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RESEARCH ARTICLE

Effect of infrared processing on functional, nutritional, antinutritional and rheological properties of mung bean (*Phaseolus aereus*) seeds

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Abstract

The effect of infrared (IR) processing on functional, nutritional, antinutritional and rheological properties of mung bean seeds were studied and the results were compared with the conventionally processed mung bean seeds. Water absorption capacity and sedimentation values were significantly increased ($p \leq 0.05$) due to IR processing. Results indicated significant decrease ($p \leq 0.05$) in bulk density with better reconstitution characteristics when compared to conventional processing methods. IR processing caused significant ($p \leq 0.05$) reduction in anti nutritional factors, higher retention ($p \leq 0.05$) of vitamin B_1 and B_2 contents as well as comparatively lesser degradation of different fatty acids. Treatment resulted in greater reduction in cooking time of mung bean seeds (3 min) as compared to conventionally processed mung bean (35 min).

INTRODUCTION

Mung bean (*Phaseolus aereus*) is an important legume crop consumed in India and its protein quality is considered almost similar to the protein quality of chick pea, black gram and pigeon pea **(Kataria *et al.*, 1989; Jood *et al.*, 1998).** Although legumes are rich in nutritive value, their utilization is limited due to their longer cooking time (**Buckle and Sambudi, 1990).** Traditional soaking and treatment of legumes in salt and bicarbonate solutions to reduce the cooking time has been broadly studied **(Buckle and Sambudi, 1990; Singh and Rao, 1995).** Reduction in cooking time of pulses and legumes have been reported earlier using freeze thaw dehydration method **(Umadevi *et al.*, 2008).** Besides this, legumes contain several antinutritional compounds such as trypsin inhibitors, phytates, polyphenols, flatulence factors and so on and their presence and absence depends on the type of legumes **(Sathe and Salunkhe, 1984).** Studies reported that, processing treatments such as IR heating, extrusion, irradiation, germination and cooking eliminated antinutritional factors significantly. **(Deshpande *et al.*, 1984; Salunkhe and Kadam, 1989; Vanderpoel, 1990; Liener, 1994).** The processing methods greatly influences the nutritive value of foods w.r.t micro and macronutrients. The food processing covers wide area starting from simple boiling to irradiation and the stability of various nutrients depends upon severity and duration of processing **(Henry and Massey, 2001).**

Micronization / IR processing is an intense heat process, wherein the exposure of an absorbent material to electromagnetic radiation takes place for a shorter time in the infrared region and used widely during recent years as one of the efficient methods to shorten the cooking time of legumes. The application of IR radiation to food processing is gaining importance due to its inherent advantages over conventional heating w.r.t its short process time, uniform heating, reduced quality loss, uniform product temperature and better quality of finished products (**Krishnamurthy *et al.*, 2008).** Effect of infra red treatments on the properties of soy bean, lentils, cow peas, kidney beans, green peas, black beans and pinto beans have been studied **(Cenkowski and Sosulski, 1997; Fasina *et al.*, 2001; Mwangwela *et al.*, 2007).** Studies have also been carried out to investigate the effect of soaking, germination, autoclaving, boiling, roasting, toasting and microwave treatments on functional, nutritional and antinutritional properties of mung bean seeds **(Mubarak, 2005; Akaerue, 2010).** However, the information on the effect of IR processing on the properties of mung bean seeds is scanty. Therefore, the study was undertaken to investigate the effect of IR processing on the functional, nutritional, antinutritional and rheological properties of mung bean seeds in comparison to the existing conventional methods of processing.

MATERIAL AND METHODS

Good quality mung bean seeds were procured from the local market and extraneous matter if any was removed. All the chemicals used for the study were of analytical reagent grade.

Tempering

Prior to micronization, the moisture content of mung bean seeds was increased to 55%. The tempering process involved the addition of pre-calculated amount of water to mung bean seeds, placing it in a sealed polypropylene pouches (PP, 75µ) for 6 h and tumbling it periodically to evenly distribute the water through out the sample. After tempering, the surface moisture from the grains was removed by pressing between muslin cloth.

Water/oil absorption capacity

Water/oil absorption capacity of raw, IR and conventionally processed mung bean seeds was performed as per **Beuchat (1977); Eke and Akobundu (1993)** methods. 1g of the sample was treated with 20 ml of distilled water/ sunflower oil in a previously weighed 20 ml centrifuge tube. The slurry was agitated on a vertex mixer for 2 min and allowed to stand for 30 min and centrifuged at 3000 rpm for 30 min. The clear supernatant was decanted and discarded. The adhering drops of water/oil were removed and the tubes were weighed. The weight of the water/oil absorbed by 1g of the sample was calculated and expressed as water/ oil absorption capacity.

Sedimentation value

The sedimentation value of raw, IR and conventionally processed mung bean seeds was measured by taking powdered sample passing through 30 mesh sieve. 10 g of the sample was mixed with 100 ml distilled water in a stoppered 100 ml measuring cylinder. The contents were thoroughly mixed and the cylinder was kept aside for 10 min and the volume of the sediment was noted at exactly after 10 min and expressed as sedimentation value **(Ghadge *et al.*, 2008).**

Bulk density

Bulk density of raw, IR and conventionally processed mung bean seeds as per **Narayana and Narasingha (1984)** was determined by weighing 500 ml sample and expressed as g/ ml. The sample was filled in to 500 ml measuring cylinder up to the mark and the cylinder was tapped gently while filling. The measured sample was weighed. The ratio of the mass of the sample to the volume of the cylinder was taken to calculate bulk density.

Swelling Index

Samples of raw, IR and conventionally processed mung bean seeds were analysed for swelling index as per the method of **Abu *et al.* (2005).** Samples were dispersed in deionized water (1:20 w/v) and vertexed for 1 min. Heated on a water bath at 90^0C for 30 min with intermittent stirring. The samples were cooled under running water for few seconds followed by cooling in ice bath for 10 min. The tubes containing gel were centrifuged at 6100 rpm for 10 min, after which the samples were held at 24^0C for 5 min. The supernatent was discarded and the residue was weighed. Swelling index was expressed as the ratio of the weight of the residue to the weight of the sample.

RVA analysis

Pasting properties of flours were measured using a Rapid Visco-Analyser 4D (Newport Scientific Pvt Ltd, Warie Wood, Australia) according to **Yadav *et al.*(2008).** The test proceeded and terminated automatically. Heating of the slurry in the equipment was done under a constant rate of shear and the increase in viscosity of material was measured as torque on the spindle and a curve was traced. Flour sample (3.5 g on 14% moisture basis) was dispersed in 25 ml distilled water. The rotating speed of paddle was 160 rev/ min except for first 10 sec (960 rev/ min) with the suspension equilibrating at 50^oC for 1 min and heated at the rate of 12^oC /min to 95^oC and then held at 95^oC for 2.5 min. The sample was then cooled to 50^oC at the rate of 12^oC min and then held for 3 min at 50^oC. Breakdown viscosity, set back viscosity, pasting temperature etc were recorded in terms of Rapid Viscosity Units (RVU).

IR processing of mung bean seeds

Optimized the conditions for the IR processing of mung bean seeds w.r.t moisture content, IR temperature and tempering time. IR temperature of 750^0C (1^{st} heating) and 650^0C (2^{nd} heating) with a seed moisture content of 55% and a tempering time of 6h was found be optimum for the best cooking of mung bean seeds.

5 kg of sound and cleaned mung bean seeds with the optimised processing conditions as described above were passed through IR heaters mounted with electrically powered ceramic heating elements (1000 watt) having the capacity of 40 kg/h (M/s Thermen Heating Technologies Pvt Ltd, Bangalore, India) and can be operated up to

900^{0}C. The cooked mung bean seeds was cooled and dried in a fluidized bed drier (Model TR 120S, M/s Alliance Engineering Company, Mumbai, India) at 70^{0}C to obtain a moisture content of about 6%.

Processing of mung bean seeds by conventional methods

Mung bean seeds was soaked in distilled water (1:4) for 14h at ambient conditions. Excess water was drained and the seeds were rinsed in distilled water, cooked in an open vessel for 35 min till they become soft. After cooking, mung bean seeds were dried in a similar way as IR processed ones as mentioned above.

Raw, IR and conventionally processed mung bean seeds were ground in an ultra centrifugal mill (M/s Retsch Zm 200, Germany) fitted with 100 µ sieve for studying the physico chemical changes and stored at -10^{0}C for further use.

Reconstitution time

10 g sample of IR and conventionally processed and dried mung bean seeds were boiled in 100 ml water. The boiling was continued until grains become soft and attained the consistency of the cooked product.

Analysis

Moisture, crude protein, crude fat, total ash and crude fibre contents were estimated as per **AOAC (1984),** the standard methods of analysis. Vitamin B_1 and B_2 contents were estimated as per **AOAC (1997)** methods. Fatty acid profile was determined as per **AOCS (1990)** methods. Phytic acid was estimated as per **Davies and Reid (1979).** Trypsin inhibition activity was performed as per **Roy and Rao (1971)** methods. Tannin content was estimated by Folin Denis method **(Schanderi, 1970).**

Statistical Analysis

All the reported values are the mean of three replicates each and statistical analysis was carried out by using statistical software (Statistica, Ver 7.0 of Stat Soft Incorporation, Tulsa OK, USA). Experimental results were subjected to one way analysis of variance for significance ($p \leq 0.05$) using Duncan's multiple range tests.

RESULTS AND DISCUSSION

Proximate composition

Proximate composition of raw, IR as well as conventionally processed mung bean seeds is presented in Table 1. The moisture content of raw, IR and conventionally processed mung bean seeds was 10.43, 9.89 and 10.23% respectively. It is evident from the results that, IR processing has not made any significant ($p > 0.05$) changes in the crude protein, crude fat and crude fibre contents of mung bean seeds in comparison to raw and conventionally processed seeds. Slight but significant ($p \leq 0.05$) decrease in total ash content in conventionally processed mung bean seeds were observed as compared to IR treated and raw mung bean seeds. The decrease might be due to the processing method employed which resulted in leaching of minerals into the water due to the prolonged cooking of seeds. The calorific values of raw, IR and conventionally processed mung bean seeds were found to be 336.28, 338.40, 338.70 Kcal respectively.

Functional properties

The changes in functional properties of raw, IR processed mung bean seeds in comparison to conventionally processed mung bean seed is represented in Table 2. The bulk density of raw mung bean seed was found to be 0.93 g/ml which decreased significantly ($p \leq 0.05$) to 0.66 and 0.58 g/ml during IR and conventional methods of processing respectively. The raw sample with high bulk density tend to have lower water absorption capacity of 1.60 g/g. The water absorption capacity of IR processed mung bean seeds was 2.42 g/g and the same was recorded 2.65 g/g in conventionally cooked one. As a result of the greater decrease in bulk density of IR and conventionally processed mung bean seeds, the rate of water absorption was noted much faster in them during reconstitution. The improved hydration during cooking of IR processed seeds has been attributed to the formation of more open structure and development of cracks which facilitate movement of water in to the seeds **(Arntfield *et al.*, 2001).** Processing treatment did not significantly ($p > 0.05$) change the oil absorption capacity of mung bean seeds. Raw mung bean seeds absorbed 1.22 g/g oil, while IR and conventionally processed mung bean seeds absorbed 1.26 g/g and 1.31 g/g of oil respectively. **Prinyawiwatkul *et al.* (1997)** also had similar observations in the oil absorption capacity of cow pea flour during the processing treatments such as boiling, milling and fermentation. Swelling index, an indicative of the starch granule swelling during gelatinization was reduced significantly ($p \leq 0.05$) during IR as well as conventional processing of mung bean seeds. The reduction was recorded as 15.52 and 20.69% in IR and conventionally processed samples respectively. Significant starch gelatinization and reduced protein solubility has been attributed to the reduction of swelling index during processing **(Arntfield *et al.*, 1997; Mwangwela *et al.*, 2006).** The sedimentation value of raw, IR and conventionally processed mung bean seeds were 14, 24 and 26 ml respectively. The higher sedimentation value of IR and conventionally processed mung bean seed indicates better dispersibilty of the particulate matter and better reconstitution characteristics.

Changes in antinutritional factors and retention of vitamins

The presence of antinutritional factors such as phytic acid, tannin and trypsin inhibitors bind food ingredients in to complexes and make them unavailable for human nutrition. Therefore elimination of anti nutritional factors becomes utmost important to get the maximum benefit of the nutrients. Phytic acid content in the raw bean was found to be 6.65 mg/g (Table 3). IR and conventional processing caused a significant ($p \leq 0.05$) reduction in phytic acid content in comparison to raw sample. IR processing reported the highest reduction (57.14%) of phytic acid content followed by conventional cooking (32.63%). The more reduction of phytic acid in IR treated sample may be due to its heat labile nature **(Udensi *et al.*, 2007)** and intense heat treatment on the surface as the antinutritional factors are predominantly present in the seed coat **(Reddy and Pearson, 1994)** of the legume seed. IR as well as conventional processing of mung bean seeds have completely eliminated typsin inhibition activity (TIA). **Khattab and Arntfield (2009)** reported 88.80-94.35% reduction of TIA in legume seeds during micronization. The inactivation of trypsin inhibiton activity may be due to the denaturation of heat labile proteins of seeds **(Vidal-Valrede *et al.*, 1994).** Tannin contents in mung bean seeds was significantly ($p \leq 0.05$) reduced by IR and conventional processing. The observed reduction was found to be 92.51 and 52.14% in IR and conventionally processed mung bean seeds respectively (Table 3).

Vitamin B_1 and B_2 contents in raw, IR and conventionally processed mung bean seeds were 0.64, 0.40, 0.28 mg/100g and 0.18, 0.12, 0.08 mg/100g respectively (Table 3). It is evident from the Table 3 that, significant ($p \leq 0.05$) retention of these vitamins was observed during IR processing in comparison to conventional methods of cooking of mung bean seeds. IR processed mung bean seeds showed 62.50 and 66.67% retention in vitamin B_1 and B_2, while conventionally processed one showed only 43.75 and 44.44% retentions of these vitamins in comparison to raw samples.

Changes in fatty acid profile

The fatty acid composition of mung bean seeds subjected to IR and conventional processing are represented in Table 4. During IR and conventional processing of mung bean seeds, there was a significant ($p \leq 0.05$) reduction in unsaturated fatty acids, but the decrease was found to be lesser in IR processed samples as compared to conventionally processed ones. Possible retention of fatty acids in IR processed mung bean seed may be due to the fact that the lipid content is mainly present in the endosperm part of the seed, as the IR heat treatment is a surface phenomenon and the length of heating is quite less in comparison to conventionally processed seeds. Saturated fatty acids such as palmitic and stearic acid contents were increased significantly ($p \leq 0.05$) from 34.67% and 4.80% to 35.18%, 5.30% and 35.62%, 5.63% respectively in IR and conventionally processed legumes. Polyunsaturated fatty acids consisting of linoleic and linolenic acids decreased from 34.98 and 18.57% to 34.29 and 18.02% in IR processed mung bean seeds and the same has been decreased to 33.76 and 17.60% in conventionally processed mung bean seed.

Changes in pasting properties

The pasting properties of starch are used in assessing the suitability of its application as functional ingredient in food and other industrial products. The most important pasting characteristic of granular starch dispersion is its amylographic viscosity **(Aviara *et al.*, 2010).** The pasting properties of raw, IR and conventionally processed mung bean seeds are presented in Table 5. The peak viscosity which is the maximum viscosity that occurs prior to the initiation of sample cooling was found to be 828.6, 110 and 33 RVU in raw, IR and conventionally processed mung bean seeds respectively. The decrease in peak viscosity may be due to partial gelatinization of starch and denaturation of protein. **Yadav *et al.* (2008)** also reported a decrease in peak viscosity due to the partial gelatinization of starch in wheat flour during microwave heat treatment. The break down viscosity which is a measure of susceptibility of cooked granules to disintegrate was found to be 48, 15 and 9 RVU in raw, IR and conventionally processed mung bean seeds respectively. The decrease in viscosity depends upon the rigidity of starch potential and amount of amylase leached out in solutions (Morris, 1990). The set back viscosity which reflects the retrogradation or reordering of starch molecules of raw, IR and conventionally processed mung bean seeds were 687, 204 and 113 RVU respectively. The decrease was found to be very significant ($p \leq 0.05$) and indicates that samples with higher set back values exhibit higher retrogradation during cooling of the products made from the flour.Final viscosity is the most commonly used parameter to define a particular sample's quality, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling. The final viscosity of raw, IR and conventionally processed mung bean seeds were found to be 1467, 299 and 137 RVU respectively.

Table 1. Proximate composition of raw, IR and conventionally processed mung bean seeds (%)

Parameters	Raw	IR processed	Con processed
Moisture	10.43^{a}	9.89^{b}	10.23^{c}
Crude protein	24.89^{a}	24.51^{a}	24.36^{a}
Crude fat	1.72^{a}	1.72^{a}	1.79^{a}
Total ash	3.42^{a}	3.36^{a}	3.13^{b}
Crude fibre	4.23^{a}	4.30^{a}	4.19^{ab}
Carbohydrate (By Difference)	55.31^{a}	56.22^{b}	56.30^{b}
Energy (K cal)	336.28^{a}	338.40^{b}	338.70^{b}

Values are mean ± SD (n=3)
Mean values with different superscripts in rows differ significantly ($p \leq 0.05$)

T**able 2.Changes in functional properties of raw, IR and conventionally processed mung bean seeds**

Parameters	Raw	IR processed	Con processed
Bulk density (g /ml)	0.93^{a}	0.66^{b}	0.58^{c}
Sedimentation value (ml)	14.00^{a}	24.00^{b}	26.00^{c}
Water absorption capacity(g/g)	1.60^{a}	2.42^{b}	2.65^{c}
Oil absorption capacity(g/g)	1.22^{a}	1.26^{b}	1.31^{c}
Swelling Index	5.80^{a}	4.90^{b}	4.60^{c}
Reconstitution/ Cooking time (min)	32.00^{a}	6.00^{b}	4.00^{c}

Values are mean ± SD (n=3)
Mean values with different superscripts in rows differ significantly ($p \leq 0.05$)

Table 3. Changes in antinutritional factors and vitamin B_1 and B_2 contents of raw, IR and conventionally processed mung bean seeds

Parameters	Raw	IR processed	Con processed
Phytic acid (mg/ g)	6.65^{a}	2.85^{b}	4.48^{c}
% Reduction/loss		57.14	32.63
Trypsin inhibitor activity (TIU/ mg)	17.23	0.00	0.00
% Reduction/loss		100	100
Tannins (mg/ g)	3.74^{a}	0.28^{b}	1.79^{c}
% Reduction/loss		92.51	52.14
Vitamin B_1 (mg/100g)	0.64^{a}	0.40^{b}	0.28^{c}
% Retention		62.50	43.75
Vitamin B_2 (mg/100g)	0.18^{a}	0.12^{b}	0.08^{b}
% Retention		66.67	44.44

Values are mean ± SD (n=3)
Mean values with different superscripts in rows differ significantly ($p \leq 0.05$)

Table 4. Changes in fatty acid composition of raw, IR and conventionally processed mung bean seeds

Fatty acids (%)	Raw	IR processed	Con processed
Myristic	0.70^{a}	0.85^{b}	1.11^{c}
Palmitic	34.67^{a}	35.18^{b}	35.62^{c}
Stearic	4.80^{a}	5.30^{b}	5.63^{c}
Oleic	4.56^{a}	3.98^{b}	3.74^{b}
Linoleic	34.98^{a}	34.29^{b}	33.76^{c}
Linolenic	18.57^{a}	18.02^{b}	17.60^{c}
Arachidic	0.67	ND	ND
Saturated Fatty Acids	40.84^{a}	41.33^{b}	42.36^{c}
Mono Unsaturated Fatty Acids	4.56^{a}	3.98^{b}	3.74^{b}
Poly Unsaturated Fatty Acids	53.55^{a}	52.31^{b}	51.36^{c}

Values are mean± SD (n=3)
Mean values with different superscripts in rows differ significantly ($p \leq 0.05$)

Table 5. Changes in pasting properties of raw, IR and conventionally processed mung bean seeds

	Peak Viscosity (RVU)	Break down (RVU)	Final Viscosity (RVU)	Set back (RVU)
Raw	828^{a}	48.0^{a}	1467.0^{a}	687.0^{a}
IR processed	110.0^{b}	15.0^{b}	299.0^{b}	204.0^{b}
Con processed	33.0^{c}	9.0^{c}	137.0^{c}	113.0^{c}

Values are mean ± SD (n=3)
Mean values with different superscripts in columns differ significantly ($p \leq 0.05$)

CONCLUSIONS

Flours from mung bean seeds processed by IR and conventional methods differ significantly in their physico-chemical, functional and pasting properties. IR processing was found to be beneficial in the retention of vitamin B_1 and B_2 and significant ($p \leq 0.05$) reduction in antinutritional factors as compared to conventional methods. The changes in fatty acid profile revealed better stability of IR processed mung bean seeds compared to conventionally processed ones. Pasting properties indicated that cooking characteristics was slightly better in conventionally processed seeds as compared to IR processed ones.

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