Nutritional characteristics of mung bean foods

Pradeep Kumar Dahiya, M.J.R. Nout and Martinus A. van Boekel
Department of Agrotechnology and Food Sciences, Wageningen University, Wageningen, The Netherlands
Neelam Khetarpaul
Department of Foods & Nutrition, CCS Haryana Agricultural University, Hisar, India
Raj Bala Grewal
Centre of Food Science & Technology, CCS Haryana Agricultural University, Hisar, India, and
Anita Linnemann
Department of Agrotechnology and Food Sciences, Wageningen University, Wageningen, The Netherlands

Received 21 November 2012
Revised 13 May 2013
Accepted 20 May 2013

Abstract

Purpose – The purpose of this paper is to address malnourishment in developing countries by a food-based approach in which locally produced and consumed foods are improved by applying food processing techniques that benefit the amount and availability of desirable nutrients.

Design/methodology/approach – To facilitate this approach, this paper reports on the composition and *in vitro* micronutrient accessibility of 14 traditional mung bean foods from India in relation to their preparation methods.

Findings – Proximate composition, *in vitro* mineral accessibility, phytic acid and polyphenol contents varied among the range of products. Products requiring either fermentation or germination, had higher *in vitro* iron, zinc and calcium accessibility. Average *in vitro* iron, zinc and calcium accessibility of the mung bean products were 16, 9 and 418 $mg\,kg^{-1}$ dry weight. Phytic acid and polyphenols averaged 2.1 and 1.8 $g\,kg^{-1}$ dry weight, respectively, and were negatively correlated with *in vitro* mineral accessibility.

Practical implications – Different mung bean products (100 g) cover 12.0-59.5, 5.2-45.6, 4.2-28.6 and 1.1-7.1 per cent of the recommended dietary allowance for protein, iron, zinc and calcium, respectively, for seven- to nine-year-old Indian children.

Originality/value – This study demonstrated the wide range of traditional mung bean foods in India and presents options to tackle malnourishment by a food-based approach.

Keywords Calcium, *In vitro* mineral accessibility, Iron, Phytate, Polyphenols, Zinc

Paper type Research paper

Introduction

Malnutrition is a serious health concern in many developing countries. A major cause is lack of access to nutritious food products. Strategies to tackle malnutrition are fortification of food products and distribution of nutrient supplements, but a

The authors gratefully acknowledge the financial support from the Department of Biotechnology, Ministry of Science and Technology, Government of India, from Wageningen University through the Interdisciplinary Research and Education Fund (INREF) via the TELFUN programme and from the International Foundation of Science (IFS) (Grant No. – A E/21294).

British Food Journal
Vol. 116 No. 6, 2014
pp. 1031-1046

0007-070X
DOI 10.1108/BFJ-11-2012-0280

food-based approach has the advantage that it is within easy reach, as indigenous foods provide variety, are well accepted, frequently consumed and readily available.

Among the indigenous foods, mung bean-based products are widely consumed in India. Mung bean or green gram (*Vigna radiata* (L.) R. Wilczek) has been cultivated in India since prehistoric times and is believed to be a native crop of India. Its grains have a protein content comparable to that of chick pea (*Cicer arietinum* L.) and contain less anti-nutritional (Chitra *et al.*, 1995) and flatulence causing compounds than soya bean (*Glycine max* (L.) Merr.) (Abdullah *et al.*, 1984). Mung bean is used in India for the preparation of different food products like dhals, sweets, snacks and savoury products. The frequency of consumption of different mung bean products is very high (Grover *et al.*, 2004; Manu and Khetarpaul, 2006), thus offering the possibility for improved products to contribute significantly to the nutritional status of the local people.

Although the nutritional composition of raw mung bean grains of different varieties has been documented (Dahiya *et al.*, 2014), little or no information is available on the proximate, mineral and anti-nutritional composition of the indigenous mung bean food products. Therefore, in the present investigation mung bean food products were analysed to determine the nutritional and anti-nutritional components and their relation with each other. This paper is the first to report on the major mung bean foods of north India and on their nutritional potential.

Material and methods

Sampling of mung bean food products

Mung bean food products were collected from rural and urban households or purchased from the market in Hisar district of Haryana state in India. Five samples of approximately 250 g of each product were collected or purchased from the different regions where the foods are known to be representatively processed and consumed. Each sample was collected as ready to eat or ready to cook. In the case of ready to cook products, they were cooked in the laboratory. Food products collected were analysed individually and not with the other products with which they are consumed in a meal. The five samples of food products were then pooled to minimise variation to form one composite food sample. After thorough mixing of the composite sample using a blender for 2 min, three representative portions of each were removed and weighed. The dried samples were ground to fine powder in an electric grinder (Cyclotec M/s Tecator, Hoganas, Sweden) and passed through a 0.5 mm mesh sieve. Powders were sealed and stored in air-tight plastic containers in a refrigerator at 5°C until analysis (maximum 20 days).

Analytical methods

Proximate composition. The following AOAC (1990) methods were used to determine proximate composition: drying at 105°C for 24 h for moisture (AOAC 925.10), incineration at 550°C for ash (AOAC 923.03), defatting in a Soxhlet apparatus using hexane for crude lipids (AOAC 920.39), digestion with NaOH and H_2SO_4 for crude fibre (AOAC 962.09) and the microKjeldahl method for crude protein (AOAC 960.52). For conversion of nitrogen to crude protein, a conversion factor of 6.25 was used. The carbohydrate content was estimated by difference of protein, fibre, ash and fat. Energy was calculated using Atwater energy conversion factors of 4.0, 4.0 and 9.0 kcal g^{-1}, for protein, carbohydrate and fat, respectively, and recalculated to kJ g^{-1}. Proximate composition was determined using dried samples.

Mineral composition. Calcium, iron and zinc contents were determined by first digesting 1 g of sample using 25 ml diacid mixture ($HNO_3/HClO_4$: 5/1, v/v) after which the digested solution was filtered through Whatman No. 42 filter paper. The volume of the solution was made up to 50 ml and then the mineral content was determined by an Atomic Absorption Spectrophotometer 2380 (Perkin-Elmer, USA) using the method of Lindsay and Norwell (1978).

In vitro mineral accessibility. In vitro iron accessibility was determined by the single enzyme method according to Rao and Prabhavathi (1978). This method is convenient, requires a minimum of chemicals, and is well suited for comparative purposes. Obviously, it does not necessarily predict exactly what will happen *in vivo*, but neither do the more sophisticated *in vitro* approaches. The method involved incubation of 2 g of powdered sample with 25 ml of 5 g l^{-1} pepsin in 0.1 N HCl solution in a water bath of 37°C for 90 min, after adjusting the pH to 1.3 using HCl. The mixture was then centrifuged at 3,000 rpm for 45 min and the supernatant was filtered through Whatman No. 44 filter paper. Iron in the filtrate was determined according to the AOAC (1995) method by treating with 1 ml hydroxylamine hydrochloride solution and 5 ml acetate buffer solution and then reacted with α, α'dipyridyl to yield a colour which was read at 510 nm and used to make a calibration line for calculating the *in vitro* iron accessibility.

In vitro zinc and calcium accessibility were assessed with the multiple enzyme method of Kim and Zemel (1986). The method involved hydration of 2 g sample with 3 ml distilled water. Hydrated samples were then treated with 20 ml pepsin solution (1 g l^{-1} pepsin in 0.1 N HCl). Next the pH was adjusted to 1.5, followed by incubation at 37°C for 1 h in a controlled temperature chamber with shaker. After incubation the pH was raised to 6.8 with NaOH and 2.5 ml of a suspension containing 5 g l^{-1} pancreatin and 50 g l^{-1} bile was added and again incubated for 1 h at 37°C in a controlled temperature chamber with shaker. Next, the volume was increased to 50 ml with distilled water and immediately centrifuged at 3,000 rpm for 45 min at 5°C. Supernatants were removed and again centrifuged at 13,000 rpm for 45 min at 5°C. The supernatant was digested with diacid mixture ($HNO_3/HClO_4$: 5/1, v/v) and then dissolved calcium and zinc were determined by an Atomic Absorption Spectrophotometer 2380 (Perkin-Elmer, USA) using the method of Lindsay and Norwell (1978).

Phytic acid and polyphenol content. Phytic acid (PA) was estimated colorimetrically by the method of Davies and Reid (1979), by incubating 500 mg of sample with 20 ml of 0.5 M HNO_3 for 3 h with continuous shaking. The suspension was then filtered through Whatman No. 1 filter paper; 1 ml of this suspension was made up to 1.4 ml using distilled water and then mixed with 1 ml ferric ammonium sulphate solution containing 50 μg of iron. The test tube containing this suspension was placed in boiling water for 20 min. Next, the suspension was cooled to room temperature and 5 ml iso-amyl alcohol was added followed by 0.1 ml ammonium thiocyanate solution (100 g l^{-1}). The content was mixed well, and centrifuged at 3,000 rpm for 10 min. Colour intensity in alcohol was read at 465 nm using a spectrophotometer and used to make a calibration line for calculating the phytic acid.

Total polyphenols were extracted from 500 mg of defatted sample by refluxing with 50 ml methanol containing 10 g l^{-1} HCl for 4 h. The extract was concentrated by evaporating methanol on a boiling water bath and brought to 25 ml with methanol-HCl solution (Singh and Jambunathan, 1981); 0.5 ml of extract was made up to 8.5 ml with distilled water, mixed with 0.5 ml Folin Denis reagent and shaken. After 3 min, 1 ml of saturated sodium carbonate was added, followed by shaking. After an hour, the absorbance was read at 725 nm. Calculations were done using absorbance and expressed as tannic acid equivalent (Swain and Hills, 1959). The PA:Zn, PA:Ca and PA:Fe molar ratios were calculated by the method of Wyatt and Triana-Tejas (1994).

Pepsin, pancreatin, pancreatic amylase and bile were obtained from Sigma-Aldrich Co., USA. All other reagents used for the analyses were of analytical grade and glassware was acid ($10\,g\,l^{-1}$ HCl) washed.

Statistical analysis. Each composite sample of mung bean product was analysed in triplicate. Mean $\pm$ standard deviation values were calculated. Comparison of means was performed by one-way analysis of variance (ANOVA) followed by Tukey multiple comparison test. Significance was accepted at $p < 0.05$ (Panse and Sukhatme, 1961). Pearson linear correlation coefficients were determined to relate the nutrient digestibility and accessibility with concentrations of anti-nutritional factors. All statistical analyses were performed with PASW Statistics (Version 18.0.2) IBM Co., USA.

Results and discussion

Description of the products

Table I presents a brief description of the mung bean products and their major ingredients. They were classified into four groups, namely *dhals*, sweets, snacks and others. *Dhals* are spiced curries of whole or split legumes, with thick soup-like consistency, commonly consumed with cereal products like rice and chapattis (Indian flat bread). Sweets include three types of products like *laddu*, *burfi* and *halwa*, prepared with ghee (clarified butter oil) and sugar along with dehulled split mung bean by shallow frying the mung bean flour or paste. Snacks are salted or spiced products like *namkeen*, *papad*, *bhalle* and *pakore*. *Namkeen* are deep fried spiced dehulled split mung bean grains. *Papad* is a spiced flat roasted product of dehulled split mung bean. *Bhalle* are round balls of deep fried dehulled fermented mung bean paste. *Wadian*, sprouts and *khichadi* products each have distinctive characteristics and thus were combined as a category of other products. *Wadian* are irregular shaped sun-dried dumplings of fermented dehulled mung bean paste, which are cooked with spices. Sprouts are germinated mung bean grains eaten as such or fried to be used in salads. *Khichadi* is prepared by cooking split mung beans with white rice.

Proximate composition

The composition of the mung bean foods is presented in Table II. Among the mung bean products, moisture content varied significantly ($p < 0.05$). The highest moisture content was found in *dhals*, *bhalle*, *wadian* and *khichadi*. The soup-like consistency of *dhals* and the soaking before *bhalle* consumption explain their relatively high moisture content. Sweets like whole *laddu*, dehulled split *laddu* and *halwa* contained less moisture with the least moisture in *burfi*, that has high amounts of fat due to the addition of ghee. *Halwa* contained most fat followed by *burfi*. Among the snacks, *namkeen* and *pakore* had fat contents comparable to that of sweets like whole *laddu* and dehulled split *laddu*; this can be explained as *namkeen* and *pakore* are deep fried, resulting in oil absorption, whereas both types of *laddu* contain ghee as an ingredient. *Dhals*, *papad*, *bhalle* and *wadian* are low in crude fat with the lowest content in sprouts and *khichadi*. The relatively low fat content of *dhals* can be attributed to the use of only small amounts of oil to sauté spices and condiments as well as to the absence of frying as a processing method. *Bhalle* contains less fat than *pakore*, despite the fact that both

Table I. Mung bean derived foods and summary of their preparation

Food type	Product	Main ingredients	Unit operations involved
Dhals	Whole dhal	Whole mung bean, red chili powder, salt, cumin seeds, vegetable oil, turmeric powder, garam masala, tomato, onion, coriander leaves garlic and water	Soaking and pressure/open cooking
	Split dhal	Same as whole dhal but with split mung beans instead of whole mung bean	Soaking and pressure/open cooking
	Dehulled split dhal	Same as whole dhal but with dehulled split mung beans instead of whole mung bean	Soaking and pressure/open cooking
Sweets	Whole laddu	Whole mung bean, sugar and ghee	Crushing and roasting
	Dehulled split laddu	Dehulled split mung bean flour, powdered sugar, ghee and nuts	Milling, flour roasting
	Burfi	Dehulled split mung bean, crystalline sugar, water, ghee and nuts	Soaking, paste making, cooking and frying
	Halwa	Dehulled split mung bean, sugar syrup, water, ghee and nuts	Soaking, paste making, cooking and frying
Snacks	Namkeen	Dehulled split mung bean, vegetable oil, water and salt	Soaking and deep frying
	Papad	Dehulled split mung bean flour, salt, black pepper, cumin seeds, asafoetida[a], water and $NaHCO_3$	Milling, dough making, drying, sheeting and roasting
	Bhalle	Dehulled split mung bean, cumin seeds, salt, water and vegetable oil	Fermentation, soaking and deep frying
	Pakore	Dehulled split mung bean, salt and red chili powder, garam masala, mango powder, coriander seed powder, water and vegetable oil	Fermentation, soaking and deep frying
Others	Wadian	Dehulled split mung bean, asafetida[a], water and salt	Soaking, fermentation, drying and pressure/open cooking
	Khichadi	White rice and split mung bean, rice, ghee, water and salt	Soaking and open cooking
	Sprouts	Whole mung bean and water	Soaking and germination

Note: [a]A dried latex (gum oleoresin) exuded from the living underground rhizome or tap root *Ferula foetida*

Table II.
Proximate composition of mung bean derived foods

Food type	Mung bean food product	Moisture ($g\,kg^{-1}$)	Crude protein ($g\,kg^{-1}$)	Crude fat ($g\,kg^{-1}$)	Crude fibre ($g\,kg^{-1}$)	Ash ($g\,kg^{-1}$)	Carbohydrate ($g\,kg^{-1}$)^{j}	Energy ($kJ\,kg^{-1}$)^{k}
Dhals	Whole dhal	$737 \pm 21^{f,g}$	236 ± 5^{i}	$48 \pm 7^{c,d}$	20.7 ± 1.2^{e}	$37 \pm 0.4^{d,e,f}$	659 ± 10^{d}	$16,780 \pm 132$
	Split dhal	827 ± 34^{h}	$206 \pm 2^{g,h}$	54 ± 4^{d}	$13.8 \pm 1.0^{c,d}$	$36 \pm 2.2^{d,e}$	$690 \pm 4^{e,f}$	$17,030 \pm 53$
	Dehulled split dhal	590 ± 18^{e}	207 ± 2^{h}	96 ± 5^{e}	8.5 ± 0.5^{b}	$42 \pm 4.3^{f,g}$	647 ± 9^{d}	$17,890 \pm 80$
Sweets	Whole laddu	137 ± 7^{b}	111 ± 6^{a}	180 ± 5^{g}	21.0 ± 1.0^{e}	$15 \pm 0.3^{a,b}$	$673 \pm 8^{d,e}$	$19,900 \pm 107$
	Dehulled split laddu	$120 \pm 11^{a,b}$	123 ± 5^{b}	142 ± 5^{f}	$7.7 \pm 0.6^{a,b}$	11 ± 0.6^{a}	717 ± 9^{f}	$19,390 \pm 98$
	Burfi	72 ± 3^{a}	154 ± 2^{c}	276 ± 10^{h}	14.0 ± 1.0^{d}	$13 \pm 0.4^{a,b}$	543 ± 11^{b}	$22,070 \pm 228$
	Halwa	64 ± 5^{a}	188 ± 4^{f}	348 ± 4^{i}	$12.9 \pm 0.6^{c,d}$	21 ± 1.0^{c}	431 ± 2^{a}	$23,450 \pm 100$
Snacks	Namkeen	211 ± 8^{c}	193 ± 3^{f}	190 ± 4^{g}	$12.8 \pm 0.7^{c,d}$	$18 \pm 0.4^{b,c}$	586 ± 3^{c}	$20,190 \pm 76$
	Papad	$168 \pm 7^{b,c}$	$168 \pm 1^{d,e}$	$40 \pm 9^{c,d}$	$12.3 \pm 0.6^{c,d}$	79 ± 0.4^{i}	701 ± 8^{f}	$16,060 \pm 170$
	Bhalle	$718 \pm 35^{f,g}$	176 ± 2^{e}	95 ± 5^{e}	5.4 ± 1.0^{a}	57 ± 0.6^{h}	$667 \pm 2^{d,e}$	$17,670 \pm 12$
	Pakore	467 ± 16^{d}	$196 \pm 2^{f,g}$	173 ± 14^{g}	$6.5 \pm 0.5^{a,b}$	$39 \pm 4.4^{e,f,g}$	586 ± 20^{c}	$19,600 \pm 234$
Others	Wadian	693 ± 28^{f}	$162 \pm 3^{c,d}$	$32 \pm 10^{b,c}$	11.4 ± 1.2^{c}	$15 \pm 0.2^{a,b,c}$	779 ± 15^{g}	$16,960 \pm 200$
	Khichadi	751 ± 7^{g}	165 ± 3^{d}	$13 \pm 2^{a,b}$	$6.7 \pm 0.6^{a,b}$	32 ± 0.4^{d}	783 ± 3^{g}	$16,370 \pm 46$
	Sprouts	546 ± 16^{e}	$170 \pm 5^{d,e}$	02 ± 2^{a}	19.0 ± 1.0^{e}	43 ± 2.3^{g}	766 ± 6^{g}	$15,740 \pm 6$

Notes: Values ($g\,kg^{-1}$) are expressed as mean ± standard deviation ($n = 3$) on dry matter basis (except for moisture). Means in the same column with the different superscripts are significantly different at $p < 0.05$. [j]Calculated by difference from protein, fat, ash, fibre and dry matter; [k]Energy = (fat (g) × 9.0 + protein (g) × 4.0 + carbohydrate (g) × 4.0) × 4.18

are fried products; *bhalle* is soaked in water for two to six hours before consumption which might expel some fat from the product. *Wadian* and *papad* are not fried and also do not contain a lot of fat as an ingredient, which explains why their fat content is lower than that of the sweets.

Dhals contain slightly more crude protein than other products, with the lowest amounts in whole *laddu* and dehulled split *laddu*. Crude protein contents of the products ranged from 111 to 236 $g\,kg^{-1}$ dry weight. Crude protein content of snacks showed no significant difference when compared with *wadian*, *khichadi* and sprouts. It seems that processing methods had no effect on the crude protein content.

Crude fibre was highest in whole *dhal*, whole *laddu* and sprouts, which are made primarily of whole mung bean grains, whereas *bhalle*, *pakore*, *khichadi*, dehulled split *laddu* and dehulled split *dhal* had lower crude fibre contents. The latter products are made of dehulled split mung beans in which the majority of the fibre is removed as husk.

The ash content of mung bean products containing hull, like whole *dhal*, split *dhal* and sprouts, was higher than in sweets made of dehulled split mung beans. *Papad* had the highest ash content although it is made from dehulled split mung beans; this may be caused by the use of black pepper as an ingredient, as it contains a considerable amount of ash (40-50 $g\,kg^{-1}$) (Parthasarathy *et al.*, 2008). Moreover, use of asafoetida (a dried latex, gum oleoresin, exuded from the living underground rhizome or tap root *Ferula foetida*) may also have contributed to the relatively high ash content of *papad* as asafoetida contains 50 $g\,kg^{-1}$ of ash (Pradeep *et al.*, 1993). *Khichadi* contained a considerable amount of ash; here the main contribution is due to the rice and not to the dehulled split mung bean. Fatty products like sweets, *namkeen* and *pakore*, contained slightly less carbohydrate than the other products. Fatty products like *burfi*, *halwa*, *laddu* and *namkeen* provide the highest amounts of calories compared to products like *papad*, *wadian*, *khichadi* and sprouts, that are non-fried nod non-fatty products.

Mineral composition

Table III presents iron, zinc and calcium in the different mung bean foods. The highest mineral concentrations were found for calcium, while iron and zinc were present in lower amounts. There are statistically significant differences between the mineral levels of the mung bean products. The variation in mineral content in products may have several reasons, like the use of whole, split or dehulled split mung bean, or the type of processing, like soaking, which results in loss of minerals. *Dhals* had higher mineral contents than *halwa*, *laddu* and *burfi*, due to the use of various spices, condiments, tomato and onion as ingredients. *Bhalle* had the highest iron content followed by *dhals*; the contents are comparable to previous studies (Pushpanjali and Khokhar, 1995). Less iron and zinc is present in *papad* despite it having the highest ash content. This may be due to the fact that the minerals are determined as elements and the ash contains their salts. Moreover, ash may also contain other elements like sodium and magnesium, which were not determined. Products involving germination, dehulling and fermentation as unit operations, like sprouts, *bhalle* and *dhals*, had higher iron contents. Calcium contents were higher in dehulled split *dhal*, dehulled split *laddu*, *papad* and *khichadi*.

Phytic acid and polyphenols

Phytic acid and polyphenol contents of mung bean products are presented in Table IV. Phytic acid content varied considerably among the various mung bean products.

Table III.
Mineral composition of mung bean derived foods

Food type	Mung bean food product	Iron (mg kg^{-1})	Zinc (mg kg^{-1})	Calcium (mg kg^{-1})
Dhals	Whole dhal	71 ± 0.8^{g}	$26 \pm 0.2^{b,c,d,e,f}$	$1,553 \pm 8^{g}$
	Split dhal	$65 \pm 0.1^{e,f}$	$24 \pm 4.6^{a,b,c,d,e}$	$1,145 \pm 8^{b}$
	Dehulled split dhal	67 ± 0.1^{f}	$30 \pm 3.2^{e,f}$	$1,953 \pm 5^{j}$
Sweets	Whole laddu	53 ± 0.1^{d}	$27 \pm 3.4^{c,d,e,f}$	$1,445 \pm 5^{f}$
	Dehulled split laddu	32 ± 2.0^{b}	$26 \pm 1.1^{b,c,d,e,f}$	$1,653 \pm 15^{h}$
	Burfi	32 ± 0.7^{b}	$21 \pm 0.5^{a,b,c}$	$1,238 \pm 18^{c}$
	Halwa	39 ± 0.5^{c}	39 ± 1.3^{g}	$1,298 \pm 14^{d}$
Snacks	Namkeen	33 ± 2.7^{b}	$22 \pm 1.6^{a,b,c,d}$	$1,141 \pm 47^{a,b}$
	Papad	26 ± 0.3^{a}	$19 \pm 1.9^{a,b}$	$1,655 \pm 10^{h,i}$
	Bhalle	79 ± 0.2^{h}	31 ± 3.0^{f}	$1,433 \pm 10^{f}$
	Pakore	62 ± 0.6^{e}	$29 \pm 0.1^{d,e,f}$	$1,093 \pm 13^{a}$
Others	Wadian	35 ± 0.5^{b}	17 ± 1.2^{a}	$1,398 \pm 15^{e,f}$
	Khichadi	27 ± 2.5^{a}	$22 \pm 0.3^{a,b,c}$	$1,705 \pm 13^{i}$
	Sprouts	61 ± 0.4^{e}	$24 \pm 3.5^{a,b,c,d,e}$	$1,355 \pm 10^{e}$

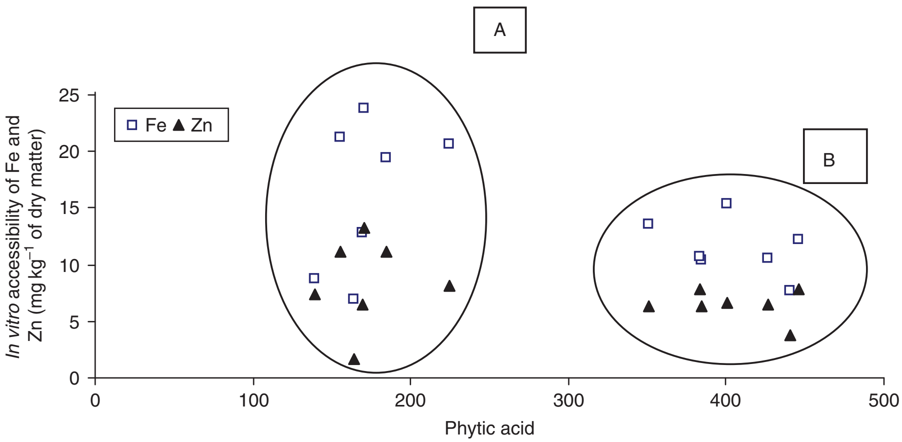
Notes: Values (mg kg^{-1} dry matter) are expressed as mean ± standard deviation ($n = 3$). Means in the same column with the different superscripts are significantly different at $p < 0.05$

Table IV.
Phytic acid, polyphenol and molar ratios of phytic acid to minerals of mung bean derived foods

Food type	Mung bean food product	Phytic acid (mg kg^{-1})	Polyphenol (mg kg^{-1})	PA:Fe Molar ratio	PA:Zn Molar ratio	PA:Ca Molar ratio
Dhals	Whole dhal	$3,510 \pm 50^{e}$	$2,436 \pm 46^{e}$	4.2 ± 0.08	13.3 ± 0.2	0.13 ± 0.002
	Split dhal	$4,009 \pm 30^{f}$	$2,378 \pm 27^{e}$	5.2 ± 0.04	16.7 ± 3.2	0.21 ± 0.002
	Dehulled split dhal	$1,703 \pm 47^{b,c}$	$1,620 \pm 68^{c}$	2.2 ± 0.06	5.6 ± 0.6	0.05 ± 0.001
Sweets	Whole laddu	$4,406 \pm 76^{g}$	$2,601 \pm 40^{f,g}$	7.0 ± 0.12	16.0 ± 2.0	0.18 ± 0.003
	Dehulled split laddu	$3,842 \pm 46^{f}$	$1,294 \pm 60^{a}$	10.2 ± 0.65	14.9 ± 0.6	0.14 ± 0.002
	Burfi	$4,264 \pm 64^{g}$	$1,821 \pm 30^{d}$	11.2 ± 0.31	20.3 ± 0.6	0.21 ± 0.004
	Halwa	$4,458 \pm 173^{g}$	$1,720 \pm 94^{c,d}$	9.7 ± 0.39	11.5 ± 0.6	0.21 ± 0.008
Snacks	Namkeen	$1,646 \pm 43^{b}$	$1,448 \pm 47^{b}$	4.2 ± 0.36	7.3 ± 0.5	0.09 ± 0.004
	Papad	$1,395 \pm 32^{a}$	$1,727 \pm 50^{c,d}$	4.6 ± 0.12	7.2 ± 0.7	0.05 ± 0.001
	Bhalle	$1,553 \pm 37^{a,b}$	$1,614 \pm 35^{c}$	1.7 ± 0.04	4.9 ± 0.5	0.07 ± 0.001
	Pakore	$1,850 \pm 48^{c}$	$1,857 \pm 25^{d}$	2.5 ± 0.07	6.3 ± 0.2	0.10 ± 0.002
Others	Wadian	$1,697 \pm 33^{b,c}$	$1,437 \pm 35^{e}$	4.2 ± 0.10	9.9 ± 0.7	0.08 ± 0.001
	Khichadi	$3,830 \pm 56^{f}$	$1,337 \pm 43^{a}$	12.1 ± 1.16	17.6 ± 0.4	0.14 ± 0.002
	Sprouts	$2,249 \pm 47^{d}$	$1,835 \pm 30^{b,d}$	3.1 ± 0.07	9.4 ± 1.4	0.10 ± 0.002

Notes: Values are expressed as mean ± standard deviation ($n = 3$) on dry matter basis. Means in the same column with the different superscripts are significantly different at $p < 0.05$

There are two distinct categories of mung bean foods in terms of phytic acid content. One category (A) includes dehulled split *dhal*, *namkeen*, *papad*, *bhalle*, *pakore*, *wadian* and sprouts, in which phytic acid ranged from 1,395-2,249 mg kg^{-1}, whereas another category (B) that includes products like whole *dhal*, split *dhal*, whole *laddu*, dehulled split *laddu*, *burfi*, *halwa*, *khichadi*, had phytic acid contents ranging from 3,510-4,468 mg kg^{-1} (Figure 1). The amount was lower in snacks than in sweets and *dhals* except for dehulled split *dhal*, which contained an amount of phytic acid comparable to that of snacks. Products involving fermentation as a processing step, like *bhalle* and *wadian*, and germination, like sprouts, contained lower amounts of phytic acid than



Note: A and B depict two distinct categories of products based on anti-nutrient composition

Figure 1. *In vitro* iron and zinc accessibility as a function of phytic acid concentration

products processed by cooking and soaking. The results seem to indicate that the degrading impact of dehulling, germination and fermentation on the phytic acid content of mung bean products results in lower phytic acid contents (Jood *et al.*, 1998). However, as the production of these products involves more than one processing step, it is not clear which processing step has the most degrading impact on the phytic acid. The relatively high phytic acid content of sweets, despite the fact that they are made of dehulled split mung bean, can be attributed to two factors. First, sweets are prepared only with sugar, ghee and dehulled split mung bean, in other words, there is no dilution of phytic acid by the addition of significant amounts of other ingredients that are low in phytic acid. Second, sweets also contain nuts, like cashews and almonds, which also contain phytates ranging from 1.5-3.5 $g\,kg^{-1}$ of edible portion (Venkatachalam and Sathe, 2006). In contrast, *dhals* need a lower amount of mung bean to prepare and also involve soaking as a processing step, which is known to have a degrading effect on phytic acid (Sattar *et al.*, 1989). The relatively high amount of phytic acid in *khichadi* could be due to the split mung bean used in its preparation instead of dehulled split mung bean.

Polyphenol was found to be higher in products prepared with whole mung bean grains, like whole and split mung bean *dhal* and whole *laddu*, as compared to sweets and snacks prepared with dehulled split mung bean *dhal*. This can be due to the fact that polyphenols are mainly present in the outer seed coat of the grain, which are removed during dehulling. The polyphenol content of fermented products, like *bhalle* and *wadian*, is lower than that of fried products like *pakore*. *Khichadi* contains the lowest amount of polyphenols, which may be due to the fact that only small amounts of mung bean are required for its preparation.

In vitro mineral accessibility

There is a significant difference in *in vitro* mineral accessibility of iron, zinc and calcium among products (Table V), which may be related to the presence of anti-nutrients such as phytic acid, polyphenols as well as dietary fibre, and to the contents of minerals themselves. There was a negative correlation of *in vitro* iron accessibility with phytic acid ($R^2 = -0.72$). The highest amount of *in vitro* accessible

Food type	Mung bean food product	*In vitro* iron accessibility (mg kg^{-1})	%^{k}	*In vitro* zinc accessibility (mg kg^{-1})	%^{k}	*In vitro* calcium accessibility (mg kg^{-1})	%^{k}
Dhals	Whole dhal	13.6 ± 0.5^{f}	19.2	6.3 ± 1.0^{b}	23.9	$315 \pm 47^{a,b}$	20.3
	Split dhal	15.3 ± 0.2^{g}	23.6	6.6 ± 0.8^{b}	27.9	$388 \pm 20^{b,c,d}$	33.9
	Dehulled split dhal	23.8 ± 0.6^{j}	35.6	13.2 ± 0.6^{c}	43.6	680 ± 16^{f}	34.8
Sweets	Whole laddu	$7.6 \pm 0.8^{a,b}$	14.4	3.7 ± 0.3^{a}	13.6	$292 \pm 52^{a,b}$	20.2
	Dehulled split laddu	$10.3 \pm 0.6^{c,d}$	32.3	6.3 ± 0.8^{b}	24.5	276 ± 23^{a}	16.7
	Burfi	10.5 ± 0.4^{d}	32.8	6.5 ± 0.5^{b}	31.3	$359 \pm 12^{a,b,c}$	29.0
	Halwa	$12.2 \pm 0.1^{e,f}$	31.4	7.9 ± 0.6^{b}	20.4	$345 \pm 34^{a,b,c}$	26.6
Snacks	Namkeen	7.0 ± 0.5^{a}	20.9	1.7 ± 0.7^{a}	7.5	$431 \pm 19^{c,d,e}$	37.8
	Papad	$8.8 \pm 0.3^{b,c}$	34.5	7.3 ± 0.5^{b}	38.0	514 ± 59^{e}	31.0
	Bhalle	21.3 ± 0.9^{i}	26.8	11.1 ± 1.2^{c}	35.6	$465 \pm 47^{d,e}$	32.5
	Pakore	19.5 ± 0.9^{h}	31.3	11.2 ± 1.0^{c}	38.5	$380 \pm 13^{b,c,d}$	34.7
Others	Wadian	12.8 ± 0.6^{f}	37.1	6.5 ± 1.0^{b}	38.6	501 ± 36^{e}	35.9
	Khichadi	$10.7 \pm 0.4^{d,e}$	40.2	7.9 ± 0.9^{b}	36.5	$292 \pm 20^{a,b}$	17.1
	Sprouts	$20.6 \pm 0.4^{h,i}$	33.6	8.1 ± 0.7^{b}	34.0	$354 \pm 31^{a,b,c}$	26.1

Notes: Values are expressed as mean ± standard deviation ($n = 3$) on dry matter basis. Means in the same column with the different superscripts are significantly different at $p < 0.05$. ^{k}%, percentage of the content present

Table V.
In vitro mineral accessibility of mung bean derived foods

iron was found in dehulled split *dhal* followed by *bhalle* and sprouts, whereas whole *laddu*, *namkeen* and *papad* had the lowest *in vitro* accessible iron. Products involving fermentation and germination and dehulling as processing method have relatively higher *in vitro* accessible iron as compared to fried and fatty products. This may be due to degradation of phytic acid present in the testa of mung bean grains during the fermentation and germination processes (Barakoti and Bains, 2007). As most of the phytic acid is present in the hull of whole mung bean grains, dehulling reduces its amount (Ghavidel and Prakash, 2007), imparting a positive effect on *in vitro* iron accessibility in split dehulled *dhal*. Whole *laddu* and whole *dhal* had the lowest *in vitro* iron accessibility, which may be due to presence of phytic acid in the hull of whole mung bean grain used to prepare these products, which has an inhibitory effect on the *in vitro* iron accessibility. *In vitro* iron accessibility in the mung bean products is high in comparison to what is expected for iron absorption in human beings. The results show *in vitro* iron accessibility in the same range as found in different cereals and legume-based foods by previous authors (Rao and Prabhavathi, 1978). Moreover, it is expected that *in vitro* iron accessibility tends to increase at low pH values due to a greater extent of dissociation of the phytic-mineral complex.

Similarly, *in vitro* accessible zinc is highest in dehulled split *dhal* followed by the fermented product *bhalle* and the germinated product, sprouts. Whole mung bean products had significantly lower *in vitro* accessible zinc. *In vitro* accessible calcium was highest in dehulled split *dhal* followed by *wadian* and *bhalle*. The relatively high *in vitro* zinc accessibility in dehulled split *dhal* is due to the fact that dehulled grains contain less phytic acid than whole grains and thus have a lower inhibitory effect on bivalent ions like zinc (Ghavidel and Prakash, 2007). *In vitro* accessible calcium in snacks was considerably higher than in sweets and whole mung bean products (Crea *et al.*, 2008).

Phytic acid to mineral molar ratios (Table IV) are used as an indicator for the bioaccessibility of divalent mineral ions. The average PA:Fe, PA:Zn and PA:Ca of the mung bean products are 5.9, 11.5 and 0.13, respectively. Critical values of molar ratios of phytic acid to a mineral for adequate mineral absorption have been reported as <0.24 for phytate/calcium (Morris and Ellis, 1980), <1 for phytate/iron (Hallberg *et al.*, 1989) and <10 for phytate/zinc (Morris and Ellis, 1980). However, in mung bean products phytic acid to mineral molar ratios are quite high, whereas the percentage *in vitro* mineral accessibility is also unexpectedly high, which might be due to the fact that effect of phytic acid on minerals not only depends on the amount of phytic acid but also on the presence of *in vivo* iron absorption enhancers, like vitamin C (Davidsson *et al.*, 2001) and the processing techniques used. Moreover, it has been reported that the effect of phytic acid on minerals is also governed by the pH (Crea *et al.*, 2008). Mung bean products have lower phytic acid to mineral ratios as compared to raw mung bean (Dahiya *et al.*, 2013), indicating the degradation effect of different processing methods on phytic acid. These ratios vary significantly among mung bean products, showing that products with lower phytic acid to mineral ratios have comparatively higher mineral accessibility. The values of PA:Ca are much lower than PA:Fe and PA:Zn due to the presence of higher amounts of calcium in the mung bean products. *In vitro* iron and zinc accessibility seem not to be affected by PA:Fe and PA:Zn in the mung bean products (Figure 2), indicating other possible factors like pH, presence of other anti-nutritional components and minerals affecting *in vitro* mineral accessibility.

Therefore, in the case of mung bean foods, PA:Fe and PA:Zn cannot be effectively used to predict mineral bioavailability. If it is assumed that calcium binds more with phytic acid due to its large amounts and forms many phytic acid-calcium complexes, then this will create a sparing effect on the iron and zinc, as the concentration of calcium is higher than iron and zinc in the products. Figure 3 indicates the possible sparing action of phytic acid-calcium on the iron and zinc accessibility in the majority of mung bean products. However, it seems that in case of split mung bean *dhal*, whole *laddu*, *burfi* and *halwa* there is still enough phytic acid to bind with Fe and Zn. This is also evident from the fact that the percentage of *in vitro* iron and zinc accessibility is higher in mung bean products than the percentage *in vitro* calcium accessibility. Figure 4 indicates PA:Ca as potential factor determining the *in vitro* calcium accessibility.

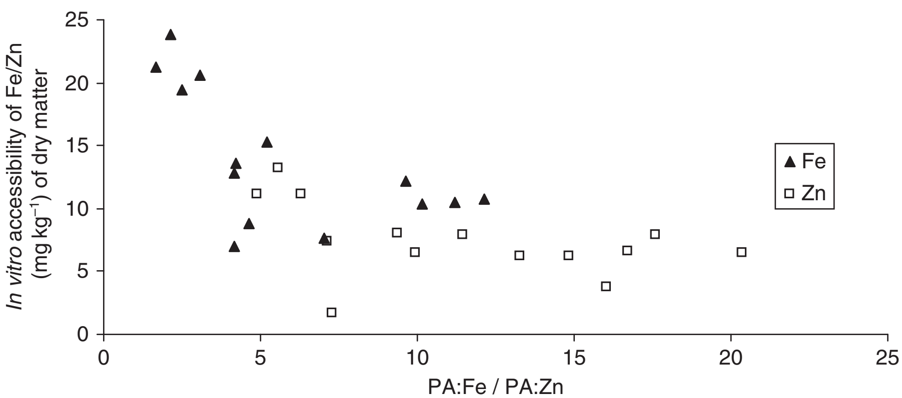
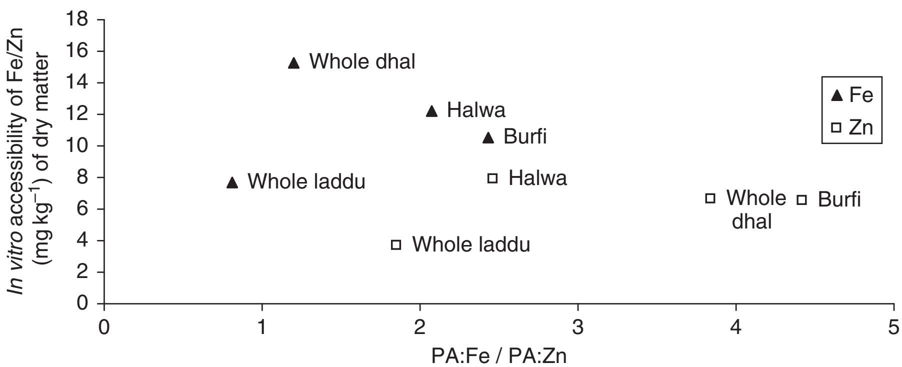


Figure 2. *In vitro* accessibility of Fe and Zn as a function of PA:Fe and PA:Zn molar ratios, respectively

Contribution to recommended dietary allowance (RDA)
The percentage of recommended dietary intake of protein, iron, zinc and calcium covered by different mung bean food products for children of seven to nine years is given in Table VI (calculated on the fresh weight of product consumed on the basis of the recommendations of the Nutrition Society of India, Hyderabad). Different mung bean products (100 g) cover 12.0-59.5 per cent, 1.6-7.2 per cent, 1.4-9.1 per cent and 1.1-7.1 per cent of the RDA for protein, iron, zinc and calcium, respectively, for seven- to nine-year-old Indian children. There is a significant difference in the percentage of RDA covered for protein, iron, zinc and calcium between products. Percentage of RDA covered for protein is highest in the sweets, as well as snacks, except *bhalle*, which covered RDA in lower amounts than *wadian*, split *dhal* and *khichadi*. *Halwa*, *burfi*, dehulled split *dhal* and *pakore* cover relatively higher percentage of RDA for iron, whereas *khichadi*, whole *dhal*, split *dhal* and *wadian* cover relatively lower percentage RDA for iron.

Conclusion

Information on nutrients and anti-nutritional factors of traditional food products is important for food composition databases (Khalil, 2000), to know the nutritional intake of populations and to select foods for product and process design and development. In the case of mung bean products, it seems that fermented and germinated products



Note: As calculated by phytic acid assuming that all calcium present is bound to phytic acid

Figure 3.
In vitro accessibility of Fe and Zn as a function of PA:Fe and PA:Zn molar ratios, respectively, in split dhal, whole laddu, burfi and halwa

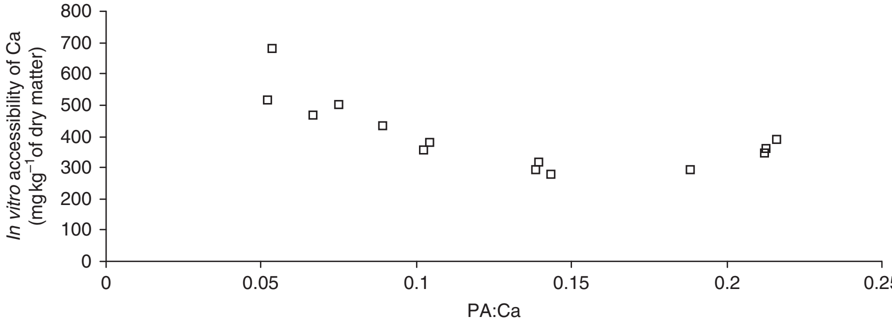


Figure 4.
In vitro calcium accessibility as a function of PA:Ca molar ratio

Food type	Products	% RDA protein	% RDA iron	% RDA zinc	% RDA calcium
Dhals	Whole dhal	21.1	2.2	2.1	1.4
	Split dhal	12.1	1.7	1.4	1.1
	Dehulled split dhal	28.7	6.1	6.8	4.7
Sweets	Whole laddu	32.6	4.1	4.0	4.2
	Dehulled split laddu	36.6	5.7	6.9	4.1
	Burfi	48.3	6.1	7.5	5.6
	Halwa	59.5	7.2	9.2	5.4
Snacks	Namkeen	51.6	3.4	1.7	5.7
	Papad	47.4	4.6	7.6	7.1
	Bhalle	16.8	3.7	3.9	2.2
	Pakore	35.4	6.5	7.5	3.4
Others	Wadian	16.9	2.5	2.5	2.6
	Khichadi	14.0	1.7	2.4	1.2
	Sprouts	26.2	5.8	4.6	2.7

Notes: Calculated for 100 fresh weight on the basis of total protein and *in vitro* mineral accessibility. [a]RDA used are 29.5 g protein, 16 mg iron, 8 mg zinc and 600 mg calcium

Table VI. Percentage of recommended dietary intake[a] of protein, iron, zinc and calcium covered by mung bean derived foods for children of seven to nine years

have higher amounts of *in vitro* accessible minerals and lower anti-nutritional compounds as compared to fried ones. This indicates the possibility to improve the non-fermented foods like *khichadi* and whole *dhal* by incorporating these processing steps. However, due to multiple processing steps it is not clear which processing step has the largest impact on the *in vitro* mineral accessibility. Therefore, controlled experiments are needed to evaluate the relative impact of the different processing methods on the mineral accessibility in mung bean foods.

Moreover, other ingredients used in mung bean products seem to play a significant role in *in vitro* mineral accessibility, as some might be acting as mineral enhancers and others as inhibitors. *Khichadi* has low amounts of *in vitro* accessible minerals and other nutrients, and therefore it needs to be consumed with mineral-rich vegetables. Products with relatively high amounts of anti-nutrients, like whole and split *dhal*, can be consumed along with food products containing enhancers of mineral absorption *in vivo*, like ascorbic acid (Jin *et al.*, 2009). In terms of *in vitro* mineral accessibility, dehulled split mung bean grains are a better ingredient for mung bean foods than whole or split mung bean grains. *In vitro* mineral accessibility in mung bean products can also be increased by using mung bean varieties with high levels of total minerals, like iron and zinc, and lower levels of anti-nutritional compounds like phytic acid and polyphenols.

References

Abdullah, A., Baldwin, R.E. and Minor, H. (1984), "Germination effects on flatus causing factors and anti-nutrients of mung beans and two strains of small-seeded soybeans", *Journal of Food Protection*, Vol. 47 No. 6, pp. 441-444.

AOAC (1990), *Official Methods of Analysis*, 15th ed., Association of Official Analytical Chemists, Washington, DC.

AOAC (1995), *Official Methods of Analysis*, 16th ed., Association of Official Analytical Chemists, Washington, DC.

Barakoti, L. and Bains, K. (2007), "Effect of household processing on the *in vitro* bioavailability of iron in mung bean (*Vigna radiata*)", *Food and Nutrition Bulletin*, Vol. 28 No. 1, pp. 18-22.

Chitra, U., Vimala, V., Singh, U. and Geervani, P. (1995), "Variability in phytic acid content and protein digestibility of grain legumes", *Plant Foods for Human Nutrition*, Vol. 47 No. 2, pp. 163-172.

Crea, F., De Stefano, C., Milea, D. and Sammartano, S. (2008), "Formation and stability of phytate complexes in solution", *Coordination Chemistry Reviews*, Vol. 252 Nos 10-11, pp. 1108-1120.

Dahiya, P.K., Linnemann, A.R., Nout, M.J.R., van Boekel, M.A.J.S. and Grewal, R.B. (2013), "Nutrient composition of selected newly bred and established mung bean varieties", *LWT – Food Science and Technology*, Vol. 54 No. 1, pp. 249-256.

Dahiya, P.K., Linnemann, A.R., Nout, M.J.R., van Boekel, M.A.J.S., Khetarpaul, N. and Grewal, R.B. (2014), "Mung bean: technological and nutritional potential", *Critical Reviews in Food Science and Nutrition*, doi:10.1080/10408398.2012.671202 (in press).

Davidsson, L., Walczyk, T., Zavaleta, N. and Hurrell, R. (2001), "Improving iron absorption from a Peruvian school breakfast meal by adding ascorbic acid or Na_2EDTA", *American Journal of Clinical Nutrition*, Vol. 73 No. 2, pp. 283-287.

Davies, N.T. and Reid, H. (1979), "An evaluation of the phytate, zinc, copper, iron and manganese contents of, and Zn availability from, soya based textured vegetable protein meat-substitutes or meat-extenders", *British Journal of Nutrition*, Vol. 41 No. 3, pp. 579-589.

Ghavidel, R.A. and Prakash, J. (2007), "The impact of germination and dehulling on nutrients, antinutrients, *in vitro* iron and calcium bioavailability and *in vitro* starch and protein digestibility of some legume seeds", *LWT-Food Science and Technology*, Vol. 40 No. 7, pp. 1292-1299.

Grover, D.K., Weinberger, K. and Shanmugasundaram, S. (2004), *Production and Consumption Status of Mungbean in India, Agricultural Situation in India*, Ministry of Agriculture, Government of India, Delhi.

Hallberg, L., Brune, M. and Rossander, L. (1989), "Iron absorption in man: ascorbic acid and dose-dependent inhibition by phytate", *American Journal of Clinical Nutrition*, Vol. 49 No. 1, pp. 140-144.

Jin, F., Frohman, C., Thannhauser, T.W., Welch, R.M. and Glahn, R.P. (2009), "Effects of ascorbic acid, phytic acid and tannic acid on iron bioavailability from reconstituted ferritin measured by an *in vitro* digestion-Caco-2 cell model", *British Journal of Nutrition*, Vol. 101 No. 7, pp. 972-981.

Jood, S., Bishnoi, S. and Sehgal, S. (1998), "Effect of processing on nutritional and antinutritional factors of moongbean cultivars", *Journal of Food Biochemistry*, Vol. 22 No. 3, pp. 245-257.

Khalil, J.K. (2000), "Food composition activities in developing countries: SAARCFOODS perspective", *Journal of Food Composition and Analysis*, Vol. 13 No. 4, pp. 669-684.

Kim, H.S. and Zemel, M.B. (1986), "*In vitro* estimation of the potential bioavailability of calcium from sea mustard (*Undaria pinnatifida*), milk, and spinach under simulated normal and reduced gastric acid conditions", *Journal of Food Science*, Vol. 51 No. 4, pp. 957-959.

Lindsay, W.L. and Norwell, W.A. (1978), "Development of a DTPA soil test for zinc, iron, manganese, and copper", *Soil Science Society of America Journal*, Vol. 42 No. 3 pp. 421-428.

Manu and Khetarpaul, N. (2006), "Food consumption pattern of Indian rural preschool children (four to five years)", *British Food Journal*, Vol. 108 No. 2, pp. 127-140.

Morris, E.R. and Ellis, R. (1980), "Bioavailability to rats of iron and zinc in wheat bran: response to low-phytate bran and effect of the phytate/zinc molar ratio", *Journal of Nutrition*, Vol. 110 No. 10, pp. 2000-2010.

Panse, Y.G. and Sukhatme, P.V. (1961), *Statistical Methods of Agricultural Coworkers*, 2nd ed., Indian Council of Agricultural Research, New Delhi.

Parthasarathy, V.A., Chempakam, B. and Zachariah, T.J. (2008), *Chemistry of Spices*, CAB International, Oxfordshire.

Pradeep, K.U., Geervani, P. and Eggum, B.O. (1993), "Common Indian spices: nutrient composition, consumption and contribution to dietary value", *Plant Foods for Human Nutrition*, Vol. 44 No. 2, pp. 137-148.

Pushpanjali and Khokhar, S. (1995), "The composition of Indian foods – mineral composition and intakes of Indian vegetarian populations", *Journal of Science of Food and Agriculture*, Vol. 67 No. 2, pp. 267-276.

Rao, B.S.N. and Prabhavathi, T. (1978), "An *in vitro* method for predicting the bioavailability of iron from foods", *American Journal of Clinical Nutrition*, Vol. 31 No. 1, pp. 169-175.

Sattar, A., Durrani, S.K., Mahmood, F., Ahmad, A. and Khan, I. (1989), "Effect of soaking and germination temperatures on selected nutrients and anti-nutrients of mung bean", *Food Chemistry*, Vol. 34 No. 2, pp. 111-120.

Singh, U. and Jambunathan, R. (1981), "Studies on desi and kabuli chickpea (*Cicer arietinum* L.) cultivars: levels of protease inhibitors, levels of polyphenolic compounds and in vitro protein digestibility", *Journal of Food Science*, Vol. 46 No. 5, pp. 1364-1367.

Swain, T. and Hills, W.E. (1959), "The phenolic constituents of *Prunus* domestica. I – The quantitative analysis of phenolic constituents", *Journal of the Science of Food and Agriculture*, Vol. 10 No. 1, pp. 63-68.

Venkatachalam, M. and Sathe, S.K. (2006), "Chemical composition of selected edible nut seeds", *Journal of Agricultural and Food Chemistry*, Vol. 54 No. 13, pp. 4705-4714.

Wyatt, J.C. and Triana-Tejas, A. (1994), "Soluble and insoluble Fe, Zn, Ca, and phytates in foods commonly consumed in Northern Mexico", *Journal of Agricultural and Food Chemistry*, Vol. 42 No. 10, pp. 2204-2209.

Further reading

National Institute of Nutrition, Hyderabad (2009), *Nutrient Requirements and Recommended Dietary Allowances for Indians*, National Institute of Nutrition, Hyderabad, pp. 156-227.

About the authors

Pradeep Kumar Dahiya completed his BSc in Biological Sciences at the Maharishi Dayanand University, Rohtak, India in 2003. Next he completed a BSc in Education in 2004. In 2006 he obtained his MSc Degree in Food Science and Technology from the Centre of Food Science & Technology, CCS Haryana Agricultural University, Hisar, India. In 2007 he obtained a PhD Research Grant from the Wageningen University through the Interdisciplinary Research and Education Fund (INREF), to undertake his PhD Research at the Wageningen University, the Netherlands. Since April 2007 he is researching the topic of redesigning mung bean foods.

M.J.R. Nout is an Externe Medewerker in the Food Microbiology Laboratory at the WU Agrotechnology & Food Sciences. His areas of expertise are foods, development cooperation, fungi and cereal products.

Martinus A. van Boekel is a Professor at the Education Institute of the Wageningen University, specialising in Food Sciences, particularly Food Quality and Safety and Food Technology.

Dr Neelam Khetarpaul obtained a BSc (1976), an MSc (1978) and a PhD (1988) Degrees in Food Science & Nutrition at the Department of Foods and Nutrition, CCS Haryana Agricultural University, Hisar, India. Since 1979, she is teaching and conducting research in the areas of foods and nutrition. She worked as Dean, College of Home Science from 6 May 2006 to 5 May 2010. She supervised more than 27 MSc and PhD Students and published 234 research articles and 22 books. She is the life member of many food and nutrition-related organisations.

Dr Raj Bala Grewal is the Dean of Post Graduate Studies at CCS Haryana Agricultural University, Hisar, India. She obtained a BSc (1977), an MSc (1980) and a PhD (1991) Degrees in Foods & Nutrition at the Department of Foods and Nutrition, CCS Haryana Agricultural University, Hisar, India. Since 1995, she is teaching and conducting research in the areas of food science and technology. She supervised three PhD students and published 68 research articles and six books. She is life member of many food and nutrition-related organisations.

Dr Anita Linnemann in 1985, she obtained a double Master Degree from the Wageningen University in Tropical Agriculture and Food Technology. She completed her PhD thesis, entitled Ecophysiology of bambara groundnut (Vigna subterranea (L.) Verdc.), in 1994. Since 1995 she is a staff member of the Food Quality and Design of the Wageningen University. Her expertise is in consumer-oriented food product development with special attention to sustainability issues. Her work in education and research is characterised by an interdisciplinary approach and the integration of natural and social sciences. At present she is supervising PhD students from Benin, Ecuador, India, Zimbabwe and Kenya, who are working on foods from cowpea, mungbean, lupin, pineapple, baobab, banana, cashew, shea and dye sorghum. Dr Anita Linnemann is the corresponding author and can be contacted at: anita.linnemann@wur.nl