Plant & Fungal Research (2022) 5(2): 63-76
https://doi.org/10.30546/2664-5297.2022.2.63

December 2022

Improvement of nutritional qualities of *Canavalia rosea* (Sw.) DC. by electron-beam irradiation

Prabhavathi Supriya
Kandikere R. Sridhar[1]
Department of Biosciences, Mangalore University, Mangalagangotri, Mangalore, Karnataka, India

Abstract: Wild legumes are ethnically valued potential nutritional sources in developing countries to combat protein-energy malnutrition. The presence of anti-nutritional traits in seeds of wild legumes is the major impediment to direct utilization, thus necessitating various methods of processing to accomplish nutritional safety. Seeds produced by *Canavalia* spp. in the coastal sand dunes of southwest India are consumed by the tribals after processing them conventionally. The present study demonstrates the consequences of electron beam (EB) irradiation of coastal sand dune C. *rosea* seeds towards selective enhancement of nutritional traits especially, the proximal qualities, minerals profile and protein bioavailability. Positive modifications in nutritional attributes at 10 kGy (standard dose) comprise a decline in crude fiber, an increase in mineral contents (phosphorus and magnesium), albumin content and albumin/globulin ratio. Other positive impacts of EB irradiation include the dosage-dependent increase of arginine, raise in the indispensable amino acids/total amino acids ratio and enhancement of digestibility of proteins. Moreover, increased protein digestibility corrected to the amino acid score (His, Ile, Leu, Lys, Thr and Val) and protein efficiency ratios were achieved at the dose of 5 kGy. Besides, selective favourable alterations in fatty acid methyl esters, functional attributes and bioactive components are the additional advantages of the EB irradiation. Even though *Canavalia* spp. grew in the coastal sand dune ecosystem, their seeds respond to EB irradiation differentially, which has been envisaged to their species-specific characteristics. The EB irradiation of seeds of *C. rosea* has several advantages such as improvement of nutritional properties, disinfestation and extension of shelf life.

Keywords: *amino acids, fatty acids, minerals, protein bioavailability, wild legume, sand dunes*

INTRODUCTION

The protein-energy malnutrition (PEM) is prevalent in various developing countries due to overdependence on diet prepared from monocarbohydrates (e.g. rice and maize), pricey animal protein as well as conventional plant protein sources [Singh et al., 2007; Bhat, Karim, 2009; Boye et al., 2010]. Recently focus is on the utilization of a huge number of least known wild plants to enhance food security [Arinathan et al., 2003; Anhwange et al., 2004; Seena, Sridhar, 2004a; Abdullahi, Abdullahi, 2005; Makhura et al., 2019]. Even though nutritionally beneficial plants have been recognized, the prospect of utilization is restricted due to a lack of awareness of their dietary composition [Baumer, 1995]. Understudied wild legumes are important in regional food production, nutritional security, nutritional benefits, agricultural development and soil fertility [Dar et al., 2012]. As the legume seeds possess a two- to three-fold increased quantity of proteins compared to the cereals [NAS, 1979], they serve as important protein-energy reservoirs to combat PEM. The wild legumes have broad distribution, adapted to adverse environmental conditions (e.g. drought, salinity and insect herbivory) and possess desired nutritional qualities [USNAS, 1975; Amubode, Fetuga, 1983; Maikhuri et al., 1991; Siddhuraju et al., 1992; Rao, 1994; Arun et al., 1999; Vadivel, Janardhanan, 2001; Seena, Sridhar, 2006; Bhat, Karim, 2009; Sridhar, Niveditha, 2014]. In addition to the nutritional attributes, the gene pool of wild legumes is also the basis of value-added bioactive compounds [Morris, 1999, 2007; Bhagya et al., 2006, 2009, 2010; Seena et al., 2007; Singh et al., 2007; Bhat, Sridhar, 2008; Bhagya, Sridhar, 2009; Sridhar, Niveditha, 2014; Shreelalitha, Sridhar, 2019].

The Indian subcontinent is bestowed with 10 biogeographic zones consisting of 25 biogeographic provinces and 400 biomes [Singh, Chaturvedi, 2017]. The long coastline of India is one among the 10 biogeographic zones, which shelters an innumerable variety of plants, animals and microbes. Mangroves and sand dunes of coastal region harbor underutilized indigenous legumes possessing versatile nutritional and agronomic significance [Rao, Meher-Homji, 1985; Rao, Suresh, 2001; Rao, Sherieff, 2002; Seena, Sridhar, 2004a;

---

[1] E-mail: kandikere@gmail.com

Received 01.07.2022; Received in revised form 23.09.2022; Accepted 28.11.2022

Sridhar, Bhagya, 2007; Bhagya et al., 2009; Bhagya, Sridhar, 2009; Kalidas, Mohan, 2012; Tresina, Mohan, 2012; Anita, Sridhar, 2019; Shreelalitha, Sridhar, 2019]. The pantropically distributed legume *C. rosea* (Sw.) DC. is also abundant on the southwest Indian coastal sand dunes, which is ranking first in the frequency of occurrence [Arun et al., 1999]. Seed burial (2-10 cm depth) in the sand is ideal for germination, while deep burial increases the forced dormancy leading to the development of seed banks [Arun et al., 2001]. This plant species has been cultivated widely in West Africa as well as Nigeria for the utilization of seeds as a dietary source of protein for livestock and humans [Abbey, Ibeh, 1987]. Owing to the presence of antinutritional constituents, these seeds do not absolutely serve as a potential source of nutrition [Arun et al., 2003; Seena, Sridhar, 2004a; Seena et al., 2005a; D'Cunha et al., 2009; Bhagya et al., 2009, 2010; Muzquiz et al., 2012]. Recently, a series of investigations were performed to assess the nutritional benefits of heat-processed seeds, split beans, germinated seeds, immature pods and *C. rosea* mature beans [Seena et al., 2005b; Bhagya et al., 2009; D'Cunha et al., 2009; Bhagya et al., 2010; Sridhar et al., 2016]. Most of these studies evaluated its proximal qualities, protein fractions, minerals, amino acids, fatty acid methyl esters (FAMEs) as well as anti-dietary components. Some studies have been carried out *in vivo* protein digestibility of untreated as well as treated seeds, split beans, ripened beans and tender pods [Seena et al., 2005b; Bhagya et al., 2009, 2010; Sridhar et al., 2016; Niveditha, Sridhar, 2017; Supriya, Sridhar, 2019b], while D'Cunha et al. [2009] studied *in vitro* protein digestibility of sprouted dry seeds. Even though processing methods were not absolutely successful in the elimination of antinutritional components, they have been decreased up to the safe or desired level of consumption. Among the above treatments, cooked germinated seeds (*C. rosea*) triggered a fair improvement in nutritional qualities [D'Cunha et al., 2009].

Irradiation using ionizing radiations (e.g. emitted by ^{60}Co or ^{137}Cs, electron beam and X-rays) is an important choice to process and preserve the seeds [Farkas, 2006]. Evaluation of nutritional composition by the impact of electron-beam irradiation (EB) is comparatively fewer than gamma irradiation [e.g. Sridhar, Bhat, 2008; Bamidele, Akanbi, 2013a,b; Osman et al., 2014;Bahrani et al., 2017; Lima et al., 2019; Supriya et al., 2019]. The machine-generated EB irradiation technique generates high-efficiency as well as high-throughput products. It has a greater rate of dose compared to gamma irradiation and the depth of penetration could be amplified through the conversion of electron beams into X-rays, besides the cost of radiation from EB sources is fairly low [Cleland, 1983]. In addition to decontamination, irradiation improves the quality as well as the shelf life of fresh agricultural products (e.g. rhizomes, spices and seeds) [Farkas, 1998; Hayashi, 1998; Bhat, Sridhar, 2007, 2008; Bhat et al., 2008, 2010; Supriya et al., 2014, 2019]. Anti-dietary principles of cereal and legume seeds will be knocked off or reduced by irradiation or irradiation plus other methods of processes [Farag, 1989; Sattar et al., 1990; Siddhuraju et al., 2002; Bhat, Sridhar, 2009; Supriya, Sridhar, 2019a]. The gamma as well as EB irradiations have fairly enhanced the seed nutritive value of Mucuna Adans, Phaseolus L., Sesbania Scop. and Vigna Savi.[Siddhuraju et al., 2002; Bhat, Sridhar, 2007, 2008; Bhat et al., 2008, 2009; Lima et al., 2019]. The major objectives of this chapter are to illustrate the improvement of nutritional traits of seeds of *C. rosea* on exposure to different doses of EB irradiation and comparison with similar earlier studies.

MATERIAL AND METHODS

Seed source and process. The wild legume *C. rosea* (beach bean) grown on the coastal sand dunes of southwest India is the most dominant horizontal creeper that supports sand binding, enriches the soil fertility with rhizobia and fungi (e.g. endophytic and mycorrhizal) [Seena, Sridhar, 2004b; Sridhar et al., 2005; D'Cunha, Sridhar, 2009]. Usually, it spreads on the hind- and mid-dunes in pure patches (Fig.1.1a) as well as in association with Ipomoea pes-caprae. It produces pink flowers during the rainy season (August-September) followed by ripened pods post-rainy season (October-January) and produces dry pods during summer (February-May). The dehiscing dry pods are composed of an average of 4-5 seeds (range 1-8) (Fig. 1.1b). The seeds are usually light-brown color, while occasionally dark-brown color (Fig. 1.1c-f). The light-brown shaded seeds have prominent longitudinal bands. The dry seeds collected from the dehiscing pods are large, heavy, sub-cylindrical and possess short hilum. The cotyledon of dry seeds weighs 66% and the seed coat 34% (Tab. 1). Such physical features facilitate the harvesting, handling, sorting and processing of seeds. Owing to the strong dormancy of seeds, tolerance to salinity, alkaline, pH and sand burial develop seed banks in the coastal sand dunes [Arun et al., 2001].

The dry seeds were separated from the pods of *C. rosea* harvested from five coastal sand dune locations during summer (February-April) (12º47′ N, 74º52′ E). The

Figure 1. *Canavalia rosea* growing on the coastal sand dunes (a), dried pods (b), light-brown seeds (c), dark-brown seeds (d, e) and striated light-brown seeds (f).

Table 1. Properties of *Canavalia roseaa* seeds (n=25; mean-SD).

Dimension:	
Length, *l* (cm)	1.45±0.23
Breadth, *b* (cm)	0.96±0.05
Thickness, *t* (cm)	0.80±0.09
l/b ratio	1.51±0.23
Dry mass:	
Dry weight/seed (g)	0.50±0.10
Dry weight of cotyledons/seed (g)	0.33±0.07
Dry weight of seed coat/seed (g)	0.17± 0.02

samples collected were separately subjected to sun-drying for up to 2-3 days or till the moisture content attains <10%. Seed lot (~20-25 g) gathered from each location was grouped in polyethylene bags measuring 6×6 cm to render irradiation (doses: 2.5, 5.0, 10.0 and 15.0 kGy) at laboratory temperature (25±2°C) by the Microtron facility (Microtron Centre, Mangalore University, India). More particulars of exposure to EB irradiation include 2 kGy per min dose rate; 8 MeV beam energy (106 or 1,000 keV; 1eV energy obtained by an electron during crossing a potential difference of 1V); 30 mA beam current and at a 30 cm distance from the sample [Siddappa et al., 1999]. The absorbed dose was assessed by a current integrator calibrated with Fricke [Fricke, Hart, 1966] as well as chemical dosimeters [Gupta et al., 1999]. Seeds in plastic bags that were not exponed to EB irradiation served as a control. Cotyledons without seed coats from control as well as irradiated seeds were milled (Wiley Mill; mesh size # 30) and saved in air-tight glass bottles for analysis.

Nutritional parameters. Proximal qualities (moisture, total lipids, ash and crude fiber) and minerals were assessed as per AOAC [1995] protocols. Protein, carbohydrates and calorific values were determined based on standard methodology [Humphries, 1956; Müller, Tobin, 1980; Ekanayake et al., 1999]. Protein fractions and amino acid composition were evaluated by adopting appropriate methods [Humphries, 1956; Gheyasuddin et al., 1970; Brand, 1994; Hofmann et al., 1997, 2003]. Protein digestibility (*in vitro*), a score of the essential amino acids (EAA), protein digestibility corrected to essential amino acid score (PDCAAS) and the ratio of protein efficiency (PER) were determined [Akeson, Stahmann, 1964; Alsmeyer et al., 1974; FAO-WHO, 1991]. The difference among parameters between the unirradiated (0 kGy) and irradiated (2.5, 5.0, 10.0, 15.0 kGy) samples were assessed by ANOVA (one-way) (ORIGEN Pro 8.1).

RESULTS AND DISCUSSION

Proximal and mineral composition. A dose-dependent decrease in moisture content was seen in irradiated seeds (8.4 vs. 5.1%) (Tab. 2). In spite of crude protein content brought down in seeds on irradiation, it was significant only at the dose of 15 kGy (32.1 vs. 26%; $p < 0.05$), while the total lipid (except for 10 kGy; $p < 0.05$), ash and calorific value were not altered by irradiation. The crude fiber content decreased in seeds at the doses of 10 kGy ($p<0.01$) as well as 15 kGy ($p<0.05$), while the content of carbohydrates shoot up in irradiated seeds at 15 kGy ($p < 0.05$).

Calcium, sodium and zinc composition did not significantly vary in all irradiated doses (Tab. 3). Potassium content increased only at 5 kGy ($p<0.05$). Phosphorus content raised at doses 2.5, 10 and 15 kGy ($p<0.001$), while it decreased at 5 kGy ($p<0.001$). At only 5 and 10 kGy, the magnesium content increased ($p<0.001$) with a decrease in the rest of the doses ($p<0.001$), while contents of iron and copper decreased at 15 kGy ($p<0.05$). Only at 15 kGy, manganese content decreased ($p<0.05$), while selenium content increased in all doses ($p<0.001$). The ratios of Na/K and C/P attained <1 in control as well as irradiated seeds.

Protein fractions and amino acids. An increase was seen in albumin content at 10 kGy ($p<0.01$), while a decrease at 15 kGy ($p<0.001$) (Tab. 4). Increased globulin content was seen at the dose of 2.5 kGy ($p<0.05$).

The decrease in prolamin content was dose-dependent up to 10 kGy ($p < 0.05$) with a slight increase

Table 2. Proximal components of control and irradiated seeds of *Canavalia rosea* on a dry mass basis (n=5; mean±SD)

	Control	Irradiated (kGy)			
		2.5	5.0	10.0	15.0
Moisture (%)	8.38±0.09	6.05±0.53**	5.61±0.36***	5.18±0.81***	5.10±0.06***
Crude protein (g/100 g)	32.11±2.8	27.73±1.01	27.73±1.82	28.02±0.88	25.98±1.34*
Total lipids (g/100 g)	2.72±0.43	3.62±0.47	3.67±0.74	2.99±0.60*	4.40±1.51
Crude fiber (g/100 g)	1.42±0.26	0.92±0.02	1.81±0.08	0.63±0.19**	0.76±0.27*
Ash (g/100 g)	3.22±0.14	3.51±0.28	3.48±0.15	3.36±0.24	3.43±0.15
Carbohydrates (g/100 g)	60.54±2.71	64.34±1.20	63.31±1.94	65.11±0.55	65.44±0.67*
Calorific value (kJ/100 g)	1650±12	1674±9	1659±19	1668±17	1693±30

Note: Figures across the columns indicated with asterisk significantly differ, One-way ANOVA: *, p<0.05, **, p<0.01, ***, p<0.001).

Table 3. Mineral contents of control and irradiated seeds of *Canavalia rosea* (mg/100 g dry weight) (n=5; mean±SD)

	Control	Irradiated (kGy)				Recommended Patterns[a, b]
		2.5	5.0	10.0	15.0	
Sodium	1.26±0.03	1.01±0.03	1.07±0.01	1.12±0.01	0.99±0.01	120–200[a]
Potassium	993±0.20	1023±0.10	1049±0.43*	1004±0.02	1039±0.29	500–700[a]
Calcium	143.75±0.62	152.74±0.33	146.17±0.18	141.30±0.18	142.54±0.19	600[a]
Phosphorus	187.27±0.20	200.95±0.08**	174.02±0.27**	209.63±0.42**	196.26±0.13**	500[a]
Magnesium	164.86±0.08	154.29±0.08**	168.72±0.04**	173.34±0.07**	154.47±0.06**	60[a]
Iron	20.28±0.01	16.07±0.01	16.12±0.01	15.22±0.001	14.57±0.001*	10[a]
Copper	1.26±0.03	1.01±0.03	1.07±0.01	1.12±0.01	0.99±0.01*	0.6–0.7[a]
Zinc	8.29±0.01	4.52±0.05	4.55±0.01	4.56±0.01	4.68±0.01	5.0[a]
Manganese	1.58±0.01	1.37±0.01	1.47±0.01	1.51±0.02	1.30±0.05*	0.3–1.0[a]
Selenium	0.13±0.01	0.78±0.01**	0.40±0.01**	0.86±0.002**	0.59±0.01**	0.05-0.2[b]
Na/K ratio	0.001	0.001	0.001	0.001	0.001	–
Ca/P ratio	0.77	0.76	0.84	0.67	0.73	–

Note: Figures across the columns with asterisks significantly differ, One-way ANOVA: *, p<0.05, **, p<0.001) (a, NRC-NAS [1989] pattern for infants b, Pennington and Young [1990].

Table 4. Protein fractions of control and irradiated seeds of *Canavalia rosea* (g/100 g) (n=5; mean ±SD)

	Control	Irradiated (kGy)			
		2.5	5.0	10.0	15.0
Albumin	10.01±0.59	7.23±0.01	8.06±0.31	15.01±1.01**	4.58±0.01***
Globulin	1.57±0.01	5.43±0.01*	2.51±0.37	2.10±0.48	2.29±0.01
Prolamin	8.61±0.01	2.41±0.48*	1.00±0.42*	0.90±0.01*	1.15±0.01*
Glutelin	4.43±0.39	1.81±0.01	8.01±1.29**	0.90±0.01	6.49±0.50**
A/G ratio[a]	6.38	1.33	3.21	7.15	2.0

Note: Figures across the columns with asterisks significantly differ, One-way ANOVA: *, p<0.05, **, p<0.01, ***, p<0.001 (a, Albumin/Globulin ratio)

at 15 kGy (p<0.01). The glutelin content showed an increase at doses of 10 kGy and 15 kGy (p<0.001). The ratio of albumin/globulin increased at 10 kGy.

Among the indispensable amino acids, a significant decrease was found in cystine, methionine, phenylalanine and tyrosine by irradiation (p<0.05), while the rest did not show significant variation (Tab. 5). However, the seeds were devoid of the indispensable amino acid tryptophan. In unirradiated seeds, the aspartic acid was highest followed by glutamic acid among the dispensable amino acids. These amino acids along with others (serine, proline, glycine, cystine, methionine, tyrosine and phenylalanine) decreased at the irradiation doses of 2.5 kGy, 5 kGy ($p<0.05$), while the increase was dose-dependent in arginine ($p<0.001$). An increased ratio of EAA/TAA was seen at the doses of 2.5 kGy and 5 kGy.

Table 5. Amino acid composition of control and irradiated seeds of *Canavalia rosea* compared with other foodstuffs (g/100 g protein; n=5, mean±SD)

	Control	Irradiated (kGy)		Soybean^{a}	Wheat^{b}	FAO-WHO^{c}
		2.5	5.0			
Indispensable amino acids:						
Threonine	3.96±0.12	3.70±0.13	3.89±0.25	3.76	2.2-3	3.4
Valine	4.14±0.32	3.76±0.13	3.94±0.25	4.59	3.7-4.5	3.5
Cystine	3.10±0.16	0.56±0.02*	0.58±0.04*	1.70	1.6-2.6	
Methionine	1.05±0.11	0.82±0.03*	0.78±0.05**	1.22	0.9-1.5	2.5^{d}
Isoleucine	3.18±0.23	3.04±0.11	3.11±0.20	4.62	3.4-4.1	2.8
Leucine	6.34±0.15	6.19±0.22	6.33±0.41	7.72	6.5-7.2	6.6
Tyrosine	3.26±0.25	2.40±0.09***	2.50±0.16**	1.24	1.8-3.2	
Phenylalanine	5.19±0.23	3.45±0.12***	3.57±0.23***	4.84	4.5-4.9	6.3^{e}
Tryptophan	ND	ND	ND	3.39	0.7-1	1.1
Lysine	5.18±0.28	4.77±0.17	4.92±0.32	6.08	1.8-2.4	5.8
Histidine	2.41±0.13	2.15±0.08	2.37±0.15	2.50	1.9-2.6	1.9
Dispensable amino acids:						
Glutamic acid	13.54±0.63	11.10±0.40**	11.44±0.73*	16.90	35.5-36.9	
Aspartic acid	14.3±0.40	9.95±0.36***	10.50±0.67***	11.30	3.7-4.2	
Serine	4.87±0.20	4.19±0.15**	4.36±0.28*	5.67	3.7-4.8	
Proline	3.04±0.12	2.68±0.10**	2.36±0.15***	4.86	11.4-11.7	
Alanine	4.14±0.26	3.95±0.14	4.09±0.26	4.23	2.8-3	
Glycine	4.06±0.13	3.22±0.12**	3.32±0.21**	4.01	3.2-3.5	
Arginine	3.11±0.15	4.26±0.15***	4.57±0.29***	7.13	3.1-3.8	
EAA/TAA ratio^{f}	0.408	0.431	0.432			

Note: Figures across the columns with asterisks significantly differ, One-way ANOVA: *, $p<0.05$, **, $p<0.01$, ***, $p<0.001$) (a, Bau et al. [1994]; b, USDA [1999]; c, FAO-WHO [1991]; d, Cystine+Methionine e, Tyrosine+Phenylalanine; f, Essential amino acid/Total amino acid; ND, Not detectable.

The IVPD decreased at 2.5 kGy ($p<0.05$) with an increase at 5 kGy ($p<0.01$) (Tab. 6). EAA scores of histidine, isoleucine, threonine and valine were adequate in control as well as irradiated seeds. EAA score pertaining to leucine and lysine in control seeds was below 100 and marginally decreased on irradiation. EAA scores of tyrosine + phenylalanine and cystine + methionine were substantially decreased on irradiation. The PDCAAS of all EAA decreased at 2.5 kGy, while the increase was seen in histidine, isoleucine, leucine, lysine, threonine and valine at 5 kGy. As seen in the EAA score, the PDCAAS of cystine + methionine and tyrosine + phenylalanine were drastically decreased on irradiation. Changes were marginal in PER1 and PER2 between control as well as irradiated seeds, while the PER3 increased substantially a the doses of 2.5 kGy and 5 kGy.

Proximal features. The net radiochemical changes of the seeds during irradiation are controlled by the initial moisture level [Wilkinson, Gould, 1998]. The moisture content of control seeds of *C. rosea* was generally low and it showed a dose-dependent decrease by irradiation. Warchalewski et al. [1998] documented that decreased moisture content is owing to the duration of irradiation dose received by the seeds. The content of crude protein in unirradiated seeds is comparable to other edible legumes [Reddy et al., 1984; Vishwanathan et al., 2001; Arinathan et al., 2003]. But a dose-dependent decrease

Table 6. Protein digestibility (n=5; mean ±SD), essential amino acid score, protein digestibility corrected to amino acid score and protein efficiency ratio of control and irradiated *Canavalia rosea* seeds.

	Control	Irradiated (kGy)	
		2.5	5.0
IVPD (%)	53.81±1.79	51.52±2.62*	59.94±5.86**
EAA Score:			
Threonine	116.35	108.90	114.25
Valine	118.23	107.28	112.42
Cystine + Methionine	166.16	55.24	54.56
Isoleucine	113.5	108.71	111.07
Leucine	96	93.71	95.83
Tyrosine + Phenylalanine	134.10	38.15	39.60
Lysine	89.28	82.23	84.74
Histidine	126.63	112.97	124.58
PDCAAS:			
Threonine	62.61	56.10	68.48
Valine	63.62	55.27	67.39
Cystine + Methionine	89.41	28.46	32.70
Isoleucine	61.07	56.01	66.57
Leucine	51.66	48.28	57.44
Tyrosine + Phenylalanine	72.16	19.66	23.73
Lysine	48.04	42.37	50.79
Histidine	68.14	58.20	74.67
PER:			
PER_1	2.06	2.01	2.09
PER_2	2.07	2.09	2.14
PER_3	1.02	1.55	1.60

Note: Figures across the columns of IVPD with asterisk significantly differ, One-way ANOVA: *, $p<0.05$; **, $p<0.01$.

of crude protein was seen on irradiation and attained the lowest level at the dose of 15 kGy (32.1 vs. 26%; $p<0.05$). On the contrary, irradiation has increased the crude protein content of seeds of velvet bean (*Mucuna pruriens* (L.) DC.) and cowpea (*Vigna unguiculata* (L.) Walp.) [Dario, Salgado, 1994; Bhat et al., 2008]. Interestingly, the crude protein content in *C. cathartica* Thouarsn seeds grown in southwest Indian coastal sand dunes was not affected significantly by EB irradiation [Supriya et al., 2019]. Possibly such changes in seed protein content on irradiation are influenced by the type of seed and its chemical constituents. According to J.P. Maity et al. [2009], the variation of nutrient values of seeds of different plant species relies on the seed proteins. The yield of total lipid in *C. rosea* seeds is higher than in several wild legume seeds [Viano et al., 1995]. The total lipid content of irradiated *C. rosea* seeds although increased, was significant only at 10 kGy ($p<0.05$). On the contrary, in *C. cathartica* as well as *M. pruriens*, irradiation showed a dose-dependent significant increase in total lipids [Bhat et al., 2008; Supriya et al., 2019]. The crude fiber in *C. rosea* seeds significantly decreased at 10 kGy as well as 15 kGy. Such a decrease in crude fiber was also evident in *C. cathartica* seeds as well as *M. pruriens* seeds [Bhat et al., 2008; Supriya et al., 2019]. It has been predicted that radiation-induced depolymerization and delignification might be responsible for the decrease in fiber content [Sandev, Karaivanov, 1977; Campbell et al., 1987]. An appreciable decrease in the crude fiber of seeds by EB irradiation could be considered nutritionally advantageous as low crude fiber traps fewer quantities of carbohydrates and proteins [Balogun, Fetuga, 1986]. Ash content in foodstuff serves as an important index of the quality (e.g. minerals) of feed for livestock [Pomeranz, Clifton, 1981]. Its content in control seeds of *C. rosea* did not significantly change on irradiation as seen in *C. cathartica* and *M. pruriens* [Bhat et al., 2008; Supriya et al., 2019], which has resulted in a lack of drastic changes in minerals composition. Carbohydrate content in *C. rosea* seeds showed a significant increase only at the high dose of irradiation (15 kGy), such dose may be required to extract the free sugars from complex polysaccharides. The energy value of *C. rosea* was not significantly altered on EB irradiation as it has no drastic impact on protein, lipid, fiber and ash contents indicating the significance of irradiation to restore the dietary quality of seeds. However, the calorific value in *C. cathartica* and *M. pruriens* decreased on irradiation [Bhat et al., 2008; Supriya et al., 2019].

Mineral constituents. There were no major alterations in the overall mineral composition among the control and irradiated seeds of *C. rosea*, which corroborates with studies on *C. cathartica* and *M. pruriens* [Bhat et al., 2008; Supriya et al., 2019]. At the 10 kGy recommended dose of EB irradiation for shelf life improvement, phosphorus, magnesium and selenium contents of *C. rosea* were significantly increased, while in *C. cathartica* only phosphorus content increased [Supriya et al., 2019], which corroborates with the earlier study on seeds of *M. pruriens* [Bhat et al., 2008]. Usually, the legume seeds are known to possess high quantities of iron, calcium, magnesium, zinc and potassium [Salunkhe et al., 1985]. In *C. rosea*, several minerals (iron, magnesium, potassium and zinc) in control as well as in irradiated seeds fulfill the recommended doses for infants as seen in *C. cathartica* [NRC-NAS, 1989; Supriya et al., 2019]. Phosphorus content showed a dose-dependent increase on irradiation of *C. rosea* seeds, but it was almost the opposite in *C. cathartica* [Supriya et al., 2019]. According to Talwar et al. [1989], iron, zinc, manganese and selenium serve as potent antioxidants. These minerals in seeds of *C. rosea* irradiated at 15 kGy are higher or comparable to the NRC-NAS [1989] standards. Magnesium, zinc and selenium are known to combat several disorders (e.g. cardiomyopathy, degradation of muscles and immunity dysfunction and congenital disorders) [Chaturvedi et al., 2004]. Except for selenium, the rest of these minerals in control and irradiated seeds are higher or comparable with NRC-NAS [1989] stipulated standards. Selenium content in control and irradiated seeds was higher compared to the recommended dose [Pennington and Young, 1990]. Similar to *C. cathartica* seeds [Supriya et al., 2019], the control and irradiated seeds of *C. rosea* showed desired ratio of Na/K (<1), such a ratio according to Yusuf et al. [2007] combats increased blood pressure. The Ca/P ratio (<1) in *C. rosea* is below the favourable limit (>1) similar to *C. cathartica* seeds [Supriya et al., 2019), the ratio <1 fails to prevent loss of calcium in urine as well as restoration in bones [Shills, Young, 1988].

Protein bioavailability. Although albumin content showed a significant decrease at 15 kGy in *C. rosea* seeds, there was a severe loss of sulfur amino acids at 2.5 and 5 kGy, which are the important components in albumin. Albumin content in *C. cathartica* also showed a dose-dependent decrease with the loss of sulfur amino acids [Supriya et al., 2019]. The globulin content significantly increased at 2.5 kGy in *C. rosea*, which likely resulted in no major changes in hemagglutinin activity on human erythrocytes (A, B and O) corroborating the results in seeds of *C. cathartica* [Supriya et al., 2019]. The A/G ratio reached the highest at the dose of 10 kGy in *C. rosea*, which reflects desired high albumin and low globulin contents, while in *C. cathartica* seeds this ratio reached the highest at 5 kGy [Supriya et al., 2019].

In unirradiated seeds of *C. rosea*, among 17 amino acids, 10 showed significant changes on irradiation. Except for arginine, irradiation decreased the rest of the amino acids. On the contrary, in *C. cathartica* seeds irradiation significantly decreased aspartic acid, lysine, methionine and proline [Supirya et al., 2019]. In *M. pruriens* seeds, aspartic acid showed a dose-depended decrease [Bhat et al., 2008]. The impact of ionizing radiation on amino acids in seeds depends on different factors like the vulnerability of the irradiated material, the nature of tissue and methods of processing [Siddhuraju et al., 2002]. The quantity of several EAA in *C. rosea* is corroborated with or higher than that of soybean or wheat or FAO-WHO stipulated standard as seen in *C. cathartica* [FAO-WHO, 1991; Bau et al., 1994; USDA, 1999; Supriya et al., 2019]. Seeds of legumes are usually low in sulphur-containing amino acids with high in lysine content [Norton et al., 1985; Jansman, 1996]. The lysine content in unirradiated seeds of *C. rosea* was higher compared to wheat [USDA, 1999]. Sulfur amino acids are well known for susceptibility to irradiation [Lee, 1962; Khattak, Kloppenstein, 1989], thus a significant decrease in cystine + methionine content in *C. rosea* is reasonable, such a trend was also seen in *C. cathartica* seeds [Supriya et al., 2019]. Increased ratio of EAA/TAA in irradiated seeds of *C. rosea* compared to unirradiated seeds is advantageous and it is similar to *C. cathartica* seeds [Supriya et al., 2019].

Similar to seeds of *C. cathartica* [Supriya et al., 2019], the IVPD of *C. rosea* seeds significantly decrease at 2.5 kGy, whereas it showed an increase at 5 kGy. A decrease in IVPD at 2.5kGy may be due to the non-susceptibility of unfolded proteins with cross-links and aggregates. However, seeds of *M. pruriens* showed a dose-dependent increase in IVPD up to 15 kGy [Bhat et al., 2008]. Thus, such differences are dependent on the variety of seeds subjected to irradiation. The IVPD on irradiation increased in some cereal as well as legume seeds [Nene et al., 1975; Reddy et al., 1979]. In *C. rosea* seeds decrease in IVPD at 2.5 kGy reflected decreased EAA score as well as PDCAAS. However, an increase of IVPD at 5 kGy showed the differential results in EAA score and PDCAAS. The EAA score of histidine, isoleucine, leucine, lysine, threonine and valine was not altered at 5 kGy. But irradiation at 5 kGy resulted in a drastic decrease in the EAA score of sulfur amino acids and tyrosine + phenylalanine. The trend of EAA score as well as PDCAAS of C. *rosea* seeds was almost similar to those of C. cathartica seeds [Supriya et al., 2019].

No major changes occurred in PER1 and PER2 in control seeds of *C. rosea* on irradiation (2.5 kGy and 5 kGy) depicting the superior quality of protein (>2) [Friedman, 1996]. Although the PER3 was poor in control seeds of *C. rosea* (<1.5), the ratio increased on irradiation at 2.5 kGy and 5 kGy to moderate level (>1.5) [Friedman, 1996]. The PER pattern of *C. rosea* seeds almost corroborates with seeds of *C. cathartica* [Supriya et al., 2019].

Fatty acids, functional and bioactive properties. The EB irradiation resulted in specific changes in FAMEs in *C. cathartica* seeds and *C. rosea* seeds [Supriya et al., 2012]. Irradiation at doses of 5 kGy as well as 10 kGy facilitates high extraction of total lipids in *C. rosea*as well as *C. cathartica*, respectively. Interestingly, the doses of 2.5 kGy as well as 5 kGy, served as hormetic doses to increase fatty acids content. Unsaturated fatty acids breakdown is beneficial as it lowers the danger of cardiovascular diseases in humans [Omode et al., 1995; Ezeagu et al., 1998]. The EB irradiation is also responsible for favourable alteration of fatty acid ratios in *Canavalia* seeds desirable for human nutrition

Functional traits of legume seed flours are known to depend on the proximal qualities. Improvement of several functional attributes (e.g. protein solubility, emulsion stability and foam capacity) was seen in *C. rosea* seeds on exposure to 5 kGy, while such properties differed in *C. cathartica* seeds [Supriya et al., 2018]. Selective changes in bioactive components were also seen in *C. cathartica* and *C. rosea* seeds exposed to EB irradiation [Supriya, Sridhar, 2019]. Application of varied doses of EB irradiation facilitates maneuvering the bioactive principles of *Canavalia* seeds to the threshold level suitable for human consumption to serve as nutraceuticals

CONCLUSIONS

At a standard dose of EB irradiation (10 kGy), several favourable changes have been documented in *C. rosea* seeds (increase in total lipids; decrease in crude fiber; increase in phosphorus and magnesium contents; increased A/G ratio). Other positive results on irradiation comprise increased arginine content; increased IVPD; marginal changes in EAA score, PDCAAS and PER. Besides, the EB irradiation resulted in favourable changes in fatty acids profile, functional properties and bioactive principles. Although two legumes *C. cathartica* as well as *C. rosea* grown in the same sand dune ecosystem of southwest India, differences in seed nutritional qualities in control and irradiated seeds could be depicted due to species-specific traits rather than edaphic or climatic variations. The major benefits of EB irradiation on *Canavalia* seeds include improvement of nutraceutical properties (nutritional, functional and bioactive), disinfestation and enhancement of shelf life.

ACKNOWLEDGEMENTS

Authors acknowledge the Bhabha Atomic Research Centre, Mumbai for the award of a research fellowship, and the University Grants Commission, New Delhi for the award of the UGC-BSR Faculty Fellowship.

REFERENCES

Abbey B.W., Ibeh G.O. (1987) Functional properties of raw and heat processed brown bean (*Canavalia rosea* DC.) flour. J. Food Sci., 52: 406–408.

Abdullahi S.A., Abdullahi G.M. (2005) Effect of boiling on the proximate, anti-nutrients and amino acid composition of raw *Delonix regia* seeds. Nigerian Food J., 23: 128–132.

Akeson W.R., Stahmann M.A. (1964) A pepsin pancreatin digest index of protein quality. J. Nutr., 83: 257–261.

Alsmeyer R.H., Cunningham A.E., Happich M.L. (1974) Equations predict PER from amino acid analysis. Food Technol., 28: 34–38.

Amubod F.O., Fetuga B.L. (1983) Proximate composition and chemical assay of the methionine, lysine and, tryptophan concentrations of some forest tree seeds. Food Chem., 12: 67–72.

Anhwang B.A., Ajibol V.O., Oniy S.J. (2004) Chemical Studies of the seeds of *Moringa oleifera* (Lam.) and

Deuterium microcarpum (Guill and Sperr). J. Biol. Sci., 4: 711–715.

Anita D.D., Sridhar K.R. (2019) Nutritional and bioactive profiles of sprouted seeds of mangrove wild legume *Canavalia cathartica*. In: Plants and human health, Volume # 2 - Phytochemistry and Molecular Aspects. Öztürk M., Hakeem K.R. (Eds.), Springer Nature, pp. 287–301.

AOAC. (1995) Official methods of analysis, 16th Edition. Association of Official Analytical Chemists, Washington, DC.

Arinathan V., Mohan V.R., De Britto A.J. (2003) Chemical composition of certain tribal pulses in South India. Int. J. Food Sci. Nutr., 54: 209–217.

Arun A.B., Beena K.R., Raviraja N.S., Sridhar K.R. (1999) Coastal sand dunes - a neglected ecosystem. Curr. Sci., 77: 19−21.

Arun A.B., Raviraja N.S., Sridhar K.R. (2001) Effect of temperature, salinity and burial on seed germination and seedling emergence of five coastal sand dune legumes. Int. J. Ecol. Environ. Sci., 27: 23–29.

Arun A.B., Sridhar K.R., Raviraja N.S., Schmidt E, Jung K. (2003) Nutritional and antinutritional components of *Canavalia* spp. seeds from the west coast sand dunes of India. Pl. Foods Hum. Nutr., 58: 1–13.

Bahrani Z., Salari S., Sari M., Fayazi J, Behgr M. (2017) Effect of radiation on chemical composition and protein quality of cottonseed meal. Anim. Sci. J., 88: 1425–1435.

Balogun A.M., Fetuga B.L. (1986) Chemical composition of some underexploited leguminous crop seeds in Nigeria. J. Agric. Food Chem., 34: 189–192.

Bamidele O.P., Akbani C.T. (2013a) Influence of gamma irradiation on the nutritional and functional properties of pigeon pea (*Cajanus cajan*) flour. Afr. J. Food Sci., 7: 265–290.

Bamidele O.P., Akbani C.T. (2013b) Effect of gamma irradiation on physicochemical properties of stored pigeon pea (*Cajanus cajan*) flour. Food Sci. Nutr., 1: 377–383.

Bau H.M., Vallaume C., Lin C.F., Evrad J, Quemener B, Nicolas J.P., Méjean L. (1994) Effect of solid state fermentation using *Rhizophus oligosporus* sp. T-3 on elimination of antinutritional substances and modification of biochemical constituents of defatted rape seed meal. J. Sci. Food Agric., 65: 315−322.

Baumer M. (1995) Food producing trees and shrubs of West Africa. Serie-Etudes-et-Recherches, Senegal, 15: 168-260.

Bhagya B., Sridhar K.R. (2009) Ethnobiology of coastal sand dune legumes of southwest India. Ind. J. Trad. Know., 9: 611−620.

Bhagya B., Sridhar K.R., Raviraja N.S., Young C.C., Arun A.B. (2009) Nutritional and biological qualities of ripened beans of *Canavalia rosea* of coastal sand dunes of India. Comp. Ren. Biol., 332: 25−33.

Bhagya B., Sridhar K.R., Seena S. (2006) Biochemical and protein quality evaluation of tender pods of wild legume *Canavalia cathartica* of coastal sand dunes. Livestock Res. Rural Develop., 18: Article # 93. http://www.cipav.org.co/lrrd/lrrd18/7/bhag18093.htm

Bhagya B., Sridhar K.R., Seena S., Young C.C., Arun A.B. (2010) Nutritional evaluation of tender pods of *Canavalia rosea* of coastal sand dunes. Front. Agric. China, 4: 481−488.

Bhat R., Karim A.A. (2009) Exploring the nutritional potential of wild and underutilized legumes. Comp. Rev. Food Sci. Food Saf., 8: 305–331.

Bhat R., Sridhar K. R., Karim A. A. (2010) Microbial quality evaluation and effective decontamination of nutraceutically valued lotus seeds by electron beams and gamma irradiation. Rad. Phy. Chem., 79, 976-981.

Bhat R., Sridhar K.R. (2007) Shelflife improvement and value addition of nutraceutically valued legume - Mucuna through application of ionizing radiation. In: International Conference on Integration of Science and Technology for Sustainable Development, King Mongkut's Institute of Technology, Bangkok, pp. 11–16.

Bhat R., Sridhar K.R. (2008) Effect of electron beam irradiation on the quality characteristics of an underutilized economically valued tropical legume *Mucuna pruriens* L. DC. Elect. J. Environ. Agric. Food Chem., 7, 2565–2581.

Bhat R., Sridhar K.R. (2009) Influence of electron beam irradiation on the antinutritional features and protein digestibility of seeds of nutraceutically valued legume *Mucuna pruriens*. In: Food Processing: Methods, Techniques and Trends. Bellinghouse V.C. (Ed.), Nova Science Publishers Inc., New York, pp. 197–209.

Bhat R., Sridhar K.R., Karim A., Young C.C., Arun A.B. (2009) Influence of ɣ-radiation on the nutritional and functional qualities of lotus seed flour. J. Agric. Food Chem., 57: 9524–9531.

Bhat R., Sridhar K.R., Young C.-C., Arun A.B., Ganesh

S. (2008) Composition and functional properties of raw and electron beam irradiated *Mucuna pruriens* seeds. Int. J. Food Sci. Technol., 43: 1338–1351.

Boye J., Zare F., Pletch P. (2010) Pulse proteins: Processing, characterization, functional properties and applications in food and feed. Food Res. Int., 43: 414–431.

Brand W.A., Tegtmeyer A.R., Hilkert A. (1994) Compound-specific isotope analysis, extending towards 15N/14N and 13C/12C. Org. Geochem., 21: 585–594.

Campbell G.L., Sosulski F.W., Classen H.L., Ballam G.M. (1987) Nutritive value of irradiated and β-glucanase treated wild oat groats (*Avena fatua* L.) for broiler chickens. Anim. Feed Sci. Technol., 16: 243–252.

Chaturvedi V.C., Shrivastava R., Upreti R.K. (2004) Viral infections and trace elements: A complex interaction. Curr. Sci., 87: 1536–1554.

Cleland M.R. (1983) Radiation processing: Basic concepts and practical aspects. J. Ind. Rad. Technol., 1: 191–218.

D'Cunha M., Sridhar K.R. (2009) Seasonal periodicity of arbuscular mycorrhizal fungi in wild legume *Canavalia maritima* of the coastal sand dunes. Mycorrhiza News, 21: 7–12.

D'Cunha M., Sridhar K.R., Bhat R. (2009) Nutritional quality of germinated seeds of *Canavalia maritima* of coastal sand dunes. In: Food Processing: Methods, Techniques and Trends. Bellinghouse V.C. (Rd.), Nova Science Publishers Inc., New York, pp. 363–384.

Dar D.D., Echeverria R.G., Solh M., Sanginga N. (2012) Grain legumes: leveraging legumes to combat poverty, hunger, malnutrition and environmental degradation In: CGIAR Research Program 3.5, pp. 1–282.

Dario A.C., Salgado J.M. (1994) Effect of thermal treatments on the chemical and biological value of irradiated and non-irradiated cowpea bean (*Vigna unguiculata* (L.)Walp. flours. Pl. Foods Hum. Nutr., 46: 181–186.

Ekanayake S., Jansz E.R., Nair B.M. (1999) Proximate composition, mineral and amino acid content of mature *Canavalia gladiata* seeds. Food Chem., 66: 115–119.

Ezeagu I.E., Petzke K.J., Lange E., Metgea C.C. (1998) Fat content and fatty acid composition of oils extracted from selected wild gathered tropical plant seeds from Nigeria. J. Am. Oil Chem. Soc., 75: 1031–1035

FAO-WHO. (1991) Protein Quality Evaluation: Reports of a Joint FAO-WHO Expert Consultation, Food and Nutrition Paper # 51. Food and Agricultural Organization of the United Nations, FAO, Rome.

Farag M.D.E.H. (1989) Radiation deactivation of antinutritional factors: trypsin inhibitor and hemagglutinin in soybeans. Egyp. J. Rad. Sci. Appl., 6: 207–215.

Farkas J. (1998) Irradiation as a method for decontamination food - A review. Int. J. Food Microbiol., 44: 189–194.

Farkas J. (2006) Irradiation for better foods. Tr. Food Sci. Technol., 17: 148–152.

Fricke H., Hart E.J. (1966) Chemical dosimetry. In: Radiation Dosimetry. Attix F.H., Raesch W.C. (Eds.). Academic Press, New York, p. 462.

Friedman M. (1996) Nutritional value of proteins from different food sources-a review. J. Agric. Food Chem., 44: 6−29.

Gupta B.L., Narayan G.R., Nilekani S.R. (1999) Preliminary dosimetry studies for a Microtron using chemical dosimeters. J. Rad. Prot. Environ., 22: 169–174.

Hayashi T. (1998) Decontamination of dry food ingredients and seeds with soft electrons (low energy electrons). Food Sci. Techno. Inst. Tokyo, 4: 114–120.

Hofmann D, Gehre M., Jung K. (2003) Sample preparation techniques for the determination of natural 15N/14N variations in amino acids by gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS). Isot. Environ. Health Stud., 39: 233–244.

Hofmann D., Jung K., Bender J., Gehre M., Schüürmann G. (1997) Using natural isotope variations of nitrogen in plants as an early indicator of air pollution stress. J. Mass Spectr., 32: 855–863.

Humphries E.C. (1956) Mineral composition and ash analysis. In: Modern methods of plant analysis, Volume 1. Peach K., Tracey M.V. (Eds.), Springer, Berlin, pp. 468–502.

Jansman A.J.M. (1996) Bioavailability of proteins in legume seeds. Grain Legumes (AEP) 11: 19–28.

Kalidas C., Mohan V.R. (2012) Biochemical composition and nutritional assessment of selected under-utilized food legume of the genus Rhynchosia. Int. Food Res. J., 19: 977–984.

Khattak A.B., Kloppenstein C.F. (1989) Effects of gamma irradiation on the nutritional quality of grain and legume. Cereal Chem., 66: 170–171.

Lee C.C. (1962) Electron paramagnetic resonance (EPR) and packaging studies on ɣ- irradiation flour. Cereal Chem. 39: 147–155.

Lima D.C., Miano A.C., Augusto P.E.D., Arthur V. (2019) Gamma irradiation of common beans: Effect on nutritional and technological properties. LWT - Food Sci. Technol. 116:

Maikhuri R.K., Nautiyal M.C., Khali M.P. (1991) Lesser known crops of food value in Garhwal Himalaya and a strategy to conserve them. Pl. Gen. Resour. Newslett., 86: 33–36.

Maity J.P., Chakraborty S., Kar S., Panja S, Jean J.S, Samal A.C, Chakraborty A., Santra S.C. (2009) Effects of gamma irradiation on edible seed protein, amino acids and genomic DNA during sterilization. Food Chem., 114: 1237–1244

Makhura M.N., Adegbite O.O., Mkandawire E., Olivier N.JJ., Nankuni F., Nyondo C.J., Hendriks S. (2019) Mapping policy responses to food systems transformation in Malawi. Policy Res. Brief, 77: 1–8.

Morris J.B. (1999) Legume genetic resources with novel value added industrial and pharmaceutical use. In: Perspectives on New Crops and New Uses. Janick J. (Ed.), ASHS Press, Alexandria, pp. 196–201.

Morris J.B. (2007) Swordbean (*Canavalia ensiformis* (L.) DC.) genetic resources regenerated for potential medicinal, nutraceutical and agricultural traits. Gen. Resour. Crop Evol., 54: 585–592.

Muzquiz M., Varela A., Burbano C., Cuadrado C., Guillamón E., Pedrosa M.M. (2012) Bioactive compounds in legumes: pronutritive and antinutritive actions. Implications for nutrition and health. Phytochem. Rev., 11: 227–244.

NAS. (1979) Tropical Legumes Resources for the Future. National Academy of Sciences, Washington DC.

Nene S.P., Vakil U.K., Sreenivasan, A. (1975) Effect of gamma radiation on red gram (*Cajanus cajan*) proteins. J. Food Sci., 40: 815–819.

Niveditha V.R., Sridhar K.R. (2017) Improvement of functional attributes of kernels of wild legume *Canavalia maritima* by Rhizopus oligosporus. In: Microbial Applications: Recent Advancements and Future Developments. Gupta V.K., Zeilinger S., Filho E.X.F., Durán-Domínguez-de-Bazúa M., Purchase D. (Eds.), Walter de Gruyter, Berlin, pp. 369–388.

Norton G., Bliss F.A., Bressani R. (1985) Biochemical and nutritional attributes of grain legumes. In: Grain Legume Crops. Summerfield R.J., Roberts E.H. (Eds.), Collins, London, pp. 73–114.

NRC-NAS. (1989) Recommended dietary allowances. National Academy Press, Washington DC.

Omode A.A., Fatoki O.S., Olaogun K.A. (1995) Physico-chemical properties of some under-exploited and non-conventional oil seeds. J. Agric. Food Chem., 43: 2850–2853.

Osman A.M.A., Hassan A.B., Osman G.A.M., Mohammed N, Rushdi M.A.H., Eiab E.E., Babiker E.E. (2014) Effects of gamma irradiation and/or cooking on nutritional quality of faba bean (*Vicia faba* L.) cultivars seeds. J. Food Sci. Technol., 51: 1554–1460

Pennington J.A.T., Young B. (1990) Iron, zinc, copper, manganese, selenium and iodine in foods from the United States total diet study. J. Food Comp. Anal., 3: 1661–1684.

Pomeranz Y., Clifton D. (1981) Food Analysis: Theory and Practices. Connecticut AVI publishing Co. Inc., Westport, USA.

Rao P.U. (1994) Nutrient composition of some less-familiar oil seeds. Food Chem., 50: 379–382.

Rao T.A., Meher-Homji V.M. (1985) Strand plant communities of the Indian sub-continent. Proc. Ind. Acad. Sci., 94: 505–523.

Rao T.A., Sherieff A.N. (2002) Coastal Ecosystem of the Karnataka State, India II: Beaches. Karnataka Association for the Advancement of Science, Bangalore, India.

Rao T.A., Suresh P.V. (2001) Coastal Ecosystems of the Karnataka State, India I: Mangroves. Karnataka Association for the Advancement of Science, Bangalore, India.

Reddy N.R., Pierson M.D., Sathe S., Salunkhe D.K. (1984) Chemical, nutritional and physiological aspects of dry bean carbohydrates - A review. Food Chem. 13: 25–68.

Reddy S.J., Pubols M.H., Mc Ginnis J. (1979) Effect of irradiation on nutritional value of dry field beans (*Phaseolus vulgaris*) for chicks. J. Nutr., 109: 1307–1312.

Salunkhe D.K, Kadam S.S., Chavan J.K. (1985) Chemical composition. In: Postharvest Biotechnology of Food Legumes. Salunkhe D.K., Kadam S.S., Chavan J.K. (Eds.), CRC Press Inc., Boca Raton, Florida, pp. 33–35.

Sandev S., Karaivanov I. (1977) The composition and digestibility of irradiated roughage treatment with gamma irradiation. Tierernahrung Fuetterung, 10: 238–242.

Sattar A., Neelofar X., Akhtar M.A. (1990) Effect of radiation and soaking on phytate content of soybean. Acta Alimentaria, 19a; 331–336.

Seena S., Sridhar K.R. (2004a) Nutrient composition and biological evaluation of an unconventional legume, *Canavalia cathartica* of mangroves. Int. J. Food Sci. Nutr., 55: 615–625.

Seena S., Sridhar K.R. (2004b) Endophytic fungal diversity of 2 sand dune wild legumes from the southwest coast of India. Can. J. Microbiol., 50: 1015–1021.

Seena S., Sridhar K.R. (2006) Nutritional and microbiological features of little known legumes, *Canavalia cathartica* Thouars and *C. maritima* Thouars of the southwest coast of India. Curr. Sci., 90: 1638–1650.

Seena S., Sridhar K.R., Arun A.B. (2007) *Canavalia cathartica* of southwest coast of India - A neglected wild legume. Pl. Gen. Resour. Newslett. 150: 16–20.

Seena S., Sridhar K.R., Bhagya B. (2005a) Biochemical and biological evaluation of an unconventional legume, *Canavalia maritima* of coastal sand dunes of India. Trop. Subtrop. Agroecosys., 5: 1–14.

Seena S., Sridhar K.R., Ramesh S.R. (2005b) Nutritional and protein quality evaluation of thermally treated seeds of *Canavalia maritima* in the rat. Nutr. Res., 25: 587–596.

Shills M.E.G., Young, V.R. (1988) Modern nutrition in health and disease. In: Nutrition. Neiman D.C., Buthepodorth D.E., Nieman C.N. (Eds.), WmC Brown Publishers, Dubugue, IA, pp. 276–282.

Shreelalitha S.J., Sridhar K.R. (2019) Functional attributes of seeds of two coastal germplasms of Sesbania. In: Phytochemistry and Molecular Aspects: Plants and Human Health, Volume 2. Öztürk M., Hakeem K.R. (Eds.), Springer Nature, pp. 159–172.

Siddappa K., Ganesh, Ramamurthy S.S., Soni H.C., Srivsthava P., Himmani Y.S. (1999) Variable energy Microtron for R and D work. Rad. Phy. Chem., 51: 441–442.

Siddhuraju P., Osoniyi O., Makkar H.P.S., Becker K. (2002) Effect of soaking and ionising radiation on various antinutritional factors of seeds from different species of an unconventional legume, Sesbania and a common legume, green gram (*Vigna radiata*). Food Chem., 79: 273−281.

Siddhuraju P., Vijayakumari K., Janardhanan K. (1992) The biochemical composition and nutritional potential of the tribal pulse Alysicarpus rugosus (Willd.) DC. Food Chem., 45: 251–255.

Singh J.S., Chaturvedi R.K. (2017) Diversity of ecosystem types in India: A review. Proc. Ind. Nat. Sci. Acad., 83: 569–594.

Singh R.J., Chung G.H., Nelson R.L. (2007) Landmark research in legumes. Genome, 50: 525–537.

Sridhar K.R., Arun A.B., Narula N., Deubel A, Merbach W. (2005) Patterns of sole-carbon-source utilization by fast-growing coastal sand dune rhizobia of southwest coast of India. Eng. Life Sci., 5: 425–430.

Sridhar K.R., Bhagya B. (2007) Coastal sand dune vegetation: a potential source of food, fodder and pharmaceuticals. Livest. Res. Rural Develop., 19: Article # 84. https://lrrd.cipav.org.co/lrrd19/6/srid19084.htm

Sridhar K.R., Bhat R. (2008) Electron beam irradiation - An emerging technology for fungal decontamination of food and agricultural commodities. In: Novel Techniques and Ideas in Mycology. Sridhar K.R., Bärlocher F., Hyde K.D. (Eds.), Fungal Diversity Research Series 20. Kunming University of Science and Technology, PR China. pp. 271–303.

Sridhar K.R., Niveditha V.R. (2014) Nutritional and bioactive potential of coastal sand dune wild legume *Canavalia maritima* (Aubl.) Thou. An overview. Ind. J. Nat. Prod. Resour., 6: 107–120.

Sridhar K.R., Shreelalitha S.J., Supriya P., Arun A.B. 2016. Nutraceutical attributes of ripened split beans of three Canavalia landraces. Int. J. Agric. Technol., 12: 1277–1297.

Supriya P., Sridhar K.R, Arun A.B. (2019) Impact of electron beam irradiation on the nutritional attributes of seeds of coastal sand dune wild legume Canavalia cathartica. In: Plants and Human Health, Volume 2 - Phytochemistry and Molecular Aspects. Öztürk M., Hakeem, K.R. (Eds.), Springer Nature, pp. 607–625.

Supriya P., Sridhar K.R. (2019a) Impact of electron beam irradiation on the bioactive principles of seeds of coastal sand dune wild legumes (*Canavalia* spp.). Recent Pat. Food Nutr. Agric., 10: 57–61.

Supriya P., Sridhar K.R. (2019b) Proximal and functional properties of edible ripened split beans of coastal wild legume *Canavalia maritima*. Curr. Nutr. Food Sci., 15: 228–233.

Supriya P., Sridhar K.R., Ganesh S. (2014) Fungal decontamination and enhancement of shelf life of edible split beans of wild legume *Canavalia maritima* by the electron beam irradiation. Rad. Phy.

Chem., 96: 5–11.

Supriya P., Sridhar K.R., Ghate S.D. (2018) Impact of electron-beam irradiation on functional attributes of seeds of two coastal wild legume landraces of *Canavalia*. Rec. Pat. Biotechnol., 12: 177–185.

Supriya P., Sridhar K.R., Nareshkumar S., Ganesh S. (2012) Impact of electron beam irradiation on fatty acid profile of *Canavalia* seeds. Food Biopro. Technol. 5: 1049–1060.

Talwar G.P., Srivastava L.M., Mudgil K.D. (1989) Textbook of Biochemistry and Human Biology, 2nd Edition. Prentice Hall of India Private Ltd, New Delhi.

Tresina P.S., Mohan V.R. (2012) Physico-chemical and antinutritional attributes of gamma irradiated *Vigna unguiculata* (L.) Walp. subsp. unguiculata seeds. Int. Food Res. J., 19: 639–646.

USDA. (1999) Nutrient Data Base for Standard Reference Release # 13, Food Group 20: Cereal Grains and Pasta. Agriculture Handbook # 8–20. Agricultural Research Service, US Department of Agriculture, USA.

USNAS. (1975) Under-Exploited Tropical Plants with Promising Economic Value. Report of Adhoc Panel of the Advisory Committee on Technology Innovation, United States National Academy of Sciences, USA.

Vadivel V., Janardhanan K. (2001) Nutritional and anti-nutritional attributers of the under-utilized legume, Cassia floribunda Cav. Food Chem., 73: 209–215.

Viano J., Masotti V., Gaydou E.M., Bourreil P.J.L., Ghiglione C., Giraud M. (1995) Compositional characteristics of 10 wild legumes from Mediterranean French pastures. J. Agric. Food Chem., 43: 680–681.

Viswanathan M.B., Thangadurai D., Ramesh N. (2001) Biochemical evaluation of Neonotonia wightii (Wight and Arn) Lackey (*Fabaceae*). Food Chem., 75: 275–279.

Warchalewski J.R., Gralik J., Zawirska-Wojtasia R., Zabielski J. (1998) The evaluation of wheat grain odour and colour after gamma and microwave irradiation. Elec. J. Polish Agric. Univ., 1: 1–11.

Wilkinson V.M., Gould G.W. (1998) Food Irradiation. A Reference Guide. Woodhead Publishing Ltd, Cambridge.

Yusuf A.A., Mofio B.M., Ahmed A.B. (2007) Proximate and mineral composition of *Tamarindus indica* Linn 1753 seeds. Sci. World J., 2: 1–4.

Canavalia rosea **(Sw.) DC toxumlarının qida keyfiyyətinin elektron şüalanma ilə yaxşılaşdırılması**

Kandikere R. Sridhar
Havathi Supriya
Bioelmlər fakultəsi, Manqalor Universiteti, Manqalaganqotri, Manqalor, Karnataka, Hindistan

Yabanı paxlalılar zülal və enerji çatışmazlığı ilə mübarizə aparmaq üçün inkişaf etməkdə olan ölkələrdə etnik cəhətdən qiymətli potensial qida mənbəyidir. Yabanı paxlalı bitkilərin toxumlarında qidalanma əleyhinə xüsusiyyətlərin olması onların birbaşa istifadəsinə əsas maneədir ki, bu da qida təhlükəsizliyinə nail olmaq üçün müxtəlif emal üsullarından istifadə etməyi tələb edir. Hindistanın cənub-qərbindəki sahil qum təpələrindən bitən *Canavalia* spp. toxumları ənənəvi emaldan sonra qəbilələr tərəfindən istehlak edilir. Bu tədqiqatda sahil qum təpələrində bitən *C. rosea* toxumlarının elektron şüalanmasının (EŞ) qida xüsusiyyətlərinə, xüsusən proksimal keyfiyyətlərin, mineral profilin və zülaldan bioyararlanmanın yaxşılaşmasına təsirini nümayiş etdirir. 10 kGy (standart doza) dozada qidalanma xüsusiyyətlərində müsbət dəyişikliklərə xam lifin azalması, mineralların (fosfor və maqnezium), albumin miqdarının və albumin/qlobulin nisbətinin artması daxildir. EŞ şüalanmasının digər faydalı təsirlərinə argininin dozadan asılı artımı, əvəzolunmayan amin turşularının/ümumi amin turşularına nisbətinin artması və zülalın mənimsənilməsinin artması daxildir. Bundan başqa, zülal mənimsənilməsi amin turşusu göstəricilərinin (His, Ile, Leu, Lys, Thr, Val) korreksiyası ilə artmış və zülal səmərəliliyi nisbətinə 5 kGy dozada nail olunmuşdur. Bundan əlavə, EŞ şüalanmasının əlavə üstünlükləri yağ turşularının metil efirlərində funksional xüsusiyyətlərində və bioaktiv komponentlərində selektiv əlverişli dəyişikliklərdir. Sahil qum təpələri ekosistemində bitən *Canavalia* spp. toxumlar EŞ şüalanmasına fərqli reaksiya verir ki, bu da onların növə xas xüsusiyyətləri ilə müəyyən olunur. *C. rosea* toxumlarının EŞ ilə şüalanması qida xüsusiyyətlərinin yaxşılaşdırılması, zərərvericilərə qarşı mübarizə və saxlama müddətinin artırılması kimi bir sıra üstünlüklərə malikdir.

Açar sözlər: *amin turşuları, yağ turşuları, minerallar, protein biomənimsənilmə, yabanı paxlalılar, qum təpələri*

Улучшение питательных качеств семян *Canavalia rosea* (Sw.) DC. при электронно-лучевом облучении

Кандикере Р. Шридхар
Прабхавати Суприя
Факультет биологических наук, Мангалорский университет, Мангалаганготри, Мангалор, Карнатака, Индия

Дикие бобовые являются этнически ценными потенциальными источниками питания в развивающихся странах для борьбы с белково-энергетической недостаточностью. Наличие антипитательных свойств у семян дикорастущих бобовых является основным препятствием для их прямого использования, что требует применения различных методов обработки для достижения пищевой безопасности. Семена *Canavalia* spp. в прибрежных песчаных дюнах на юго-западе Индии потребляются племенами после традиционной обработки. Настоящее исследование демонстрирует последствия облучения электронным лучом (ЭЛ) семян прибрежной песчаной дюны *C. rosea* для селективного улучшения питательных свойств, особенно проксимальных качеств, профиля минералов и биодоступности белка. Положительные изменения питательных свойств при дозе 10 кГр (стандартная доза) включают снижение содержания сырой клетчатки, увеличение содержания минералов (фосфора и магния), содержания альбумина и соотношения альбумин/глобулин. Другие положительные эффекты облучения ЭЛ включают дозозависимое увеличение содержания аргинина, увеличение соотношения незаменимых аминокислот/общего количества аминокислот и повышение усвояемости белков. Кроме того, при дозе 5 кГр были достигнуты повышенная усвояемость белка с поправкой на аминокислотный уровень (His, Ile, Leu, Lys, Thr и Val) и коэффициенты эффективности белка. Кроме того, дополнительными преимуществами облучения ЭЛ являются селективные благоприятные изменения количества метиловых эфиров жирных кислот, функциональных свойств и биологически активных компонентов. Несмотря на то, что *Canavalia* spp. выращенных в экосистеме прибрежных песчаных дюн, их семена по-разному реагируют на облучение ЭЛ, что было предусмотрено их видоспецифичными характеристиками. ЭЛ облучение семян *C. rosea* имеет ряд преимуществ, таких как улучшение питательных свойств, дезинфекция и увеличение срока хранения.

Ключевые слова: аминокислоты, жирные кислоты, минералы, биодоступность белка, дикие бобовые, песчаные дюны.