Nutritional and microbiological features of little known legumes, *Canavalia cathartica* Thouars and *C. maritima* Thouars of the southwest coast of India

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There is an alarming demand for inventory as well as exploitation of the indigenous plant wealth of India. *Canavalia cathartica* and *Canavalia maritima* are the two little known wild legumes distributed widely on the coastal sand dunes and mangrove areas of the southwest coast of India. Over a decade, the Department of Biosciences, Mangalore University, Karnataka is involved in unravelling the importance of the coastal germplasm of *Canavalia* spp. with a view to exploit their potential for nutritional and agricultural needs. The current article emphasizes the biochemical features (proximal, mineral, amino acids, fatty acids and antinutritional features) and bioavailability of protein (growth and nitrogen balance in rat model) of raw and thermally processed *Canavalia* seeds. Nutritional features of *Canavalia* seeds have been compared with other food sources (rice, wheat, soybean and whole egg) and recommended patterns (FAO/WHO and NRC/NAS). Further, the potential of stress-tolerant rhizobia and fungi (arbuscular mycorrhizae and endophytes) of these two germplasms have been highlighted. Importance of landraces of *Canavalia* in coastal sand-dune stabilization, traditional knowledge and utility in agriculture has been briefly discussed.

Keywords: *Canavalia* sp., nutritional and biochemical features, sand dune, wild legumes.

COASTAL sand dunes (CSDs) and mangroves are ecologically important as they provide niches for a variety of distinct flora, fauna and microbiota. Even though the family Fabaceae encompasses more than 1300 species, only 20 are consumed in appreciable quantities[1]. The CSDs and mangroves of the southwest coast of India are rich niches for two under-exploited legumes, *Canavalia cathartica* Thouars (synonyms: *C. microcarpa* (DC.) Piper; *C. turgida* Graham *ex* A. Gray; *C. virosa* (Roxb.) Wight *et* Arn.; *Dolichos virosus* Roxb.; *Lablab microcarpus* DC.), and *Canavalia maritima* Thouars (synonyms: *C. lineata* (Thunb.) DC.; *C. obtusifolia* (Lam.) DC.; *C. rosea* (Sw.) DC.; *Dolichos maritimus* Aublet; *D. obtusifolius* Lam.; *D. roseus* Sw.). The history of *C. maritima* (beach bean) can be traced way back to the seventeenth century (1768–71), serving as a food source for the British sea voyager, Captain James Cook and his crew (http://www.floridata.com/ref). *C. maritima* is a pantropical pioneer plant species[2] widely distributed exclusively on CSD[3], while *C. cathartica* (maunaloa), a native of mangroves, drift disseminates through seeds or propagules to CSDs paving way for two germplasms in these biomes. *C. cathartica* is a wild ancestor of *C. gladiata* (Jacq.) DC. (*Dolichos gladiatus* Jacq.), distributed throughout the tropical Asia and Africa[4]. These perennial landraces as strand vegetation are mat-formers and check the erosion of the soil. *C. cathartica* and *C. maritima* share a common challenge to their development as new viable crops. Cultivability, nutritional versatility and symbiotic microbial potentiality of *C. cathartica* and *C. maritima* remain unrevealed[5]. The aim of this article is to highlight the outcome of the research work done at Mangalore University to discover the nutritional and microbial features of *Canavalia* species of CSD and mangrove biomes of the southwest coast of India.

Nutritional features

Production of grain legumes has not kept pace with the increasing population, resulting in inadequate nutrition over the past decades. For instance, children under the age group 5 suffer from moderate to severe underweight (29%), wasting (10%) and stunted growth (33%) in developing countries[6]. Extreme habitats such as CSDs and mangroves are known to harbour under-exploited wild legume species (e.g. *C. cathartica* and *C. maritima*), which may serve as future food source (Figure 1 *a*, *b*)[7,8]. These wild legumes are more attractive due to their in-built traits such as fast growth, tolerance to adverse environmental conditions and resistance to diseases and pests. It is necessary to investigate the nutritional qualities of wild legumes in order to combat the protein–energy malnutrition. Although the coastal wild legumes, *C. cathartica*

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Figure 1. *Canavalia maritima* plants with flowers and pods grown as mat-forming creepers on the coastal sand dunes of Someshwara, Mangalore (***a***), *Canavalia cathartica* plants with flowers and pods grown as climbers on a tree of Nethravathi mangrove, Mangalore (***b***), dry seeds of *C. cathartica* (***c***) and *C. maritima* (***d***) of coastal sand dunes, germinated seeds and seedlings of *C. maritima* (***e***) and intra-nodal roots with root nodules of *C. maritima* (***f***).

and *C. maritima* possess large and heavy seeds, there is scanty information on their nutritional value and protein quality.

Seed features

C. cathartica and C. maritima are perennial, herbaceous and stoloniferous plant species, which have the capacity to withstand dry conditions of the tropical coasts. In CSDs, *C. cathartica* is distributed in fore dunes to hind dunes (6.1–40.7%), while *C. maritima* in the mid and hind dunes (7.4–44.4 %)[9,10]. *C. cathartica* possesses larger and heavier pods and seeds than *C. maritima* (Table 1). The pods of *C. cathartica* and *C. maritima* are smooth, elongated, thick-walled and green turning yellowish with age and ripen simultaneously in October–November on the

Table 1. Physical characteristics of seeds of *Canavalia* species of coastal sand dunes and mangroves (mean, $n = 20$)

	Canavalia cathartica[a]			*Canavalia maritima*[b]		
Characteristics	Pod[c]	Bean[c]	Seed	Pod[c]	Bean[c]	Seed
Number of seeds per pod	3.5–5.9	–	–	4.5	–	–
Fresh weight (g)	8.8–32.5	1.2–1.86	–	6.4	0.63	–
Dry weight (g)	2.3–8.5	0.43–0.6	0.64–0.97	1.55	0.19	0.42–0.5
Cotyledon weight (g)	–	0.26–0.28	0.44–0.69	–	0.16	0.29–0.35
Coat weight (g)	–	0.15–0.16	0.20–0.28	–	0.05	0.13–0.15
Length (cm)	8.4–12.5	1.8–2.3	1.54–1.89	6.8	1.49	1.3
Width (cm)	2.65–3.89	1.3–1.44	1.17–1.27	1.8	0.69	0.86
Thickness (cm)	2.4–2.69	0.9–0.96	0.83–0.93	1.25	0.68	0.76
Hilum length (cm)	–	1.2–1.23	0.94–1.24	–	0.42	0.55
L/*B* ratio	–	–	1.5	–	–	1.51
Bulk density (g/ml)	–	–	0.55	–	–	0.51
Hydration capacity (g/seed)	–	–	0.08	–	–	0.02
Hydration index	–	–	0.1	–	–	0.06
Swelling capacity (ml/seed)	–	–	0.15	–	–	0.05
Swelling index	–	–	0.1	–	–	0.1

[a]Seena and Sridhar[8]; Arun *et al.*[15]; Seena *et al.*[17,20]; [b]Arun *et al.*[15]; Seena *et al.*[18]; [c]Unpublished observations.

Table 2. Optimum conditions for seed germination (% germination in parenthesis) of *Canavalia* species of coastal sand dunes[a]

Optimium conditions	*C. cathartica*	*C. maritima*
Temperature (°C)	28 (59)	36 (43)
Salinity (% sea water)	25 (52)	25 (40)
Sand burial with (cm)		
Freshwater	2 (60)	2 (33)
Sea water	2 (52)	2 (40)

[a]Arun *et al.*[9].

southwest coast. Dry seeds of *C. cathartica* and *C. maritima* of dunes (Figure 1 *c*, *d*) are subcylindric, while *C. cathartica* ripened beans and dry seeds of mangroves are flattened and are slightly larger than the dune germplasm. Seeds of *C. cathartica* have longer hilum than *C. maritima* (0.94–1.24 vs 0.55 cm). Seed colour ranges from maroon to brown, with or without striations. *C. cathartica* seeds absorb water much faster than *C. maritima*, resulting in higher hydration and swelling capacity (Table 1). The optimum conditions required for seed germination differ between *C. cathartica* and *C. maritima* (Table 2; Figure 1 *e*). Due to the higher hydration capacity, per cent germination was more in *C. cathartica* than *C. maritima* on burial in sand with freshwater or sea water (52–60 vs 33–40%). Germination studies carried out in our laboratory indicated enforced seed dormancy at elevated physical conditions (temperature, salinity and sand burial), which might be responsible for the formation of seed bank on the CSDs. Such adaptation helps in perpetuation of plant species at the onset of favourable conditions.

Seed processing and proximal features

Seeds of *Canavalia* collected from CSDs and mangroves of the southwest coast of India were sun-dried before processing. The raw, roasted (sand bath, 180°C, 20 min) and cooked (pressure-cooker, 30 min with 1 : 3 v/v freshwater) seed flours of *Canavalia* were assessed for nutritional, antinutritional, functional and cooking properties and their protein quality was evaluated using rat model.

Cooked seed flours have low moisture than raw and roasted seeds, warranting longer shelf-life (Table 3). Thermal processing of *Canavalia* seeds reduced the moisture, protein and fibre contents and improved lipids, carbohydrates and calorific value. Ash was low in cooked seeds than raw seeds, while it was unchanged in roasted seeds, as cooking is known to drain the minerals. Raw *Canavalia* seeds possess adequate amount of proteins (31.2–35.5%), and it is one of the desirable traits essential to combat poor nutrition. As the excess protein consumption results in formation of toxic substances, it has been deemed to maintain an upper bound not more than twice the recommended daily allowances of proteins. Animal proteins tend to possess high fat and their consumption should be reduced in favour of legumes such as *Canavalia*, as the fat content is low (1.3–1.86%). Generally, in seeds, an increase of 1% protein is accompanied by a decrease of 0.5% oil. Such negative correlation between protein and oil is one of the reasons for lack of interest in lipids of high-protein seed varieties. Although fat is low in *Canavalia*, it cannot be ignored as it consists of essential fatty acids. Fibre content of raw seeds of *Canavalia* ranges between 1.7 and 10.2%. It is essential as it regulates digestion, detoxifies and normalizes bowel function, reduces blood cholesterol and prevents colon cancer. Carbohydrates of raw seeds of *Canavalia* are 50.5–61.4% and easily provide the energy required for oxidative metabolism. In addition, carbohydrate-rich food maintains glycemic homeostasis, gastrointestinal integrity and also serves as the vehicle for important micronutrients and

Table 3. Proximate composition (% dry matter) and energy (kJ/100 g) of seed flours of *Canavalia* species of coastal sand dunes and mangroves in comparison with soybean and wheat

	Moisture	Crude protein	Crude lipid	Crude fibre	Ash	Crude carbohydrate	Energy
C. cathartica[a]							
Raw	9.18–11.2	31.2–35.5	1.3–1.86	1.7–7.0	3.08–3.36	52.8–61.4	1520–1600
Roasted	7.18–8.61	29.6–30.5	1.38–1.88	1.66–2.38	3–3.32	62.5–65.3	1620–1618
Cooked	5.32–5.65	28–29.2	1.36–1.92	0.96–1.68	3.1–3.15	65–65.4	1630
C. maritima[b]							
Raw	9.28–9.3	34.1	1.65–1.70	2.26–10.2	3.5	50.5	1586–1590
Roasted	6.54	30	1.78	2.14	3.5	60.53	1622
Cooked	5.65	28.39	1.7	1.7	3.18	65.8	1625
Soybean[c]	8.4–8.54	36.49–40	17.5–20	9.31	3.18–4.9	30.16–35	1739–1810
Wheat[d]	8–18	10–16	1.5–2	2–2.7	1.2–3	65.4–78	1377–1431

[a]Seena and Sridhar[8], Arun *et al.*[15]; Seena *et al.*[17,20]. [b]Arun *et al.*[15]; Seena *et al.*[18,19]. [c]Longvah[1]; Cheftel *et al.*[46]; USDA[47].
[d]USDA[47]; Ensminger *et al.*[48]; Matz[49]; Belderok[50].

Table 4. Mineral composition (mg/100 g) of seed flours of *Canavalia* species of coastal sand dunes and mangroves in comparison with soybean and NRC/NAS recommended pattern

	Sodium	Potassium	Calcium	Phosphorus	Zinc	Iron	Copper	Zinc	Manganese
C. cathartica[a]									
Raw	40.2–49.2	828–895	27.3–83.78	115–137	5.14–6.86	1.22–2.88	0.14–0.35	0.98–11.43	0.12–1.44
Roasted	39.5–43.8	821–825	28.9–69.9	112–120	4.55–6.8	1.23–2.45	0.13–0.34	0.84–7.44	0.13–1.22
Cooked	20.8–24.1	190–240	26.2–44	83.8–99.4	3.58–3.96	0.89–2.18	0.1–0.3	0.91	0.1–0.7
C. maritima[b]									
Raw	47.96–48.0	974–974.3	86.2	158	23.1	4.53–4.54	0.28	13.1	2.02–2.04
Roasted	41.13	931.07	69.03	124.14	22.77	2.57	0.18	9.7	2.31
Cooked	25.53	251.49	59.91	111.62	17.51	1.99	0.11	9.16	1.13
Soybean[c]	2	1797	277	704	280	15.1	1.658	4.89	2.517
NRC/NAS[d]	120–200	500–700	600	500	60	10	0.6–0.7	5	0.3–1

[a]Seena and Sridhar[8]; Arun *et al.*[15]; Seena *et al.*[17,20]. [b]Arun *et al.*[15]; Seena *et al.*[18,19]. [c]USDA[47]. [d]NRC/NAS[12] recommended pattern for infants.

phytochemicals. Unlike fats and proteins, high level of carbohydrate intake is not associated with adverse health effects. The energy of thermally processed and raw *Canavalia* seeds ranges between 1520 and 1625 kJ/100 g, and it is higher than that of many commonly cultivated pulses (1358.3–1426.2 kJ/100 g)[11]. Protein, fibre, ash and energy of *Canavalia* seeds were higher than that of wheat. Proteins of *Canavalia* seeds were lower than those in soybean only by 5%, indicating their richness next to soybean (Table 3).

Table 5. True protein and fractions (%) of seed flours of *Canavalia* species of coastal sand dunes and mangroves

Fraction	*C. cathartica*[a]	*C. maritima*[b]
True protein	28.3–28.8	28.8–29.3
Albumins	7.28–7.4	7.4–7.46
Globulins	18.2–18.5	18.5–18.7
Prolamins	0.3–0.74	0.28–0.3
Glutelins	2–2.7	2.7–2.86

[a]Seena and Sridhar[8]; Arun *et al.*[15]; Seena *et al.*[17]. [b]Arun *et al.*[15]; Seena *et al.*[18].

Minerals and protein fractions

Among the minerals assessed, potassium and phosphorus were the highest quantity followed by sodium (*C. cathartica*) and calcium (*C. maritima*; Table 4). Difference in minerals within the species is likely due to distinct geographical locations. On cooking the seeds, most of the minerals are drained leading to the considerable loss, which warrants alternate methods of cooking (e.g. extrusion cooking). The minor minerals comprise trace elements of nutritional importance such as zinc, iron and copper. Potassium and manganese surpassed the NRC/NAS recommended pattern[12] for infants. Sodium (*C. cathartica* and *C. maritima*) and zinc (*C. maritima*) were higher than in soybean. Fortification with minerals is ideal for *Canavalia* seeds, as they are not a good source of minerals.

In legumes, usually 50–65% of the seed protein is contributed by the globulin fraction. Globulins are multimeric molecules consisting of two major components, viz. legumin and vicilin. Convicilin, a third component is also present in minor quantities[13]. Among the true protein fractions in *Canavalia* seeds, globulins were the highest followed by albumins, glutelins and prolamins (Table 5).

Albumin fractions are known for their rich sulphur amino acids and essential amino acids (EAA)[14]. On separation of raw seed proteins by SDS–PAGE, CSD *C. cathartica* and *C. maritima* yielded 14 bands (6–91 kDa). However, mangrove *C. cathartica* exhibited only six bands (13.4–49.4 kDa)[8,15–18]. Higher number of bands in the CSD species might be due to the stress proteins. On roasting, the number of bands of CSD *C. cathartica* reduced to four (33.3–52.6 kDa), *C. maritima* to five (16.4–63 kDa) and mangrove *C. cathartica* to three (51.4–33.1 kDa). Cooking of *Canavalia* seeds did not show any bands, except for a smear[17,19,20]. The difference in number, molecular weight and formation of smear may be due to denaturation of proteins on thermal processing.

Amino acids and fatty acids

Generally, legume seed proteins are rich in lysine and deficient in sulphur amino acids (methionine and cystine) and tryptophan. Interestingly, the sulphur amino acids and lysine of the raw *Canavalia* seeds were more than soybean, rice or wheat (Table 6). All the amino acids in *Canavalia* seeds meet over 50% of the whole egg protein amino acid profile. The EAA of the raw seeds surpassed FAO/WHO recommended pattern[21]. Glutamic acid and aspartic acid formed the major bulk of the amino acids of *Canavalia* seeds, which is similar to soybean, rice and whole egg proteins. Pressure-cooking of seeds drained amino acids to a greater extent than roasting. Thermal processing declined the amino acids, but the sulphur amino acids of raw, processed seeds and lysine of raw and roasted seeds surpassed the FAO/WHO recommended pattern[21]. As the *Canavalia* gene pools of CSDs and mangroves of the southwest coast of India are a rich source of essential and sulphur amino acids, their conservation, domestication and exploitation are worthwhile.

Fat plays an important role in meeting the energy requirement by providing concentrated supply of energy and thus reduces the bulk of the diet. Fat is also an excellent solvent for organic compounds. Fat makes the food more palatable and acts as a carrier for compounds that provide characteristic flavour and aroma to food. Creamy or milky taste of raw seed flours, eucalyptic aroma of roasted seed flours and coffee aroma of mature beans dried at 80°C are attributed to the presence of specific fatty acids in *Canavalia* seeds. The sum of polyunsaturated fatty acids of raw *C. cathartica* seeds exceeded those in wheat and soybean, so also *C. maritima* for wheat (Table 7). Thermal processing of *C. cathartica* seeds showed considerable increase in essential fatty acids (EFA), unlike *C. maritima*. The P/S ratio of thermally processed *Canavalia* seeds was higher than those of raw seeds, soybean and wheat. The EFA are necessary for normal foetal and infant growth and development of brain. The EFA, linoleic acid (vitamin F) was one of the major fatty acids in soybean and wheat, but it was oleic acid in *Canavalia* seeds. In raw *Canavalia* seeds, among the polyunsaturated fatty acids, oleic acid content was the highest followed by the EFA linoleic acid.

Table 6. Amino acid composition of *Canavalia* seeds (g/100 protein) of coastal sand dunes and mangroves in comparison with soybean, rice, wheat, whole egg and FAO/WHO recommended pattern

	C. cathartica[a]			*C. maritima*[b]							
Amino acid	Raw	Roasted	Cooked	Raw	Roasted	Cooked	Soybean[c]	Rice[d]	Wheat[e]	Whole egg protein[f]	FAO/WHO pattern[g]
Glutamic acid	8.3–17.32	6.4–9.8	5.6–8.43	17.52–18	9.52	8.10	17	15.2	35.5–36.9	13	
Aspartic acid	8–21.6	6.8–7.5	5.8–6.23	22.85–23	7.05	6.87	11	8.8	3.7–4.2	9.6	
Serine	1–5.17	0.9–2.78	0.6–2.43	5	3.40	1.84	5.7	5.4	3.7–4.8	7.6	
Threonine	3.7–3.77	2.02–2.2	0.6–1.82	5.2	2.35	1.34	3.8	3.2	2.2–3	5.1	3.4
Proline	3.8–4.72	2.96–3.2	2.3–2.47	4.49–4.5	2.81	2.34	4.9	4.3	11.4–11.7	4.2	
Alanine	2.4–5.4	2.2–2.87	1.4–2.55	5.2	3.01	2.07	4.2	5.8	2.8–3	5.9	
Glycine	1.5–4.58	1.3–2.2	1.2–2.03	4.4	2.41	1.53	4.0	4.5	3.2–3.5	3.3	
Valine	3.2–5.95	2.9	2–2.23	6.8	2.73	2.18	4.6	6.6	3.7–4.5	6.9	3.5
Cystine	4.8–6.39	4–4.13	2.9–3	6.1	5.01	2.03	1.7	1.2	1.6–2.6	5.9	2.5[h]
Methionine	0–1.72	0.3–1.47	0.9–1.11	0–1.9	1.57	1.29	1.2	2.6	0.9–1.5	3.4	
Isoleucine	3.2–5.14	2.57–2.6	1.9–2	5.32–5.4	2.32	2.00	4.6	4.3	3.4–4.1	6.3	2.8
Leucine	4.2–11.65	3.8–5.1	3.4–3.9	10.3	4.90	4.20	7.7	8.2	6.5–7.2	8.8	6.6
Tyrosine	3.27–4.07	0.28–2.6	0.24–2	4	0.32	0.19	3.4	3.7	1.8–3.2	4.2	6.3[i]
Phenylalanine	5.2–7.33	4–5.8	3.6–5.65	7.53–8	7.21	6.43	4.8	5.1	4.5–4.9	5.7	
Tryptophan	0	0	0	0	0	0	1.2	1.3	0.7–1	1.7	1.1
Lysine	7.6–14.7	6.05–6.6	4.58–5.6	12.6–13	7.52	3.72	6.1	3.7	1.8–2.4	7.0	5.8
Histidine	0	0	0	0	0	0	2.5	2.4	1.9–2.6	2.4	1.9
Arginine	1–3.95	0.8–2.96	0.6–1.92	2.75–3	2.03	1.92	7.1	7.7	3.1–3.8	6.1	

[a]Seena and Sridhar[8]; Arun *et al.*[15]; Seena *et al.*[17,20]. [b]Arun *et al.*[15]; Seena *et al.*[18,19]. [c]Bau *et al.*[51]. [d]Livsmedelsverk[52]. [e]USDA[47]; Ensminger *et al.*[48]; Lookhart and Bean[53]; Pomeramz[54]; Posner[55]. [f]FAO[56]. [g]FAO/WHO[21] recommended pattern. [h]Cystine + methionine. [i]Tyrosine + phenylalanine.

Table 7. Fatty acid composition of seed flours of *Canavalia* species (% total lipids) of coastal sand dunes and mangroves in comparison with soybean and wheat

	C. cathartica[a]			*C. maritima*[b]				
Fatty acid	Raw	Roasted	Cooked	Raw	Roasted	Cooked	Soybean[c]	Wheat[d]
Saturated fatty acids								
Lauric acid ($C_{12:0}$)	–	–	0.02	–	–	–	Trace–4.5	–
Tridecanoic acid ($C_{13:0}$)	0.15	0.053–0.17	0.034–0.26	–	0.089	0.103	–	–
Myristic acid ($C_{14:0}$)	–	0.001	0.02	–	–	–	Trace–4.5	–
Pentadecanoic acid ($C_{15:0}$)	0.14	0.064–0.16	0.05–0.09	–	0.062	0.066	–	–
Palmitic acid ($C_{16:0}$)	–	–	0.29	2.18–2.3	0.056	0.041	11–11.6	11–32
Heptadecanoic acid ($C_{17:0}$)	–	–	–	–	0.168	–	–	–
Stearic acid ($C_{18:0}$)	28.2	0.022	0.002	20.9–21.6	0.037	0.045	2.5–4.1	0–4.6
Arachidic acid ($C_{20:0}$)	–	–	–	–	–	–	Trace	–
Tricosanoic acid ($C_{23:0}$)	–	–	0.001	–	–	–	–	–
Lignoceric acid ($C_{24:0}$)	–	0.09	–	–	–	–	–	–
Pentacosanoic acid ($C_{25:0}$)	–	0.156	–	–	–	–	–	–
Polyunsaturated fatty acids								
Myristoleic acid ($C_{14:1}$)	0.23	0.11–0.3	0.077–0.23	–	0.144	0.156	–	–
Palmitoleic acid ($C_{16:1}$)	9.44	5.673–13.2	1–4.068	–	8.368	7	Trace	–
Oleic acid ($C_{18:1}$)	71–71.4	0.08–0.334	Trace–0.014	63–63.9	0.148	0.075	21.1–22	11–29
Elaidic acid ($C_{18:1}$)	0.1	–	–	–	–	–	–	–
Linoleic acid ($C_{18:2}$)	6.28	8.135–9.8	7.41–7.635	11.5–11.9	7.1	7.836	52.4–54	44–74
Linolelaidic acid ($C_{18:2}$)	9.91	–	–	–	–	–	–	–
Linelaidic acid ($C_{18:2}$)	–	13.4	10.2	–	–	–	–	–
Linolenic acid ($C_{18:3}$)	–	–	3.364	–	–	–	7.1–7.5	0.7–4.4
Eicosadienoic acid ($C_{20:2}$)	4.76	3.572–7.44	1.957–7.12	–	4.168	3.218	–	–
Arachidonic acid ($C_{20:4}$)	–	–	0.08	–	–	–	–	–
Eicosapentaenoic acid ($C_{20:5}$)	–	0.04	Trace–0.06	–	–	0.049	–	–
Nervonic acid ($C_{24:1}$)	–	–	–	–	–	0.0001	–	–
Sum of essential fatty acids	6.28	8.135–9.8	10.9–11.1	11.5–11.9	7.1	7.836	59.5–61.5	44.7–78.4
Sum of saturated fatty acids	28.5	0.39–0.6	0.42–0.68	23.1–23.9	0.412	0.255	13.5–24.7	11–36.6
Sum of polyunsaturated fatty acids	101.7–102.1	31–44.51	24–33	74.5–75.8	19.928	18.369	80.6–83.5	55.7–107
P/S ratio[e]	3.57–3.6	79.49–72.97	49–57	3.17–3.2	48.37	72.04	3.38–5.97	2.92–5.06

[a]Seena and Sridhar[8]; Arun *et al.*[15]; Seena *et al.*[17,20]. [b]Arun *et al.*[15]; Seena *et al.*[18,19]. [c]Cho[57]; Wahnon *et al.*[58]. [d]Pomeranz[54]; Davis *et al.*[59].
[e]Ratio of polyunsaturated/saturated fatty acids.

Functional and cooking properties

Knowledge on functional properties facilitates optimal utilization of food sources. Many uses of food are essentially based on the functional properties of proteins. The functional properties of food source are related to spatial configuration of the proteins, intramolecular forces of secondary and tertiary structure of proteins and primary structure of the amino acids. Proteins of *Canavalia* seeds projected unique functional properties and constitute an important tool for formulating 'fabricated foods'. Highest and lowest limits of functional properties of *Canavalia* seed flours are given in Table 8. Protein solubility profile with respect to pH did not indicate wide variation within *Canavalia* species. Proteins of *Canavalia* seeds can be characterized by their solubility, as it is strongly influenced by variation in pH. This quality can be exploited for isolation of protein for commercial purpose. *C. cathartica* flour exhibited lower lipophilic tendency than *C. maritima*. However, seed flours of both germplasms have a considerable oil-absorption capacity. The water absorption capacity was enhanced with addition of salt. Similarly, addition of carbohydrates and salt increased the gelation property. Emulsion and foaming capacities were influenced with flour concentration, salt and pH. Water-absorption capacity, least gelation concentration, emulsion activity/stability and foaming capacity/stability improved and/or reduced on incorporation of salt or changes in ionic strength and pH of the flours. Based on the cooking properties of *Canavalia* seeds, minimum cooking time ranged between 29 and 34 min (Table 9). The gruel solid loss for *C. cathartica* cotyledons was more than those for *C. maritima* (13.33 vs 11.76%). Higher gruel loss is due to bigger seed size of *C. cathartica*, which offers large surface area for water contact. Further, precise knowledge on functional and cooking properties of *Canavalia* seed flours facilitates the fine-tuning of flour texture to meet the requirements of specific food commodity.

Antinutritional features

Most of the legume antinutritional factors (ANFs) are heat-labile. Heat-stable ANFs (e.g. phytate and polyphe-

Table 8. Highest and lowest (in parenthesis) limits of functional properties of seed flours of *Canavalia* species of coastal sand dunes and mangroves[a]

Functional property	Parameter	*C. cathartica*	*C. maritima*
Protein solubility (%)	pH	10 (4)	10 (4)
Oil-absorption capacity (ml/g)		1.43	1.53
Water-absorption capacity (ml/g)	Ionic strength	0.2 (1)	0.1 (1)
Least gelation concentration (%)	Ionic strength	0.1 (1)	0.1 (1)
	pH	4, 7 (2, 10)	4 (2, 10)
	Carbohydrate	Potato starch (maltose)	Potato starch (lactose, maltose, sucrose)
Emulsifying activity (%)	Concentration	2 (10)	2 (10)
	Ionic strength	0.4 (1)	0.4 (0.8, 1)
	pH	10 (4)	10 (4)
Emulsifying stability (%)	Concentration	2 (10)	2 (10)
	Ionic strength	0.4 (1)	0.4 (1)
	pH	10 (4)	10 (4)
Foaming capacity (%)	Concentration	6 (2)	6 (2)
	Ionic strength	0.4 (0.1, 1)	0.4 (0.1)
	pH	10 (4)	10 (4)
Foaming stability (%)	Concentration	2,8 (10)	6 (2)
	Ionic strength	0.4 (1)	0.2 (1)
	pH	10 (4)	10 (4)

[a]Seena and Sridhar[60].

Table 9. Cooking properties of cotyledons of *Canavalia* species of coastal sand dunes and mangroves[a]

Property	*C. cathartica*	*C. maritima*
Bulk density (g/ml)	0.48	0.46
Minimum cooking time (min)	34	29
Water uptake ratio	2.1	2.22
Elongation ratio	1.17	1.33
Gruel solid loss (%)	13.33	11.76
L/*B* ratio	1.73	1.17

[a]Seena and Sridhar[60].

nols) cannot be eliminated easily by simple soaking and thermal processes, but need some alternate approaches (e.g. germination and fermentation). A few ANFs such as total phenolics, trypsin inhibitors, tannins and hemagglutinins of *Canavalia* seeds have been assessed in our laboratory. Many other ANFs like saponins, phytates, protease inhibitors, canaline, canavanine and canatoxin are reported in the seeds of *Canavalia* species[22]. Tannins and trypsin inhibitors were absent, while total phenolics were insignificant in *C. cathartica* and *C. maritime*. Seeds offer nutritional advantage (see Table 10). Concanavalin A (Con A) like lectin was found to be the most potent among the ANFs studied. Thermal treatments are known to decrease the extent of hemagglutinin activity. Roasting and cooking of *Canavalia* seeds partially diminished the hemagglutinin activity. Interestingly, the hemagglutinin activity of processed seeds employing human blood group O was slightly higher than the A and B groups. Hemagglutinins bind to the mucosal glycolipids of the intestine, which inhibit the activity of the brush border enzymes, paralyse immune functions, protein metabolism and hormonal regulation and interfere with enterobacterial adherence[23–26].

Table 10. Antinutritional components of seed flour of *Canavalia* species of coastal sand dunes and mangroves

Component	Raw	Roasted	Cooked
C. cathartica[a]			
Total phenolics (%)	1.42–1.5	1.44–1.53	0.9–1.29
Tannins	NP	NP	NP
Trypsin inhibition activity	NP	NP	NP
Phytohemagglutinin activity			
Rabbit RBC	+++	+	+
Human RBC (A)	+++	+	+
Human RBC (B)	+++	++	++
Human RBC (O)	+++	+	+
C. maritima[b]			
Total phenolics (%)	1.37–1.4	1.42	1.1
Tannins	NP	NP	NP
Trypsin inhibition activity	NP	NP	NP
Phytohemagglutinin activity			
Rabbit RBC	+++	++	++

[a]Seena and Sridhar[8]; Arun *et al.*[15]; Seena *et al.*[17,20]. [b]Arun *et al*[15]; Seena *et al.*[18,19].

NP, Not present; +, RBC showed clumpy patches; ++, Grainy; +++, Clumped strongly.

Bioavailability of proteins

The quality and bioavailability of a protein cannot be understood only by biochemical analysis. It has to be strongly supported by growth and nitrogen balance studies. Protein nutritional quality is determined by important features such as EAA composition, digestibility and amino acid requirements of the experimental animal consuming it. The growth and nitrogen balance studies conducted in our laboratory provide the baseline data for raw, roasted and cooked seeds of *C. cathartica* and *C. maritima*

Table 11. Growth and nitrogen balance studies of *Canavalia* seeds of coastal sand dunes and mangroves

	C. cathartica[a]			*C. maritima*[b]		
Assay	Raw	Roasted	Cooked	Raw	Roasted	Cooked
Growth studies						
FER	0.014	0.05	0.073	0.01	0.04	0.07
PER	0.09	0.47	0.77	0.1	0.38	0.48
NPR	1.07	1.32	1.43	0.99	1.2	1.34
PRE	17.12	21.12	22.88	15.84	20.48	21.09
Nitrogen balance studies						
TD (%)	49.68	53.48	56.01	42.26	51.29	53.71
BV (%)	40.48	46.68	48.31	37.55	43.34	47.83
NPU (%)	20.1	24.97	27.06	16.88	22.23	25.72

[a]Seena and Sridhar[8], Seena *et al.*[20]. [b]Seena *et al.*[18,19].

Table 12. Optimum growth conditions of rhizobial isolates of *Canavalia* species of coastal sand dunes[a]

Optimum growth conditions	*C. cathartica*	*C. maritima*
Temperature (°C)	35	30–35
Salinity (% NaCl)	2.5	1–2.5
pH	5–5.5	5.5–7.5

[a]Arun and Sridhar[61].

(Table 11). All the biological indices analysed for the raw proteins of *Canavalia* seeds were significantly different with casein-fed rats. Bioavailability studies proved that the pressure-cooked seeds have better biological indices than roasted seeds. Food efficiency ratio (FER), net protein retention (NPR), protein retention efficiency (PRE) and biological value (BV) of cooked and roasted seeds of *C. maritima* were significantly different, so also all the biological indices except for NPR, PRE, BV and net protein utilization (NPU) of roasted and pressure-cooked seeds of *C. cathartica*. Although the raw seeds contain appreciable quantity of proteins and EAA, the quality of the protein was poor mainly due to the presence of ANFs. Slight improvement in the biological indices of the thermally treated seeds fed to rats indicates the method employed (roasting and pressure-cooking) was effective only in partial detoxification of ANFs. A better understanding of the various ANFs is necessary to develop appropriate processing methods to eliminate specific ANFs of *Canavalia* seeds. The gaps with regard to the occurrence and extent of ANFs in *Canavalia* seeds need to be filled for maximizing utility as food.

Canavlia and microbes

C. cathartica and *C. maritima* are stress-tolerant legumes on CSDs and mangroves providing an excellent platform to understand the interaction and adaptation of microbes to extreme environmental conditions. Distribution of legumes on CSDs is governed mainly by the association of rhizobia and arbuscular mycorrhizal (AM). Our research team investigated the association of rhizobia, pattern of colonization of AM fungi and endophytic fungi with CSD *Canavalia* spp. Intense studies on rhizobia, mycorrhizae and endophytic fungi of mangroves are yet to be initiated.

Rhizobia

Tropical soils are known for their deficiency in nitrogen under high temperature and acidic stress, which demands stress-tolerant microorganisms for precise agricultural development[27]. Rhizobia are the microaerophilic, Gram-negative, motile symbionts of legumes that cause root nodulation to fix atmospheric nitrogen. In addition to nodal roots, the CSD *Canavalia* produce intra-nodal roots with profuse nodulation (Figure 1*f*), which has been attributed as an important trait desired for an edible or cover crop legume. Our team isolated rhizobia from CSD *Canavalia*, which are stress-tolerants (temperature, salinity and pH) and some are phosphate-solubilizers. Based on the 16s rRNA analysis, rhizobia were isolated from *Canavalia* belonging to *Rhizobium etli*, *R. leguminosarum*, *R. massiliae* and *R. tropici* (Arun, A. B. and Sridhar, K. R.; unpublished results). They showed elevated growth at 30–40°C (Table 12). Salt-tolerance capacity of rhizobia is known to be more than that of the host plant species[28]. Rhizobial isolates of *Canavalia* showed maximum growth at 1–2.5% salinity and also withstood up to 4.5% salinity. Nitrogen-fixing bacteria (*Sinorhizobium*) isolated from root nodules of *C. maritima* in Southern Taiwan are also efficient halotolerants (3–3.5% w/v NaCl)[29]. There are fair chances that these indigenous rhizobia grow above 4.5% salinity as it was the maximum salinity tested in our laboratory. The CSD rhizobial isolates also tolerated acidic pH (pH 5; Table 12). Stress-tolerant rhizobia are desirable for further selection and improvement of the strain and other commercial applications. Extremophilic rhizobia tolerant to temperature, salt and acid stress might be useful for wasteland rehabilitation and reclamation.

Table 13. Efficiency of rhizobial isolates of *Canavalia* species of coastal sand dunes on food legumes[a]

Legume	Increase in biomass		Nodule	Nodule
	Shoot (%)	Root (%)	(mg/plant)	(number/plant)
C. cathartica				
Macrotyloma uniflorum (horse gram)	181–638	193–676	4–5	5.2–6.4
Vigna mungo (black gram)	125–380	144–258	5–7	1.8–2.4
V. radiata (green gram)	283–727	377–527	4–5	1.4–19
V. unguiculata (cowpea)	148–1444	91–285	8–19	47–52
C. maritima				
M. uniflorum	547–1257	676–1641	3–6	7.2–12.2
V. mungo	122–609	249–472	3–7	9.6–10.2
V. radiata	188–1119	209–2156	1–4	1.6–3.2
V. unguiculata	136–745	235–998	6–18	39–91

[a]Arun and Sridhar[30].

Table 14. Per cent sole-carbon source utilization (BIOLOG GN2 plates) by rhizobia isolated from *Canavalia* species of coastal sand dunes[a]

Sugar	*C. cathartica* and *C. maritima*
Total sugars	94.7–100
Guilds	
Polymers	100
Carbohydrates	92.9–100
Carboxylic acid	91.7–100
Amides and amines	100
Amino acids	95–100
Miscellaneous[b]	91.7–100

[a]Sridhar *et al.*[62].
[b]Esters, brominated chemical, aromatic chemicals, alcohols and phosphorylated chemicals.

Phosphate solubilizaton index of rhizobia of *Canavalia* species ranged between 2 and 1.46, and this could improve the soluble phosphorus supply to the plants[30].

Rhizobial isolates of *Canavalia* were tested for symbiotic performance on cross-inoculating to edible legumes (*Vigna unguiculata*, *V. radiata*, *V. mungo* and *Macrotyloma uniflorum*)[30]. Table 13 gives the per cent increase in legume biomass versus control plants. These fast-growing wild rhizobial isolates did not project species specificity and were also successful in inducing early flowering. The rhizobia are functionally diverse as they utilize a variety of sole-carbon sources (Table 14). The symbiotic performance of rhizobia of *Canavalia* species is worth exploring further through field trials. Stress-tolerant *Canavalia* species being nitrogen fixers with rhizobia in extreme habitats may serve as efficient cover crops, mixed crops and mulches in coastal agricultural and plantation practices.

AM fungi

The AM fungi as obligate symbionts, invade the roots of healthy plants and facilitate the supply of minerals, particularly phosphorus. In CSDs, three distinct phases of soil aggregate formation by AM fungi have been evident: hyphae entangling the soil particles along with roots, creating favourable conditions to form microaggregates by enmeshing and binding the microaggregates to form macroaggregates[31,32]. Colonization of AM fungi helps in plant growth on CSDs by enhancing the uptake of phosphorus[33]. Increase in dune disturbance is known to diminish the AM fungal population in CSDs[34], projecting the possibilities of employing AM fungi as indicators of magnitude of dune disturbance or stability[10,34]. Root colonization, number of taxa and spores of AM fungi are higher in CSD *C. cathartica* than *C. maritima* (Table 15). The number of AM spores of *C. cathartica* and *C. maritima* ranged between 8 and 111 per 100 g rhizosphere sand. *Gigaspora albida* (10–60 spores/100 g) and *Glomus microaggregatum* (20 spores/100 g) were the major AM taxa on the CSDs[35]. *Gigaspora gigantea* and *Glomus dimorphicum* associated with *Canavalia* are known to withstand severe CSD disturbance[34] and may have special significance in agriculture. Increase in AM fungal diversity is appreciated as it improves the equilibrium and productivity of dune ecosystem, satisfying the major requirement of its stability[36].

Endophytic fungi

Endophytic fungi are inhabitants of healthy live tissues of plants and live mutualistically without causing pathological symptoms[37]. The CSD *Canavalia* were colonized by an assemblage of 46 taxa of endophytic fungi belonging to ascomycetes, zygomycetes, mitosporic fungi and sterile morphospecies (Table 16). Among these, 17 were core-group taxa as their colonization frequency was ≥ 10% in at least one of the age or tissue classes. On assessing the endophytic fungal assemblage in age and tissue classes of CSD *C. cathartica* and *C. maritima*, the highest number was recorded in the seedlings or mature plants (Figure 2) and lowest in seed segments[38] (Figure 3). Based on rarefaction indices, the highest number of fungal species was found in *C. cathartica*. However, no significant difference in colonization frequency was observed between *Canavalia* species unlike core-group fungi. The ascomycete, *Chaetomium globosum* exhibited single-species dominance in root, stem and leaf segments of *C. maritima* and root segments of *C. cathartica*. The colonization frequency of *C. globosum* was 5–12.5% in seeds and increased up to 40–64.4% in seedlings or mature plants. *C. globosum* is known to produce chaetoglobicins (cytotoxins)[39] and flavipin (nematicide)[40]. Extensive colonization of root, stem and leaf of *Canavalia* by *C. globosum* might have definite protective role against herbivores and nematodes. Endophytic *C. globosum* of *Canavalia* may also serve as a source of novel metabolites, as endophytic fungi are known for rare and interesting secondary metabolites.

Traditional knowledge

There are several direct and indirect uses of different parts of *C. cathartica* and *C. maritima* throughout the tropical regions of the world. We have recorded a few traditional uses during our survey of the coastal regions of Goa, Karnataka and Kerala, while collecting *Canavalia* germplasm for ecological, nutritional and microbiological studies.

C. cathartica as wild ancestral form of *C. gladiata*, are distributed throughout the tropical Asia and Africa[7,8,41].

Table 15. Arbuscular mycorrhizal (AM) fungal association with *C. cathartica* and *C. maritima* of two coastal sand dunes of Karnataka (spores/100 g rhizosphere sand; arranged in decreasing order)

AM fungus	*C. cathartica*[a]	*C. maritima*[b]
Someshwara		
Gigaspora albida	60	7
Glomus microaggregatum	20	0
Acaulospora spinosa	7	0
Glomus aggregatum	7	0
Glomus tortuosum	7	0
Acaulospora sp.	5	0
Scutellospora erythropa	0	3
Scutellospora gregaria	3	0
Glomus dimorphicum	0	2
Glomus deserticola	2	0
Scutellospora calospora	0	2
Padubidri		
G. albida	10	0
Gigaspora gigantea	2	3
G. tortuosum	0	5
S. erythropa	2	0
Acaulospora spinosa	2	0
Total species	9	6
Colonization (%)	65–73	36–56
Spores/100 g rhizosphere sand	16–111	8–40
Species/100 g rhizosphere sand	4–9	2–6

[a]Arun[35]. [b]Arun[35]; Kulkarni *et al.*[63].

Table 16. Total colonization frequency (%) of endophytic fungi in live tissue segments of *Canavalia cathartica* and *C. maritima* (arranged in decreasing order; *Core-group fungi, ≥ 10% in at least one of the age or tissue classes[a])

Endophytic fungus	*C. cathartica*	*C. maritima*
Ascomycetes		
*Chaetomium globosum**	26.2	47.7
Yeast sp. 2 (white)	2.3	2.3
Yeast sp. 3 (white)*	1.5	3.1
Yeast sp. 1 (pink)	0.8	0.8
Yeast sp. 4 (white)	0.8	0
Halosarpheia sp.	0	0.8
Mitosporic fungi		
Aspergillus sp. 4*	6.9	2.3
*Colletotrichum dematium**	6.9	1.5
Acremonium sp.*	6.9	0.8
*Cadophora fastigata**	4.6	3.1
*Colletotrichum lindemuthianum**	4.6	1.5
Aspergillus sp. 7*	4.6	0.8
*Fusarium solani**	3.9	0.8
Drechslera halodes	2.3	2.3
*Fusarium oxysporum**	1.5	3.1
Fusarium sp.*	1.5	3.9
Penicillium sp.	0.8	3.1
Nigrospora sphaerica	1.5	2.3
Aspergillus sp. 2	1.5	2.3
*Penicillium citrinum**	0	3.1
Coelomycete sp.*	0.8	2.3
Phoma sp.	1.5	1.5
Aspergillus sp. 3	0.8	1.5
Aspergillus sp. 8*	2.3	0
Drechslera rostrata	1.5	0.8
Phomopsis sp.	2.3	0
Alternaria longipes	0.8	0.8
Aspergillus sp. 1	0.8	0.8
Alternaria alternata	0	0.8
Aspergillus sp. 5	0	0.8
Aspergillus sp. 6	0	0.8
Codinaea sp.	0.8	0
Colletotrichum truncatum	0.8	0
Curvularia pallescens	0.8	0
Drechslera indica	0.8	0
Penicillium glabrum	0	0.8
Pestalotiopsis neglecta	0.8	0
Trichoderma harzianum	0.8	0
Trichoderma sp.	0.8	0
Zygomycetes		
Rhizopus sp.*	0	2.3
Mucor sp.	0.8	0.8
Morphospecies (sterile)		
MS 2*	5.4	6.2
MS 1*	1.5	6.5
MS 3	3.1	1.5
MS 4	0.8	0.8
MS 5	1.5	0
Number of segments assessed	65	65
Number of endophytes	39	35
Number of core-group endophytes	1	1
Number of endophytes per segment	1.6	1.5

[a]Seena and Sridhar[38].

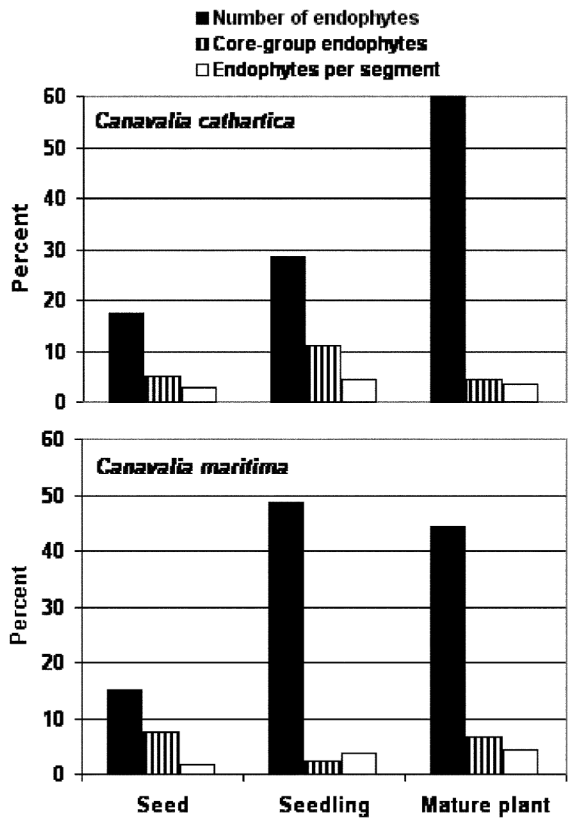

Figure 2. Occurrence of endophytic fungi on different age classes of *C. cathartica* and *C. maritima*.

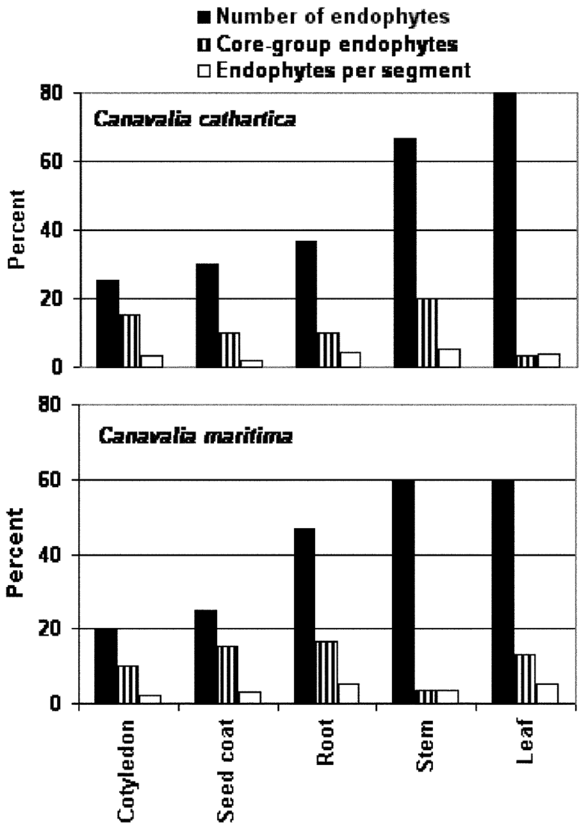

Figure 3. Occurrence of endophytic fungi on different tissue classes of *C. cathartica* and *C. maritima*.

These plants are allowed to grow deliberately in agricultural fields adjacent to estuaries of Karnataka as cover crops after harvest of main crops (e.g. paddy, sugarcane) to improve soil fertility. Coastal inhabitants of Karnataka and Kerala consume seeds and immature pods of *C. cathartica* during shortage of food. Fishermen community eat cooked immature pods occasionally after removing the fibres. Leaves of *C. cathartica* serve as food for rabbits and hares reared by coastal dwellers.

Seeds of *C. maritima* are widely consumed by humans and animals, and serve as an important source of dietary protein in West Africa and Nigeria[42]. Tender pods and seeds (boiled or roasted) are edible in northern Australia. In Karnataka coast (Padubidri and Sasihithlu), the fishermen community consumes occasionally processed tender pods as well as ripened beans. Mature beans are cooked for curry after soaking in water for long period prior to cooking. Long-term soaking followed by cooking might detoxify the beans and they may become fit for consumption. *C. maritima* leaves are used as food for hares, rabbits (Someshwara) and cattle (Thalapady, Baikampady, Padubidri, Chitrapura, and Mulki) in Karnataka coast.

C. maritima is a common biomass cover crop in arid countries and arid lands of Australia and Africa. It is also a potent cover crop and checks soil erosion in dry and sandy areas of the southwest coast of India. The roots of *C. maritima* are collected by coastal dwellers of Karnataka (Udyavara) and used in curing skin diseases. Australian aboriginals also use *C. maritima* plants for medicinal purposes. In South America, Africa and Gulf Coast of Mexico, beans of *C. maritima* are ingested or smoked with dried leaves as marijuana. An active principle, L-betonicine has been isolated from *C. maritima*, and is suspected to be similar to marijuana, but no conclusive evidences are available for it being hallucinogenic.

Future outlook

This article has provided an overview of the importance of *Canavalia* species of coastal sand dunes and mangroves as food and novel microbial source through investigations carried out at the Department of Biosciences, Mangalore University over a decade. Seeds of *Canavalia* species are a rich source of proteins, sulphur and essential amino acids, carbohydrates and energy. These under-explored landraces would be ideal plants for breeding programmes, mass cultivation, domestication and conservation. Detoxification studies conducted have been successful in partial elimination of antinutritional compounds. Concanavalin A (lectin) of *Canavalia* species has several applications as blood grouping substance for anti O and anti Oh (Bombay group)[43], tissue marker and immunomodulator. More information on other antinutritional factors is essential to assess the overall toxicity of *Canavalia* seeds in test animals or utilization as pharmaceutics. Alternate processing methods like extrusion cooking, fermentation and treating with consumer-friendly chemicals would favour elimination of antinutritional factors. There is a clear gap in our knowledge with respect to vitamins, sugar and dietary fibre fractions, toxins (canatoxin, canavanine, saponins and phytates) and enzymes. Information pertaining to agrobotanic features of *C. cathartica* and *C. maritima* would help in domestication of these gene pools. Among the tissues of *Canavalia* species assessed, leaves showed the highest ^{210}Po activity and opened up possibilities to employ the foliage of *Canavalia* as bioindicators of radionuclides, particularly in the coastal areas where these plants are well distributed[44]. ^{210}Po accumulation in the ripened beans (0.13–0.2 Bq/kg) and dry seeds (0.74–1.6 Bq/kg) is within the permissible limit[45], confirming that it is consumable. The coastal vegetation might depend on microbes to cope up with the extreme conditions prevailing in coastal sand dunes and mangroves. Future investigations need to address the significance of microbes such as ectomycorrhizae, diazotrophs and actinomycetes. Bioprospecting approaches of *Canavalia* species of coastal sand dunes and mangroves might yield novel metabolites and biocontrol agents.

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