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Nutrient retention in microwave cooked germinated legumes

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Abstract

The effects of germination on the cooking quality and nutrient retention in pressure and microwave-cooked Bengal gram, green gram and horse gram were studied. Ungerminated (UGL) and germinated legumes (GL) cooked in a microwave oven, and under pressure were analysed for moisture, protein, ash, iron, thiamin, ascorbic acid, in vitro protein digestibility (IVPD) and starch digestibility (IVSD) and bioavailable iron. Results revealed that microwave cooking required more water and time than did pressure cooking. The range of analysed constituents on dry weight basis in UGL and GL legumes, respectively, were as follows: protein, 18.2–23.5 and 19.4–25.7 g, ash, 2.1–2.9 and 2.2–2.9 g, iron, 5.4–7.3 and 7.3–10.3 mg, thiamin, 0.10–0.34 and 0.54–1.83 mg, ascorbic acid, 2.4–3.9 and 3.1–25.6 mg/100 g. The effect of germination and method of cooking on nutrient retention varied, depending on nutrient and severity of heat treatment. Microwave cooking caused 36–57% reduction of ascorbic acid while pressure cooking caused 10–30% loss. The IVSD in raw samples ranged from 18.4% to 22.1% in UGL and 33.6% to 43.6% in GL. Cooking of UGL and GL, by both methods, increased the starch digestibility threefold. The IVPD of raw UGL ranged from 64.6% to 66.2% and that of GL was 72.4–73.9%. In cooked UGL the IVPD ranged from 70.9% to 82.3% and, in GL, from 78.4% to 84.2%, showing a significant difference in cooking methods only in UGL. The iron bioavailability ranged from 11.5% to 18.7% in raw UGL while it was 18.3–20.6% in GL. GL had a higher content of thiamin and ascorbic acid, higher protein and starch digestibility and bioavailable iron, even after cooking.

Keywords: Ungerminated legumes; Germinated legumes; Pressure cooking; Thiamin; Ascorbic acid; Protein and starch digestibility; Bioavailable iron

1. Introduction

Legumes, consumed after processing and germination, are most economical food (Jaya & Ventkataraman, 1980). This process is also an appropriate low cost low technology option for household processing in lesser developed countries (Wang, Lewis, Brennan, & Westby, 1997). It causes important changes in the biochemical, nutritional and sensory characteristics in legumes. It is known to enhance the nutritional value of legumes, by increasing essential amino acids, protein digestibility, amino acid availability and certain vitamins, including thiamin, riboflavin, niacin and ascorbic acid (Fernandez & Berry, 1988). A decrease in CHO content of legumes, ranging from 35% to 40% on germination, has also been reported by many workers (Chavan, Kadam, & Salunkhe, 1987; Fernandez & Berry, 1988; Giami, 1993; Jaya & Ventkataraman, 1980; Subbulakshmi, Kumar, & Venkataraman, 1976). The decrease in total CHO and reducing sugar contents was attributed to their consumption, as a source of energy, during the germination process (Khalil & Mansour, 1995). An increase in the digestibility of starch/CHO, due to metabolic and structural changes, hydrolytic breakdown and increased amylolytic activity has been reported (Adsule, Kadam, & Salunkhe, 1987; Chavan et al., 1987). Germinated legumes can be consumed as such or processed further

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for different products. These processing techniques, in turn, can alter the nutritional quality. Microwave cooking is a relatively new method of household cooking. The present study was planned with an objective to see the effect of microwave cooking on cooking quality, nutrient content, in vitro protein and starch digestibilities and available iron of germinated legumes in comparison with pressure-cooked samples.

2. Materials and methods

2.1. Materials

Three whole legumes, namely Bengal gram (*Cicer arietinum*), green gram (*Phaseolus aureus Roxb*) and horse gram (*Dolichos biflorus*), were selected. They were procured from the local market, cleaned free of stone, sand and other extraneous material, soaked in water and germinated. Germinated grains were cooked by microwave or pressure-cooking methods. The soaking time of all legumes was standardized individually. Green gram was soaked for four and a half hours and other legumes were soaked for eight hours. The cooking time (determined as development of tactile tenderness in the whole grain) and water uptake for legumes were standardized. The soaking and cooking was done in glass-distilled water. The chemicals used for the analysis were all of analytical grade and procured from SD fine chemicals, BDH, Qualigens and Loba Chemicals, India and Sigma Chemicals USA. The enzymes used for the study were amyloglucosidase (66HO483), heat-stable α-amylase (57H8000), pancreatin (100H0159), pepsin (60H0821) from Sigma Chemicals, USA, diastase (0797/297/250513) and papain (0993/493/130811) from SD Fine Chemicals, India and Termamyl (20KNU/g AAN 4306) from Novo, Denmark.

2.2. Analysis

2.2.1. Cooking quality

The raw weight, sprouting time, sprout length, sprouted weight, cooking time, water-uptake and cooked weight were the parameters used to determine the cooking quality and physical characteristics of legumes.

2.2.2. Nutrient analysis

Freshly cooked legumes were used for estimation of moisture, protein (estimated by Kjeldahl method as nitrogen × 6.25), ascorbic acid (Ranganna, 1986), thiamine by fluorimetry (Mickelson, Condiff, & Koys, 1945) and in vitro protein digestibility (Akeson & Stahmann, 1964). For analysis of total iron, starch (Ranganna, 1986), bioavailable iron (Rao & Prabhavathi, 1978) and in vitro starch digestibility (Bjorck, Eliasson, Drews, Gudmundsson, & Karlsson, 1990; Kon, Wagner, Booth, & Robbins, 1971; Singh, Kherdekar, & Jambunathan, 1982), cooked samples were dried overnight at 50 °C in a hot air oven, cooled, powdered in a grinder, passed through a 60-mesh sieve and stored in polythene bags in air-tight containers in a refrigerator. All estimations were carried out in duplicate from two separate batches of legumes.

2.2.3. Statistical analysis

Data presented are averages of duplicate determinations of two separate batches. Analysis of variance (one-way ANOVA) and post "*t*" test (Bonferroni '*P*' value) were used to find the level of significant differences due to processing and between methods of processing.

3. Results and discussion

3.1. Physical characteristics and cooking quality of germinated legumes

The physical characteristics and cooking quality of pressure- and microwave-cooked germinated legumes are presented in Table 1. The sprouting time required by green gram was less than those of other legumes. The yield of sprouted legumes ranged from 200 to 214 g for 100 g of raw grains. Pressure-cooking required much less time for cooking than did microwave cooking.

Table 1
Physical characteristics and cooking quality of germinated legumes

Characteristics	Green gram		Bengal gram		Horse gram	
Physical characteristics (for 100 g raw legumes)						
Sprouting time (h)	27		48		48	
Sprout length (cm)	1.5–2.0		2.0–2.5		1.5–2.0	
Weight after sprouting (g)	218		200		204	
Cooking quality (for 100 g of germinated legumes)						
	Pre.	Mic.	Pre.	Mic.	Pre.	Mic.
Cooking time (min)	7	30	10	40	40	60
Water uptake (ml)	150	400	125	450	150	700
Cooked weight (g)	149	139	119	114	133	126

Values are averages of duplicate determinations of two separate batches. Pre.: pressure-cooked, Mic.: microwave-cooked.

Green gram and Bengal gram were cooked within 7–10 min under pressure but required 30–40 min in a microwave oven. Horse gram required 40 min of cooking under pressure and 60 min in a microwave. Germination is known to reduce the cooking time of legumes by the tenderizing effect on seed coat and softening of structural polysaccharides (Bhatty, 1995). The water uptake correlated well with cooking time. The increment in weight of cooked sprouted legumes, as compared with raw sprouted, is due to the additional water taken up during cooking. When the increment in weight of raw legumes due to soaking/sprouting and cooking is compared, it can be seen that maximum hydration of legumes or imbibition of water occurs during soaking and, relatively, much less water is taken up by the legume during cooking. Here again, the weight of pressure-cooked legume was more than that of microwave cooking due to hardening.

3.2. Chemical composition

The chemical composition of ungerminated and germinated legumes are given in Tables 2 and 3, respectively. The moisture content of raw ungerminated legumes ranged from 10.1% to 11.2% and that of germinated samples was 55.7–65.8%. Hence, germination resulted in 82% increase in moisture content of raw legumes. The moisture content of cooked germinated legumes was more than that of the cooked ungerminated samples and, in both the cases, these values were higher for pressure-cooked legumes.

The protein content of ungerminated legumes was in the range of 18.2% (Bengal gram) to 23.5% (green gram and horse gram). Cooking (both methods) resulted in a slight decrease of protein content. The crude protein contents of raw germinated legumes ranged from 19.8% to 25.7%, showing an increase of 4.9% due to germination. In cooked samples, a 2.5–10.5% increment in protein content was recorded. Here again, there was no significant difference between the protein contents of pressure- and microwave-cooked legumes. A varying extent of increase ranging from 8% to 39% in crude protein content of germinated chick pea, mung bean and Phaseolus bean has been reported by Giami (1993). The ash content of raw ungerminated legume and germinated legume was 2.5–2.9%. There was no significant difference in ash content due to germination or due to cooking or between cooking methods. Ahmad and Pathak (2000) also report that no significant changes were observed in protein, total sugars, reducing sugars or ash contents of germinated soy bean seed flours. The iron content was in the range of 5.3–7.3 mg/100 g in ungerminated legumes. Cooking decreased the iron content of legumes. This may be due to leaching of minerals due to soaking and cooking. The iron content of germinated raw green gram was 9.3, Bengal gram 9.8 and horse gram 8.0 mg/100 g.The increment in iron values due to germination was 17–43%. This increase might possibly be due to

Table 2
Chemical composition of ungerminated legumes (per 100 g)

Legume	Moisture (g)	Protein (g)	Ash (g)	Total iron (mg)	Thiamin (mg)	Ascorbic acid (mg)
Green gram						
Raw	11.2	23.5	2.9	5.3	0.34	3.9
Pressure-cooked	63.1	22.8	2.8	6.3	0.25	–
Microwave-cooked	69.1	23.3	2.7	6.0	0.19	–
P-value	0.0003***	–	–	–	–	–
F ratio	–	3.419 ns	1.9545 ns	7.4393*	1036.363***	–
Bengal gram						
Raw	10.5	18.2	2.5	7.3	0.31	2.4
Pressure-cooked	62.1	18.9	2.2	6.8	0.26	–
Microwave-cooked	61.8	18.5	2.2	6.8	0.29	–
P-value	0.9020 ns	–	–	–	–	–
F ratio	–	0.9941 ns	13.1861**	0.0097 ns	7599.905***	–
Horse gram						
Raw	10.1	23.5	2.5	6.6	0.39	3.1
Pressure-cooked	62.2	22.5	2.1	5.7	0.14	–
Microwave-cooked	60.5	22.5	2.2	5.4	0.10	–
P-value	0.1720 ns	–	–	–	–	–
F ratio	–	17.9996***	34.199***	1.5947 ns	2939.399***	–

Values are average of duplicate determinations of two separate batches.
ns: not significant.
* Marginally significant.
** Significant.
*** Highly significant.

Table 3
Chemical composition of germinated legumes (per 100 g)

Legume	Moisture (g)	Protein (g)	Ash (g)	Total iron (mg)	Thiamin (mg)	Ascorbic acid (mg)
Green gram						
Raw	65.8	25.7	2.9	9.3	1.83	25.6
Pressure-cooked	79.1	25.5	2.9	10.3	0.54	23.0
Microwave-cooked	75.8	24.9	2.5	9.5	0.62	18.1
F ratio	116.4289***	7.6231*	3.8642 ns	1.2360 ns	546.9548***	280.082***
Bengal gram						
Raw	57.5	19.8	2.5	9.8	1.23	8.2
Pressure-cooked	67.7	19.4	2.2	7.3	0.87	6.8
Microwave-cooked	63.0	19.4	2.6	8.7	0.84	3.1
F ratio	110.4289***	1.9339 ns	0.0003 ns	4.7693*	23.1478***	599.755***
Horse gram						
Raw	55.7	24.6	2.8	8.0	1.50	9.6
Pressure-cooked	67.9	24.4	2.4	8.3	0.78	6.7
Microwave-cooked	64.0	24.3	2.5	8.0	0.78	4.1
F ratio	27.6259***	0.4478 ns	4.7216*	0.0511 ns	14.2733**	368.568***

Values are averages of duplicate determinations of two separate batches.
ns: not significant.
* Marginally significant.
** Significant.
*** Highly significant.

the release of iron from protein-bound complexes and better extractability of iron (Rani & Hira, 1993). The thiamin content of raw ungerminated legume ranged from 0.31 to 0.39 mg/100 g. The reported values for thiamin content of green gram range from 0.12 to 0.68 mg/100 g (Adsule et al., 1987), Bengal gram, 0.28–0.40 mg/100 g (Chavan et al., 1987) and horse gram, 0.42 mg/100 g (Kadam & Salunkhe, 1985). The estimated values are in consonance with the reported values. In germinated legumes (raw) the thiamin content ranged from 1.23 to 1.83 mg/100 g. Increased levels of ascorbic acid, thiamin, riboflavin, carotene, choline, tocopherol, pantothenic acid, folic acid, biotin, niacin, pyridoxin, inositol and vitamin K on germination of dry beans have been reported in the literature. An increase of 100–300% in the vitamin B group during germination has been reported (Deshpande, Sathe, & Salunkhe, 1984). Although germination increased the thiamin content of legumes 3–4-fold, cooking caused partial destruction of thiamin in all samples. The retention was higher in ungerminated Bengal gram and green gram and germinated Bengal gram and horse gram (30–94%). In raw soaked ungerminated legumes, the vitamin C content ranged from 2.4 to 3.9 mg/100 g. On germination it increased to 8.2–25.6 mg/100 g, indicating a 3–7-fold increase. Cooking by both methods reduced ascorbic acid, depending on the time of processing. Pressure- and microwave-cooking resulted in 10–30% and 29–62% reduction, respectively. From results cited in the literature, Cross and Fung (1982) concluded that no appreciable losses in ascorbic acid were caused by microwave heating compared to conventional heating methods. In the present study, increase in ascorbic acid due to germination was 3–7-fold.

3.3. In vitro digestibility of starch

The starch content of raw ungerminated legumes ranged from 34.9 to 49.0/100 g. These results are within the range of published work (Reddy, Pierson, Sathe, & Salunkhe, 1984). Cooking by both methods brought about a slight decrease in starch content, ranging from 7.5% to 25.1%, with the microwaved sample exhibiting a higher decrease. This may be because prolonged cooking in excess of water results in more solid loss. The total starch content of germinated raw legumes was 45.2 for green gram, 38.9 for Bengal gram and 30.1 for horse gram. Data on total starch of legumes showed that germination resulted in 7.0–11.1% reduction. Jood, Bishnoi, and Sehgal (1998) report a decrease of 36.5% in rajmah, 21.7% in Bengal gram and 11.3% in broad bean total starch due to germination for 24 h, while Kumar and Venkataraman (1976) report a decrease of 28% in chick pea, 27.7% in cowpea and 29.5% in green gram total starch after germination for 48 h. Germination decreases the starch content of legumes, thereby raising the level of soluble sugars (Kataria, Chauhan, & Punia, 1990). The reduction in starch content with a corresponding increase in reducing sugars can be attributed to increased amylase and phosphorylase activities for utilization in respiratory metabolism during germination (Kumar & Venkataraman, 1976). Even in germinated legumes, pressure-cooking resulted in 3.2–9.6% starch loss and 9.8–16.5% reduction in microwave-cooking, showing a higher loss in the latter technique.

Starch digestibility, measured as mg maltose released and calculated as % hydrolysis, is presented in Table 3. Maltose released was significantly lower in raw

ungerminated legumes (7.0–10.0 mg maltose/100 mg) than in cooked ones. When a comparison is made between germinated and ungerminated legumes, the reducing sugar release (maltose) is greater in germinated raw legumes, indicating a starch breakdown. In terms of starch hydrolysis, the starch digestibility was 18.4–22.1% in ungerminated raw sample and 33.6–43.6% in germinated samples, indicating a significant increase due to sprouting. Germination can be considered as a process for improving digestibility and reducing or eliminating the flatus factors, for various legumes (Reddy et al., 1984). In the uncooked legumes, a progressive increase in starch hydrolysis was noted with increasing periods of germination due to metabolic and structural changes that made the starch more digestible (Dreher, Dreher, & Berry, 1986). The rate of amylolysis of cooked samples has been reported to be three times higher than that of the uncooked samples (Geervani & Theophilus, 1980). A similar trend was observed in the present study. On application of post-test, Bonferroni P value, the differences were insignificant between pressure and microwave-cooking or germinated and ungerminated legumes. This observation is supported by reports that cooking of germinated and ungerminated green gram eliminated the differences in digestibility (Sathe, Deshpande, & Salunkhe, 1984) and in the cooked legumes no significant differences in starch hydrolysis were noted between ungerminated and germinated samples (Dreher et al., 1986). In addition, Reddy et al. (1984) point out that cooking further increases the digestibility of starches from germinated beans, as cooking may gelatinize and germination may mobilize starch thereby resulting in improved digestibility of starch by alpha amylase.

3.4. In vitro digestibility of protein

In raw ungerminated legumes, the protein digestibility was 64.6% in green gram, 65.1% in Bengal gram and 66.2% in horse gram (Table 4). The values obtained for raw samples were significantly ($P < 0.001$) lower than for cooked samples. The in vitro digestibility of pressure-cooked legumes ranged from 78.0% to 82.6% and in microwave-cooked samples it was 70.9–80.0%. Preet and Punia (2000) report the protein digestibility of cowpea varieties to be in the range 75.5–78.3%. Hence, the observed values are in consonance with published work. The digestibility values obtained in the present study for germinated raw legumes were 72.4% for green gram, 73.9% for Bengal gram and 73.78% for horse gram. The data showed that germination significantly ($P < 0.01$) improved the in vitro protein digestibility in raw legumes. Germination has been reported to increase the protein digestibility of mung bean, moth bean, soy bean, chickpea and urd bean. This improvement in protein digestibility may be attributed to the modification and degradation of storage proteins. Sprouting causes mobilization of proteins with the help of proteases, leading to the formation of polypeptides, oligopeptides and free amino acids. Further, during sprouting, trypsin inhibitor, tannins and phytate are catabolised, leading to lower levels of these anti-nutritional factors in the legume sprouts, which may be responsible for increasing the protein digestibility (Kaur

Table 4
In vitro starch and protein digestibility and bioavailable iron in ungerminated legumes

Variations	In vitro starch digestibility			In vitro protein digestibility (%)	Bioavailable iron (%)
	Total starch g/100 g	Maltose released mg/100 mg	Percent hydrolysis		
Green gram					
Raw	49	9.5	18.4	64.6	12.7
Pressure-cooked	44.3	36.7	80.6	82.6	11.0
Microwave-cooked	42.9	36	79.7	80.0	10.4
F ratio	6.3251 ns	173.956***	2404.497***	610.654***	3.5839 ns
Bengal gram					
Raw	42.8	10	22.1	65.1	11.5
Pressure-cooked	39.6	31.9	76.5	79.4	9.2
Microwave-cooked	38.9	30.6	74.7	75.7	9.9
F ratio	3.5267 ns	492.462***	1394.5***	65.2102***	6.5540*
Horse gram					
Raw	34.9	7.0	19.1	66.2	18.7
Pressure-cooked	28.6	23.1	76.7	78	13.2
Microwave-cooked	25.3	19.9	74.7	70.9	11.4
F ratio	2.555 ns	453.428***	2094.836***	31.7328***	8.4512**

Values are averages of duplicate determinations of two separate batches.
ns: not significant.
* Marginally significant.
** Significant.
*** Highly significant.

Table 5
In vitro starch and protein digestibility and bioavailable iron in germinated legumes

Variations	In vitro starch digestibility			In vitro protein digestibility (%)	Bioavailable iron (%)
	Total starch g/100 g	Maltose released mg/100 mg	Percent hydrolysis		
Green gram					
Raw	45.2	16.0	33.6	72.4	18.3
Pressure-cooked	41.6	37.8	86.3	84.2	17.3
Microwave-cooked	40.8	36.2	84.3	83.5	16.0
F ratio	3.1436 ns	1020.111***	930.004***	38.9157***	2.0547 ns
Bengal gram					
Raw	38.9	15.0	36.6	73.9	19.1
Pressure-cooked	35.2	29.7	80.2	81.2	16.5
Microwave-cooked	32.5	26.7	78.0	80.6	16.0
F ratio	1.0588 ns	295.715***	807.705***	17.648***	8.2277**
Horse gram					
Raw	30.1	13.8	43.6	73.7	20.6
Pressure-cooked	28.4	24.5	82.0	82.6	18.3
Microwave-cooked	26.4	22.9	82.4	78.4	19.0
F ratio	0.9847 ns	72.0217***	125.184***	28.5573***	8.6559***

Values are averages of duplicate determinations of two separate batches.
ns: not significant.
** Significant.
*** Highly significant.

& Kapoor, 1990). Pressure- and microwave-cooking further increased the digestibility of germinated legumes, showing an insignificant difference ($P > 0.05$) between the cooking methods. Here again there was no significant difference between protein digestibility of cooked ungerminated and germinated legumes. But, though not significant, the values were slightly higher in germinated cooked legumes.

3.5. Bioavailability of iron

The bioavailable iron in raw ungerminated legumes was 12.7% in green gram, 11.5% in Bengal gram and 18.7% in horse gram. Chitra, Singh, and Rao (1997) report that, in chick pea, nearly 26% of the total iron in the grain was in the ionizable iron. The iron availability in legumes is lower than in cereals and this was attributed to their high polyphenol and phytate contents. The bioavailable iron content of pressure-cooked legumes was 9.2–13.2% and in microwave-cooked samples, 9.9–11.4%. There was no significant difference ($P > 0.05$) in iron bioavailability between the cooking methods. It has been reported that food processing, such as germination, cooking, roasting and milling, showed 2–4-fold increase in biologically available iron. The significant increase in absolute iron may be due to decrease in polyphenols after cooking (Annapurani & Murthy, 1985). But,in the present study, there was a reduction in the cooked samples, though not significant except between raw and pressure-cooked Bengal gram, and raw and microwave-cooked horse gram, which showed a significant difference ($P < 0.05$). In germinated raw legumes, the iron availability was 18.3% in green gram, 19.1% in Bengal gram and 20.6% in horse gram. The increases in ionizable iron, as a result of germination, can be attributed to a decrease in the phytic acid due to an increase in the activity of endogenous phytase and probably to an increase in ascorbic acid content (Chitra et al., 1997). Among the legumes studied, green gram recorded an increase of 44%, Bengal gram 66% and horse gram 10% in iron bioavailability over the ungerminated samples (see Table 5).

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