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Physico-chemical properties and nutrient composition of beach pea (*Lathyrus maritimus* L.)

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Abstract

Physico-chemical properties of Beach pea (*Lathyrus maritimus* L.) seeds were evaluated and their proximate composition determined. Results were also compared with those of green pea (*Pisum sativum*) and field pea (*Lathyrus sativus*). Beach pea seeds had a very low grain weight, density, hydration capacity, hydration index, swelling capacity and swelling index as compared to green pea and field pea. The contents of crude protein (29.2%), crude fibre (12.0%), reducing sugars (0.2%), total phenolics (1.2%) and ash (3.0%), and total free amino acids (0.6%) of beach pea were substantially higher than other pea varieties examined. The contents of cysteine (1.6%), methionine (1.1%), and tryptophan (0.3%) in beach pea proteins were low, but higher than those in green pea and field pea varieties from Canadian and Indian cultivars. Beach pea lipids were dominated by linoleic acid (69.1%), and were similar to green pea (45.1%) and Canadian grown field pea (57.0%). The macroelements of beach pea were dominated by potassium (476 mg/100 g), phosphorus (413 mg/100 g), magnesium (1180 mg/100 g), and calcium (144 mg/100 g). The contents of microelements, namely manganese, zinc, and iron in beach pea were 3.5, 3.0 and 9.4 mg/100 g, respectively.

1. Introduction

Lathyrus maritimus (L.) Bigel, commonly known as beach pea, grows along the shorelines of Arctic and subarctic regions from Greenland to Siberia and Japan (Fernald, 1950). In Canada, it is mostly found in Newfoundland, Nova Scotia and Quebec (Scoggan, 1950; Hitchcock, 1952; Lamourex and Grandtner, 1977). Beach pea is a food legume which may serve as a potential source of several important nutrients for human nutrition. Incorporation of new legumes in human diet depends largely on their nutritional quality; no such information is available for beach pea. This relatively unknown legume, though not commercially available, is occasionally eaten by populations where it grows. Commercial production of beach pea has also not taken place. Therefore, it is necessary to analyze beach pea for its nutrient composition and physico-chemical properties. The present paper evaluates some physico-chemical properties and proximate composition of beach pea. Results are compared with those of green pea (*Pisum sativum*) and field pea (*Lathyrus sativus*). While green pea is a well-established leguminous crop, field pea belongs to the *Lathyrus* genus, the same as that of beach pea.

2. Materials and methods

2.1. Seeds

The seeds of beach pea were collected from Bellevue Beach in September and October of 1995 and 1996. Seeds of green pea and field pea were obtained from Crop Science and Plant Ecology Department, University of Saskatchewan (Saskatoon, SK) and Agriculture and Agri-Food Canada (Morden, MB), respectively. A sample of field pea was also procured from a local market in Calcutta, India.

2.2. Physico-chemical properties

Fully mature beach pea seeds were analyzed for their physico-chemical properties and results were compared with those of field pea and green pea. The colour of

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seeds was determined subjectively. The density of seeds was calculated by weighing one hundred seeds and subsequently measuring their volume using a cylinder containing 100 ml of deionized water. The seeds were placed in water to sink them and the volume of the displaced water was recorded. The hydration capacity of seeds was determined in the following manner. Seeds weighing 100 g were counted and transferred to a measuring cylinder along with 100 ml of water. The cylinder was covered with aluminium foil and left overnight at room temperature. After 24 h, seeds (swollen) were separated and weighed. Hydration capacity per seed was determined from the ratio of the weight difference data between that of the soaked and unsoaked seeds divided by the number of seeds. Hydration index was then calculated as the ratio of the hydration capacity per seed and the weight of one seed. For determination of swelling capacity, seeds weighing 100 g were counted, their volume noted and soaked overnight. The volume of the soaked seeds was noted in a graduated cylinder. Swelling capacity per seed was calculated from the volume difference data of soaked and unsoaked seeds and the number of seeds used. Swelling index was then calculated as the ratio of the swelling capacity per seed to the volume of one seed.

2.3. Seed composition

The content of moisture, crude protein, lipid, ash, and crude fibre in samples was determined using the standard methods of analyses (AOAC, 1990). The carbohydrate content was determined as the weight difference using moisture, crude protein, lipid and ash content data. The amount of soluble proteins was determined by Lowry *et al.*'s method (1951).

Soluble sugars were extracted into 80% (v/v) ethanol according to the procedure of Cerning and Guilhot (1973). The residue obtained after extraction of soluble sugars was used for determination of starch. Starch was extracted in 52% (v/v) perchloric acid at room temperature. Quantitative determination of starch was carried out according to the colorimetric method of McCready et al. (1950). Soluble sugars and reducing sugars were estimated by the modified method of Nelson (1944). The amount of non-reducing sugars was calculated from the difference between the content of soluble sugars and reducing sugars.

For determination of phenolics, samples were isolated according to the method of Shahidi and Naczk (1989). One gram of sample was extracted three times with 10 ml of 70% (v/v) aqueous acetone at room temperature using a Polytron PT 3000 homogenizer (Brinkman Instruments, Rexdale, ON) for 1 min at 10 000 rpm. The slurry was centrifuged at 5000×***g*** for 10 min, the supernatants were collected, combined and evaporated to dryness at 30°C under vacuum. The extracted phenolics were then dissolved in 25 ml of methanol, centrifuged again and the content of phenolics in methanol was determined colorimetrically (Swain and Hillis, 1959). To 0.5 ml of a methanolic solution of phenolics, 0.5 ml Folin-Denis reagent, 1 ml saturated solution of sodium carbonate and 8 ml water were added and mixed well. Absorbance was measured at 725 nm after 30 min standing at room temperature; trans-sinapic acid was used as a standard in these experiments. The content of phenolics was expressed as trans-sinapic acid equivalents, on a dry weight basis.

2.4. Total amino acids

Total amino acids were determined as described by Shahidi et al. (1992). Samples were freeze-dried and then hydrolysed for 24 h at 110°C in 6 M HCl (Blackburn, 1978). The HCl was removed under vacuum, and dried samples were reconstituted using a lithium citrate buffer at pH 2.2. The hydrolysed amino acids were then determined using a Beckman 121 MB amino acid analyzer (Beckman Instruments, Inc., Palo Alto, CA; Shahidi et al., 1992). Tryptophan was determined separately by hydrolysis of the sample under vacuum in 3 M mercaptoethanesulphonic acid at 110°C, as described by Penke et al. (1974). Cysteine and methionine were determined after performic acid oxidation of the sample prior to hydrolysis in 6 M HCl, and were measured as cysteic acid and methionine sulphone, respectively (Blackburn, 1978).

2.5. Free amino acids

For determination of free amino acids, 2 g of sample were homogenized using a Polytron PT 3000 homogenizer (Brinkman Instruments) in a 50 ml centrifuge tube with 20 ml of ice-cold 6% (v/v) perchloric acid for 2 min in an ice bath. The homogenized sample was then incubated in ice for 30 min before centrifugation (IEC Centra MP4 centrifuge, International Equipment Co., Needham Heights, MA) at 2000×***g*** for 15 min. The residue was then re-extracted with 20 ml ice-cold perchloric acid and centrifuged, as described above. The supernatants from the first and second extraction were combined and filtered through a Whatman No. 4 filter paper. The pH of the filtrate was adjusted (Accumet pH meter, model 810, Fisher Scientific Co., Fair Lawn, NJ) to 7.0 using a 33% (w/v) KOH solution and centrifuged at 2000×***g*** for 10 min to remove precipitates of potassium perchlorate. The supernatant was acidified to pH 2.2 with a 10 M HCl solution and then diluted to 50 ml with distilled water. Two millilitres of the extract were transferred into a clean tube and 1.0 ml of lithium citrate buffer (pH 2.2; Beckman Instruments, Inc., Palo Alto, CA) was added to it. Samples were then analyzed on a Beckman 121 MB amino acid analyzer using

Benson D-X 8.25 resin and a single column employing a three-buffer lithium method as per Beckman 121 MB-TB017 application notes. Results were calculated and reported as mg amino acids/100 g sample.

2.6. Lipid fatty acid composition

Fatty acid composition of lipids of beach pea, green pea and Canadian field pea was determined using gas chromatography (GC; Hewlett Packard Series II, Type 5890, Canada Ltd., Mississauga, ON), as described previously (Wanasundara and Shahidi, 1994). Ten to 60 milligrams of lipids were transmethylated overnight at 61.8°C in a vial in 6% (v/v) H_2SO_4 in 99.9% methanol containing 15 mg of butylated hydroxyanisole (BHA) which was placed in an oven (Theco, Model 2, Precision Scientific Co., Chicago, IL). After incubation, 1.0 ml of distilled water was added to the vial and the solution was then extracted three times with 1.5 ml of pesticide grade hexane. During the first extraction, a few more crystals of BHA were added. The hexane layer was removed into a clean tube and then washed twice with 1.5 ml of H_2O by vortexing. On the first wash, H_2O layer was discarded. On the second wash, the hexane layer was transferred into a clean tube. The hexane was then evaporated under N_2 in a fumehood. The dried matter was dissolved in 1 ml of carbon disulphide prior to GC analysis.

2.7. Determination of minerals and vitamins

Dried and ground samples (1 to 2 g) were subjected to dry ashing in well cleaned porcelain crucibles at 550°C in a muffle furnace (Blue M Electric Company, Blue Island, IL). The resultant ash was dissolved in 5 ml of $HNO_3/HCl/H_2O$ (1:2:3, v/v/v) while heating on a hot plate at the boiling temperature of the solution until brown fumes disappeared. To the remaining content in each crucible, 5 ml of deionized water were added and the mixture was heated until a colourless solution was obtained. The mineral solution in each crucible was transferred into a 100 ml volumetric flask by filtering through a Whatman No. 42 filter paper and the volume made to the mark with deionized water. The concentration of elements (Ca, Na, K, Mg, Mn, Zn, Fe, Cu, Li, Al, and Si) in each solution, prepared as described above, was determined using a Perkin-Elmer 8650 atomic absorption spectrophotometer (Perkin-Elmer Co., Montreal, PQ). Calibration curves of absorbance values versus concentration of each element at appropriate concentrations (to obey Beer's-Lambert Law) were constructed using their respective standards of 1000 μg/litre (Fisher Scientific, Unionville, ON). A 10 cm-long cell was used and concentration of each element in the sample was calculated as mg/100 g of dry matter. Phosphorus content of the digest was determined colorimetrically according to the method described by Nahapetian and Bassiri (1975). To 0.5 ml of the diluted digest, 4 ml of demineralized water, 3 ml of 0.75 M H_2SO_4, 0.4 ml of 10% (w/v) $(NH_4)_6Mo_7O_{24}.4H_2O$ and 0.4 ml of 2% (w/v) ascorbic acid were added and mixed. The solution was allowed to stand for 20 min and absorbance reading was recorded at 660 nm. The content of phosphorus in the extracts was determined using a standard curve obtained for KH_2PO_4 and expressed as mg phosphorus per 100 g of sample.

Vitamins in beach pea were determined using the standard procedures of the AOAC (1990). These determinations were carried out, in duplicate, by Labstat Incorporated (Kitchener, ON).

2.8. Statistical analyses

All experiments and/or measurements reported in this study were replicated three times or more. In each case a mean value of standard deviation was calculated. Analysis of variance (ANOVA) was performed and differences in mean values determined using Tukey's studentized test and $p < 0.05$ and employing ANOVA and Tukey procedures of statistical analytical systems (SAS, 1990).

3. Results and discussion

Physico-chemical characteristics of beach pea seeds, namely grain weight, density, hydration capacity, hydration index, swelling capacity, swelling index and colour are presented in Table 1. This table also compares the results presented with those of green pea and field pea. The data presented clearly show that beach pea seeds are much smaller in size and lighter in weight than those of green and field peas; this is also reflected in a significantly ($p < 0.05$) lower density of beach pea seeds in comparison with other seeds examined. Meanwhile, the hydration capacity, hydration index and swelling capacity of beach pea were lower than those of green pea and field pea. These characteristics may be a reflection of the fact that beach pea seeds have a very hard and impermeable coat and as such do not get hydrated easily. Therefore, beach pea seeds may require a longer time in order to germinate or cook and these could also influence the preference of consumers and processors for seeds (Akinyele et al., 1986; Bishnoi and Khetarpaul, 1993). However, swelling index of beach pea seeds depends on their state of maturity. In general, the results of physico-chemical properties of beach pea seeds follow a similar trend to those reported for other leguminous seeds (Ojomo and Chheda, 1972; Ahmed and Shehata, 1982; Sharma, 1989; Latunda Dada, 1991; Bishnoi and Khetarpaul, 1993).

As compared to green pea and field pea, beach pea seeds had a much higher protein content Table 2 and

Table 1
Physico-chemical properties of different peas[1]

Parameter	Beach pea, mature	Beach pea, immature	Green pea	Field pea[2]
Colour of seed	Black	Green	Green	Light Brown
Grain weight (g/100 seeds)	3.01 ± 0.07^{c}	3.09 ± 0.06^{c}	25.27 ± 0.05^{a}	16.33 ± 0.47^{b}
Density (g/ml)	0.56 ± 0.05^{b}	0.59 ± 0.07^{b}	1.27 ± 0.00^{a}	1.21 ± 0.02^{a}
Hydration capacity (g/seed)	0.005 ± 0.001^{c}	0.0005 ± 0.0001^{d}	0.24 ± 0.00^{a}	0.15 ± 0.002^{b}
Hydration Index	0.16 ± 0.03^{c}	0.016 ± 0.003^{d}	0.95 ± 0.00^{a}	0.89 ± 0.007^{b}
Swelling capacity (ml/seed)	0.008 ± 0.003^{bc}	0.003 ± 0.0003^{c}	0.04 ± 0.00^{a}	0.015 ± 0.005^{b}
Swelling index	0.16 ± 0.07^{ab}	0.07 ± 0.006^{b}	0.20 ± 0.00^{a}	0.11 ± 0.03^{ab}

[1] Results are mean values of four determinations, ± standard deviation. Means followed by different superscripts in each row are significantly ($p < 0.05$) different from one another.
[2] Canadian variety.

Table 2
Chemical composition of beach pea, green pea and field pea.[1]

Constituent (%)	Beach pea[2]	Green pea	Field pea[3]	Field pea[4]
Moisture	9.7 ± 0.29^{b}	8.2 ± 0.23^{c}	8.6 ± 0.05^{c}	10.4 ± 0.05^{a}
Protein	29.2 ± 0.15^{a}	23.5 ± 0.39^{b}	23.6 ± 0.07^{b}	21.3 ± 1.21^{c}
Soluble proteins (mg/100 g)	306 ± 2.72^{c}	456 ± 6.90^{a}	344 ± 6.09^{b}	219 ± 4.90^{d}
Lipid	1.1 ± 0.14^{b}	1.5 ± 0.09^{a}	1.3 ± 0.15^{a}	1.2 ± 0.02^{a}
Ash	3.0 ± 0.03^{a}	2.6 ± 0.01^{d}	2.9 ± 0.01^{b}	2.7 ± 0.01^{c}
Crude Fibre	12.0 ± 0.24^{a}	5.5 ± 0.31^{bc}	5.0 ± 0.53^{c}	6.4 ± 0.39^{b}
Carbohydrates[5]	57.0 ± 0.39^{b}	64.2 ± 0.28^{a}	63.5 ± 0.72^{a}	64.3 ± 0.32^{a}
Soluble sugars	3.3 ± 0.04^{c}	5.7 ± 0.13^{a}	3.8 ± 0.04^{b}	2.2 ± 0.05^{d}
Reducing sugars (mg/100 g)	172 ± 3.19^{a}	122 ± 3.01^{b}	105 ± 1.02^{c}	103 ± 5.92^{c}
Non-reducing sugars	3.2 ± 0.01^{c}	5.6 ± 0.13^{a}	3.7 ± 0.04^{b}	2.1 ± 0.05^{d}
Starch	24.7 ± 0.46^{d}	34.1 ± 0.06^{b}	39.0 ± 0.46^{a}	29.0 ± 0.16^{c}
Phenolics	1.2 ± 0.001^{a}	0.3 ± 0.003^{b}	0.3 ± 0.001^{b}	0.2 ± 0.002^{c}

[1] Results are mean values of triplicate determinations, ± standard deviation. Results other than moisture content are on a dry weight basis. Means followed by different superscripts in each row are significantly ($p < 0.05$) different from one another.
[2] Values are for composite seed samples as harvested, containing both mature and immature seeds.
[3] Canadian variety.
[4] Indian variety.
[5] By difference, as 100-(moisture + crude protein + lipid + ash).

this was counteracted by a lower content of carbohydrates and starch. However, beach pea seeds contained a relatively high fibre and mineral (ash) content. Furthermore, the content of total phenolics in beach pea seeds was higher than that in other pea seeds examined. The higher content of phenolics may affect the nutritional value of the seeds as these and their oxidation products interact with free amino acids, especially the ϵ-NH_2 group of lysine. Phenolic compounds are also known to possess astringent taste and may affect the colour of products once heat processed. However, antioxidant activity of phenolic compounds, in general, may exert a positive influence on potential beneficial health effects of beach pea seeds. The existing differences in the total crude fibre content among beach pea, green pea and field pea may perhaps originate from the differences in testa structure and the thick and leathery skins of seeds examined as was also noted by Ene-Obong and Carnovale (1992) for other legumes.

With respect to its amino acid composition (Table 3), beach pea was somewhat deficient in sulphur-containing amino acids (methionine and cysteine); this was similar to green and field peas. The relatively low content of methionine and cysteine in legumes has been reported by many investigators (Patwardhan, 1962; Owusu-Domfeh et al., 1970; Apata and Ologhobo, 1990, 1994). Although the profiles of amino acids for seeds examined in this study were similar to other legumes (Moran et al., 1968; Hsu et al., 1980; Abdus Sattar et al., 1989; Singh et al., 1990; Kumar et al., 1991), they contained a higher amount of lysine than those reported by others (Evans and Bendemer, 1967; Meredith and Thomas, 1982). Meanwhile, beach pea contained a somewhat higher amount of free amino acids as compared to other seeds examined (Table 4). Although free amino acids have little effect on the nutritional value of the seeds, their effect on taste properties can not be ignored.

The lipid fatty acids of beach pea and those of green and field pea are given in Table 5. Beach pea lipids contained 14.8% saturated and 76.2% polyunsaturated fatty acids. Linoleic acid (69.1%), palmitic acid (12.5%), oleic acid (7.9%) and linolenic acid (5.2%) were the

Table 3
Total amino acid composition of beach pea, green pea and field pea (g/16 g N)[1]

Amino acid	Beach pea[2]	Green pea	Field pea[3]	Field pea[4]
Alanine	4.3 ± 0.11^{a}	4.5 ± 0.09^{a}	1.9 ± 0.06^{c}	2.1 ± 0.04^{bc}
Arginine	7.9 ± 0.19^{b}	9.3 ± 0.90^{a}	9.0 ± 0.22^{ab}	9.8 ± 0.21^{a}
Aspartic acid + Asparagine	13.1 ± 0.69^{a}	12.3 ± 1.06^{a}	13.2 ± 0.60^{a}	13.5 ± 0.40^{a}
Cysteine	1.6 ± 0.03^{a}	1.4 ± 0.06^{b}	0.7 ± 0.10^{cd}	0.5 ± 0.01^{d}
Glutamic acid + Glutamine	17.4 ± 0.26^{a}	16.9 ± 1.10^{a}	17.3 ± 1.06^{a}	18.4 ± 0.64^{a}
Glycine	4.2 ± 0.10^{a}	4.4 ± 0.11^{a}	4.6 ± 0.56^{a}	4.5 ± 0.35^{a}
Histidine	2.6 ± 0.03^{ab}	2.4 ± 0.04^{b}	2.8 ± 0.09^{a}	2.7 ± 0.30^{ab}
Isoleucine	4.1 ± 0.06^{d}	4.3 ± 0.06^{c}	4.8 ± 0.08^{b}	5.1 ± 0.09^{a}
Leucine	7.7 ± 0.14^{cd}	7.6 ± 0.12^{d}	7.8 ± 0.56^{bcd}	8.6 ± 0.10^{a}
Lysine	7.7 ± 0.13^{a}	7.6 ± 0.10^{a}	7.6 ± 0.50^{a}	7.9 ± 0.18^{a}
Methionine	1.1 ± 0.02^{a}	1.0 ± 0.01^{b}	0.4 ± 0.01^{c}	0.4 ± 0.01^{d}
Phenylalanine	4.7 ± 0.10^{a}	4.9 ± 0.11^{a}	5.0 ± 0.14^{a}	5.2 ± 0.60^{a}
Proline	4.2 ± 0.12^{bc}	4.1 ± 0.12^{c}	4.5 ± 0.06^{a}	1.7 ± 0.01^{d}
Serine	5.0 ± 0.09^{bc}	4.9 ± 0.13^{c}	5.3 ± 0.41^{abc}	5.8 ± 0.21^{a}
Threonine	4.3 ± 0.08^{a}	3.8 ± 0.07^{b}	4.2 ± 0.11^{a}	4.2 ± 0.12^{a}
Tryptophan	0.3 ± 0.01^{a}	0.2 ± 0.01^{b}	0.1 ± 0.01^{d}	0.1 ± 0.01^{cd}
Tyrosine	3.3 ± 0.05^{a}	3.5 ± 0.50^{a}	3.7 ± 0.12^{a}	3.7 ± 0.06^{a}
Valine	4.8 ± 0.07^{b}	4.9 ± 0.40^{a}	5.3 ± 0.16^{a}	5.5 ± 0.09^{a}

[1] Results are mean of triplicate determinations, on a dry weight basis, ± standard deviation. Means followed by different superscripts in each row are significantly ($p < 0.05$) different from one another.
[2] Composite flour of beach pea seeds.
[3] Canadian variety.
[4] Indian variety.

Table 4
Free amino acid composition of beach pea, green pea and field pea (mg/100g)[1]

Free amino acid	Beach Pea[2]	Green Pea	Field Pea[3]	Field Pea[4]
Alanine	20.3 ± 0.32^{a}	12.9 ± 0.60^{b}	7.1 ± 0.33^{d}	8.7 ± 0.18^{c}
Arginine	91.9 ± 1.24^{c}	220.5 ± 2.23^{a}	27.8 ± 1.23^{d}	98.4 ± 2.10^{b}
Asparagine	124 ± 3.27^{a}	64.2 ± 0.98^{b}	53.7 ± 0.83^{c}	45.2 ± 1.20^{d}
Aspartic acid	19.8 ± 0.33^{d}	20.9 ± 1.03^{cd}	29.7 ± 1.15^{b}	38.4 ± 2.10^{a}
Cysteine	15.5 ± 0.95^{bc}	12.2 ± 0.56^{d}	25.4 ± 0.83^{a}	13.6 ± 0.60^{cd}
Glutamic acid	115 ± 2.32^{b}	147.7 ± 2.60^{a}	52.8 ± 1.73^{c}	38.0 ± 1.13^{d}
Glutamine	2.1 ± 0.73^{cd}	1.8 ± 0.12^{d}	2.5 ± 0.31^{bcd}	5.7 ± 0.18^{a}
Glycine	20.9 ± 0.41^{a}	7.2 ± 0.43^{bc}	4.5 ± 0.12^{d}	6.9 ± 0.20^{c}
Histidine	11.6 ± 1.03^{a}	2.7 ± 0.52^{cd}	3.4 ± 0.18^{bcd}	2.6 ± 0.06^{d}
Hydroxyproline	1.7 ± 0.30^{a}	0.9 ± 0.10^{c}	1.2 ± 0.03^{bc}	1.3 ± 0.08^{abc}
Isoleucine	5.1 ± 0.26^{a}	1.2 ± 0.14^{b}	0.9 ± 0.06^{d}	0.9 ± 0.02^{cd}
Leucine	8.9 ± 0.18^{a}	2.0 ± 0.52^{d}	2.1 ± 0.04^{cd}	8.0 ± 0.23^{b}
Lysine	12.7 ± 0.59^{a}	8.2 ± 0.18^{c}	5.8 ± 0.18^{d}	9.3 ± 0.36^{b}
Methionine	30.5 ± 0.16^{a}	3.1 ± 0.06^{c}	1.5 ± 0.10^{d}	4.1 ± 0.22^{b}
Phenylalanine	4.2 ± 0.07^{a}	4.4 ± 0.26^{a}	3.5 ± 0.23^{b}	2.3 ± 0.09^{c}
Proline	44.4 ± 1.32^{a}	11.3 ± 1.20^{b}	1.5 ± 0.08^{cd}	1.1 ± 0.03^{d}
Serine	20.7 ± 0.12^{a}	7.9 ± 0.24^{b}	2.0 ± 0.03^{d}	2.9 ± 0.08^{c}
Tyrosine	3.0 ± 0.52^{b}	4.2 ± 0.08^{a}	1.9 ± 0.08^{cd}	1.9 ± 0.05^{d}
Threonine	6.1 ± 0.10^{a}	5.4 ± 0.04^{b}	2.1 ± 0.38^{d}	2.4 ± 0.08^{cd}
Tryptophan	6.4 ± 0.42^{a}	3.3 ± 0.03^{cd}	3.2 ± 0.42^{d}	3.6 ± 0.18^{bcd}
Valine	6.1 ± 0.13^{a}	4.5 ± 0.10^{b}	3.5 ± 0.23^{c}	2.6 ± 0.30^{d}
Total	571.4	546.7	235.9	297.7

[1] Results are mean of triplicate determinations, on a dry weight basis, ± standard deviation. Means followed by different superscripts in each row are significantly ($p < 0.05$) different from one another.
[2] Composite flour of mature and immature seeds of beach pea.
[3] Canadian variety.
[4] Indian variety.

Table 5
Fatty acid composition of beach pea, green pea and field pea (% area)[1]

Fatty acid	Beach pea	Green pea	Field pea[2]
C8:0	0.1 ± 0.09	ND	ND
C10:0	0.1 ± 0.08	ND	ND
C12:0	0.1 ± 0.01	ND	ND
C14:0	0.4 ± 0.01^{c}	0.5 ± 0.00^{b}	0.5 ± 0.01^{a}
C15:0	0.4 ± 0.02^{a}	0.2 ± 0.00^{c}	0.3 ± 0.01^{b}
C16:0	12.5 ± 0.42^{a}	11.2 ± 0.01^{b}	8.4 ± 0.03^{c}
C17:0	0.1 ± 0.02^{c}	0.2 ± 0.01^{b}	0.2 ± 0.00^{a}
C18:0	0.9 ± 0.03^{c}	3.7 ± 0.01^{b}	4.2 ± 0.01^{a}
C20:0	ND	0.5 ± 0.00^{b}	1.0 ± 0.01^{a}
C22:0	0.2 ± 0.03^{bc}	0.2 ± 0.00^{c}	0.4 ± 0.01^{a}
C14:1	ND	ND	0.1 ± 0.00
C16:1	0.2 ± 0.01^{c}	0.2 ± 0.00^{b}	0.3 ± 0.01^{a}
C17:1	ND	ND	0.2 ± 0.00
C18:1	7.9 ± 0.22^{c}	26.5 ± 0.07^{a}	16.7 ± 0.02^{b}
C18:2	69.1 ± 1.88^{a}	45.1 ± 0.07^{c}	56.0 ± 0.03^{b}
C18:3	5.2 ± 0.11^{c}	11.1 ± 0.00^{a}	10.6 ± 0.06^{b}
C20:1	0.8 ± 0.12^{a}	0.5 ± 0.01^{c}	0.5 ± 0.00^{bc}
C20:2	0.2 ± 0.02^{a}	ND	0.2 ± 0.00^{b}
C20:3	1.7 ± 0.01	ND	ND
C22:1	0.0 ± 0.01^{c}	0.2 ± 0.00^{b}	0.6 ± 0.02^{a}
Total saturated fatty acids	14.8	16.5	15.1
Total monounsaturated fatty acids	8.9	27.4	18.2
Total polyunsaturated fatty acids	76.2	56.1	66.7

[1] Results are mean of triplicate determinations, ± standard deviation. Means followed by different superscripts in each row are significantly ($p < 0.05$) different from one another. ND, not detected.
[2] Canadian variety.

major fatty acids present. Thus, the total content of unsaturated fatty acids in beach pea (85.2%) is higher than those of cow pea (68.1%) and chick pea (67.1%) (Salunkhe et al., 1982; Salunkhe and Kadam, 1989), but is similar to those of field pea (85.0%) and green pea (83.5%). Although lipids constitute a minor portion of many leguminous seeds, their profiles indicate the desirable nature of fatty acid constituents present.

The results for mineral composition of beach pea are summarized in Table 6. Potassium was the most abundant mineral present in beach pea (476 mg/100 g), but this was lower than those of green and field peas. In addition, all pea samples examined contained a higher amount of phosphorus and calcium than other macroelements present. However, beach pea contained lower amounts of microelements than other pea seeds examined and silicon was clearly absent in beach pea seeds. In general, the minerals in seeds examined in this study were similar, but slightly higher than those in other legumes such as Mexican and North American beans (Meiners et al., 1976; D'mello et al., 1985; Apata and Ologhobo, 1989; Zacharie and Ronald, 1993; Barrado et al., 1994).

Such variations in the content of minerals for pea samples might be due to their genetic origin, geographical source and soil conditions.

Table 6
Mineral/vitamin composition of beach pea, green pea and field pea (mg/100g)[1]

Minerals	Beach Pea[2]	Green Pea	Field Pea[3]	Field Pea[4]
Macroelements				
Calcium	144 ± 0.61^{c}	129 ± 0.21^{d}	156 ± 0.41^{b}	187 ± 0.68^{a}
Magnesium	180 ± 1.28^{ab}	181 ± 0.98^{a}	150.0 ± 1.37^{c}	178 ± 1.26^{b}
Phosphorus	413 ± 1.22^{b}	401 ± 1.34^{c}	482 ± 0.96^{a}	384 ± 0.27^{d}
Potassium	476 ± 1.00^{d}	1045 ± 2.33^{b}	1098 ± 2.15^{a}	988 ± 2.17^{c}
Sodium	84.1 ± 0.43^{b}	73.5 ± 0.30^{c}	60.5 ± 0.13^{d}	93.8 ± 1.13^{a}
Microelements				
Aluminum	4.5 ± 0.29^{d}	5.1 ± 0.31^{cd}	6.7 ± 0.10^{b}	20.5 ± 0.80^{a}
Copper	0.9 ± 0.16^{b}	2.4 ± 0.30^{a}	2.4 ± 0.18^{a}	2.2 ± 0.16^{a}
Iron	9.4 ± 0.21^{ab}	7.5 ± 0.85^{c}	9.7 ± 0.40^{a}	8.2 ± 0.41^{bc}
Lithium	0.9 ± 0.12^{d}	4.2 ± 0.55^{bc}	3.1 ± 0.65^{c}	5.9 ± 0.35^{a}
Manganese	3.5 ± 0.58^{b}	1.2 ± 0.15^{d}	1.5 ± 0.16^{cd}	8.7 ± 0.39^{a}
Silicon	ND	6.4 ± 0.13^{c}	15.9 ± 0.25^{b}	22.7 ± 0.13^{a}
Zinc	3.0 ± 0.08^{d}	5.1 ± 0.25^{c}	6.7 ± 0.09^{a}	5.4 ± 0.10^{bc}
Vitamins[5]				
Ascorbic acid	1.60	6.50	—	ND
β-Carotene	0.17	0.04	—	0.12
Folic acid	0.08	0.008	—	NR
Riboflavin (B_2)	0.06	0.19	—	0.17
Thiamin(B_1)	0.59	0.47	—	0.39
Niacin	3.44	3.40	—	2.90

[1] Results are mean of triplicate determinations, on a dry weight basis, ± standard deviation. Means followed by different superscripts in each row are significantly ($p < 0.05$) different from one another. ND, not detected; NR, not reported.
[2] Composite flour of beach pea seeds.
[3] Canadian variety.
[4] Indian variety.
[5] Vitamins of green pea and Indian field pea are from Gopalan et al., 1982.

The contents of selected vitamins/provitamins of beach pea and the control samples, namely green and field peas, are given in Table 6. A close scrutiny of the results indicates that the contents of β-carotene, thiamine, niacin and folic acid in beach pea were comparable to or higher than those in the other pea seeds examined. Meanwhile, the contents of ascorbic acid and riboflavin in beach pea were lower than those in green pea; no ascorbic acid was detected in field pea. However, it is important to note that genetic and environmental factors, as well as processing and storage conditions, might result in considerable variations in the vitamin content of pea samples (Lynch et al., 1959; Uzogara et al., 1991).

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