses

These are not the only uses of the *P. cineraria* tree. The good bark considered a good source of woods that can be used to make tool handles, boat frames, posts, and houses. While the poor or bad quality bark can be used as timber [40]. In India; especially in the Punjab region; the purplish brown bark used as fuel, firewood and used to produce high-quality charcoal. Leaf galls of *P. cineraria* tree can be used also for tanning. While, leaves can be used as a source of compost on the agricultural field and flowers are considered a good source for honey bee forage. The produced honey is light yellow with pleasant taste and slight aroma and generally of good quality [69].

7. Phytochemicals

There are few studies on the chemistry and bioactive compounds of *Prosopis* species have been published recently. Studies referred to the secondary metabolites compounds in plants that are considered bioactive compounds and has diverse antinutritional and nutraceutical features. Therefore, it can be potential as a source of bioactive products and used in functional products. Refs. [61, 84–86] mentioned that *Prosopis* spp. tree generally contains various phytochemical compounds as tannins, 5-hydroxytryptamine, isorhamnetin-3-diglucoside, L-arabinose, quercetin, apigenin, and tryptamine. Studies conducted on phytochemical compounds of *P. cineraria* showed that each part of the plant contains different types of these compounds (Tables 2 and 3).

Plant part	Chemical constituent present	Medicinal effect
Flowers	Patuletin glycoside patulitrin, luteolin and rutin sitosterol, and spicigerine. Flavone derivatives Prosogerin A and Prosogerin B	-Flowers are known as an anti-diabetic agent. -Flowers can be mixed with sugar when administered orally prevent miscarriage. -It contains Patulitrin3, 5, 6, 3, 4-pentamethoxy-7-hydroxy flavone which has significant activity against Lewis lung carcinoma in vivo. References: [70, 71]
Leaves	-Alkaloid: spicigerine -Steroids: campesterol, cholesterol, sitosterol, stigmasterol, actacosanol -Alcohol: octacosanal, triacontane-1-ol, Tricosan-1-ol, -Alkane: hentriacontane, Diisopropyl-10,11-dihydroxyicosane-1,20-dioate References: [6, 72–76]	-Leaf paste of <i>P. cineraria</i> is applied on boils and blisters, including mouth ulcers in livestock and leaf infusion on open sores on the skin -Smoke of the leaves is considered good for eye troubles and infections. References: [72, 77–80]
Seeds	Prosogerin C, Prosogerin D, Prosogerin E, gallic acid, patuletin, patulitrin, luteolin, and rutin	
Pods	3-benzyl-2-hydroxy-urs-12-en-28-oic acid, maslinic acid-3 glucoside, linoleic acid, prosophylline, 5,5'-oxybis-1,3-benzenediol, 3,4,5-trihydroxycinnamic acid 2-hydroxyethyl ester and 5,3',4'trihydroxyflavanone 7-glycoside	-Dry pods help in preventing protein calorie malnutrition and iron calcium deficiency in blood. References: [3, 64]
Barks	Hexacosan-25-on-1-ol, a new keto alcohol along with ombuin and a triterpenoid glycoside.vitamin K1, n-octacosyl acetate, the long-chain aliphatic acid. Presence of glucose, rhamnose, sucrose and starch	-Bark used in the treatment of asthma, bronchitis, dysentery, leucoderma, leprosy, muscle tremors and piles. -Different extracts of stem bark possessed a weak antibacterial activity. References: [81–83]

Table 2. Phytochemical constituents of the *Prosopis cineraria*.

Phytochemicals	Plant parts									
	Flower	Leaf		Pod		Seed		Stem		
	Aqueous	Ethanol	Aqueous	Ethanol	Aqueous	Ethanol	Aqueous	Ethanol	Aqueous	Ethanol
Carbohydrates	+	+	–	–	+++	+++	+	+	–	–
Proteins	–	–	+	+	++	++	+	+	–	–
Tannin	–	–	+	+	+	+	+	+	–	–
Flavonoids	++	+++	+	+	+	++	++	++	+	–
Cardia glycoside	–	–	–	–	+	+	–	–	–	–
Alkaloids	++	++	++	++	++	++	++	+	–	–
Terpenes	–	–	+	+	+	+	+	++	+	+
Steroids	+	+	+++	+++	–	–	+	++	–	–

+, low concentration, ++, moderate concentration, +++; high concentration, –, absent.

Table 3. Concentration of phytochemicals of different parts of *Prosopis cineraria* among different solvents (water and ethanol extracts) [87].

8. Conclusions

P. cineraria is a naturalized constituent of many natural and cultivated ecosystems in the world. Its value, however, lies not only in its ability to thrive under adverse conditions, but also it provide wide range of useful product. In this unifying review, it was shown the morphological trait, ecological and economical importance in addition to the nutritional value and health benefits.

The authors tried to drag the attention toward this significant tree as alternative type for the traditional legumes and possibility to use it as a source of protein in free-gluten products and functional foods which can be added value in food product development.

Future efforts are required to be focus on integrated management of *P. cineraria* in their natural ecosystem and implement environmental conservation strategies for achieving sustainable uses and maintain its benefits to livelihood and coming generation.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this chapter.

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