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Assessment of physical, nutritional and functional attributes of *Parkia biglandulosa* W. & A.: An underexplored semi-wild tree legume species of *Parkia* genera

N J Varkekar[a, b] & N I Singh[*, a, b, +]

[a]Department of Fruit and Vegetable Technology, CSIR-Central Food Technological Research Institute, Mysuru-570 020, India.

[b]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad- 201 002, India

E-mail:[+] ngibo@yahoo.com; iboyaima@cftri.res.in

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Parkia biglandulosa W. & A. found growing in different parts of India is an underexplored species of *Parkia* genera. It is scarcely known for ethno-medicinal, food and nutrition potential, unlike other well-known Indo-Pacific and African species. In this study, the dry ripened pods, pulp and seeds were undertaken for physical and descriptive characterization. Further whole seeds (PBSF) and pulp (PBPP) powders were analyzed for proximate, physico-chemical, mineral content and functional properties. PBPP was found to have high crude fiber (17.64%) and ash content (5.86%), whereas, PBSF was found to contain high amounts of crude fat (20.37%) and crude protein (37.44%). PBSF was found to be high in magnesium (192.34 mg/100g), iron (6.06 mg/100g), zinc (6.86 mg/100g) and copper (2.11 mg/100g) and PBPP showed significantly major amounts of calcium (266 mg/100g) and potassium (1035.08 mg/100g). The results for functional properties showed significant differences between PBSF and PBPP. This is the first account about the nutrition and functional attributes of the pulp and seeds from dried pods of *P. biglandulosa.* This study highlights the potential utilization of this legume species to boost efficient processing and consumption and in addressing food and nutrition insecurity crisis.

Keywords: Legume, Nutrition, *Parkia*, Protein, Tree Bean, Under-utilized

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In an effort to further legume resources, many developing countries including India are identifying unconventional legume species as primary target for conducting scientific research for efficient resource exploitation and also, in addressing food and nutrition insecurity crises. Although major legumes *viz.* soybean, peas, and beans are being exploited extensively, there are various under-utilized species which remain uncharted for their nutrition potential and prospective utilization in food processing industry. *Parkia* is one of the genera belonging to the Family *Leguminosae*, pan-tropical in nature comprising of 30 or more species, out of which, only a handful are either traditionally utilized and recognized expansively[1]. In African continent, *P. biglobosa* (Jacq.), *P. bicolour* A. Chev., and *P. Filicoidea* Welw. Ex.Oliv. are three well-known species, and in Asian continent, *P. timoriana* (DC.) Merr.(Syn. *P. roxburghii* G. Don), and *P. speciosa* Hassk. are two most common species used traditionally in medicine, food and fodder. All these species are of high economic, ecological and environmental importance due to their multipurpose values[1,2]. In contrast, many other *Parkia* species are confined to geographical areas and limited to traditional knowhow, local consumption and various regional non-food uses. *Parkia biglandulosa* Wight & Arnott (Badminton Ball Tree) is one such seasonal tree legume distributed in the Indian subcontinent only through cultivation[1]. The morphological characteristic that defines the species is the presence of double glands at the base of each common petiole on the upper side[3]. It is found growing in botanical and community gardens for ornamental purposes and as avenue trees without special care[3,4]. Extensive literature is available about the pods and seeds for the distinct species of North-east India[5,6] *viz. P. timoriana* (DC.) Merr. (Synonyms: *P. roxburghii* G. Don., *P. javanica (*Auct.) and *P. biglobosa* (Jacq.) of Africa but very scarce studies are published for *P. biglandulosa* W. & A. The various plant parts are found to have anti-inflammatory, antibacterial, antifungal and antiulcer activities[7]. The seeds of the South American variety are utilized for small-scale oil

*Corresponding author

production and also, roasted for coffee substitution[8]. The pollens when mixed with water makes a refreshing drink and the seeds are fermented into a cheese-like flavoring agent[9]. The stem bark is reported to contain phytochemicals *viz.* tannins, saponins, glycosides, tri-terpenoids and sterols *viz.* campesterol, lupeol and beta-sitosterol[7,10]. The pods are highly nutritive and the bark is used traditionally in tanning and Ayurvedic practices for heamagglutination and ulcer[11]. The *in-vivo* study of various tropical seeds carried out by Grant *et al.*[8] reported that *P. biglandulosa* seeds did not show any toxic effects on the rat growth and metabolism; in contrast, it supported moderate growth with significantly high N content and low amounts of non-toxic seed lectins. The overall results suggested that these seeds which are apparently not utilized as foodstuffs at present can be put to a far greater use. Although the tree provides edible seed, leaves and fruit pulp for the local populace its use in food is not widely known around the regions in the Indian subcontinent. To boost utilization and consumption, ascertaining food and nutrition potential is crucial. This research study was therefore undertaken to gain insights into the proximate composition, mineral content, physico-chemical, and functional attributes and is the first account for the pulp and seeds from the dried pods of *P. biglandulosa* W. & A.

Materials and Methods

Chemicals

Petroleum ether, sodium hydroxide, hydrochloric acid, sulfuric acid, phenolphthalein indicator and other required chemicals were of analytical grade and purchased from Merck, Mumbai.

Plant authentication and sampling

The different parts of *Parkia biglandulosa* W. & A. *viz.*stem, leaves, flower bulb inflorescence, fruiting body (pods) were collected from the avenue trees growing in the vicinity of Bogadi' to 'Vijayanagar 3rd Stage' area in Mysuru district, Mysuru, Karnataka, during the maturity period. The plant species was identified and authenticated by Dr. K. A. Sharvani, Assistant Professor, Department of Botany, University of Mysore. The voucher specimen (YCM/BOT/ YCMUOM/15/0268) has been deposited in the Herbarium Centre (YCMUOM) of the University.

Sample preparation

The dehisced pods were de-stemmed from bunches and each one was opened further to obtain the powdery pulp with hard-coated seeds. The dried mature seeds were separated from pulp. The dried pods, pulp and seeds were undertaken for physical and descriptive characterization. Known amount of seeds were powdered in a laboratory scale pulveriser. Both the pulp and seed powders were allowed to pass through a 60-mesh screen. The dry pods and dry seed samples were stored at room temperature (28±2ºC) for a period of four days until all the physical attributes were analyzed whereas fine powder obtained from whole seeds (PBSF) and pulp (PBPP) were stored under refrigerated temperature (10±2ºC)for all further analysis of nutritional and functional properties (Fig. 1).

Physical and descriptive characteristics

The average weight proportion of pod shell, pulp and seed was determined based on the average weight measurement. The length, L, in centimeter and the width, W, in centimeter of the dry pods were measured using a standard measuring scale. Pod shape and Pod Color were observed and noted. An average number of pods per bunch was calculated by counting pods on randomly selected bunches as an important parameter for physical pod specification. Average weight of pods, in grams (g) was measured using the laboratory scale electronic weighing balance accurate to 0.001g.

The seed size in terms of the length, L, width, W, and thickness, T, in centimeter was measured using a Vernier caliper to 0.01mm. Average weight of single seed, in grams (g), was determined using the laboratory scale weighing balance. Weight of one hundred seeds, in grams (g), was carefully recorded after careful selection and counting of seeds. The

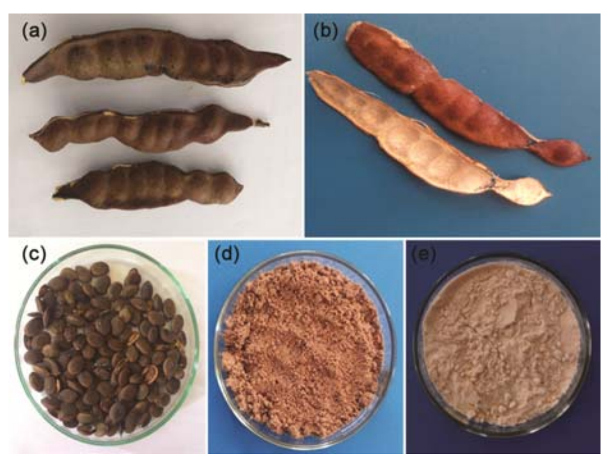

Fig. 1 — *Parkia biglandulosa* W. & A. A) Mature dry pods, B) Pod outer shell, C) Mature dry seeds, D) Seed Flour (PBSF), and E) Pulp Powder (PBPP).

descriptive characteristics *viz.* seed coat and cotyledon color and seed shape were visually recorded. Numbers of seeds per pod were counted for randomly selected pods and an average was determined. The cooking time, in minutes, was determined by boiling method[12]. Approximately 5-10g seeds were weighed and added to water in the ratio of 1:4 so that the seeds are immersed completely in the water. The mixture was boiled and the time taken for the average cooking of the seed was determined. The cooking time, in minutes, is where the grain is found to be firm but smashes easily and cotyledon softens.

Proximate composition, physico-chemical parameters and mineral content

Percent content of moisture, ash, crude fat, crude fibre and crude protein were determined by the standard methods[13]. Total carbohydrate content (%) was calculated by difference and energy values (kcal/100g) were measured by using conversion factors.

The L*, a*, b* color measurement was carried out using CIELAB instrument (Minolta CM5)[14]. The pH of the samples was determined by following the standard AOAC method[13]. Sample suspension of 10% (w/v) was prepared and the pH of the homogenate was measured using digital pH meter (pHTestr 30, Eutech Instruments) with 0.01 pH accuracy. Percent total titratable acidity (TTA) was determined using the AOAC method[13]. Total soluble solid (TSS) values were recorded by digital refractometer in ^{0}Brix units (Atago RX-5000).

Mineral estimation of eight elements *viz.* calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), manganese (Mn), iron (Fe), zinc (Zn) and copper (Cu) was conducted using Microwave Plasma-Atomic Absorption Spectroscopy (MP-AAS). The samples were kept for six hours in a muffle furnace at 550ºC for ashing, ash digestion was carried out using AOAC method[13].

Functional properties

Functional properties *viz.*bulk density (BD), water absorption capacity (WAC), oil absorption capacity (OAC), swelling power (SP), foaming capacity (FC), foaming stability (FS), and least gelation concentration (LGC) were analysed as given below.

Bulk density

The bulk density (g/cm^3) was determined according to the method of Onuma & Bello[15] using a 10ml graduated cylinder. The fine powder samples were measured into the cylinder till 5ml mark and the change in volume was observed and marked after constant tapping of the cylinder.

Water and oil absorption capacity

WAC and OAC were determined using methods from Heywood *et al.*[16] with slight modifications.

Approximately 2g of sample was dissolved in distilled water and allowed to stand at room temperature for 30 min. The mixture was then centrifuged at 3000 rpm for 30 min. After decanting supernatant, the paste was weighed and the WAC value was calculated as follows,

WAC (g of water/g of sample) = [(W2- W0) -W1]/W1

Where, W0- Weight of empty bottle, W1- weight of the dry sample, W2- weight of the sample after decanting

Approximately 2g of sample was dissolved in 20ml refined vegetable oil and incubated at room temperature for 30 min. It was then centrifuged at 3000 rpm for 30 min. After decanting supernatant, the paste was weighed and the OAC value was calculated as follows,

OAC (g of oil/g of sample) = [(W2- W0) -W1]/W1

Where, W0- Weight of empty bottle, W1- weight of the dry sample, W2- weight of the sample after decanting

Swelling power

Swelling power (g/g) was determined based on the method by Leach *et al.*[17] with some modifications. Approximately 2grams of sample was dissolved in 20ml distilled water and the mixture was heated at 80^{0}C for 30 min and cooled. This was then centrifuged at 10,000 rpm for 15 min. After decanting the supernatant, the weight of the paste was recorded and the swelling power was calculated in terms of weight of the paste per sample weight.

Foaming capacity and foam stability

The method of Nath and Narasinga Rao[18] was used with changes. A 2% (w/v) sample suspension was whipped for 5 min and foam volume was recorded. Foam capacity (FC) was expressed as percent increase in foam volume after 30 sec, and Foam Stability (FS) was expressed as percent constant volume after standing for 30 min.

Least gelation concentration

The least gelation property was determined by employing the methods of Coffman and Garcia[19]. Powder suspensions ranging from 2-20% (w/v) were prepared using distilled water and exposed to boiling water bath for 1h. After rapid cooling the samples were kept refrigerated at 4°C for 2 h and samples were then inverted to determine the Least Gelation Concentration (LGC) in percent whereby the inverted suspension did not slide from the tube.

Statistical analysis

The data were analyzed in triplicates and expressed as Mean±SD. One-way Analysis of Variance (ANOVA) followed by Student 't' test was performed using GraphPad Prism version 5.00 for Windows, GraphPad Software (California, USA). Significance was accepted at 0.05 level of probability ($p < 0.05$).

Results and Discussion

Physical and descriptive characteristics

The proportion by weight of pod shell, powdery pulp and matured seeds was found to be 60:34:6. Ripened and dehisced pod shells are considered as waste due to their inedible nature since the pod wall becomes dry, hard and fibrous after the ripening process. Pod shells were found to account for 34% of total weight and pulp weight (60%) was found to be higher than matured seeds (6%).

The results of physical and descriptive characteristics of mature pods and seeds of *P. biglandulosa* W. & A. are presented in Tables 1-2. As per the qualitative characteristics, the color of outer coat of mature pods of *P. biglandulosa* W. & A. was observed to be dark brown with pod shape slightly twisted and lightly constricted between every seed. The hard pod was found to contain creamish-yellow powdery pulp surrounding the hard-coated mature seeds. The seeds were found to be dark brown in color with broad-ovate shape and light green cotyledon content. The seed and pulp weight was amounting up to 66% of the total legume weight.

The average length and width of the pods were found to be 14.38 and 1.84 cm, respectively. The pod size for this tree legume was recorded to be smaller in comparison with the literature findings of two other related species belonging to the genus *Parkia*. The pod length and breadth was reported to be in the range of 24.06 - 39.76 and 2.94 - 4.02 cm, respectively for ten sample dry pods of *Parkia timoriana* (DC.) Merr (Synonym: *P. roxburghii* G. Don) growing in North-East India[20]. Another study reported pod length and pod breadth to be from 17.09 - 27.13 cm and 1.33 - 2.53 cm, respectively on 26 different pod samples of *P. biglobosa* in South Africa (common name: African Locust Bean)[21]. The pod numbers for *P. biglandulosa* W. & A. were recorded to be 15 numbers per bunch, which is found to be similar among the species *viz. P. timoriana* with cluster range of 10-15 numbers[22], and *P. biglobosa* with 6 - 15 numbers per bunch[21]. Number of seeds in each pod was found to be 5 which are due to the small pod length and the overall size. In comparison with inter species, *P. timoriana*, *P. biglobosa* and *P speciosa* Hassk. were reported to consist 13-18, 8.78-21.33 and 15-18 number of seeds per pod respectively[20,21,23].

Furthermore, the mean value of length, width and thickness of the mature seeds was 1.22, 0.80 and 0.51 cm, respectively. This indicates the tiny seed size in contrast to seeds of *P. roxburghii* G. Don which was reported to exhibit length, breadth and thickness ranging from 14.2-17.56, 10-15.06 and 5.56-8.63 mm, respectively[20] and *P.speciosa* Hassk seeds with 3.5cm

Table 1 — Physical and descriptive characteristics of *Parkia biglandulosa* W. & A. mature pods

Parameters	Mature Pods
Outer Coat Color	Dark Brown
Pod Shape	Slightly twisted, Constricted
Pulp Color	Creamish-yellow
Pods per bunch* (Nos.)	15± 4.0
Weight of dry pods** g	5.42± 1.53
Length** cm	14.38±2.10
Width** cm	1.84±0.22

The measured values are represented as Mean±SD, *n=30 bunches **n=50 pods

Table 2 — Physical and descriptive characteristics of *Parkia biglandulosa* W. & A. mature seeds

Parameters	Mature Seeds
Seed Coat Color	Dark Brown
Seed Shape	Broad- ovate
Cotyledon Color	Light green
Seeds per pod* (nos.)	5.02 ±1.78
Weight of dry seeds**, g	0.36± 0.07
Length** cm	1.22 ±0.09
Width** cm	0.80± 0.05
Thickness** cm	0.51± 0.06
100 seed weight[1], g	35.76 ±0.02
Cooking time[1] (min)	20 ± 0.06

The values are represented as Mean±SD, *n=50 pods **n=50 seeds [1]The values are represented as Mean±SD, after conducting the measurements in triplicates.

in length and 2cm in width. *Parkia* species are reported to exhibit overall similarity to one another. The close ranges of characteristics are found in Asian and African Species[23]. However, interspecies difference can be influenced by various geographical and environmental factors around the species distribution region[2]. The average weight of mature seed was found to be 0.36g and it was quite higher as compared to seeds of *P. biglobosa* ranging from 0.25g to 0.26g[24], and low as compared to the big seeds of *P. timoriana* weighing in the range of 0.47-0.72 g[20]. The mass of hundred seeds was found to be 35.76 g for *P. biglandulosa* which as per the hundred seed weight reported in 24 cultivars of *P. timoriana* in Manipur was within the range (17.04 - 117.24 g)[25]. Unlike most of the hard-to-cook legumes (HTCL) belonging to the family Leguminosae, *Parkia* species *viz. P. biglobosa* and *P. timoriana* (DC.) Merr seeds were reported to be easy to cook without soaking or any prior treatment. Similarly seeds of *P. biglandulosa* W. & A. were found to cook within 20 minutes in boiling water without prior soaking or other treatments. The hard seed coat was easily pulled apart which revealed the cooked light greenish cotyledon which could be mashed smoothly without using any instruments. Since dry legume seeds are normally cooked in water, one of the beneficial aspects of less cooking time is to retain nutrients, bioactive compounds and sensory quality.

Proximate composition, physico-chemical parameters and mineral content

Table 3 represents the result of the proximate composition of PBSF and PBPP. The data showed significant differences in all the analyzed components for proximate composition between PBSF and PBPP. The moisture content of seed flour and powdery pulp was found to be 4.29% and 11.48%, respectively. PBPP was found to be slightly hygroscopic owing to its more moisture retentive ability compared to the free flowing PBSF. Ash content indicative of presence of mineral elements was found to be 5.57% and 5.86%, respectively. These values were higher compared to ash values of 3.68%, 3.22% and 3.56% reported for Pigeon pea, Lima and Lablab bean, respectively[26]. For PBSF, results for crude fat content (20.37%) revealed its potential as an oilseed. Also the protein content of PBSF (37.44 %) was found to be in close range with Soybean (Glycine max) having protein content of35-40%[27] and higher than three major seeds belonging to the genus *Parkia viz. P. speciosa* (6-27.5%), *P. biglobosa* (33.64%), and *P. timoriana* (32.82%)[22,24,28]. The crude fat and protein content was also comparably higher to most leguminous seeds like mung bean, lentil, kidney beans, lima beans, chick peas and cow peas which were in the range of 20-31% for protein and 3-18% for fat content[29]. Legumes are known to be an excellent source of fibre. Crude fibre content was found to be significantly high in PBPP (17.64%) as compared to PBSF (2.47%). Although *P. timoriana* and *P. biglobosa* reported 22 and 9% content of fibre in mature seed kernels, respectively [20,24], the content in the seed flour of *P. biglandulosa* W. & A. was found to be very low. The pulp was found to contain significantly higher amount of fibre than most food legumes. *P. biglobosa* pulp flour reported 15% and *P. timoriana* 27.86% total fibre content[30]. From the results, it appeared that pulp was found to show highest carbohydrate content owing to its low lipid content. The high energy values for PBSF as compared to PBPP were due to higher concentration of crude fat and crude protein in the seeds. The energy values of the seeds were also found to be superior to other food legume seeds *viz*. cow peas (288-320 kcal), velvet beans (370-380 kcal) and lima beans (216-385 kcal) and very close to the energy values of soybean (440-540 kcal)[31].

The physico-chemical characteristics showed significant differences among PBSF and PBPP samples in all the parameters (Table 4.). The color parameters showed significant differences in the lightness (L*) value for both the seed flour and pulp (Table 3). The higher L* value of PBPP (66.55)indicated that it is lighter as compared to the seed flour (84.95), due to its creamish-yellow hue. Also, a* and b* values differed to some extent for both the pulp powder and seed flour. There was no

Table 3 — Proximate composition of *Parkia biglandulosa* W. & A. seed flour (PBSF) and pulp powder (PBPP)

Parameters	PBSF	PBPP
Moisture (%)	4.29 ±0.22^{b}	11.48 ±0.14^{a}
Ash (%)	5.57 ±0.07^{b}	5.86± 0.1^{a}
Fat (%)	20.37± 4.06^{a}	6.71± 0.87^{b}
Fiber (%)	2.47 ±0.23^{b}	17.64± 2.2^{a}
Protein (%)	37.44 ±1.15^{a}	5.97 ±0.27^{b}
Total Carbohydrates (%)	29.87 ±4.34^{b}	52.34± 2.66^{a}
Energy (Kcal/100g)	429.22 ±5.48^{a}	293.66± 5.58^{b}

Values are expressed as Mean ± SD (n=4). Means followed by a different superscript letter within a row are significantly different (Student‘t’ test, p< 0.05).

significant difference observed in pH and total titratable acidity (TTA), however, total soluble solids (ºBrix) was found to be 4.35±0.03 for PBPP and 1.93±0.04 for PBSF. The TSS for PBPP was found to be low as compared to *P. biglobosa* fruit pulp (9 ºBrix) relating that the powdery pulp is mildly sweet as compared to African Locust bean pulp. The pH values were close to the literature values for *P. biglobosa* seed flour (5.39) and fruit pulp (5.22)[32].

As observed in Table 5, the mineral composition of PBSF was found to demonstrate higher amount of calcium (238.85 mg/100 g), zinc (6.86 mg/100 g) and copper (2.11 mg/100 g) as compared to calcium (180 mg/100 g), zinc (5.6 mg/100 g), and copper (0.7 mg/100g) values in *P. timoriana* mature seeds[22]. PBPP was found to be high in calcium (266 mg/100 g) and potassium (1035.08 mg/100g) whereas PBSF was found to be high in magnesium (192.34 mg/100 g), iron (6.06 mg/100 g), zinc and manganese (1.29 mg/100g). There was no significant difference observed in the values of sodium and copper between seed flour and pulp. A diet with low level of sodium and high level of potassium are always encouraged, both PBSF and PBPP were found to agree to the level of very high potassium and very low sodium content in the samples. Unlike other food legumes, low sodium content of both samples renders them useful in low-sodium or sodium restricted products and diets. In case of micronutrient deficiency and malabsorption, Fe:Zn ratio is of high importance. If non-heme Fe/Zn ratio is 2:1 or more it reduces the Zn absorption drastically[33]. But low Fe:Zn ratio which was found in PBSF (0.8:1) and PBPP (0.2:1) may help boost the Zn absorption significantly. Apart from regular consumption of dairy products, legume seed and pulp can also provide additional calcium requirement in the diet, either independently or through processed products.

Table 4 — Physico-chemical parameters of *Parkia biglandulosa* W. & A. seed flour (PBSF) and pulp powder (PBPP)

Parameters	**PBSF**	**PBPP**
Color		
L*	66.55 ±0.20[b]	84.95 ±0.29[a]
a*	1.21 ±0.05[a]	1.02± 0.12[b]
b*	19.85 ±0.40[a]	16.97 ±0.32[b]
pH	5.33±0.01[b]	5.53±0.06[a]
TTA (%)	0.82±0.09[a]	0.45±0.01[b]
TSS (ºBrix)	1.93±0.04[b]	4.35±0.03[a]

Values are expressed as Mean ± SD (n=4). Means followed by a different superscript letter within a row are significantly different (Student‘t’ test, p< 0.05). TTA-Total Titratable Acidity TSS-Total Soluble Solids

Table 5 — Mineral estimation of *Parkia biglandulosa* W. & A. seed flour (PBSF) and pulp powder (PBPP)

Minerals	**PBSF**	**PBPP**
Calcium	238.85 ±4.40[b]	266 ±7.25[a]
Magnesium	192.34± 3.22[a]	112.65± 15.73[b]
Sodium	8.25± 0.55[a]	7.49± 0.13[a]
Potassium	820.04± 3.05[b]	1035.08± 41.08[a]
Copper	2.11± 0.09[a]	2.03± 0.04[a]
Iron	6.06± 0.10[a]	0.93± 0.05[b]
Zinc	6.86± 0.05[a]	4.83± 0.25[b]
Manganese	1.29 ±0.04[a]	0.64± 0.05[b]

Values are expressed as Mean ± SD (n=3). Means followed by a different superscript letter within a row are significantly different (Student‘t’ test, p< 0.05).

Functional properties

Various functional attributes were evaluated and are presented in Table 6. All the data showed significant differences for PBSF and PBPP samples. The bulk density of PBPP (0.32 g/ cm^3) was found to be lower than PBSF (0.44 g/ cm^3) owing to the presence of fibrous materials which are known to have low bulk density[30]. Uniformity in bulk density as in PBSF and PBPP is important in wet processing of foods and in formulation of complementary foods. The water absorption capacity of PBPP (9.78 g/g) was observed to be much greater than that of PBSF (2.72 g/g). The higher carbohydrate and fibre content might have contributed to higher WAC. Powdery pulp was found to hold water completely and lead to high viscosity without any separation of water.WAC for both PBSF and PBPP was found to be higher than soybean flour (1.3 g/g)[34], wheat flour (1.4 g/g) and rice flour (1.92 g/g) and potato flour (7.52 g/g)[35]. Oil absorption capacity of PBSF (0.97 g/g) was found to be slightly higher as compared to soybean seed flour (0.8 g/g), whereas, for PBPP (2.19 g/g) it was

Table 6 — Functional properties of *Parkia biglandulosa* W. & A. seed flour (PBSF) and pulp powder (PBPP)

Parameters	**PBSF**	**PBPP**
Bulk density g/cm^3	0.44±0.003[a]	0.32±0.002[b]
Water absorption capacity g/g	2.72± 0.007[b]	9.78± 0.12[a]
Oil absorption capacity g/g	0.97± 0.09[b]	2.19 ±0.007[a]
Swelling power g/g	3.41± 0.07[b]	9.23 ±0.41[a]
Foaming capacity %	10± 0.00	ND
Foaming stability %	33.37± 0.06	ND
Least gelation concentration %	20± 0.00[a]	12 ±0.00[b]

Values are expressed as Mean ± SD (n=4). Means followed by a different superscript letter within a row are significantly different (Student‘t’ test, p< 0.05).

moderately comparable to sunflower seed flour (2.07 g/g)[34] and higher compared to wheat flour (1.46 g/g) rice flour (1.24 g/g) green gram flour (1.6 g/g) and potato flour (1.68 g/g)[35].The swelling power was much higher in PBPP (9.23g/g) compared to in PBSF (3.41 g/g). Additionally, both PBPP and PBSF showed higher swelling power compared to reported values for wheat flour (0.17 g/g) and rice flour (0.15 g/g)[35]. The swelling capacity depends on flour particles uniformity and size. The high WAC, OAC and SP placed PBSF and PBPP above the reported flours used in dough making, in bakery and confectionery. High OAC also improves palatability of final products by flavor retention[30]. The foaming capacity of PBSF (10%) was found to be lower compared to given values for wheat flour (35%). Foam stability was also reported to be higher in wheat flour (75%) as compared to PBSF (33.37%) but it was low as reported for Green Gram flour (14%)[35].The low foaming capacity and foaming stability could be attributed to low solubility of flour protein and moderate levels of carbohydrates which are known to have stabilizing effects, respectively. PBSF and PBPP formed gels at 20/100ml and 12/100ml concentration, respectively. If LGC is lower there is better gelling ability of flours. The flour high in protein (PBSF) gelatinized at higher concentration. Ratios of carbohydrates, proteins and fat are related to gelling behavior of legume flours. Hence, PBSF and PBPP can be used as thickening and gelling agents as per requirements.

Conclusion

Current over-reliance on handful of major staple crops with limited land resources has inherent agronomic, ecological, nutritional and economic stress and risks and is probably unsustainable in the long run. Many traditional, indigenous and underutilized legumes are valuable components to attain food and nutritional security, especially in developing countries. One such indigenous and underexplored legume in India, *P. biglandulosa* W. & A. is a promising species belonging to *Parkia* genera. As a result this study was undertaken and it concludes that the pulp and seed flour from *Parkia biglandulosa* W. & A. can be prospectively a good source of balanced nutrition and can compete favourably with other commercially available legumes and also other tribal, wild and semi-wild legumes within the *Parkia* genera and among other genus of the Leguminosae family. The comparison of literature data of other *Parkia* species with *P. biglandulosa* confirmed the physical differences in pod and seed shape, size and color owing to varied geographical and climate differences which is also known to influence the nutrient composition.

The seed flour was found to be a good source of protein, crude fat and minerals while pulp was significantly rich in fibre. The proximate composition, thus, indicated that both seed flour and pulp are good sources of both macro and micronutrients. In addition, due to their high values in functional capabilities both seed and pulp flour can find applications in various food systems. High WAC, OAC and SP in both flours can render good texture and overall quality in baked goods, confectionery, desserts and snacks. There is also a great potential to use the pulp in gum and gel-forming products for its significant gelation property.

These findings highlight the prospective utilization of this scarcely known legume species to boost efficient processing, development and diversification of healthier products and in turn boost consumption potential. Further this can aid in addressing food and nutrition insecurity crisis since its potential is highly vital as an alternative source of low-cost dietary vegetable protein in diet and in food industry sector.

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Conflict of interest

The authors have no conflict of interest to declare.

Author Contributions

NJV and NIS contributed to the planning of the current research study, discussion of research findings and preparation of the final version of the manuscript. NJV carried out all the bench work experiments, result analysis, calculations and writing of the manuscript. NIS supervised the research study with encouragement, critical feedback, data interpretation, result discussion and article presentation.

References

1 Hopkins H C F, The Indo-Pacific species of *Parkia* (Leguminosae: Mimosoideae), *Kew Bull*, 49 (2) (1994) 181-234.

2 Suwannarat K & Nualsri C, Genetic relationships between 4 *Parkia* spp. and variation in *Parkia speciosa* Hassk. based on

random amplified polymorphic DNA (RAPD) markers, *Songklanakarin J Sci Technol*, 30 (4) (2008) 433-440.

3 Pingale R, Pokharkar D, Phadatare S P & Gorle A M, Pharmacognostic Evaluation of *Parkia biglandulosa* bark, *Int J Pharmacogn Phytochem Res*, 8 (7) (2016) 1160-1163.

4 Rao K S, Sringeswara A N, Kumar D, Pulla S & Sukumar R, A digital herbarium for the flora of Karnataka, *Curr Sci*, 102 (9) (2012) 1268-1271.

5 Khan M H & Yadava P S, Anti-diabetic plants used in Thoubal district of Manipur, Northeast India, *Indian J Tradit Know,* 9 (3) (2010) 510-514.

6 Bhardwaj S & Gakhar S K, Ethnomedicinal plants used by the tribals of Mizoram to cure cuts and wounds, *Indian J Tradit Know,*4 (1) (2005) 75–80.

7 Rupesh P, Pal S C, Pavani A & Gadge M S, Quantitative estimation of the active constituents of *Parkia biglandulosa* by using HPTLC and FTIR, *Int J Pharma Bio Sci*, 1 (4) (2010) 315-322.

8 Grant G, More L J, McKenzie N H, Dorward P M, Stewart J C, *et al*., A survey of the nutritional and haemagglutination properties of several tropical seeds, *Livest Res Rural Dev*, 3 (3) (1991) 33-55.

9 Hampaiah R, Bhanja M, Reddy C A & Reddy C M, Commemoration of CoP-11 to CBD: Biodiversity Complex, In: Commemoration Book on the occasion of CBD, (CoP-12, National Biodiversity Authority), 2014, 28.

10 Pingale R, Pokharkar D, Phadatare S P & Gorle A M, Pharmacognostic Evaluation of *Parkia biglandulosa* bark. *Int J Pharmacogn Phytochem Res*, 8 (7) (2016) 1160-1163.

11 Khond M, Bhosale J D, Arif T, Mandal T K, Padhi M M, *et al*., Screening of some selected medicinal plants extracts for in-vitro antimicrobial activity, *Middle East J Sci Res*, 4 (4) (2009) 271-278.

12 Siqueira D S B, Vianello R P, Fernandes K F & Bassinello P Z, Hardness of Carioca beans (*Phaseolus vulgaris* L.) as affected by cooking methods, *LWT-Food Sci Technol*, 54 (1) (2013) 13-17.

13 AOAC, *Official methods of analysis,* (Association of Official Analytical Chemists, 17th *ed.* Washington DC, USA), 101(a) (2000) 108-111.

14 Ranganna S, Colour Measurement In: Handbook of Analysis and Quality Control for Fruit and Vegetable Products. (NewDelhi-Tata McGraw-Hill Publications), 12 (2) 2005 527-556.

15 Onuma O B & Bello A B, Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate, *J Food Sci,* 53 (2) (1988) 450-454.

16 Heywood A A, Myers D J, Bailey T B & Johnson L A, Functional properties of low-fat soy flour produced by an extrusion-expelling system, *J Am Oil Chem Soc*, 79 (12) (2002) 1249–1253.

17 Leach H W, McCowen L D & Scotch T J, Structure of starch granule 1. Swelling and solubility patterns of various starches, *Cereal Chem*, 36 (1959) 534–544.

18 Nath J P & Narasingarao M S, Functional properties of guar proteins. *J Food Sci*, 46 (4) (1981) 1255-1259.

19 Coffman C V & Garcia V V, Functional properties and amino acid content of a protein isolate from mung bean flour. *J Food Technol,* 12 (5) (1977) 473–480.

20 Singh K H & Singh S G, Effect of physical characters of pods and seeds of *Parkia timoriana* (DC.) Merr.on protein contents of seeds, *Bioscan*, 9 (3) (2014) 1043-1045.

21 Olorunmaiye K S, Fatoba P O, Adeyemi O C & Olorunmaiye, P M, Fruit and seed characteristics among selected *Parkia biglobosa* (Jacq) G. Don. Populatio, *Agric biol J N Am*, 2 (2) (2011) 244-249.

22 Roy S S, Kumar S, Sharma S, Devi A R, Singh N A, *et al*., Tree Bean (*Parkia roxburghii*): A potential multipurpose tree legume of North East India, In: National Symposium on Vegetables, (Legumes for Soil and Human Health), 2016, 201-208.

23 Chhikara N, Devi H R, Jaglan S, Sharma P, Gupta P, *et al*., Bioactive compounds, food applications and health benefits of *Parkia speciosa* (stinky beans): a review, *Agric Food Secu*, 7 (1) (2018) 46.

24 Ijarotimi O S & Keshinro O O, Comparison between the amino acid, fatty acid, mineral and nutritional quality of raw, germinated and fermented African locust bean (*Parkia biglobosa*) flour, *Acta Sci Pol Technol Aliment,* 11 (2) (2012) 151-165.

25 Salam J S, Singh P K, Dutta B K & Sahoo U K, Chemical composition and nutritive indices in *Parkia roxburghii* G. Don, a leguminous plant of India, *Ind J Agric Biochem*, 22 (2) (2009) 87-93.

26 Aletor V A & Aladetimi O O, Compositional evaluation of some cowpea varieties and some under-utilized edible legumes in Nigeria, *Food-Nahrung*, 33 (10) (1989) 999–1007.

27 Etiosa O R, Chika N B & Benedicta A, Mineral and Proximate Composition of Soya Bean, *Asian J Physic Chem Sci,* 4 (3) (2017) 1-6.

28 Kamisah Y, Othman F, Qodriyah H M S & Jaarin K, *Parkia speciosa* hassk.: A potential phytomedicine, *Evid Based Complement Alternat Med*, 10 (1) (2013) 126-134.

29 Messina M J, Legumes and soybeans: overview of their nutritional profiles and health effects, *Am J* Clin Nutr, 70 (3) (1999) 439-450.

30 Akubor P I. Chemical composition, functional and pasting properties of cashew pomace and wheat flours, *Int J Agric Vet Sci*, 2 (1) (2016) 28-37.

31 Vadivel V & Janardhanan K, Preliminary agrobotanical traits and chemical evaluation of *Mucuna pruriens* (itching beans): a less-known food and medicinal legume, *J Med Aromat Plant Sci*, 22 (2/3) (2000) 191-199.

32 Gernah D I, Atolagbe M O & Echegwo C C, Nutritional composition of the African locust bean (*Parkia biglobosa*) fruit pulp, *Niger Food J*, 25 (1) (2007) 190-196.

33 Fox B A & Cameron A G. Chapter 3: Legume seeds In: Food science-a chemical approach,(Hodder & Stoughton Ltd. Publications), 1977, 353-367.

34 Akintayo E T, Adebayo E A & Arogundade L A, Chemical composition, physicochemical and functional properties of akee (*Bilphia sapida*) pulp and seed flours, *Food Chem*, 77 (3) (2002) 333-336.

35 Suresh C, Assessment of functional properties of different flours, *Afr J Agric Res*, 8 (38) (2013) 4849-4852.