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Starch and Protein Digestibility of Rice Bean (*Vigna umbellata*): Effects of Domestic Processing and Cooking Methods

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ABSTRACT

The present investigation was conducted to study the in-vitro *starch and protein digestibility of five high-yielding varieties (RB-4, RB-32, RB-37, RB-40 and RB-53) of rice bean (*Vigna umbellata*) and one variety each of green gram (K-851) and black gram (MT-9) as affected by various domestic processing and cooking methods which included soaking in tap water for 6, 12 and 18 h; sprouting for 40 and 60 h; ordinary cooking of unsoaked seeds and seeds soaked for 12 h; and autoclaving of unsoaked and soaked seeds.* In-vitro *starch digestibility (mg maltose released/g meal) and protein digestibility (per cent) of raw rice bean varied from 29·3 to 36·5, and 57·2 to 62·8, respectively. Both starch and protein digestibilities improved significantly on soaking, sprouting, cooking and autoclaving. There was a progressive and significant increase in starch and protein digestibility with successive increase in soaking and sprouting period.*

INTRODUCTION

Legumes are used as a major source of dietary proteins in developing nations, not only because of cultural and religious beliefs, but also due to expensiveness of animal foods and their non-availability. They also act as an essential supplement to cereal-based meals. Although the production of grain legumes is increasing, the *per capita* consumption in some countries is

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decreasing as the production has not kept pace with increasing population. Therefore, it becomes imperative to explore some unconventional high-yielding grain legumes, as well as breeding programmes.

Rice bean (*Vigna umbellata*), a non-conventional pulse having high-yielding potential even in adverse agro-climatic conditions, is attracting the attention of plant breeders throughout the world. Rice bean, like other legumes, contains anti-nutritional factors such as amylase inhibitor, phytic acid, polyphenol, which lower the utilisation of starch and protein (Singh *et al.*, 1982; Deshpande & Cheryan, 1983, 1984; Tan *et al.*, 1984; Kaur, 1986). Studies on other legumes have shown that different processing and cooking methods affected the level of these factors negatively, and thus enhanced the utilisation of the legumes (Tan *et al.*, 1984; Knuckles *et al.*, 1985; Kataria, 1986). Therefore, the present study was undertaken to investigate the effect of various domestic processing and cooking methods on starch and protein digestibilities of different varieties of rice bean and to compare them with other common grain legumes.

MATERIALS AND METHODS

Materials

The grains of five high-yielding varieties (RB-4, RB-32, RB-37, RB-40 and RB-53) of rice bean (*Vigna umbellata*) and one variety each of green gram (K-851) and black gram (MT-9) were obtained from the Department of Plant Breeding, Haryana Agricultural University, Hisar. Green gram and black gram have been included in the present study as standard because these are acceptable and widely used legumes. Grains were thoroughly cleaned and freed from broken seeds, dust and other foreign materials.

Processing and cooking methods

Soaking in tap water
Seeds were soaked in tap water (seed:water, 1:5, w/v) for 6, 12 and 18 h at room temperature (30°C). The water left after soaking was discarded. The soaked seeds were washed twice with ordinary water followed by rinsing with distilled water and then dried in a hot air oven at 60°C. Dried samples were ground in a Cyclotic sample mill (60 mesh sieve) and then stored in air-tight plastic containers for further chemical analysis.

Sprouting
The seeds were placed in sterile Petri plates lined with wet filter paper and kept in an incubator at 30°C for 40 and 60 h. The sprouted samples were

dried in a hot air oven maintained at 60°C, ground (60 mesh sieve) and stored for further analysis. The sprouted sample of black gram could not be prepared because of growth of fungus during sprouting which appeared repeatedly in the samples.

Ordinary cooking
The seeds soaked for 12 h in water and unsoaked seeds were cooked in beakers. The ratio of seed to water in the case of soaked seeds was 1:5 (w/v) and in the case of unsoaked 1:6 (w/v). The water was allowed to boil before the addition of seeds. The seeds were cooked until soft as felt between fingers. The cooking time for soaked seeds was 10 min and unsoaked seeds, 15 min. The cooked samples were then mashed and dried in a hot air oven maintained at 60°C and then ground to a fine powder (60 mesh sieve) and stored.

Autoclaving
The seeds soaked for 12 h and unsoaked seeds were autoclaved at 1·05 kg/cm^2 for 5 and 10 min, respectively. The ratio of seed to water was 1:5 (w/v) for unsoaked seeds and 1:4 (w/v) for soaked seeds. The autoclaved seeds were then mashed, dried at 60°C, finely ground (60 mesh sieve) and stored.

Chemical analysis

In-vitro starch digestibility was assessed by employing pancreatic amylase (Singh *et al.*, 1982) and protein digestibility by pepsin and pancreatin (Akeson & Stahman, 1964). The nitrogen content of the samples and the supernatant containing digestible proteins was determined by the micro-Kjeldahl method (AOAC, 1980).

The data thus obtained were subjected to analysis of variance (Panse & Sukhatme, 1961).

RESULTS AND DISCUSSION

Starch digestibility
Total starch and in-vitro starch digestibility of raw rice bean varieties varied from 52·4 to 55·9 g/100 g and 29·3 to 36·5 mg maltose released/g meal, respectively (Table 1). The total starch content of rice bean varieties was higher than that of green gram and black gram. Variety RB-32 had the lowest starch digestibility and differed significantly ($P < 0{\cdot}05$) from other varieties. Green gram had a comparable value of digestibility whereas black

TABLE 1
Effect of Soaking, Sprouting, Ordinary Cooking and Autoclaving on Starch Digestibility of Rice Bean, Green Gram and Black Gram (mg maltose released/g meal, on dry matter basis)[a]

Varieties	*Raw pulses*		*Soaking*			*Sprouting*		*Ordinary cooking*		*Autoclaving*	
	Total starch (g/100 g)	*Digestibility*	*6 h*	*12 h*	*18 h*	*40 h*	*60 h*	*Unsoaked*	*Soaked*	*Unsoaked*	*Soaked*
Rice bean											
RB-4	54·5	36·5	40·5	49·5	63·1	169	203	170	321	287	393
RB-32	52·9	29·3	33·1	48·0	64·9	151	196	165	358	299	403
RB-37	55·9	31·2	35·1	52·8	60·8	159	208	195	368	264	398
RB-40	53·1	34·1	38·1	46·9	59·8	168	215	189	331	270	402
RB-53	52·4	35·3	40·0	49·7	62·8	178	216	187	364	293	385
Green gram											
K-851	50·3	37·1	41·3	50·1	67·6	190	230	273	369	305	416
Black gram											
MT-9	49·1	26·1	29·9	34·8	53·5	—	—	144	302	244	371

	Soaking	*Sprouting*	*Cooking*	*Autoclaving*
Varietal SE (m)	1·1	2·3	8·3	8·5
CD ($P < 0{\cdot}05$)	3·1	6·8	24·0	24·8
Treatment SE (m)	0·7	1·3	5·5	4·5
CD ($P < 0{\cdot}05$)	2·1	3·9	16·0	13·2
Varietal × Treatment				
SE (m)	1·9	3·3	14·9	13·1
CD ($P < 0{\cdot}05$)	5·5	9·6	41·1	38·1

[a] Values are means of three replicates.

gram had significantly ($P < 0.05$) lower digestibility than that of rice beans, except RB-32. Differences observed in the starch digestibilities of different legumes in the present study may occur because some granular starches resist digestion much more strongly than others (Fuwa *et al.*, 1980). The exact reasons for this are not known but may involve the crystal packing structure of the starch in the granules and/or the granule size. The reason for the poor digestibility of legume carbohydrates as compared with that of cereal carbohydrates is not known at present. However, it has been claimed that the content and chain length of the amylose component of the starch may play a part in causing such low digestibilities (Rao, 1976). The higher the content of amylose the lower is the digestibility of the starch because there is a positive correlation between amylose content and the formation of resistant starch (Berry, 1986; Sievert & Pomeranz, 1989). Studies conducted to evaluate the nutritional properties of resistant starch (Asp *et al.*, 1986; Bjorck *et al.*, 1987; Wyatt & Horn, 1988) show that resistant starch in the processed foods resists not only amylolytic hydrolysis *in vitro* but also in the human small intestine. Factors that were shown to affect starch digestion in foods include degree of gelatinisation, granule particle size, amylose/amylopectin ratio, starch–protein interactions, amylose/lipid complexes and percentage of resistant or retrograded starch (Holm *et al.*, 1987). The presence of other non-starchy carbohydrates (dietary fibre) may also influence the starch digestibility. Several dietary fibres have been reported to decrease the activity of human pancreatic amylase, lipase, trypsin and chymotrypsin, and this may be due to enzyme inhibitors or nonspecific absorption of enzyme molecules to dietary fibres (Dunaif & Schneeman, 1981) or entrapment of starch in the fibrous-walled cells (Wursch *et al.*, 1986).

Soaking of seeds for 6, 12 and 18 h enhanced the level of digestible starch of all rice bean varieties as well as other legumes ($P < 0.05$). Rice bean and green gram had significantly ($P < 0.05$) higher starch digestibility than black gram. A successive and significant ($P < 0.05$) increase was observed in starch digestibility with increase in time period of soaking. Factors such as amylase inhibitors, phytic acid and polyphenols are reported to inhibit amylase (Deshpande & Cheryan, 1984; Thompson & Yoon, 1984). Soaking may improve the starch digestibility, possibly by decreasing the level of these anti-nutritional factors in the seed. Reduction in the content of polyphenols and phytic acid of the legume seeds may explain this phenomenon (Deshpande & Cheryan, 1983; Boralkar & Reddy, 1985).

On sprouting there was a significant ($P < 0.05$) increase in starch digestibility in all the legumes with some varietal differences. After sprouting green gram had a starch digestibility significantly ($P < 0.05$) higher than rice bean. The increase in starch digestibility on sprouting was four- to six-fold. This increase in starch digestibility may be because, during germination, amylase and phosphorylase may become active and catalyse amylolysis. The resulting increased concentration of oligosaccharides may contribute towards better starch digestibility of legume sprouts (Jaya & Venkataraman, 1980; El Faki *et al.*, 1984; Boralkar & Reddy, 1985).

Cooking of unsoaked seeds brought out significant ($P < 0{\cdot}05$) increase in starch digestibility of all pulses. The starch digestibility was further significantly enhanced ($P < 0{\cdot}05$) when soaked seeds were cooked. Some significant ($P < 0{\cdot}05$) varietal differences in starch digestibility of rice bean were observed. Black gram had significantly ($P < 0{\cdot}05$) lower starch digestibility than those of rice bean and green gram.

Autoclaving of unsoaked seeds increased starch digestibility five- to nine-fold. When the soaked seeds were autoclaved, the starch digestibility further increased significantly ($P < 0{\cdot}05$) in all the legumes. This increase was 10- to 14-fold. A similar increase in starch digestibility of legumes after autoclaving was noted by Traianedes and O'Dea (1986).

Enhancement of starch digestibility in cooked legumes may be attributed to the swelling and rupturing of starch granules. This facilitates a more randomised configuration for α-amylase to affect hydrolysis. Increased in-vitro digestibility of carbohydrates after cooking has been reported for other legumes such as chick pea, green gram, cow pea and red gram (Rao, 1969; Kumar & Venkataraman, 1976; El Faki *et al.*, 1984; Boralkar & Reddy, 1985).

Protein digestibility

The protein content of rice bean varieties was slightly lower than that of green bean and black gram (Table 2). The protein digestibility of rice bean varieties, which varied significantly ($P < 0{\cdot}05$) from one another, was higher ($P < 0{\cdot}05$) than that of black gram and lower than green gram except for RB-4. The relatively low protein digestibility of legumes may be attributed to the resistance of globulins, the major protein in pulse seed, to the proteolytic enzymes (Walker & Kochhar, 1983). Anti-nutritional factors, such as trypsin inhibitors, phytate and polyphenols, adversely affect protein digestibility (Tan *et al.*, 1984; Singh, 1984; Knuckles *et al.*, 1985). The protein digestibility has been reported to vary from 59 to 93 per cent among the various legumes (Jaffe, 1950).

On soaking for 6, 12 and 18 h, RB-4 had significantly ($P < 0{\cdot}05$) higher protein digestibility than the other four varieties of rice bean which varied significantly from one another. When compared with other legumes, it was found that green gram had significantly ($P < 0{\cdot}05$) lower starch digestibility than rice bean.

TABLE 2
Effect of Soaking, Sprouting, Ordinary Cooking and Autoclaving on In-Vitro Protein Digestibility of Rice Bean, Green Gram and Black Gram (per cent, on dry matter basis)[a]

Varieties	*Raw pulses*		*Soaking*			*Sprouting*		*Ordinary cooking*		*Autoclaving*	
	Total protein (g/100 g)	*Digestibility*	*6 h*	*12 h*	*18 h*	*40 h*	*60 h*	*Unsoaked*	*Soaked*	*Unsoaked*	*Soaked*
Rice bean											
RB-4	17·2	62·8	68·1	72·4	76·8	81·8	84·1	70·1	75·5	74·1	83·1
RB-32	17·5	58·6	63·8	67·7	70·3	78·1	83·3	66·2	72·0	71·6	80·7
RB-37	18·5	57·9	62·5	67·8	74·0	78·9	82·3	63·8	71·5	70·6	80·7
RB-40	18·1	57·1	62·2	67·2	73·7	77·5	80·8	65·2	72·4	69·6	80·0
RB-53	18·1	58·4	62·2	67·2	72·4	77·5	80·8	64·9	73·7	69·8	80·8
Green gram											
K-851	20·6	64·8	70·5	75·9	78·3	84·8	87·2	74·4	79·2	77·8	85·4
Black gram											
MT-9	20·2	50·9	55·5	60·0	67·9	—	—	59·2	66·8	61·1	70·2

	Soaking	*Sprouting*	*Cooking*	*Autoclaving*
Varietal SE (m)	0·8	0·8	0·9	0·7
CD ($P < 0{\cdot}05$)	2·6	2·6	2·6	2·2
Period SE (m)	0·5	0·6	0·4	0·5
CD ($P < 0{\cdot}05$)	1·7	1·9	1·4	1·4
Varietal × Period				
SE (m)	1·3	1·5	1·4	1·2
CD ($P < 0{\cdot}05$)	4·3	4·5	4·1	3·7

[a] Values are means of three replicates.

The protein digestibility of soaked seeds was better than that of unsoaked seeds. The digestibility further improved significantly ($P < 0{\cdot}05$) with increase in the period of soaking. Loss of various anti-nutritional factors such as the trypsin inhibitors, phytic acid and polyphenols may partly be responsible for better protein digestibility.

The in-vitro protein digestibility of all the legumes studied increased significantly ($P < 0{\cdot}05$) on sprouting. The protein digestibility showed a progressive and significant ($P < 0{\cdot}05$) increase with increase in sprouting time. This improvement in protein digestibility on sprouting may be attributed to the modification and degradation of storage proteins. Sprouting has been reported to increase in-vitro protein digestibility of soybean (Boralkar & Reddy, 1985), chick pea, cow pea and horse gram (El Faki *et al.*, 1984) and moth bean (Subhalakshmi *et al.*, 1976; Khokhar & Chauhan, 1986). Sprouting causes mobilisation of proteins with the help of proteases leading to the formation of polypeptides, oligopeptides and free amino acids. Further, during sprouting trypsin inhibitors, tannins, phytate, etc., are catabolised leading to lower levels of these anti-nutritional factors in the legume sprouts. This may also be responsible for increasing the protein digestibility during sprouting.

On ordinary cooking and autoclaving of unsoaked seeds of all pulses, RB-4 had a significantly ($P < 0{\cdot}05$) higher protein digestibility than the other four varieties which did not differ significantly from one another. Green gram had significantly ($P < 0{\cdot}05$) higher protein digestibility than rice bean, but black gram had significantly ($P < 0{\cdot}05$) lower protein digestibility. Thus, ordinary cooking and autoclaving significantly ($P < 0{\cdot}05$) increased the protein digestibility over that of the raw pulse which was further significantly ($P < 0{\cdot}05$) enhanced when soaked seeds were cooked. The data further show that autoclaving is better than ordinary cooking in improving the protein digestibility.

Cooking and heat-processing have been shown to increase protein digestibility (Ray, 1969; Kamalakanan *et al.*, 1981). The increase in the protein digestibility of legumes on cooking and autoclaving may be due to the inactivation of proteinase inhibitor and by opening up of protein structures through denaturation. Legumes contain a wide range of anti-nutritional factors; some of these, including tannins and phytates, may be involved in lowering protein digestibility in raw seeds. Reduction in the contents of these anti-nutritional factors, brought about by processing and cooking, may be responsible for increasing the protein digestibility.

The varietal × period interaction in protein digestibility was significant ($P < 0{\cdot}05$) on soaking, sprouting, ordinary cooking and autoclaving.

The results of the present study show that rice bean, which has a great potential to alleviate protein malnutrition due to its high yield and adaptability to adverse agroclimatic conditions, has protein and starch digestibilities comparable to other legumes and these are enhanced by processing and cooking treatments. However, to obtain the best results for improvement of starch and protein digestibility in rice bean, grain should be soaked in plain water and then pressure cooked.

REFERENCES

Akeson, W. P. & Stahman, M. A. (1964). A pepsin pancreatin digest complex for protein quality evaluation. *J. Nutr.*, **83**, 257–9.

AOAC (1980). *Official Methods of Analysis.* Association of Official Analytical Chemists, Washington, DC.

Asp, N. G., Bjorck, I., Holm, J., Nymen, M. & Siljestrom, M. (1986). Enzyme resistant starch fractions and dietary fibre. *Scand. J. Gastroenterol. Suppl.*, **129**, 29–35.

Berry, C. S. (1986). Resistant starch: Formation and measurement of starch that survives exhaustive digestion with amylolytic enzymes during determination of dietary fibre. *J. Cereal Sci.*, **4**, 301–14.

Bjorck, I., Nyman, M., Pedersen, B., Siljestrom, M., Asp, N. G. & Eggum, B. O. (1987). Formation of enzyme resistant starch during autoclaving of wheat starch: studies *in vitro* and *in vivo*. *J. Cereal Sci.*, **6**, 159–64.

Boralkar, M. & Reddy, S. N. (1985). Effect of roasting, germination and fermentation on the digestibility of starch and protein present in soybean. *Nutr. Rep. Int.*, **31**(4), 833–9.

Deshpande, S. S. & Cheryan, M. (1983). Changes in phytic acid, tannins and trypsin inhibitor activity on soaking of dry beans (*Phaseolus vulgaris* L.), *Nutr. Rep. Int.*, **27**, 371–8.

Deshpande, S. S. & Cheryan, M. (1984). Effects of phytic acid, divalent cations, and their interactions on amylase activity. *J. Food Sci.*, **49**, 516–19.

Dunaif, G. & Schneeman, B. O. (1981). The effect of dietary fibre on human pancreatic enzyme activity *in vitro*. *Am. J. Clin. Nutr.*, **34**, 1034–5.

El Faki, H. A., Venkataraman, L. V. & Desikachar, H. S. R. (1984). Effect of processing on the *in vitro* digestibility of proteins and carbohydrates in some Indian legumes. *Qual. Plant Foods for Human Nutr.*, **34**, 127–33.

Fuwa, H., Takaya, T. and Sugimoto, Y. (1980). Degradation of various starch granules by amylase. In *Mechanism of Saccharide Polymerization and Depolymerization*, ed. J. J. Marshall. Academic Press, New York, pp. 73–100.

Holm, J., Asp, N. G. & Bjorck, I. (1987). Factors affecting enzymatic degradation of cereal starches *in vitro* and *in vivo*. In *Cereal in a European Context.* First European Conference on Food Science and Technology, ed. I. D. Morton. Ellis Horwood, Chichester, UK, pp. 169–87.

Jaffe, W. G. (1950). Estudio sobre la inhibición del erecimento de rates esusada por algunas semillas de leguminoses. *Acta Cient. Venezolana*, **1**, 62 (cited from Liener, I. E. (1969) *Toxic Constituents of Plant Foodstuffs*).

Jaya, T. V. & Venkataraman, L. V. (1980). Effect of germination on the nitrogenous constituents, essential amino acids, carbohydrates, enzymes and antinutritional factors in chick pea and green gram. *Indian Food Packer*, **34**, 3–9.

Kamalakanan, V., Safhyamonshy, A. V. & Motlang, D. B. (1981). Studies on black gram (*Vigna mungo*) trypsin inhibitor. *J. Sci. Food Agric.*, **39**, 461–7.

Kataria, Anita (1986). Studies on nutrient composition and antinutritional factors of amphidiploids. MSc thesis, Haryana Agricultural University, Hisar, India.

Kaur, Deepinder (1986). Studies on nutrient composition and antinutritional factors of rice bean (*Vigna umbellata*). MSc thesis, Haryana Agricultural University, Hisar, India.

Khokhar, S. & Chauhan, B. M. (1986). Effect of domestic processing and cooking on *in vitro* protein digestibility of moth bean, *J. Food Sci.*, **51**(4), 1083–7.

Knuckles, B. E., Kunzmicky, D. D. & Batachart, A. A. (1985). Effect of phytate and partially hydrolysed phytate on *in vitro* protein digestibility. *J. Food Sci.*, **50**(4), 1080–2.

Kumar, K. G. & Venkataraman, L. V. (1976). Studies on the *in vitro* digestibility of starch in some legumes before and after germination. *Nutr. Rep. Int.*, **13**, 115–20.

Panse, Y. G. & Sukhatme, P. V. (1961). *Statistical Methods for Agricultural Workers* (2nd edn). Indian Council of Agricultural Research, New Delhi, India, pp. 12, 87.

Rao, P. S. (1969). Studies on the digestibility of carbohydrates in pulses. *Indian J. Med. Res.*, **57**(11), 215–21.

Rao, P. S. (1976). Nature of carbohydrates in pulses. *J. Agric. Food Chem.*, **24**, 958–61.

Ray, P. K. (1969). Nutritive value of horse gram (*Dolichos biflourus*) Part I. Effects of feeding raw and treated seed flour on the growth of rats. *Ind. J. Nutr. Dietet.*, **6**, 329–35.

Sievert, D. & Pomeranz, Y. (1989). Enzyme-resistant starch. I. Characterisation and evaluation of enzymatic, thermoanalytical and microscopic methods. *Cereal Chem.*, **66**, 342–7.

Singh, U. (1984). The inhibition of digestive enzymes by polyphenols of chickpea and pigeon pea. *Nutr. Rep. Int.*, **29**(3), 745–50.

Singh, U., Kherdekar, M. S. & Jambunathan, R. (1982). Studies on Desi and Kabuli chickpea (*Cicer arietinum* L.) cultivars. V. The levels of amylase inhibitors, levels of oligosaccharides and *in vitro* starch digestibility. *J. Food Sci.*, **47**, 510–13.

Subhalakshmi, G., Kumar, K. G. & Venkataraman, C. V. (1976). Effects of germination on the carbohydrates, protein, trypsin inhibitors, amylase inhibitors and haemagglutinins in horse gram and moth bean. *Nutr. Rep. Int.*, **13**, 19–31.

Tan, N. H., Wong, K. C. & de Lumen, B. O. (1984). Relationship of tannin levels and trypsin inhibitor activity with the *in vitro* protein digestibility of raw and heat treated winged beans. *J. Agric. Food Chem.*, **32**(9), 819–22.

Thompson, L. U. & Yoon, J. H. (1984). Starch digestibility as affected by polyphenols and phytic acid. *J. Food Sci.*, **49**(4), 1228–9.

Traianedes, K. & O'Dea, K. (1986). Commercial canning increases the digestibility of beans *in vitro* and postprandial metabolic response to them *in vivo*. *Am. J. Clin. Nutr.*, **44**, 390–7.

Walker, A. F. & Kochhar, N. (1983). Effect of processing including domestic cooking on nutritional quality of legumes. *Proc. Nutr. Soc.*, **21**, 41–8.

Wursch, P., Vedovo, S. D. & Koellreutter, B. (1986). Cell structure and starch nature as key determinants of the digestion rate of starch in legumes. *Am. J. Clin. Nutr.*, **43**, 25–9.

Wyatt, G. M. & Horn, N. (1988). Fermentation of resistant food starches by human and rat intestinal bacteria. *J. Sci. Food Agric.*, **44**, 281–8.