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REVIEW

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Bioactive compounds, food applications and health benefits of *Parkia speciosa* (stinky beans): a review

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Abstract

The plant community comprises certain underutilized plant species which has proven to be beneficial to human health. *Parkia speciosa* is considered as one of the highly underutilized plants with multidimensional utility and benefits. The nutritional composition of the seeds is substantial with rich proteins (6.0–27.5%), fats (1.6–13.3%), carbohydrates (68.3–68.7%), minerals (0.5–0.8%) and fibers (1.7–2.0%). Edible part (100 g) contains essential minerals like calcium (108–265.1 mg), magnesium (29 mg), potassium (341 mg), phosphorous (115 mg), and iron (2.2–2.7 mg) required for different metabolic reactions in human body. Bioactive compounds like phenols [51.9–84.24 mg Gallic acid equivalent (GAE)/g], flavonoids [47.4–49.6 mg retinol equivalent (RE)/100 g on dry weight basis], terpenoids like β-sitosterol (3.42% of fatty acid content), stigmasterol (2.18% of fatty acid content), lupeol (0.71% of fatty acid content), campesterol (2.29% of fatty acid content) are also present. These bioactive compounds and peptides possess different medicinal properties like anti-hypertensive, antioxidative, anti-inflammatory, anticancer, anti-microbial activity and antinociceptive. *P. speciosa* is traditionally consumed as vegetable, salad and in boiled form. Rich nutrient value and photochemistry suggest that there is tremendous need of scientific work to explore its food utilization. The review describes nutritional, phytochemical compound and the potential of *P. speciosa* for functional food formulation.

Keywords: Flavonoids, Phytochemicals, Terpenoids, Antioxidants, Stigmasterol

Background

The quality of our lives is notably dependent on our diet as well as following a healthy lifestyle. The increasing awareness and consciousness about health lead to the development of food providing nutrients along with health benefits [1].

Methodology: The well-known bibliometric sources such as Scopus, Google Scholar, Web of Science and Mendeley were used to collect the database. Keywords used were nutrition value of *Parkia speciosa*, *P. speciosa* utilization, *P. speciosa* pharmaceutics, health benefit of *P. speciosa*, *P. speciosa* products, food application of *P. speciosa*, to obtain a pool of papers to analyse. After analysis an inventory of 70 scientific sources was made after sorting and classifying them according to different criteria based on topic, academic field, country of origin, and year of publication. Final inventory of 62 articles was reviewed thoroughly and provided in reference list. The recent rise of consumer interest for health promoting product has opened up new vistas for *Parkia speciosa* products' research and development.

This revolution leads to a rapid and constant growing requirement of raw materials and new ingredients from natural sources in the food industry due to their biologically active nutritional value and health benefits [2]. Some of the underutilized crops and fruits can fulfill this demand for the food industries as well as the consumers. *Parkia speciosa* has the nutritional and phytochemical

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potential to fulfill this demand of food industry. The seed cotyledons, cell walls, mucilage and non-starchy polysaccharide compounds from this tree can be widely used as gelling agents, thickeners and fat substitutes [3].

It is a rainforest tree belonging to the genus '*Parkia*', family 'Fabaceae' and it is commonly found in India, Malaysia, Indonesia, Thailand, Singapore, Borneo, Africa, Madagascar and Philippines. The distribution of the species along the Indo-Pacific region occurs from India to Fiji [4]. It is commonly known as 'petai' in the south-east Asian countries like Malaysia and Indonesia, as 'sator' in Thailand and as 'yongchak' in the north-eastern part of India [5].

Plant description

The plants are propagated via seed sowing, stem cutting and budding [6]. The agronomic practices used for the pre-treatment of seeds to overcome dormancy and accelerate seed germination are seed coat shelling or soaking of the seeds in water, ample light and space provision. These propagation practices are recommended as efficient and effective pre-treatment management practice for obtaining uniformity in seed germination and seedling growth [7]. Seeds are cut opposite to the micropyle for preventing damage to the embryo during seed coat cutting. 1 year after sowing, at the described growth of 0.5–1 m tall, they are transplanted to the field at a distance of 10 m between the rows and 10 m between the plants (10 m × 10 m) [8].

The stinky bean trees can grow up to 40 m in height and 1 m in stem diameter. It bears bulb shaped flowers that hang at the end of long stalks. The color of the flower is creamy white and it possesses long stalk of 30–45 cm length, 2–6 cm width with a leathery texture. Long and twisted pods come out at the border of the stalk upon maturation of the plant [9]. The fruit comprises an oblong pod with length of 35–55 cm and width of 3–5 cm and contain 15–18 seeds. Seeds are 3.5 cm in length and 2 cm in width which increases in size and exhibits round shape on maturity. The pods are shed from the mother trees when their moisture content is high (around 80% on a fresh weight basis). The plant thrives well on sandy, loamy, sandy loam, podzolic soil and areas nearby the riverbanks [10]. The optimum annual temperature for proliferation of the plant is 24 °C. The trees are cultivated in the plains up to elevations of 1500 m. The majority of the *Parkia* species are considered as chiropterophilous plants, while a few species are thought to be pollinated by insects at daytime or nocturnally [11]. Hopkins [4] proposed that bats are the main pollinators of the Asian *Parkia* species and the same was also theorized for the African and South American species [12, 13]. The pinnacle of flowering and fruiting time ranges from August to October [9].

Classification of Parkia species

Parkia genus is divided into three sections viz. *Parkia*, *Platyparkia* and *Sphaeroparkia* [14]. These three sections are classified through the clear differences in configuration of flower formation (Table 1). The Indo-Pacific species is grouped in the section *Parkia* and the other two sections are specified to the Neotropics. The specific sobriquet speciosa means handsome in Latin. It defines the appearance of the tree when mature.

Parkia species have pendent capitula, clavate, pyriform in shape, with a ball of fertile flowers at the apex. A ring of nectar secreting flower is found below and neuter or staminoidal flowers at the base which varies in number and length according to species [4]. They exhibit overall similarity to one another, especially in the capitula and fruits. These ranges of characteristics are also found in the African species. However, the African counterparts possess red flowers, while the Asian species have creamy or yellow flowers. A wider range in morphological variations is described for the Neotropical sections [13]. The capitula of the Neotropical species are pendent shaped

Table 1 Classification of Parkia species and flower description [4]

Section	Species	Capitulum length (cm)	Diameter of fertile part (cm)	Flower color
Parkia	*P. cachimboensis*	5.0–6.0	5.0	Yellow fertile flower and creamy staminoidal flowers
	P. decussate	6.9–7.9	4.5	Yellow fertile flower and red staminoidal flowers
	P. discolor	4.5–5.5	2.2–2.5	Pink brown fertile flower and creamy staminoidal flowers
	P. speciosa	5.4–6.7	3.2–4.2	Creamy white fertile flowers and green buds
Platyparkia	*P. pendula*	3.0–3.4	4.5	Red fertile flower
	P. platycephala	2.7–3.5	4.0–5.2	Red fertile flower
Sphaeroparkia	*P. ulei*	1.4	1.4	Creamy fertile flower

cm Centimetre

with a well-developed fringe and flower color includes reddish, yellow or a combination of both.

Nutritional composition

The *P. speciosa* seeds are rich in carbohydrates (68.3–68.7%), proteins (6–27.5%), fats (1.6–13.3%), fibers (1.7–2.0%) and minerals (0.5–0.8%) content [5]. *Parkia speciosa* contains abundant amount of minerals such as calcium (108–265.1 mg), magnesium (29 mg), potassium (341 mg), phosphorous (115 mg), iron (2.2–2.7 mg) per 100 g of the edible portion of the plant [5] (Table 2). Phenolic content is 84.24 mg GAE/g in pods and seed contains 51.9 mg GAE/g [15, 16]. Flavonoid content is 20.3 mg retinol equivalent (RE)/g in seed [16] and pod methanolic extract is 5.28 mg RE/g DW [17]. The seeds contain 19.3 mg vitamin C and 4.15 mg vitamin E per 100 g (Table 2) of the edible portions [5]. The edible portion of the tree includes the flower, pods and the seeds. The flower is commonly eaten raw as a side dish in a local Indian delicacy known as 'singju' or by mixing with traditionally fermented pickles [18].

The seeds are foul smelling, green in color, elliptical in shape with diameter of 2.3 cm across. The fresh seeds can be eaten purely raw or in their cooked or roasted conditions as a side dish or as vegetables. In North-East India, the beans as a whole are eaten in a local delicacy known as 'eromba'. In Thailand, the seeds are eaten with Nam Prik, a spicy paste. It is also eaten fried with curry paste mixed with shrimp or pork [10]. The semi-ripe seeds are used for pickling processes along with salt [5]. Dried seeds are black in color. Export of *P. speciosa* seeds is done in tin cans or bottled jars after pickling in salt solution [2]. The peel and pod residue of the plants are often the waste portion, which are not utilized and treated as waste materials. These waste materials viz. the peels and pods are used as fertilizers, as animal feeds or landfills [19]. However, peel and pod also contain valuable nutrients like high-value polysaccharides, attracting the researchers to explore the food applications of these parts of plant [2]. Wide variations in the nutritional composition and color characteristics of flower, pods, and seeds are due to changes in variety, seasonal change and different agronomic conditions.

Table 2 Nutritional information of *Parkia speciosa* [5]

Component	Amount (per 100 g edible portion)
Ash (g)	1.2–4.6
Protein (g)	6.0–27.5
Fat (g)	1.6–13.3
Carbohydrate (g)	13.2–52.9
Crude fiber (g)	1.7–2.0
Energy (kcal)	91.0–441.5
Calcium (mg)	108.0–265.1
Iron (mg)	2.2–2.7
Phosphorus (mg)	115.0
Potassium (mg)	341.0
Magnesium (mg)	29.0
Copper (ppm)	36.7
Zinc (ppm)	8.2
Vitamin C (mg)	19.3
α—Tocopherol (mg)	4.15
Thiamin (mg)	0.28

g Gram, *kcal* kilocalorie, *mg* milligram, *ppm* parts per million

Carbohydrates present in edible parts are binding sites of highly specific proteins such as lectins and it holds a huge potential for cancer therapy. Hexathionine, tetrathiane, trithiolane, pentathiopane, pentathiocane and tetrathiepane were found in the seeds of *P. speciosa*. Fatty acids such as undecanoic, myristic, palmitic, oleic, elaidic, stearic, steroic, lauric, arachidonic and linoleic acids were found in the seeds under chromatography analysis [20].

Phytochemistry

The bioactive compounds present in all fruits and vegetables may be essential and non-essential compounds from plant secondary metabolites and have abundant therapeutic benefits [21]. These benefits are mainly due to high antioxidant potential of these compounds. *Parkia speciosa* (stinky beans) contain phenolics, flavonoids, alkaloids and terpenoids in all parts of the plants that account for its diverse health benefits. Alkaloids and terpenoids were evidently found to be present in *P. speciosa* with no specifics on their quantity. Sonia et al. [22] also supported the presence of alkaloids and terpenoids in the methanolic extracts and aqueous extracts of the plant without properly mentioning the quantity. Other than this, seventy-seven chemicals were identified in fresh *P. speciosa* seeds and the major constituents are ethanol, H_2S (Hydrogen Sulphide) and $C_2H_4S_3$ (1,2,4-trithiolane), CH_3CH_2COOH (propanoic acid) and $C_{30}H_{58}O_4S$ (3,3-thiobis-didodecyl ester) [20]. The polysaccharide from pods with 17–18% yield is found to contain 97–99 mg/g uronic content and high antioxidant property (48–50% DPPH scavenging activity). High phenolic and flavonoid contents accompanied by high antioxidant properties were also found in the pod [2].

Phenolics

Phenols are ever-present bioactive compounds in plants and possess antioxidant activity responsible for good health. Plants are the origin of polyphenolic compounds that synthesize secondary metabolites during normal development [23]. Proteins, tyrosine and tryptophan are the major contributors for biosynthesis of polyphenolic compounds. Polyphenols occur in compacted form such as flavonoid glycosides, and phenolic acid derivatives. The major polyphenolic constituents in stinky beans include gallic acid, catechin, ellagic acid and quercetin [17]. It was deduced that phenolic compounds carry the major antioxidant substances. The mode of action of the phenolics is through oxidation termination by scavenging free radicals to form stabilized radicals [24].

Flavonoids

Flavonoids are significant naturally occurring compounds possessing various biological and pharmacological activities. They have great antioxidant activity and health benefits such as reduction in risk of various diseases such as hypertension, hyperbilirubinemia, stress-induced gastric lesion, hyperhomocysteinemia, cancer and atherosclerosis [16]. Reports have shown that flavonoids inhibit xanthine oxidase and have superoxide scavenging activities. So, it could be a promising remedy for certain human disease and disorder such as human gout and ischemia by their action of decreasing uric acid and superoxide concentrations in human tissues [25]. The flavonoid content of the pod methanolic extract is 5.28 mg RE/g DW [17] and the seeds contain 20.3 mg RE/g DW [16]. Scavenging or chelating processes are the mechanism behind their mode of action (Table 4). Flavonoids such as quercetin, myricetin, luteolin, kaempferol and apigenin were found present in the ethanolic extract of *P. speciosa* seed. Flavonoids show antioxidant activity, antibacterial, antifungal, hepatoprotective, anti-inflammatory, anti-diabetic effects, etc. [26].

Terpenoids

Terpenoids include β-sitosterol, stigmasterol, lupeol, campesterol and squalene. Liliwiriani stated that only the leaves of the *P. speciosa* plants were excluded from the presence of alkaloids [27]. A quantitative amount of 3.42% β-stigmasterol, 2.29% campesterol and 2.18% stigmasterol were found as the main non-fatty acid component in *P. speciosa* [20].

β-sitosterol

β-sitosterol, main fatty component, content was found to be 3.42% of the total fatty acid content in stinky bean [20]. β-sitosterol is a phytosterol (22, 23-Dihydrostigmasterol, Stigmast 5-en-3-ol, β-Sitosterin) having similar chemical structure with cholesterol (Fig. 1a). It is white, waxy material with a characteristic odor [28], hydrophobic in nature and highly soluble in alcohol. β-sitosterol retards cholesterol absorption in the intestines and is

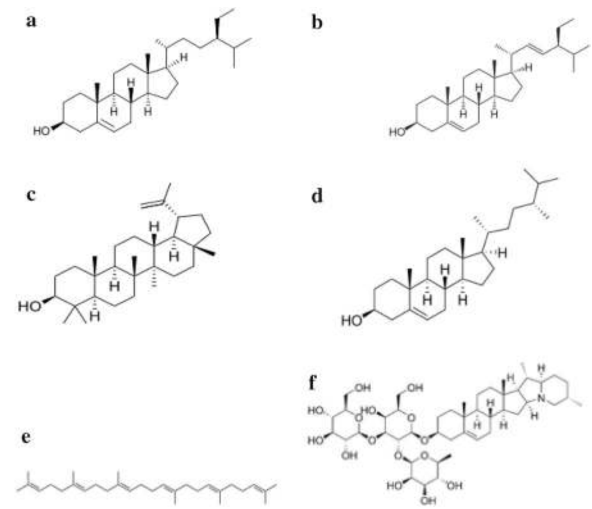

Fig. 1 Phytochemistry of *Parkia speciosa*, β-sitosterol (**a**), Stigmasterol (**b**), Lupeol (**c**), Campesterol (**d**), Squalene (**e**), Saponin (**f**)

thus considered to be highly effective in treating prostate enlargement, boosting the function of T cells and priming the immune system to function and operate more efficiently. β-sitosterol has been proven to be chemopreventive in the colon cancer and breast cancer cell lines by hampering cancer cell proliferation [29]. β-sitosterol along with its glycosides also plays a part in multistage treatment of HIV, by maintenance of the CD4 lymphocyte count and regulating the immune system [28].

Stigmasterol

It is an unsaturated phytosterol present in the fats/oil of plants such as soyabean, calabar bean, *P. speciosa* and other medicinal herbs. Stigmasterol present in *Parkia speciosa* is 2.18% of the fatty acid content [20] (Fig. 1b).

Lupeol

Lupeol is a pharmacologically active triterpenoid, present in the concentration of 0.71% of the total fatty acid content (Fig. 1c). Lupeol acetate inhibits nitric oxide production, iNOS and COX-2 expression resulting in antinociceptive, antimutagenic as well as anti-inflammatory properties [30]. The major components of cooked *P. speciosa* seeds were the cyclic polysulfides accounting for the strong pungent smell and taste [31]. Cyclic polysulfides also contain thiazolidine-4-carboxylic acid, a thioproline, which is reported to possess anticancer activity [5]. The substituted compound 2-aryl-thiazolidine-4-carboxylic acid amide is favorably potent and selective as anti-proliferative agents against melanoma. The comparison between this compound and sorafenib, a clinically checked compound for melanoma, showed that 2-aryl-thiazolidine-4-carboxylic acid amide is more potent and selective based on in vitro cell assays [30].

Campesterol

Campesterol is the main non-fatty acid component (2.29%) in *P. speciosa*. Rahman et al. [32] also support the evidence of campesterol content in *P. speciosa* at 2.41% under low pressure and low temperature. It is a phytosterol having similar chemical structure to cholesterol (Fig. 1d). Campesterol is present in low concentration in various vegetables, nuts, seeds and fruits. Cholestatin, a phytosterol complex isolated from vegetable oils, is marketed as a dietary supplement and it contains campesterol as a main ingredient [33].

Squalene

The squalene concentration in *P. speciosa* is 0.25% of the fatty acid content. It is a naturally occurring 30-carbon organic compound (Fig. 1e). Squalene is a significant interest in pharmaceutical and cosmetics because of its antioxidant properties, cholesterol lowering effects, protection against coronary heart disease, tumor reduction properties and thus potential anticancer activity [34]. The proposed mechanism was the inhibition of cell proliferation by decreasing the level of farnesyl pyrophosphate (FPP) required for oncogene activation. Its antioxidant activity was highlighted by the inhibition of isoprenaline-induced lipid peroxidation and its capability to lower blood cholesterol levels. In the cosmetics sector, the emollient and hydration properties of squalene possess compatibility with the skin surface lipids. Squalene along with its hydrogenated analog is used for the formulation of varied personal care products such as moisturizing creams, lipstick, nail and hair products [34].

Anti-nutrients

Anti-nutrient factors either reduce the absorption of nutrients or interfere in further metabolic pathways, thus decreasing the nutrients bioavailability. However, these substances can be removed/reduced by simple household and industrial techniques such as soaking, boiling, autoclaving, roasting, fermentation and microwaving. Anti-nutrients such as tannin, trypsin inhibitor and hemagglutinin are present in low amount in *P. speciosa* and are readily destroyed by heat treatment. Zaini and Mustaffa [16] reported that stinky beans contain tannins (0.18 g/100 g), trypsin inhibitors (26.8 TIU/mL) and hemagglutinins (320 HU/g w/w) [16].

Pharmacology

Huge bioactive potential of stinky beans accounts for the diverse health benefits and thus for the pharmacological properties of the plant [5]. More vegetable consumption is highly beneficial in terms of various health promoting and protective benefits as compared to fruits [35]. Traditionally; a rich diet in stinky beans is believed to be useful in the treatment of certain diseases such as diabetes, cholera and kidney pain. But so far, there has been no scientific evidence to support this [36]. Several escalating evidence supports the function of hydrogen sulfide (H_2S) as a cardioprotective vascular cell-signaling molecule. Hydrogen sulphide, nitrous oxide and carbon monoxide which are entitled as gaso-transmitter exhibit certain important physiological and pharmacological roles. Production of H_2S is done internally by the action of pyridoxal 50-phosphate-dependent enzyme cystathionine-c-lyase (CSE) on cysteine in smooth muscle tissues [37]. Several studies indicate the fact that the H_2S produced from biological conversion of organosulfides is related to several cardiovascular health benefits which also include vascular smooth muscle relaxation [38], systolic blood pressure reduction and cardio-protection during myocardial ischemia and acute myocardial infarction [39].

Lectins have the ability to induce apoptosis through different pathways which are effective in specific cell lines. This can be performed by stimulation of carpases production in the molecular pathway. These pathways are involved in down-regulation or up-regulation of certain genes included in apoptotic suppression or induction, respectively. Certain mRNA behaves as ribosomal inactivating proteins (RIPs) inhibitor and can be down-regulated through lectin activity which allows the RIPs to function properly and impede neoplastic growth [16] and thus reduces the chances of cancer. Aiona et al. [40] proclaimed that ethno-botany is the science of survival [40]. Based on the ethnobotanical record of Malaysia, *P. speciosa* is classified as traditional medicinal plant [16].

Table 3 Antioxidant activity of *Parkia speciosa* extracts

Plant part	Extract	Total phenolic content (mg GAE/g)	DPPH assay (µ mol Trolox/g)	FRAP assay (µ mol Trolox/g)	References
Pod and seed	Aqueous	1557.6	7418.3	1617.3	[42]
Pod and seed	Methanol	2464.3	5936.9	1898	[42]

Antioxidant properties

The antioxidant capacity was comparatively high in the mixture of pods and seeds where the methanolic extract had larger capacities than the aqueous extract in three assays (Table 3). Antioxidant potential is strongly correlated with the reduction in risk of various critical diseases of humans such as hypertension, atherosclerosis, diabetes, stress-induced gastric lesion and cancer. Phenolic compounds and flavonoids contribute directly to antioxidative functions as these possess impeding actions on genetic mutation and carcinogenesis in human [41]. The leaves and seeds of the plants also showed antioxidant activity which was relatively low when compared with the activity in the pod and seed mixture. This suggests that the pods retain greater antioxidant content than the other parts of the plant.

Ayub et al. [42] reported that methanolic extract contains hydrophilic and intermediate hydrophilic compounds, whereas the aqueous extract contains hydrophilic constituents only and, thus, methanolic extract has higher antioxidant activity [42]. Udenigwe and Aluko 2011 demonstrated that the excess amount of electrons is donated and bonded with free radicals making peptidic amino acids the potent antioxidants [43]. The radical quenching activities of food antioxidants are attributed towards the ability of the antioxidants to engage in single electron transfer reaction; so the amplitude of peptidic amino acid residues that can transfer electrons to the free radicals at physiological pH can bestow enhanced antioxidative properties [43]. Patterson and Rhoades [44] reported that cysteine's SH group could be used as a radical scavenger and protect tissues from high oxidative stress. It was proposed that N-acetyl cysteine operated to scavenge free radicals yielded as a result of endotoxin cascade, but the possibility remained that it might have acted through maintenance of intracellular glutathione levels. With oxidative stress, glutathione (GSH) acts to protect cell constituents which were shown by increased turnover of GSH to GSSG (an oxidized form of GSH) and formation of mixed disulfide of proteins, utilization of NADPH and utilization of glucose in the pentose pathway [44].

Phenols and flavonoids possess the antioxidative properties and are utilized for the formulation of different drugs [45]. The methanolic extracts from the empty pods aid in lowering the blood pressure through prevention of plasma nitric oxide loss and vascular resistance reduction (Table 4). It also possesses cardio-protective effects by reducing angiotensin-converting enzyme activity [46]. The chloroform extract of the seeds, through the combined action of β-sitosterol and stigmasterol, helps in blood sugar reduction. When tested individually, β-sitosterol and stigmasterol showed no hypoglycemic effects, indicating that the synergism of the two compounds is necessary for hypoglycemic activity [47] (Table 4).

Food application

Functional foods are alike conventional foods consumed as part of daily diet and demonstrate physiological benefits along with reduction in chronic diseases along with basic nutritional functions. *P. speciosa* belongs to the category of functional foods as it possesses good nutritional value, various bioactive compounds such as polyphenols and flavonoids along with wide health benefits in terms of chronic health problems such as cancer, inflammation, and atherosclerosis. The species has the potential to produce functional fibers and flour-forming capabilities [2]. Antioxidants also help in enhancing the shelf life of food, reducing nutritional losses and avoiding the formation

Table 4 Health benefits of bioactive compounds in *Parkia speciosa*

Plant part	Component	Condition	Mechanism	Impact on health	References
Pod and seed mixture	Flavonoids	Free radical scavenger	Scavenging and chelating activity	Antioxidative effects	[5]
Pods	Phenolics	Free radical scavenger	FRAP, TEAC and DPPH assay	Antioxidative effects, impede genetic mutation and carcinogenesis	[2, 59]
Empty pods	Methanolic extracts	Atherosclerosis, hypertension	Plasma nitric oxide loss prevention and reduction of vascular resistance	Lowers blood pressure and heart oxygen demand	[46]
Seeds	Lectins	Cancer	Incorporation of thymidine into human DNA	Anti-proliferative effect and effective nitrite trapping	[60, 61]
Seeds	Protein extract	Laxative effect	Contraction of duodenum	Blood glucose level reduction	[62]
Seeds	Chloroform extract	Hypoglycemic activity	united actions of β-sitosterol and stigmasterol	Blood glucose level reduction	[47]

of free radicals [41]. *Parkia speciosa* pod contains pectin content varied from 83.3 to 63.6% along with other soluble fibers in the plant. This makes it a suitable substrate for extraction of colloidal agent pectin for further usage in food industry. Pod also contains a good amount of protein (9.5–10.7%), carbohydrate content (68.3–68.75%) along with crude fibers (16.5–16.8%) and very low fat content (0.1–0.2%) and, thus, can be used as a potential flour in baked goods formulation [2]. The starch content and the fibers could boost texture and gastric health for the consumers since the health food trend in bakery such as whole grain breads and cookies is introduced [2].

Different antioxidant formulations are being sold as diet supplements by neutraceutical and food companies in industrialized nations [48]. The pods could be used to produce a high antioxidant polysaccharide that acts as functional carbohydrate in food applications. *Parkia speciosa*, as an important source of antioxidant and anti-hypertensive bioactive peptides, could be considered essential in development of natural functional food ingredients. The bioactive peptides were successfully derived from the seeds using the enzyme alcalase. A total of 29 peptide sequences were identified from the peptide fraction [49]. Food-derived bioactive peptides are distinct protein fragments having beneficial pharmacological properties to human body [50]. Plant proteins are a necessary constituent for modern food improvements, in particular in nutrition and health [49].

Fermented food products have a strong association with the culture and tradition of a country [51]. The functional potential of lactic acid bacteria is evaluated in technological terms and its application is provided in fermented stinky beans. The beans sustain spontaneous fermentation in brine and have its own characteristic flavors and taste. Lactic acid bacteria were isolated from the fermented beans using PCR-denaturant gel gradient electrophoresis and evaluated for its functional characteristics [52]. The major lactic acid bacteria identified were *Lactobacillus plantarum*, *Lactobacillus fermentum*, *Lactobacillus pentosus* and *Enterococcus feacium*. These bacteria along with its probiotic properties can be utilized as a starter culture in the fermentation process. The colonization of probiotic bacteria averts the growth of harmful bacteria through competition exclusion and production of organic acid and anti-microbial compounds [52, 53]. Live probiotic Gram-positive bacteria belonging to cocci cell morphology are beneficial for human heath such as decrease of cancer risk, improvement of immune and mucosal barrier system [53].

Industrial applications

Activated carbon production

Activated carbon has various applications in industry, medicine, environment and agriculture such as solution purification, clarification and adsorption. Activated carbon can be used for removal of off-flavors and odors from domestic and industrial water supply, waste water treatment, clarification and degumming of fats and oils from vegetable and animal sources, and removal of off-flavors and odors from alcoholic beverages [54]. Commercial activated carbon is a preferred adsorbent for the removal of micro-pollutants. The main purpose is removal of the organic and inorganic compounds from the gaseous and liquid streams [55]. However, the usage of activated carbon is limited due to its high cost of production and, thus, agricultural wastes are also considered as the potential precursors for activated carbon (AC) due to low cost and abundant supply. The low ash content and reasonable hardness make agricultural waste a rich source of activated carbon. Different agricultural wastes of apricot, coconut, sugarcane and corn possess considerable rigidity, such as the shells and the stones and, thus, *P. speciosa* is also considered as a potential precursor to produce AC.

The pod of the plant is used in the development of AC through phosphoric acid activation. There are two methods for AC synthesis viz. physical activation and chemical activation. The precursor of physical activation is first carbonized and activated in a stream of carbon dioxide. In case of chemical activation, the precursor is impregnated with a dehydrating agent, usually zinc chloride or organic acids prior to carbonization. However, zinc chloride method increases the environment contamination by zinc compounds and so utilization of phosphoric acid as the dehydrating agent is considered as the safe and effective method [56].

Dye production

Artificial colors and dyes used in food industries to manipulate quality may lead to carcinogenicity, hypersensitivity, behavioral effects on prolonged consumption and thus not considered as safe [57]. The pod extract produces polyphenolic, betalain dye and chlorophyll content which is used in dyeing. It is being used for purposes of dyeing silk fabrics and it produces a natural dying procedure in color fastness and provides UV protection [58]. Betalain dye present in the pod extracts, when combined with sodium hydroxide, resulted in light brown to yellow dye to shade fabric.

Conclusion

Parkia speciosa is a traditionally cultivated and locally consumed crop. The seeds and pods are eaten as a local delicacy in certain parts of the world as raw, cooked or pickled. *P. speciosa* contains biologically active compounds such as phenols, flavonoids, cyclic polysulfides and other phytochemicals. These phytochemicals are beneficial in terms of anti-diabetic, anti-microbial, antioxidants, anti-hypertensive and hypoglycemic effects. Commercial utilization has also begun in exporting department; pharmacological departments as the understanding of the benefits have come to light. So, as a whole, the plant is worth understanding and utilizing. Cholestatin, a phytosterol complex isolated from vegetable oils, is marketed as a dietary supplement and it contains campesterol as a main ingredient. Bioactive peptides are considered beneficial in the food industries. Food-derived bioactive peptides are distinct protein fragments having beneficial pharmacological properties to human body. Live probiotic Gram-positive bacteria belonging to cocci cell morphology are beneficial for human heath such as the decrease of cancer risk, improvement of immune and mucosal barrier system.

Authors' contributions

NC, HRD and AP carried out a major part of the literature review and drafted the manuscript. SJ, PS and PG carried out literature review for selected sections and helped to revise the manuscript. AP co-authored and supervised manuscript preparation, and helped to finalize the manuscript. All authors read and approved the final manuscript.

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