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Physical and Cooking Properties of Seeds of Two Wild Legume Landraces of *Sesbania*

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Abstract Seeds of *Sesbania* species are known for nutritional, medicinal and industrial applications (e.g. proteins, minerals, fatty acids, carbohydrates, fibre, phenolics, antioxidants and galactomannan). For commercial exploitation of *Sesbania*, fair knowledge on the physical, mechanical, cooking and functional properties of seeds and kernels are of immense value. *Sesbania bispinosa* and *S. speciosa* are well adapted to the mangrove and coastal sand dune ecosystems of the southwest India. The present study compared the physical and cooking properties of seeds of *S. bispinosa* and *S. speciosa* grown in the mangroves. The mean seed mass was species-dependent ranging from 7 mg (*S. bispinosa*) to 14 mg (*S. speciosa*), which increased three-fold on boiling seeds of *S. bispinosa* ($p<0.001$) and 2.5-fold in *S. speciosa* ($p<0.001$). The *l*/*b* ratio was higher in boiled seeds of *S. bispinosa* ($p<0.01$), while it was high in unboiled seeds of *S. speciosa* ($p<0.05$). The geometric mean diameter was high in boiled seeds of both species ($p<0.001$). Seeds showed increased surface area on boiling ($p<0.001$), but it was opposite for the bulk density ($p<0.01$). Hydration ($p<0.01$) and swelling ($p<0.001$) capacities were increased in boiled seeds. The hydration index ($p<0.01$) as well as swelling index ($p<0.01$) were raised in seeds of *S. bispinosa* on boiling. The minimum cooking time for seeds was 1.5 times higher in *S. bispinosa* compared to *S. speciosa* (45 vs. 30 min, respectively) possibly due to higher surface area. The water uptake ratio ($p<0.01$), moisture absorbed ($p<0.01$), elongation ratio ($p<0.001$) and gruel solid loss ($p<0.05$) were higher in *S. bispinosa* than *S. speciosa*. The physical and cooking properties evaluated in this study facilitate selection of genetically suitable landraces or cultivars from different habitats and geographic locations. Commercial exploitation of different *Sesbania* species along with their seeds are yet to be fully visualized for profitable use in the fields of agriculture, medicine and industry.

Keywords: *Sesbania bispinosa*, *Sesbania speciosa*, seed characteristics, industrial applications, mangroves

Introduction

Plant-derived proteins are popular worldwide in food industry owing affordability and functional ingredients useful in food formulations to replace

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expensive and scarcity of animal proteins (Chel-Guerrero *et al*., 2002; Bernardino *et al*., 2005). Functional properties of foods are dependent on the composition, structure and physicochemical properties, which influence the behavior of proteins during processing, storage, preparation of food stuffs and consumption (Kinsella, 1982; Kohnhorst *et al*., 1990; Guéguen, 1998; Alobo *et al*., 2009). The most important attributes in food processing includes solubility, water-holding, fat-holding, emulsification, foaming, gelation, thickening and flavor-binding properties (Boye *et al*., 2010). Such functional properties are dependent on the amino acid composition, protein structure/conformation and interactions between proteins with other components (e.g. salts, fats, carbohydrates and phenolics). There is a shift in the emphasis to employ lesser known legumes instead of popular legumes owing to demand to develop inexpensive protein-rich supplementary foods (Alobo, 1999; Eneche, 2005; Seena and Sridhar, 2005; Tosh and Yada, 2010). Food industries are in need of appropriate functional properties in legume seed flours to develop cost effective and novel food products (Boye *et al*., 2010).

Nearly 60 species of *Sesbania* consisting of annuals, perennials, herbs, shrubs and trees have wide distribution in tropical as well as subtropical regions (Evans, 1990; Veasey *et al*., 1999). Agricultural, food, pharmaceutical and industrial applications of *Sesbania* have been documented by many investigators (Siddhuraju *et al*., 1995; Hossain and Becker, 2001; Bhat and Karim, 2009; Vadivel and Biesalski, 2010; Anita, 2010; Pollard *et al*., 2011; Shreelalitha, 2011). According to Siddhuraju *et al*. (1995), the mature seeds of *Sesbania* are consumed after cooking by the tribals of southeast India (e.g. Kharis and Ghondas). The average seed yield of *S. bispinosa* ranges between 600 and 1,000 kg/ha (India, 600 kg/ha; Peru, 900 kg/ha; California, 1,000 kg/ha), while the fibre yield ranges between 100 and 1,000 kg/ha. Seed yield in *S. bispinosa* in coastal region of southwest coast of India ranges between 150 and 200 g per plant (Shreelalitha, 2011).

Sesbania bispinosa is highly adapted to the coastal region of southwest coast of India (e.g. mangroves and coastal sand dunes) due to tolerance to wide soil, geographic and climatic conditions (e.g. water logging; high temperature, 36-44 °C; alkaline, pH 10) (Prasad, 1993; Ipor and Oyen, 1997; Anita, 2010). It is one of the germplasms conserved in Plant Genetic Resources Conservation Unit (PGRCU), University of Georgia due to its industrial applications (e.g. fibre, pulp, cover crop, fodder, green manure, ornamental and galactomannan) (Morris, 1999). *Sesbania bispinosa* serves as an ornamental plant, fodder, green manure and possesses medicinal and industrial values (Bhagya and Sridhar, 2009). Flowers of *S. bispinosa* are used to treat skin diseases, seed power is used to treat cough, head ache and the seed oil is useful in treating body ache

(Bhagya and Sridhar, 2009; Morris, 1999). *Sesbania* seeds are commercially viable as an excellent source of nontoxic food-grade polysaccharide galactomannan (Hossain *et al*., 2003; Pollard *et al*., 2011). Galactomannan has smooth, transparent, coherent and elastic properties useful in sizing textiles, in paper industry and also to stabilize mud during oil drilling (Vietmeyer, 1986). As the galactomannan is food-grade gel, it will be useful as stabilizer and thickener in several food products especially ice cream, bakery mixes and salad dressings. Recent investigation revealed that the galactomannan of *Sesbania* seeds is equivalent to the guar gum (Pollard *et al*., 2011).

The novelty of legume-based food/feed and pharmaceutically/ industrially useful product sould be evaluated precisely by assessment of physical, cooking and functional properties (Boye *et al*., 2010; Karaj and Müller, 2010; Tosh and Yada, 2010; Pollard *et al*., 2011). Evaluation of seed size, shape and internal morphology would be beneficial for exploitation of *Sesbania* seeds as potential source of nutrition, medicine and industrial applications (Siddhuraju *et al*., 1995; Hossain and Becker, 2001; Hossain *et al*., 2002; Vadivel and Biesalski, 2010; Vadivel *et al*., 2011). Assessment of nutritional and functional properties of seeds of wild legumes helps in optimum utilization and possibilities to produce desired food or feed or pharmaceutical products. As an extension of evaluation of nutritional, bioactive and functional properties of seeds of *Sesbania* spp. (Anita, 2010; Shreelalitha, 2011; Shreelalitha and Sridhar, 2016; Sridhar *et al*., 2016), the current study envisaged to compare the physical and cooking properties of seeds of two landraces (*S. bispinosa* and *S. speciosa*) adapted to grow in salt-prone habitats of mangroves of southwest India.

Materials and Methods

Seeds and processing

The dry pods of *Sesbania bispinosa* (Jacq.) W.F. Wight (Fig. 1a) and *Sesbania speciosa* Taub. (Fig. 1b) were harvested from five locations of Nethravathi mangroves, Mangalore, southwest coast of India (12°50′ N, 74°49′ E) during post-monsoon season. Seeds were separated from dry pods. Damaged, sunken, aborted and malformed seeds were eliminated and sun-dried until the moisture attains below 10% followed by evaluation of physical and cooking properties. The seeds of *Sesbania* spp. studied belonged to two types: cylindrical capsule- or bullet-like seeds (*S. bispinosa*) (Fig. 1c) and pea-shape seeds (*S. speciosa*) (Fig. 1d).

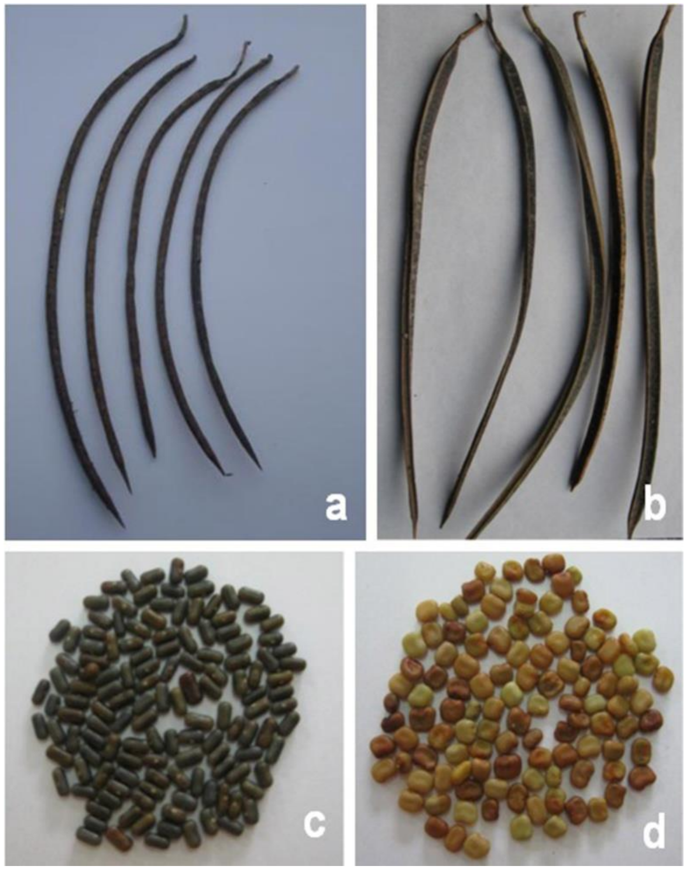

Figure 1. Dry pods of *Sesbania bispinosa* with smooth surface (a); dry pods of *S. speciosa* with prominent ridges (b); capsule- or bullet-like dry seeds of *S. bispinosa* (c); pea-shaped dry seeds of *S. speciosa* (d) collected from the Nethravathi mangroves of southwest India.

Physical properties

Seed mass. Mass of randomly selected single seed (n=25), 100 seeds (n=5) and 1000 seeds (n=5) were determined using an electronic precision balance with an accuracy of 0.0001 g (Shimadzu #D445929124, Model, AY120, Capacity 120 g, Japan).

Seed dimensions. Length (*l*), breadth (*b*) and thickness (*t*) of seeds (n=25) were recorded using vernier caliper with a resolution of 0.01 mm (Mitutoyo Vernier Caliper, Model # 530-312, Japan). The length-breadth (*l*/*b*) ratio was calculated by dividing *l* by *b*.

Geometric diameter. The geometric mean diameter (D_g) (in mm) of seed (n=25) was calculated using principal dimensions (Mohsenin 1970).

D_g (mm) = $(l\,b\,t)^{1/3}$

Sphericity. Sphericity (S_ϕ) is defined as the ratio of the surface area of a sphere having the same volume as the seed to the surface area of the seed. Sphericity (%) (n=25) was calculated according to Mohsenin (1970).

S_ϕ(%) = $(l\,b\,t)^{1/3} \div l$

Surface area. Surface area (S_s) (mm^2) of seeds (n=25) was calculated using the formula proposed by McCabe *et al*. (1986).

S_s (mm^2)= πD^2

Bulk density. The bulk density (ρ_b) is defined as the ratio of the mass of the sample of the seeds to its total volume. To determine the bulk density (g/ml), 25 g of seeds (n=5) were poured into a measuring jar from a fixed height of 30 cm. The volume occupied by the sample was determined and the ratio was calculated in g/ml (Singh *et al*., 2005).

Hydration capacity. To determine hydration capacity (g/seed), 25 g seeds (n=5) were enumerated and transferred to a measuring jar containing 100 ml distilled water and it was left for 24 hr at room temperature (27±2°C). Later, water was drained, seeds were blotted to remove adhered water and weighed (Adebowale *et al*. 2005).

Hydration capacity (*g/seed*) = $(W_2 - W_1) \div N$

(where W_2, weight of seeds after soaking; W_1, weight of seeds before soaking; N, number of seeds)

Hydration index. Hydration index is the ratio of hydration capacity per seed to that of weight of one seed.

Hydration index = (*Hydration capacity/seed* ÷ *Weight/seed*)

Swelling capacity. To determine swelling capacity (ml/seed), 25 g seeds (n=5) were enumerated and its volume was determined on soaking overnight in distilled water. The volume of the soaked seed was noted in a graduated cylinder (Adebowale *et al*. 2005).

Swelling capacity (*ml/seed*) = $(V_2 - V_1 \div N)$

(where V_2, volume of seeds after soaking; V_1, volume of seeds before soaking; N, number of seeds)

Swelling index. Swelling index is the ratio of swelling capacity of seed to that of volume.

Swelling index = (*Swelling capacity/seed* ÷*Volume/seed*)

Cooking properties

Minimum cooking time, cooked weight, water uptake ratio, moisture absorbed, elongation ratio and gruel solid loss of seeds of *S. bispinosa* and *S. speciosa* were determined based on the procedures outlined by Singh *et al*. (2005).

Minimum cooking time

Two grams of the seeds (n=5) were dispensed in to a test tube and cooked in 20 ml distilled water on a boiling water bath. The cooking time was determined on removing a few seeds at different time intervals during cooking and pressing between two glass slides until no uncooked core was left.

Cooked weight

Seeds (10 g; n=5) were cooked in distilled water (50 ml) for minimum cooking time in boiling water bath (98.5±1.5°C) and water was drained, blotted to remove surface moisture. Cooked weight was expressed as g/10 g of seeds.

Water uptake ratio

Two grams of seed samples (n=5) were cooked in distilled water for a minimum cooking time in a boiling water bath (98.5±1.5°C), drained and blotted to remove surface water. The cooked samples were weighed and water uptake ratio was calculated.

Moisture absorbed

Moisture absorbed was determined as difference between cooked and uncooked seed samples (n=5) and expressed as water absorbed (in ml) per 10 g of seed.

Elongation ratio

Length of cooked seed was divided by the length of uncooked seed (n=25) to determine the elongation ratio.

Gruel solid loss

Two grams of seeds (n=5) were cooked in distilled water for a minimum cooking time in a boiling water bath (98.5±1.5°C), the gruel was transferred to 50 ml capacity standard flask after many washings and made up the volume with distilled water and mixed. Gruel was evaporated at 110°C to determine the gruel solids in percentage.

Data analysis

The relationship in physical properties of two *Sesbania* seeds between unboiled and boiled seeds as well as cooking properties between seeds of *S. bispinosa* and *S. speciosa* were assessed by *t*-test using Statistica version # 8.0. (StatSoft Inc., 2008).

Results

Physical properties

Table 1 provides comparison of physical properties of unboiled and boiled seeds *S. bispinosa* and *S. speciosa*. The mean seed mass was species-dependent ranged from 7 mg (*S. bispinosa*) to 14 mg (*S. speciosa*), which increased on boiling (20 mg and 36 mg, respectively) ($p<0.001$). The dimensions (length and breadth) of unboiled and boiled seeds of *S. bispinosa* were substantially lower than *S. speciosa* ($p<0.001$). The l/b ratio increased in boiled seeds of *S. bispinosa* ($p<0.01$), while it was opposite for *S. speciosa* ($p<0.05$). Sphericity decreased in boiled *S. bispinosa* seeds ($p<0.001$), while increased in boiled seeds of *S. speciosa* ($p<0.01$). On boiling, geometric mean diameter of both seeds increased ($p<0.001$). Both seeds on boiling showed significant increase in surface area ($p<0.001$), however the bulk density decreased ($p<0.01$). The hydration and swelling capacities in boiled seeds were significantly increased in both seeds ($p<0.001$), while the hydration index and swelling index were raised only in *S. bispinosa* ($p<0.01$).

Cooking properties

Table 2 registers the cooking properties of seeds of *Sesbania* spp. Minimum cooking time was 1.5 times higher in *S. bispinosa* compared to *S. speciosa* (45 vs. 30 min) possibly due to higher surface area, while the cooked weight was one-third higher in *S. bispinosa* ($p<0.01$). The water uptake ratio ($p<0.01$) as well absorption of moisture ($p<0.01$) were higher in seeds of *S. bispinosa* than *S. speciosa*. The elongation ratio ($p<0.001$) and gruel solid loss ($p<0.05$) of *S. bispinosa* were also higher compared to *S. speciosa.*

Discussion

Physical properties

Evaluation of physical, mechanical and chemical properties of seeds are essential to design an equipment to handle, transport, process, store and to assess the product quality (Aktas *et al*., 2006; Coskuner and Karababa, 2007; Sirisomboon *et al*., 2007). Based on the shape, seeds *Sesbania* spp. have been classified into two categories: small cylindrical (capsule- or bullet-like) (e.g. *S. aculeata, S. bispinosa, S. cannabina, S. rostrata* and *S. sesban*) and large pea-shaped (e.g. *S. formosa, S. grandiflora* and *S. speciosa*) (Evans and Rotar, 1987; Pollard *et al*., 2011). The mean weight of the seeds of *S. speciosa* is almost double to that of *S. bispinosa*, which may lead to changes in several physical properties (see Table 1). The seed dimensions are useful to determine the seed shape and have significance in determining the aperture size of the machine to process the seeds. Similarly, the geometric mean diameter is useful to determine the volume and sphericity of the seeds.

Sphericity of seeds is one of the important parameters in designing of hopper (particulate collection container) to process the seeds. The low sphericity of *Sesbania* seeds studied indicates their sliding property than rolling on flat surfaces. The seed surface area of *S. speciosa* was almost double than that of *S. bispinosa* seeds, which may also result in higher percentage of seed germination (Pollard *et al*., 2011). As predicted by Pollard *et al*., (2011), germination of seeds of *S. speciosa* was about three-fold higher than *S. bispinosa* (Shreelalitha *et al*., 2015). The bulk density is a function of particle size and low bulk density is advantageous for weaning foods. The bulk density is a measure of heaviness of a flour sample, which is important in determining the storage capacity, packaging requirements, material handling and application in wet-processing in the food industries. The bulk density of *Sesbania* seeds studied (0.83-0.87 g/ml) was substantially higher than that of soy meal (0.5g/ml), soy protein isolates (0.33 g/ml) (Dench, 1982) and soy protein concentrates (0.52 g/ml) (Wang and Kinsella, 1976). The bulk density of *Sesbania* seed flours are comparable with the raw flour of jackfruit seeds (0.61 g/ml) (Odoemelan, 2005), tiger nut flours (0.55-0.62 g/ml) (Oladele and Aina 2007), African breadfruit kernel flour (0.54 g/ml) and wheat flour (0.71 g/ml) (Akubor and Badifu, 2004). The hydration capacity, hydration index and swelling capacity of seeds of *Sesbania* spp. substantially differed between the species and increased drastically in boiled seeds, which assumes importance in future exploitation of these seeds.

Table 1. Physical properties of unboiled and boiled seeds of *Sesbania* spp. (mean±SD) (Asterisks between uncooked and cooked seeds are significantly differed, *t*-test: *p<0.05, ** p<0.01, *** p<0.001).

	Sesbania bispinosa		***Sesbania speciosa***	
	Unboiled	Boiled	Unboiled	Boiled
Unit mass/seed (n=25) (g)	0.007±0.0009	0.020±0.0028***	0.014±0.001	0.036±0.003***
Unit mass/100 seeds (n=5) (g)	0.71±0.025	2.089±0.318***	1.27±0.005	3.39±0.216***
Unit mass/1000 seeds (n=5) (g)	7.05±0.250	20.89±3.183***	12.72±0.052	33.93±2.162***
Length, *l* (n=25) (mm)	0.27±0.030	0.52±0.041***	0.41±0.028	0.53±0.036***
Breadth, *b* (n=25) (mm)	0.16±0.021	0.26±0.023***	0.27±0.007	0.37±0.028[b]***
Thickness, *t* (n=25) (mm)	0.14±0.007	0.18±0.014***	0.16±0.007	0.25±0.022***
Length-breadth (*l*/*b*) ratio (n=25)	1.71±0.072	1.99±0.263**	1.53±0.107*	1.43±0.103
Geometric diameter, D_g (n=25) (mm)	0.18±0.017	0.28±0.016***	0.26±0.009	0.37±0.018***
Sphericity, S_ϕ (n=25) (%)	67.00±1.700***	56.07±3.457	63.25±2.362	69.35±3.897**
Surface area, S_s (n=25) (mm^2)	0.11±0.021	0.26±0.030***	0.21±0.015	0.42±0.042***
Bulk density, ρ_b (n=5) (g/ml)	0.87±0.018**	0.73±0.012	0.82±0.016**	0.71±0.001
Hydration capacity (n=5) (g/seed)	0.001±0.0001	0.010±0.0001***	0.005±0.0001	0.015±0.0003***
Hydration index (n=5)	0.117±0.020	0.525±0.044**	0.342±0.017	0.376±0.013
Swelling capacity (n=5) (ml/seed)	0.003±0.0004	0.020±0.0001***	0.011±0.0003	0.026±0.0005***
Swelling index (n=5)	0.374±0.017	1.049±0.056**	0.748±0.043	0.667±0.021

Cooking properties

Among the six cooking properties of *Sesbania* seeds studied, all parameters were significantly higher in *S. bispinosa* than *S. speciosa* (Table 2). The seeds with higher bulk density exhibit slow water uptake and thus resulting in longer cooking periods. As the bulk density of seeds of *S. bispinosa* was higher than the seeds of *S. speciosa*, the cooking time was substantially increased in *S. bispinosa*. However, the cooked weight, water uptake ratio, moisture absorbed, elongation ratio were significantly higher in seeds of *S. bispinosa* than *S. speciosa*. The higher length-breadth (*l*/*b*) ratio of seeds offers large surface area for water contact, which influences the higher gruel solid loss in seeds. The higher *l*/*b* ratio of *S. bispinosa* seeds resulted in significantly higher gruel solid loss than seeds of *S. speciosa*.

Table 2. Cooking properties of seeds of *Sesbania* spp. (except for cooking time: mean ±SD) (Asterisks between cooked seeds of *Sesbania* spp. are significantly differed, *t*-test: *p < 0.05, ** p < 0.01, *** p < 0.001).

	Sesbania bispinosa	***Sesbania speciosa***
Minimum cooking time (min) (n=5)	45	30
Cooked weight (n=5) (g/100 g seed)	18.79 ±0.57**	12.53 ±0.08
Water uptake ratio (n=5)	1.76 ±0.11**	0.51 ±0.01
Moisture absorbed (n=5) (ml/10 g seed)	8.79 ±0.57**	2.53 ±0.08
Elongation ratio (n=25)	1.90 ±0.23***	1.30 ±0.14
Gruel solid loss (n=5) (%)	5.09 ±0.33*	4.32 ±0.07

Conclusion

The current study provided basic information on physical and cooking properties of seeds of two landraces of *Sesbania* growing in the mangrove habitats of southwest India. Deshelled *Sesbania* seeds (endosperm) are useful nutritionally as well as industrially owing to presence of food-grade gel galactomannan. Husk of *Sesbania* seeds possess value-added constituents especially phenolics. Knowledge on seed quality with physical, mechanical, cooking and functional attributes is necessary to strengthen the selection and genetic improvement of superior landrace or cultivars from different habitats or geographic locations. Evaluation of nutritional and functional properties of defatted *Sesbania* seed flours and seed mechanical properties (e.g. hardness, rupture force, energy for rupture force, deformation at rupture point and deformation ratio at rupture point) will be highly useful in large-scale processing.

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