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EFFECT OF GERMINATION ON CHEMICAL COMPOSITION, ANTI-NUTRITIONAL FACTORS, FUNCTIONAL PROPERTIES AND NUTRITIONAL VALUE OF KIDNEY BEAN (*PHASEOLUS VULGARIS*)

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ABSTRACT

The aim of this study was to analyze the impact of germination on the proximate composition, trace elements, anti-nutritional factors and amino acid profile of kidney bean. Results revealed positive effect of germination on the composition and nutritional attributes. Anti-nutritional factors (trypsin inhibitor, phytic acid, tannins, polyphenols and oxalates) decreased during germination which ensure the high bioavailability of minerals and other nutritional components. Protein content of sprouted beans was higher and leads to more available amino acids and its nutritional value. Essential amino acid content of beans increased after germination and inter-conversion of amino acids lead to lower non-essential amino acids. Amino acid profile revealed higher essential amino acid index (EAAI), protein efficiency ratio and nutritional index after germination. The nutritional value of amino acid was further analyzed by observing the amino acid score w.r.t. the pattern described by FAO, which showed improved nutritional value of essential and limiting amino acids.

1.Introduction

Legumes are the edible grains utilized by both humans and animals as food stuff throughout the history. Legumes are also known as poor man's meat due to its high protein content (20-40%) and low cost as compared to meat (Manay and Shadaksharaswamy, 2008). Like other beans, the kidney beans possess high nutritional value with good amount of starch, protein, dietary fiber and minerals. Fiber content also provides support to digestive system by flourishing the beneficial bacteria in colon (Tang, 2008). However, contribution of nutrition through edible legumes to the consumer is limited due to the presence of some toxic factors, enzyme inhibitors and anti-nutritional factors which limits their digestibility (El-Adawy, 2002). The presence of these anti-nutritional factors or secondary metabolites causes interference to digestibility and availability of nutrients (Zhang et al., 2015). In developing countries, foods are rarely modified at the household level to increase nutrient density to meet the needs of infants. The nutritional value of edible grains and its products (like porridges) depend primarily on their nutrient availability or presence/absence of anti-nutritional factors and thus have impact on physical and cognitive development of consumer (Neumann *et al.*, 2002). Various techniques have been currently applied by plant breeding experiments to lower the effect of these

anti-nutritional factors and secondary metabolites. Recent trend has also shown the utilization of processing of edible grains to enhance the nutritional quality of a product. Processing techniques may include germination of grains (Nkhata et al., 2018), fortification (Stabnikova et al., 2019), and fermentation (Bourré et al., 2019) of edible grains. Germination is one of best and inexpensive method to enhance the nutritional qualities and functional characteristic of grains. Germination allows the digestion of some components of grain like carbohydrates and also enhance free amino acids (Hallén, Ibanoglu, & Ainsworth, 2004).

2. Materials and methods

2.1. Materials

2.2.1. Raw material preparation

Kidney bean (light speckled kidney beans) were procured from certified seed agency. Grains were germinated as per the method described by Sibian et al. (2016-a). The sprouts were cleaned and rinsed in water after germination. Drying of sprouts was initially carried out at 80°C for 15 min to halt the enzyme activity, and then final drying was done at 60±5°C to attain moisture content of 8.00 ± 2% (db). Dried sprouts and un-germinated kidney bean grains were grinded separately in lab grinder to form flour and passed through 60 mesh sieves (US size 60 mesh = 250 μm). Both samples were kept at ambient condition for further analysis.

2.2.2. Composition analysis

The proximate analysis for the components like moisture content, protein (Kjeldahl method), crude fat (solvent extraction), crude fiber, ash and dietary fiber of raw and germinated kidney bean was carried out in triplicates using standard AOAC (2005) methods. Starch content was estimated by the modified anthrone method using variable range of glucose as standard solution.

Folic acid content of sample was estimated using IS 7234 (BIS, 1974) colorimeter at 660nm. Folic acid content was estimated by interpolation of graph readings on standard curve. Following relationship was used to calculate the folic acid per gram of sample.

$$\mu g \text{ of folic acid per g of sample} = \frac{\text{Average}(\mu g/ml) \times \text{Dilutionfactor}}{\text{Mass of sample}} \quad (1)$$

2.2.3. Trace element analysis

Sodium, phosphorus, calcium, magnesium and iron were estimated by the standard method described by AOAC (2005). The samples were ashed at 550 °C. The ash was boiled with 10 ml of 20% hydrochloric acid in a beaker and then filtered into a 100 ml standard flask. This was made up to the mark with deionized water. The minerals were determined from the resulting solution. Sodium [Na] was determined using the standard flame emission photometer using NaCl as the standards. Phosphorus was determined calorimetrically using KH_2PO_4 as the standard. Calcium [Ca], Magnesium [Mg] and Iron [Fe] were determined using Atomic Absorption Spectrophotometer.

2.2.4. Microstructure analysis

Microstructure of kidney bean flour from raw and un-germinated grains were observed using scanning electron micrographs obtained from scanning electron microscopy (SEM, JEOL, Tokyo, Japan, Model No. JSM 6610-LV) at varying range of magnification. Dried flour sample were directly positioned on S.E.M stub using two faced cellophane adhesive tape and then smeared with gold pladinum (60:40 g/g) by means of auto fine coater (JEOL-JFC-1600).

2.2.5. Functional properties

Effect of germination on functional properties of kidney bean flour was observed by analyzing various physical attributes of flour. Water absorption capacity was calculated by the method described by Yamazaki (1953) and expressed as water absorbed by 1.0 g of sample. Oil absorption capacity was estimated by the method of Lin et al. (1974) as oil absorbed by per gram of flour. Bulk density was measured as volume of 100 g of sample in 250 ml volumetric cylinder and values were expressed as g/ml of sample. Sedimentation value was estimated by calculating the swelling power of flour suspended in lactic acid as described in ICC

116/1 standard method (Zeleny's method). Percentage foaming capacity was calculated according to the method described by Mizubuti et al. (2000). Emulsification capacity was calculated by the method of Naczk, Diosady, and Rubin (1985) and expressed as ml of oil emulsified by 1.0 g of the sample. The emulsion stability was determined by heating the emulsified sample for 15 min at 85°C followed by cooling and centrifugation (5000×g) for 5 min. The emulsion stability was expressed in percentage activity of emulsion remained after heating.

2.2.6. Antinutritional factor analysis

The trypsin inhibition activity (TIA) was estimated as inhibition of bovine trypsin using the substrate benzoyl-DL-arginine-pnitrianilide (BAPNA) hydrochloric (Kakade et al., 1969). Tannin content was evaluated by vanillin-HCl methods (Price et al., 1978). For analysis sample was defatted and extracted for tannin in methanol (acidic). Vanillin-HCl reagent was added to develop color in the solution. Catechin was used as standard and run along with the sample. Spectrophotometer reading was measured at 500 nm. Results of tannins were expressed as mg/100g dry weight. Oxalate content was determined by AOAC (2005) method. The concentration of oxalate in each sample was obtained from the equation as 1 ml of 0.1 N permanganate = 0.006303 g oxalate. Phytic acid was estimated by the method of Davies and Reid (1979). Extraction was carried out with nitric acid and reacted with ferric ammonium sulphate in a boiling water bath. After cooling of solution, isoamyl alcohol and ammonia solution were added. Solution was centrifuged at 3000 rpm for 10 min and the alcoholic layer was separated. Spectrophotometer reading was measured at 465 nm with amyl alcohol taken as blank. The results were expressed as mg phytic acid/100g dry weight.

Polyphenols were estimated using method described by Singleton et al. (1999), with slight modification. Defatted sample was extracted using 1% HCl in methanol and content was refluxed for 2 h. Volume was made up to 100ml with water and 0.2ml extract was taken, to this 0.5ml Folin-denis reagent was added and mixed with saturated sodium carbonate again volume was made to 10 ml with water. The OD was taken at 765 nm after 30 min. The results were calculated as mg gallic acid equivalent/g sample and expressed as mg/100g on dry weight basis.

2.2.7. Amino acid analysis

Raw and un-germinated samples were analyzed for amino acid profile, using the physiological kits for gas chromatography flame ionization detection (Phenomenex, USA). The grain samples were milled to flour (60 mesh) and then hydrolyzed with concentrated HCl. Analysis was performed as directed in the kit's manual. The GC column used was the ZB-AAA GC column, which was provided in the kits and standard analysis conditions were used, as described in the kit's manual. Amino acids were further analyzed for estimation of essential amino acid index (EAAI), protein efficiency ratio (PER-1 and 2), nutritional index (NI) and biological value (BV). EAAI was calculated by using the ratio of relative essential amino acids in the test protein as compared to the respective values in whole egg protein used as reference value. Essential amino acids (g/16g N) were converted into g/g nitrogen basis and then the ratio of test to reference was calculated. The whole calculation was done according to the equation of Oser, (1959) as:

$$\mathrm{EAAI} = \sqrt{\frac{\mathrm{Lys_a} \times \mathrm{Tyr_a} \times \ldots\ldots \times \mathrm{His_a}}{\mathrm{Lys_b} \times \mathrm{Tyr_b} \times \ldots\ldots \times \mathrm{His_b}}} \quad (2)$$

Where “a” is the amino acid in test sample and “b” is the amino acid in reference protein sample.

Biological value, Protein efficiency ratio and nutritional index was calculated according to the method described by Alsmeyer et al. (1974) and Ijarotimi (2012).

Amino acid score for infants (pre-school) and adult were calculated as the ratio of observed value of amino acid to the appropriate reference patterns as provided by FAO (2013). Indispensable amino acid values (g/16 gN) were taken as test amino acids and individually each amino acid was observed for scoring.

$$\text{Amino acid score} = \frac{\text{Value of observed amino acid in test sample}}{\text{Value of amino acid in reference sample}} \quad (3)$$

3.Results and discussions

3.1. Proximate composition

Proximate composition of kidney bean was observed and as shown in table 1. Composition of flour varied significantly as a result of germination. After germination the protein content increased significantly and varied from 20.77±0.04 to 23.36±0.06 g/100g flour. Increment in the protein content could be attributed to the biosynthesis of amino acids (Zhang et al., 2015). Insignificant increment in the ash content of was observed. Chiemela et al. (2009), observed similar results after germination of tiger-nut seed flour. Carbohydrate content of kidney bean varied significantly after germination. Decrease in the complex carbohydrate molecules like starch, amylose and amylopectin was observed. The change might be attributed to the increase activity of amylase and other hydrolyzing enzymes (Zhang et al., 2015).

Non-reducing sugars and reducing sugar, enhanced as a result of increase in total sugar. Non-reducing sugar in raw kidney bean was observed as 2.86±0.03 g/100g which increased to 4.07±0.03 after germination. Reducing sugar was also high in germinating kidney bean and varied from 0.29±0.01 to 0.43±0.09 g/100g. Activity of α-amylase promotes the breakdown of carbohydrates and converted the complex molecules into more easily digestible polysaccharides sugar. Various researchers observed the same pattern and conclusions for increment of sugars after germination (Zhang et al., 2015; Nkhata et al., 2018).

Table 1. Proximate composition of raw and germinated kidney bean flour

Constituents (%)	Kidney bean (Raw)	Kidney bean (Germinated)
Protein	20.77±0.04^{b}	23.36±0.06^{a}
Ash	1.28±0.03^{a}	1.36±0.04^{a}
Carbohydrates	72.84±0.03^{a}	67.76±0.03^{b}
Starch	67.32±0.02^{a}	63.54±0.03^{b}
Amylose	17.83±0.02^{a}	16.24±0.03^{b}
Amylopectin	49.49±0.02^{a}	47.30±0.03^{b}
Sugar	3.15±0.02^{b}	4.51±0.02^{a}
Non-reducing sugar	2.86±0.03^{b}	4.07±0.03^{a}
Reducing sugar	0.29±0.01^{b}	0.43±0.09^{a}
Fats	1.20±0.01^{a}	1.18±0.03^{a}
Crude fiber	5.28±0.03^{b}	6.18±0.04^{a}
Dietary Fibers	10.28±0.02^{b}	15.13±0.03^{a}
Folic Acid (mcg/100g)	153.17±0.32^{b}	182.12±0.12^{a}

*n=3, Results are expressed as mean values ± standard deviations. Means in a row with different superscripts are significantly different ($p<0.05$)

Fat content of kidney bean decreased during germination. Fat content in raw kidney bean flour was higher and ranged from 1.20±0.01 to 1.18±0.03 g/100 in germinated kidney bean. Some researchers attributed this decrease to total solid loss during soaking process (Sibian et al., 2016-a). Crude fiber and dietary fiber increased as a result of germination. Increase in the fiber content might be due to synthesis of cell wall components and other polysaccharide based substances required for synthesis of cell structures, which enhanced the fiber content. Crude and dietary fibers in raw kidney bean were reported as 5.28±0.03 and 10.28±0.02 g/100g and after germination the values varied to 6.18±0.04 and 15.13±0.03 g/100g respectively. Increase in the total fiber content was observed by Jan, Saxena, & Singh (2017) in *Chenopodium album* after germination. Folic acid content was also high in germinated kidney bean. Folic acid content varied from 153.17±0.32 to 182.12±0.12 mcg/100g after germination. Folic acid plays an important role in seed germination by promoting the biochemical and functional development in plant cells, therefore during germination growth of seedling took place and could be correlated to enhanced folic acid content. Kariluoto et al. (2006), observed the prominent increment in folates of germinating rye and observed that thermal treatments could cause folate loss.

3.2. Trace element analysis

Significant increase in all trace elements was observed as shown in table 2. Calcium, iron, magnesium, phosphorus, sodium and zinc were observed for the deviation after germination. Minerals of kidney bean flour varied as calcium 78.32±0.05 to 82.09±0.04; iron-5.67±0.03 to 5.84±0.04, magnesium-135.51±0.09 to 146.39±0.05, phosphorus- 64.61±0.05 to 69.28±0.05, sodium- 14.74±0.05 to 16.21±0.04 and zinc- 3.53±0.04 to 3.96±0.07 mg/100g after germination. Increment in mineral content with germination of some cereals and legumes have been reported previously by Desai et al. (2010) and Laxmi et al. (2015).

3.3. Microstructure analysis

Effect of germination on the morphology of starch was observed as shown in figure 1 (a-b). Germination enhanced the protein content and degraded starch therefore, as a result morphological changes occurred. Undamaged starch molecules were observed before germination with smooth surface and in less association with protein matrix. Germination brought changes in the starch structure molecules and also increment in protein which was observed as matrix and in association with starch molecules. As a result of germination starch molecules become distorted and smooth surfaces become rough. Scanning electron micrographs of wheat showed similar observations after germination due to the action of alpha amylase (Sibian et al., 2016-b).

Table 2. Changes in the trace elements of kidney bean (cranberry bean) after germination

Trace elements (mg/100g flour sample)	**Kidney bean (Raw)**	**Kidney bean (Germinated)**
Calcium	78.32±0.05^{b}	82.09±0.04^{a}
Iron	5.67±0.03^{b}	5.84±0.04^{a}
Magnesium	135.51±0.09^{b}	146.39±0.05^{a}
Phosphorus	64.61±0.05^{b}	69.28±0.05^{a}
Sodium	14.74±0.05^{b}	16.21±0.04^{a}
Zinc	3.53±0.04^{b}	3.96±0.07^{a}

*n=3, Results are expressed as mean values ± standard deviations. Means in a row with different superscripts are significantly different ($p<0.05$)

3.4. Functional properties

Effect of germination on the functional properties of kidney bean is as shown in table 3. Germination enhanced the functional capabilities of kidney bean flour. Functional properties are determinant factor for evaluating the flour components and its behavior during processing or food formulation (Siddiq *et al.*, 2009). Water absorption capacity of kidney bean (g/g water absorbed) was higher in germinated flour sample. The value of water absorption capacity ranged from 1.13±0.01 to 1.27±0.02.

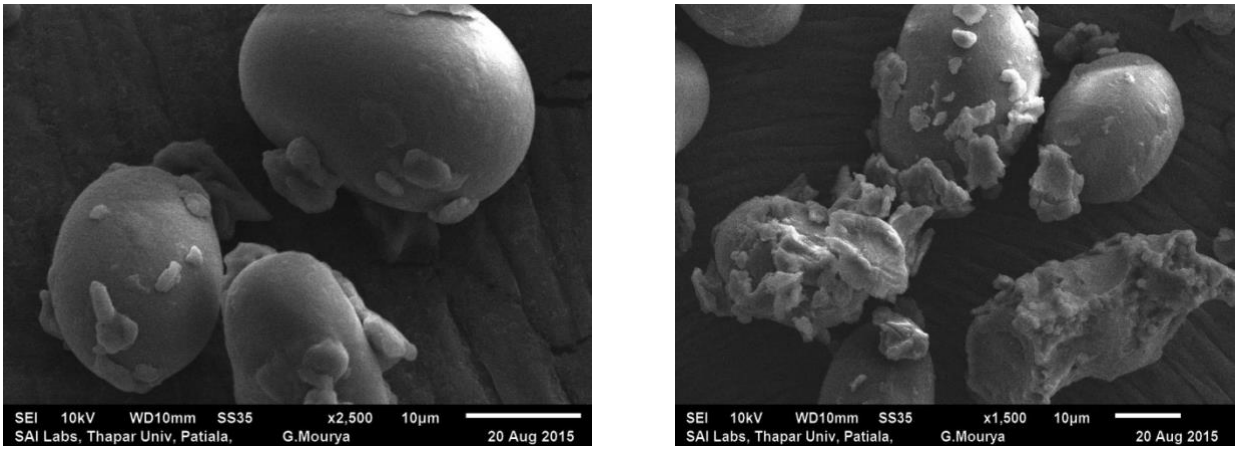

Figure1 (a-b): Effect of germination on the microstructure of kidney bean

Table 3. Effect of germination on functional properties of kidney bean

Functional parameters	**Kidney bean (Raw)**	**Kidney bean (Germinated)**
Water absorption capacity (g/g water absorbed)	1.13 ± 0.01^{b}	1.27 ± 0.02^{a}
Oil absorption capacity (g/g oil absorbed)	1.31 ± 0.02^{b}	1.39 ± 0.03^{a}
Bulk density (g/cm^3)	0.81 ± 0.02^{a}	0.77 ± 0.02^{b}
Foaming capacity (%)	26.01 ± 0.01^{b}	38.67 ± 0.04^{a}
Sedimentation value (ml)	9.03 ± 0.02^{ab}	11.02 ± 0.01^{a}
Emulsification activity (%)	55.67 ± 0.06^{b}	61.67 ± 0.05^{a}
Emulsification capacity (ml oil/g sample)	128.67 ± 0.05^{b}	151.12 ± 0.06^{a}
Emulsification stability (%)	46.34 ± 0.05^{b}	58.08 ± 0.06^{a}

*n=3, Results are expressed as mean values ± standard deviations. Means in a row with different superscripts are significantly different (P<0.05)

Improvement in the protein content during germination and breakdown of complex carbohydrates led to increment in the water absorption capacity (Sibian et al., 2020). Raw kidney bean flour showed lower oil absorption capacity (g/g oil absorbed) which was reported as 1.31±0.02 and enhanced to 1.39±0.03 after germination. Oil absorption capacity is function of hydrophobic protein molecules; increase in the protein content enhanced the oil absorption capacity of kidney bean flour (Chiemela et al., 2009). Due to the change in the conformation of physical structure of particle bulk density decreased. Bulk density depends on the number of factor like structure of particle, moisture content of flour, dispensability and particle size. Milling conditions and techniques also affected bulk density. Foaming capacity of kidney flour showed increment after germination. Germination enhanced the protein properties and therefore lowered the surface tension at the interface of air and water to effectively form foam (Kaur *et al*., 2010). Foaming capacity of raw kidney bean flour was reported as 26.01±0.01 and 38.67±0.04% in germinated kidney bean flour sample. Sedimentation value of raw kidney bean flour was 9.00 ml which increased slightly to 11.00 ml. Sedimentation values might be lower due to lack of gluten like protein in legume flour.

Significant increase in the emulsification properties was observed as an effect of germination. Emulsion forming and stability behavior of flour depends on the amphiphilic nature of protein. Emulsion stability is function of lipid-protein interaction, more the protein-lipid interaction more would be the stability of emulsion formed (Sibian et al., 2017). Emulsion activity in raw flour was 55.67±0.06% and enhanced to 61.67±0.05% after germination. Emulsion capacity (ml oil/g sample) was also increased from 128.67±0.05 to 151.12±0.06. Emulsion stability was lower in raw kidney bean flour and was reported as 46.34±0.05% which increased to 58.08±0.06% after germination. Similar observations in improvement of the emulsion properties were already observed in germinated sorghum and brown rice flour (Elkhalifa *et al*., 2010).

Table 4. Variability of anti-nutritional factors in kidney bean

	Trypsin Inhibitor activity (TIU)	**Phytic Acid (g/100g)**	**Tannins (mg/100g)**	**Polyphenol (mg/100g)**	**Oxalate (mg/100g)**
Kidney bean (Raw)	158.05±0.03^{a}	0.780±0.06^{a}	0.330±0.04^{a}	0.564±0.03^{a}	1.54±0.05^{a}
Kidney bean (Germinated)	86.54±0.04^{b}	0.495±0.07^{b}	0.219±0.03^{b}	0.317±0.05^{b}	0.76±0.03^{b}
Variability (%)	45.24	36.53	33.63	43.79	50.64

*n=3, Results are expressed as mean values ± standard deviations. Means in a column with different superscripts are significantly different (P<0.05)

3.5. Effect of germination on anti-nutritional factors of kidney bean

Effect of germination and variability of anti-nutritional factors in kidney bean was observed as shown in table 4. Significant reduction in trypsin inhibitor, phytic acid, tannin, polyphenol and oxalate was observed as result of germination (Nkhata et al., 2018). Trypsin inhibitor activity in raw kidney bean was observed as 158.05±0.03 TIU and after germination it was reduced to 86.54±0.04 TIU with overall variability of 45.24%. Similar results were also observed by Zhang et al. (2015), after germination of buckwheat. Phytic acid was reduced by 36.53% and the value of raw and germinated kidney bean varied from 0.780±0.06 to 0.495±0.07 g/100g sample. Germination of legumes activates phyates enzyme which digests phytate (Luo et al., 2014). Tannin content was reduced by 33.63% with

reduction from 0.330±0.04 to 0.219±0.03 mg/100g. Polyphenol content of raw legume was observed 0.564±0.03 mg/100g which reduced to 0.317±0.05 mg/100g after germination. The percentage variability in reduction of polyphenol was observed as 43.79%. Oxalate content of kidney bean was also reduced as a result of germination. Raw kidney bean contains 1.54±0.05 mg/100g which reduced significantly to 0.76±0.03 with variability of 50.64%. The reason for reduction of water soluble secondary metabolites could be solid leaching during soaking due to their hydrophobic interactions (Dongyan *et al*., 2014).

3.6. Effect of germination on total amino acid content of kidney bean

Legumes are considered as good source of proteins and essential amino acids. Total amino acid profile was observed for both raw and germinated kidney bean as shown in figure 2. Total non-essential amino acid proportion decreased as a result of germination and varied from 47.17±0.03 to 39.74±0.04 g/100g protein. On the other hand total essential amino increased from 52.83±0.07 to 60.26±0.06 g/100g protein. Increment in the amino acid content was also observed by Bhathal & Kaur (2015). Aromatic amino acid and acidic amino acid content in germinated kidney bean was observed with lower values, whereas basic amino acid content increased. Leucine to isoleucine ratio was maintained during germination due to proportionate increment in both branched chain amino acids.

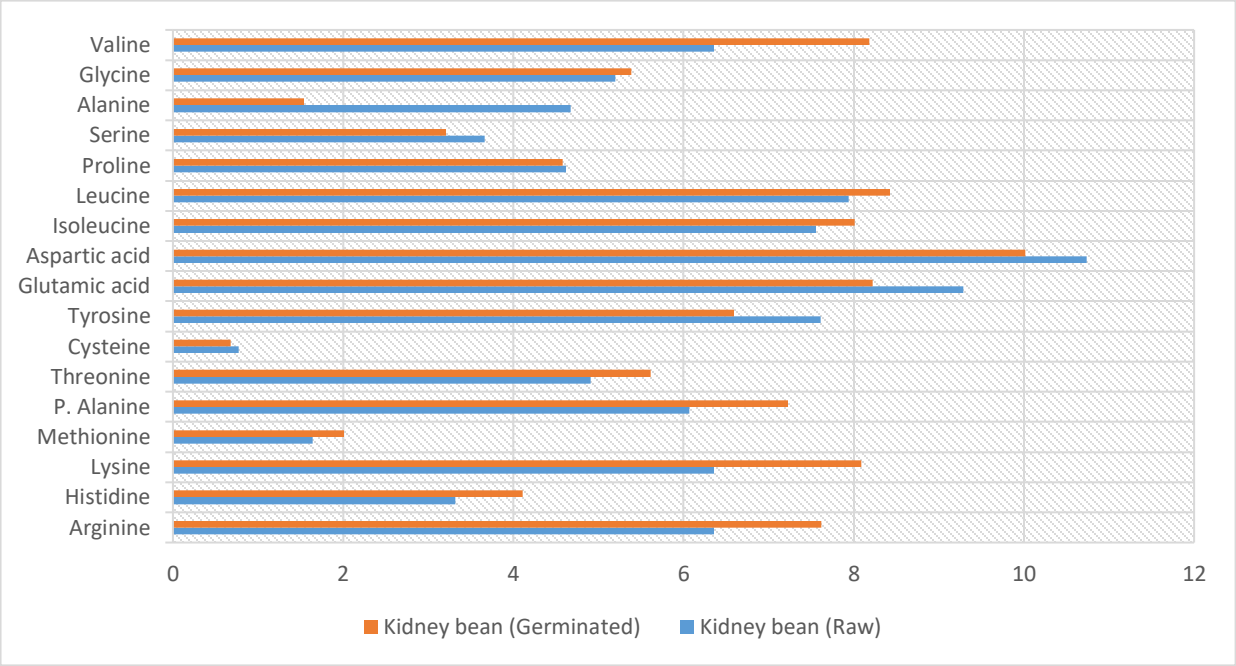

Figure 2. Amino acid contents of raw and germinated kidney bean

Essential amino acid index, biological value, protein efficiency ratios, nutritional index are the parameters to evaluate quality of protein on the basis of amino acids. Food arbitrated on the basis of protein profile should have biological value between 70 to 100% and essential amino acid index above 90% (Larson & Beevers, 1965). Essential amino acid index of kidney bean was reported 80.26±0.09 in raw kidney bean which was further improved by germination to 91.05±0.06 (Table 5). Biological value of kidney bean protein was also reported higher after germination. Biological value of kidney bean protein varied from 75.78±0.06 to 87.54±0.07. Protein efficiency ratios were also improved during germination and varied from 2.72±0.04 to 2.94±0.01 and 2.34±0.04 to 2.66±0.03. With the increase in essential amino

acid and improvement in protein content, nutritional index of kidney bean protein was reported higher in germinated kidney bean (Sibian et al., 2016-a). Nutritional index increased from 16.67±0.02 to 21.27±0.05. Similar observations in the increment of amino acid profile of wheat, brown rice and triticale was observed by Sibian et al. (2017).

Table 5. Effect of germination on the total amino acid profile and nutritional profile of kidney bean (cranberry bean)

Amino acid profile (%)	Kidney bean (Raw)	Kidney bean (Germinated)
Total non-essential amino acid	47.17±0.03^{a}	39.74±0.04^{b}
Total essential amino acid	52.83±0.07^{b}	60.26±0.06^{a}
Total Aromatic Amino acid	14.09±0.06^{a}	13.89±0.06^{b}
Total Acidic amino acid	20.63±0.02^{a}	18.32±0.03^{b}
Total Basic Amino Acid	16.52±0.08^{b}	19.91±0.06^{a}
Leucine/Isoleucine ratio (BCAA)	1.05±0.03^{ab}	1.05±0.06^{ab}
Essential amino acid index	80.26±0.09^{b}	91.05±0.06^{a}
Biological Value	75.78±0.06^{b}	87.54±0.07^{a}
PER-1	2.72±0.04^{b}	2.94±0.01^{a}
PER-2	2.34±0.04^{b}	2.66±0.03^{a}
Nutritional index	16.67±0.02^{b}	21.27±0.05^{a}

*n=3, Results are expressed as mean values ± standard deviations. Means in a row with different superscripts are significantly different (P<0.05)

3.7. Effect of germination on amino acid score

Amino acid score of raw and germinated kidney bean was observed as per the reference values of FAO (2013) as shown in Table 6. The detrimental factor for food protein quality greatly depends on the content and availability of amino acids (Graciela Caire-Juvera et al., 2013).

Table 6. Amino acid score for infants/preschool and adults (FAO, 2013) in raw and germinated kidney bean

Amino Acid Score (for infants/pre-school(1-2 yrs)	**FAO (2013)**	**Kidney bean**	
		Raw	**Germinated**
Isoleucine	3.2	236.22	250.16
Leucine	6.6	120.36	127.78
Lysine	5.7	111.50	141.94
Methionine + Cystiene	2.7	89.16	99.89
Phenylalanine + Tyrosine	5.2	262.95	265.90
Threonine	3.1	158.42	180.90
Valine	4.3	147.80	190.15
Amino Acid Score (for adults)	**FAO (2013)**	**Kidney bean**	
		Raw	**Germinated**
Isoleucine	3.0	251.97	266.84
Leucine	5.9	134.65	142.94
Lysine	4.5	141.23	179.79
Methionine + Cysteine	2.2	109.42	122.59
Phenylalanine + Tyrosine	3.8	359.83	363.87
Threonine	2.3	213.52	243.82
Valine	3.9	162.96	209.65
Histidine	1.5	221.47	273.97

All the amino acids has shown higher amino acid score and were reported above 100 except sulfur containing amino acids. Sulfur containing amino acids were found limited in both raw and germinated kidney bean in amino acid scoring pattern of infants/pre-school, which could be attributed to lower value of methionine in legume. Sulfur containing amino acid content improved with germination. The values for methionine plus cystine varied from 89.16 to 99.89 in infant amino acid scoring pattern whereas the amino acid score for sulfur containing amino acid was varied from 109.42 to 122.59 in adult amino acid scoring pattern. The difference in the values were attributed to the reference values in both cases. Isoleucine and aromatic amino acid content of kidney bean was found quite higher in both amino acid scoring patterns of infants/pre-school and adults. Overall amino acid score showed increment as a result of germination (Sibian et al., 2017).

4. Conclusions

Germination proved as an effective processing method in the improvement of nutritional attributes of kidney bean. Overall nutritional profile including proteins, amino acids, sugars, and fiber content improved significantly during germination. Functional properties showed the increased water and oil absorption capacities, which could be beneficial in formulation of number of products. Decrease in anti-nutritional factors would contribute to improved bio-availability and digestibility. Improved protein quality and amino acid profile further enhances the nutritional value of legume.

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