ELSEVIER

Food Chemistry 67 (1999) 347–352

Food Chemistry

www.elsevier.com/locate/foodchem

# Chemical composition, antinutritional factors and effect of cooking on nutritional quality of rice bean [*Vigna umbellata* (Thunb; Ohwi and Ohashi)]

P. Saikia, C.R. Sarkar*, I. Borua

*Department of Biochemistry and Agricultural Chemistry, Assam Agricultural University, Jorhat-13, Assam, India*

Received 19 January 1996; received in revised form and accepted 20 August 1998

**Abstract**

The mature seeds of four cultivars of rice bean [*Vigna umbellata* (Thunb; Ohwi and Ohashi)] were analysed for some nutritional and antinutritional factors. The cultivars showed little variation in their chemical composition. On a dry matter basis, the percentage of crude protein varied from 16.9 to 18; crude fat 0.46 to 0.52, crude fibre 6.3 to 7.5, total soluble sugar 4.9 to 5.6, starch 52.2 to 55 and ash 4.2 to 4.4. The amounts (mg/100 g) of calcium ranged from 280 to 325, sodium 43 to 52, potassium 171 to 210, phosphorus 216 to 275 and iron 6 to 7, respectively. The cultivars had trypsin inhibiting activities (TIA) of 2456 to 2534 TIU $g^{-1}$ phytic acid 1976 to 2170 mg per 100 g and tannins 513 to 572 mg per 100 g, respectively. Two cooking treatments, namely, 15 min pressure cooking (15 MPC) and 50 min boiling (50 MB) showed a considerable decrease in antinutritional factors. 

## 1. Introduction

Grain legumes are the major source of dietary proteins in all the developing countries, as animal proteins are expensive. Legumes are rich, not only in protein, but also in other nutrients such as starch, oil, vitamins and mineral elements (Lolas & Merkakis, 1975). Although, legume proteins have low digestibility and antinutritional factors such as, trypsin inhibitor activity and phytic acid and are deficient in sulphur-containing amino acids, in combination with cereals they give nutritionally balanced food. Thus, they appear to constitute the only feasible approach for eliminating 'protein calorie malnutrition' in the developing countries. To alleviate the protein deficiency currently, greater attention is being paid to the exploitation of non-conventional legumes in addition to the programme for development of high-yielding varieties through hybridization.

Rice bean, known as climbing mountain bean, mambi bean, oriental bean and locally as Beziamah, is one of the 10 different legumes identified by the Advisory Committee on Technology Innovation Board on Science and Technology for International Development, National Academy of Science, USA as an under exploited tropical legume. Rice bean is a native of South East Asia and is cultivated by the tribals in various ethnic groups in the Eastern and North-Eastern regions of India. These ethnic groups consume rice bean as a pulse mixed with rice. The tender pods and the green shelled seeds are cooked and consumed as vegetables.

Rice bean has a rich genetic diversity and high agricultural and nutritional potential in terms of its being able to grow well in comparatively poor soils in hot and humid climates and resistance to storage pests and serious diseases (Chandel, Joshi, Arora & Pant, 1978; Mukherjee, Roquib & Chatterjee, 1980; Singh, Mishra, Chandel & Pant, 1980). Since rice bean is a new addition to pulses, information on its nutrient composition and antinutritional factors is scanty. Rice bean was reported to be free of cyanagenic glycosides (Kay, 1979). Kaur and Kapoor (1991) studied the nutrient and antinutrient profiles in rice bean and reported that, despite its antinutritional factors, rice bean was comparable to commonly-consumed pulses such as blackgram and greengram. Effects of sprouting, dehulling and cooking on rice bean were studied by Verma and Mehta (1988) who observed that these processes can reduce antinutritional factors considerably.

The present study was undertaken to determine the chemical composition of some rice bean cultivars grown in agro-climatic conditions of North-East India. The

* Corresponding author.

0308-8146/99/$ - see front matter 
PII: S0308-8146(98)00206-4

effects of domestic cooking processes on nutritional quality of rice bean were also studied.

## 2. Materials and methods

Four cultivars of rice bean, namely, RBL-4, RBL-6, RBL-121 and Beziamah (a local variety) were collected from the Regional Agricultural Research Station, Nagoan, Assam and crops were raised in the experimental field of Assam Agricultural University, Jorhat, Assam, India, during the summer season of 1994. Seeds were collected from mature plants for each variety and were utilized for the present investigation.

### 2.1. Description of materials

Table 1 describes the cultivars selected for the present study.

### 2.2. Sample preparation

The oven-dried seeds were ground in an electric sample grinder to pass through a 0.25 nm screen and stored in air-tight containers for chemical analysis.

### 2.3. Chemical analysis

The proximate composition of seeds was determined according to procedures of AOAC (1980): moisture, 14.084, ash 14.085, crude protein 14.086, crude fibre 14.087, fat 14.088. Crude protein was calculated using the factor 6.25. Total soluble sugar (TSS) was determined by using the calorimetric method of Yem and Willis (1954), after refluxing in 80% ethanol. Starch was determined by using the method of Clegg (1956).

Total phosphorus (Fiske & Subbarow, 1925) and iron (Wong, 1928) were determined colorimetrically and calcium, sodium and potassium were determined according to the AOAC methods (1970); sodium and potassium, 3.016 and calcium 3.012.

Trypsin inhibitor activity (TIA) was determined by the method of Kakade, Simsons, and Liener (1969) and expressed as the number of units inhibited per gram dry matter.

Phytic acid was determined by using the method of Thompson and Erdman (1982) in which ferric chloride was used to precipitate ferric phytate. Phytate phosphorus was calculated from the ratio of Fe:P in the ferric phytate as 3.5:6 (Fe:P). Phytic acid content was determined by assuming the empirical formula $C_6P_5O_{24}H_{18}$.

Tannin content was determined by the calorimetric method as given in AOAC (1970): tannin 9.081.

### 2.4. Cooking quality

Cooking quality of rice bean was studied by determining cooking time, water absorption and solid dispersion. Five grammes of sample was put in a test tube with excess of deionized water (20 ml) and kept in boiling water till done. Grains were tested for 'doneness' between two glass slides and cooking time was noted. The grains were then separated from cooking water and put in between the layers of filter paper to blot off excess of water. These grains were then weighed and percent water absorption was calculated. Excess water left behind after removing the grains was put into a preweighed crucible and oven dried at 110°C and the weight of the residue was noted. Percent solid dispersion was calculated as follows:

$$\text{Solid dispersion}(\%) = \frac{\text{Weight of the residue}}{\text{Weight of the sample cooked}} \times 100$$

### 2.5. Cooking effect

To examine the cooking effect, two cooking treatments, namely, 50 min boiling (50 MB) of 100 g seeds in deionized water and 15 min pressure cooking (15 MPC) of the same amount of seeds in the same volume of water with 15 lb pressure were studied. The excess water was decanted and seeds were dried at 40°C in an oven for 12 h. The dried samples were ground and stored in air-tight containers for all the subsequent chemical analyses, as described earlier.

### 2.6. Statistical analysis

The data obtained from laboratory determination were subjected to statistical analysis by following a standard method (Snedecor & Cochran, 1967).

Table 1
Description of cultivars of rice bean

| Cultivars | 100 seed weight (g) | Approximate length of seed (cm) | Description of seed |
|---|---|---|---|
| RBL-4 | 6.12 | 5.5 | Brown, slightly flattened hilum, distinct and almost half of seed length |
| RBL-6 | 5.65 | 6.0 | Light brown, cylindrical, hilum distinct and almost half of seed length |
| RBL-121 | 5.56 | 6.0 | Greenish brown, cylindrical, hilum distinct and almost half of the seed length |
| Beziamah | 3.25 | 5.0 | Light brown, cylindrical, hilum dintinct and almost half of seed length |

## 3. Results and discussion

The cooking qualities of different rice bean cultivars are listed in Table 2.

Cooking times of 60 min for kidney beans, 27–49 min for green gram and 50–74 min for black gram have been reported (Vimala & Pushpamma, 1987). Results of the present investigation showed that cooking time for rice bean varieties were comparable to that of black gram. Water absorption and per cent solid dispersion were selected as criteria of cooking quality because the higher the values for these parameters the better is the liking for the cooked pulse. Water absorption (102–125%) and solid dispersion (10–12%) of rice bean were comparable, more or less, to the reported value of black gram (Narasimha & Desi Kachar, 1978; Vimala & Pushpamma, 1987).

Some of the chemical constituents of rice bean which are determining factors for nutritional quality and effect of cooking on them are presented in Table 3.

The low moisture content of the bean seeds accounted for its corresponding high dry matter content. The moisture content was in good agreement with literature values (Kaur & Kapoor, 1991). Low crude fat content of rice bean made it an uneconomic source of commercial oil. Compared to other legumes, though protein content was low (about 18%) it could be a possible additional source of protein. The high starch and total soluble sugar (TSS) contents of the bean made it a good source of calories. The percentages of crude fibre and ash were higher than the values in green gram as reported by Kaur and Kapoor. The ash content of the bean was important to the extent that it contained the nutritionally important mineral elements, some of which are shown in Table 4. Though legumes are generally relatively high in calcium, iron, phosphorus and potassium and low in sodium content, the present investigation reveals that rice bean contains a high level of sodium. Calcium content was also found to be very high in comparision to values reported for other traditional legumes by Meiners et al. (1976).

The two different cooking conditions studied showed a considerable extent of deviation of nutrients from the uncooked condition (Tables 3 and 4). The highly significant increase in moisture content might be due to the heating treatment which affected the water absorption capacity of starch and protein. This is supported by the earlier finding of Lin, Humbert and Sosulski (1974) who reported that heat-denaturation of sunflower protein increased the water-imbibing capacity. The increasing trend of moisture content from 12.3 to 60.0 g per 100 g in cowpea was reported by Akinyele (1989). In the present investigation the increase in moisture content probably had a dilution effect on all other nutrients in the cooked rice bean. The decrease in nutrient contents on cooking was probably also due to leaching of water-soluble nutrients into the cooking water. This was reflected in the decrease of nutrient levels, namely, crude protein, crude fat, crude fibre, starch and mineral elements with heat treatments. Similar findings of decrease in nutrient contents with cooking were reported by many workers in legumes (Onayemi, Osibogun & Obembe, 1986; El-Refal, Gouda & Ameer, 1987; Egbe & Akinyele, 1990 for protein; Khalil, Sawaya & Al-Mohammad, 1986 for fat; Shakib, Zouil, Yousef & Mohammed, 1985 for crude fibre; Meiners et al., 1976 for ash and minerals; Jood, Chauhan & Kapoor, 1988 for starch).

The TSS content in the present investigation was found to increase with cooking. This was obvious, as degradation of starch into simple soluble sugars could increase the TSS content in cooked rice bean. Similar findings in chick pea and black gram were reported by Jood, Chauhan and Kapoor (1988).

Among the two cooking treatments studied, 50 MB showed a higher reduction of nutritional composition compared to 15 MPC except for starch and fat contents. The observed trend of decrease under the 50 MB condition might be because the prolonged cooking treatment liberated more nutrients into a free form, most of which were leached out to cooking water.

The presence of antinutritional factors is one of the major drawbacks limiting the nutritional quality of legumes (Kakade et al., 1969). A preliminary evaluation of some of these factors in rice bean seeds was carried out (Table 5).

The TIA values for all the cultivars showed significant differences between the cultivars and were found to be higher than the reported values (Kaur & Kapoor, 1991; Verma & Mehta, 1988). Although the trypsin inhibitor was established to be heat-labile (Khokhar & Chouhan, 1986) and cooking and autoclaving have been reported to be effective in inactivating protease inhibitors in several food legumes (Deka & Sarkar, 1990; Gupta & Wagle, 1980; Monorama & Sarojini, 1982; Ologhobo & Fetuga, 1983), in the present investigation TIA was not found to be completely destroyed under heat treatments. TIA compared to uncooked samples decreased by about 53% under 50 MB and about 64% under 15 MPC. Verma and Mehta (1988) also reported similar findings of TIA under heat treatments. It is possible that, for complete elimination of TIA in rice bean, more severe cooking is necessary as in the case of soybean (Liener, 1980).

Rice bean has a fairly high content of phytic acid and its content among cultivars varied significantly. The

Table 2
Cooking qualities of different rice bean cultivars[a]

| Cultivars | Cooking time (min) | Water absorption (%) | Solid dispersion (%) |
|---|---|---|---|
| RBL-4 | 50 | 102 | 11 |
| RBL-6 | 52 | 125 | 12 |
| RBL-121 | 53 | 113 | 12 |
| Beziamah | 57 | 117 | 10 |

[a] Each value is mean of four analyses.

Table 3
Chemical composition of rice bean seeds under uncooked (UC), 15 min pressure cooking (15 MPC) and 50 min boiling (50 MB) conditions (g per 100 g on dry weight basis)[a]

| Cultivars | Moisture | | | Crude protein | | | Crude fat | | | Crude fibre | | | TSS | | | Starch | | | Ash | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UC | 15 MPC | 15 MB | UC | 15 MPC | 50 MB | UC | 15 MPC | 15 MB | UC | 15 MPC | 15 MB | UC | 15 MPC | 15 MB | UC | 15 MPC | 15 MB | UC | 15 MPC | 50 MB |
| RBL-4 | 10.3 | 31.2 | 44.9 | 17.2 | 13.8 | 13.0 | 0.49 | 0.12 | 0.22 | 6.6 | 3.9 | 3.0 | 5.6 | 6.3 | 6.1 | 54.3 | 41.6 | 45.4 | 4.3 | 4.2 | 3.8 |
| | | (+207)[b] | (+319) | | (−20) | (−25) | | (−78) | (−58) | | (−44) | (−56) | | (+17) | (+11) | | (−24) | (−19) | | (−4) | (−11) |
| RBL-6 | 10.5 | 33.1 | 45.7 | 17.6 | 14.1 | 13.4 | 0.49 | 0.14 | 0.25 | 7.5 | 4.4 | 3.3 | 5.1 | 6.0 | 5.8 | 55.0 | 42.9 | 45.5 | 4.2 | 4.1 | 3.8 |
| | | (+208) | (+346) | | (−20) | (−24) | | (−75) | (−55) | | (−42) | (−55) | | (+12) | (+9) | | (−23) | (−16) | | (−4) | (−12) |
| RBL-121 | 10.4 | 33.3 | 44.4 | 18.0 | 15.1 | 13.9 | 0.52 | 0.16 | 0.25 | 7.2 | 4.0 | 3.3 | 5.4 | 6.5 | 6.0 | 52.2 | 38.0 | 44.7 | 4.4 | 4.3 | 4.0 |
| | | (+227) | (+353) | | (−20) | (−24) | | (−73) | (−50) | | (−42) | (−56) | | (+17) | (+12) | | (−22) | (−17) | | (−3) | (−11) |
| Beziamah | 10.6 | 32.4 | 44.2 | 16.9 | 13.6 | 12.7 | 0.46 | 0.10 | 0.20 | 6.3 | 3.5 | 2.8 | 4.9 | 5.8 | 5.4 | 53.5 | 40.6 | 43.4 | 4.4 | 4.3 | 4.0 |
| | | (+229) | (+340) | | (−16) | (−23) | | (−69) | (−52) | | (−44) | (−55) | | (+20) | (+12) | | (−27) | (−14) | | (−3) | (−9) |
| *S.Ed +*[c] | | | | | | | | | | | | | | | | | | | | | |
| Cultivars | | 0.54 | | | 0.11 | | | 0.069 | | | 0.13 | | | 0.67 | | | 0.79 | | | 0.022 | |
| Cooking | | 0.47 | | | 9.93 | | | 0.06 | | | 0.11 | | | 0.058 | | | 9.69 | | | 0.019 | |
| *F test* | | | | | | | | | | | | | | | | | | | | | |
| Cultivars | | 1.20 | | | 45.71[e] | | | 0.46 | | | 17.65[e] | | | 45.13[e] | | | 5.01[d] | | | 33.04[e] | |
| Cooking | | 2749. 43[e] | | | 977. 43[e] | | | 17.79[e] | | | 619.43[e] | | | 121.25[e] | | | 184.92[e] | | | 295.63[e] | |

[a] Means of three determinations in each of four replicate samples.
[b] Figures in parentheses represent % increase or decrease of control values.
[c] S.Ed + is the standard error of difference of two means.
[d] Significant at 5% level of probability.
[e] Significant at 1% level of probability.

Table 4
Mineral element contents of rice bean seeds under uncooked (UC), 15 min pressure cooking (15 MPC), 50 min boiling (50 MB) conditions (mg/100 g on dry weight basis)[a]

| Cultivars | Ca | | | Na | | | K | | | P | | | Fe | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UC | 15 MPC | 50 MB | UC | 15 MPC | 50 MB | UC | 15 MPC | 50 MB | UC | 15 MPC | 50 MB | UC | 15 MPC | 50 MB |
| RBL-4 | 325 | 312 | 220 | 46 | 42 | 42 | 200 | 185 | 171 | 275 | 265 | 171 | 7 | 5 | 3 |
| | | (−3)[b] | (−31) | | (−3) | (−3) | | (−4) | (−11) | | (−3) | (−35) | | (−32) | (−55) |
| RBL-6 | 280 | 275 | 208 | 43 | 41 | 40 | 180 | 157 | 148 | 231 | 227 | 137 | 6 | 4 | 3 |
| | | (−4) | (−36) | | (−7) | (−7) | | (−8) | (−15) | | (−4) | (−38) | | (−29) | (−54) |
| RBL-121 | 310 | 295 | 210 | 48 | 45 | 41 | 171 | 153 | 140 | 216 | 206 | 116 | 7 | 5 | 3 |
| | | (−2) | (−25) | | (−5) | (−7) | | (−7) | (−13) | | (−2) | (−41) | | (−34) | (−56) |
| Beziarnah | 321 | 310 | 222 | 52 | 50 | 51 | 210 | 203 | 188 | 242 | 234 | 158 | 7 | 4 | 3 |
| | | (−5) | (−29) | | (−7) | (−14) | (−11) | (−18) | | (−5) | (−46) | | (−31) | (−52) | |
| *S.Ed.* +[c] | | | | | | | | | | | | | | | |
| Cultivars | | 8.91 | | | 1.7 | | | 4.28 | | | 4.17 | | | 0.049 | |
| Cooking | | 7.72 | | | 1.47 | | | 3.71 | | | 3.61 | | | 0.042 | |
| *F test* | | | | | | | | | | | | | | | |
| Cultivars | | 4.27 | | | 11.76[d] | | | 63.21[d] | | | 66.93[d] | | | 82.95[d] | |
| Cooking | | 88.25[d] | | | 4.35 | | | 30.36[d] | | | 431.98[d] | | | 3565.30[d] | |

[a] Means of three determinations in each of four replicate samples.
[b] Figures in parentheses represent % decrease of control values.
[c] S.Ed + is the standard error difference of two means.
[d] Significant at 1% level of probability.

Table 5
Level of antinutritional factors of rice bean seeds under uncooked (UC), 15 min pressure cooking (15 MPC) and 50 min boiling (50 MB) conditions (on dry weight basis)[a]

| Cultivars | Phytic acid (mg/100 g) | | | Tannin (mg/100 g) | | | Trypsin inhibitor activity (TIU/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | UC | 15 MPC | 50 MB | UC | 15 MPC | 50 MB | UC | 15 MPC | 50 MB |
| RBL-4 | 2040 | 1712 | 1758 | 572 | 398 | 332 | 2456 | 878 | 1119 |
| | | (−16) | (−14) | | (−30) | (−42) | | (−64) | (−55) |
| RBL-6 | 1976 | 1625 | 1687 | 612 | 422 | 376 | 2512 | 902 | 1218 |
| | | (−18) | (−15) | | (−31) | (−34) | | (−64) | (−52) |
| RBL-121 | 1998 | 1656 | 1712 | 513 | 326 | 298 | 2477 | 889 | 1131 |
| | | (−17) | (−14) | | (−37) | (−42) | | (−64) | (−54) |
| Beziamah | 2170 | 1845 | 1890 | 548 | 360 | 303 | 2534 | 919 | 1205 |
| | | (−15) | (−13) | | (−34) | (−45) | | (−64) | (−53) |
| *S.Ed* +[c] | | | | | | | | | |
| Cultivars | | 5.1 | | | 7.41 | | | 15.64 | |
| Cooking | | 4.4 | | | 6.42 | | | 13.54 | |
| *F test* | | | | | | | | | |
| Cultivars | | 643.38[e] | | | 56.22[e] | | | 9.16[e] | |
| Cooking | | 3363.39[e] | | | 738.76[e] | | | 7970.09[e] | |

[a] Means of three determinations of four replicate samples.
[b] Figures in parentheses represent % decrease of control values.
[c] S.Ed + is the standard error of difference of two means.
[d] Significant at 5% level of probability.
[e] Significant at 1% level of probability.

high content of phytate is of nutritional significance as not only is the phytate phosphorus unavailable to the human, but it also lowers the availability of many other essential minerals. The phytate, however, could be substantially eliminated by soaking and cooking (Reddy, Sathe & Salunkhe, 1982). The present decrease in phytic acid content in cooked rice bean was comparable to the report of Kataria, Chauhan and Punia (1989).

Tannins have been claimed to adversely affect the digestibility of dietary protein and, to a lesser extent, that of available carbohydrate and lipid (Mosely & Griffiths, 1979). Rice bean was found to have a low level of tannin in comparision to values reported by Rao and Deosthale (1982) in some traditional pulses. The percent decrease in tannin content was about 40% under the 50 MB condition, which was more than the percent decrease under 15 MPC. The greater decrease under the 50 MB condition might be because prolonged cooking time caused more tannin diffusion into cooking water.

From the present investigation, it could be established that, though rice bean is low in protein content in comparision to other traditional pulses, most of the nutrients studied are more or less comparable to commonly-consumed legumes. It is rich in starch, TSS and fibre. Considerable amounts of minerals, particularly, calcium and sodium are present in rice bean. The antinutritional factors, TIA and phytic acid, though showing a high concentration, should not pose a problem in human consumption if the beans are properly processed.

## Acknowledgements

The authors wish to thank Dr. K. C. Chandra and Dr. G. N. Hazarika of Assam Agricultural University, Jorhat-13, Assam, for initiating interest in evaluating the rice bean and Dr. A. K. Borthakur, for TIA determination.

## References

AOAC (1970). Official Methods of Analysis (11th ed.). Washington, DC: Association of Analytical Chemistst.

AOAC (1980). Official Methods of Analysis (13th ed.). Washington, DC: Association of Analytical Chemists.

Akinyele, I.O. (1989). Effect of traditional methods of processing on the nutrient contents and some antinutritional factors in cow pea (*Vigna unguiculata*). *Food Chemistry, 33*, 291.

Chandel, K. P. S., Joshi, B. S., Arora, R. K., & Pant, K. C. (1978). Rice bean—a new pulse with higher potential. *Indian Farming, 28*, 9, 19–22.

Clegg, K. M. (1956). The application of the anthrone reagent to the estimation of starch in cereals. *Journal of the Science of Food and Agriculture, 7*, 40–42.

Deka, R., & Sarkar, C. R. (1990). Nutrient composition and antinutritianal factors of *Dolichos lablab* (L) seeds. *Food Chemistry, 38*, 239.

Egbe, I. A., & Akinyele, I. O. (1990). Effect of cooking on the antinutritional factors of lima bean (*Phaseolus vulgeris*). *Food Chemistry, 35*, 81.

El-Refal, A. A., Gouda, M. S., & Ameer, K. A. (1987). Effect of processing and storage on protein and lipid composition of pea. *Food Chemistry, 23*, 117.

Fiske, D. B., & Subbarow, Y. (1925). The colorimetric determination of phosphorus. *Journal of Biological Chemistry, 66*, 375.

Gupta, K., & Wagle, D. S. (1980). Changes in antinutritional factors during germination in *P. mungoreus*, a cross between *P. Mungo* ($M_1$) and *P.aureus* ($T_1$). *Journal of Food Science, 45*, 394–397.

Jood, S., Chauhan, B. M., & Kapoor, A. C. (1988). Contents and digestibility of carbohydrates of chick pea and black gram as affected by domestic processing and cooking. *Food Chemistry, 30*, 113–127.

Kakade, M. L., Simsons, N., & Liener, I. E. (1969). An evaluation of natural and synthetic substances for measuring the antitryptic activity of soybean samples. *Cereal Chemistry, 46*, 518.

Kataria, A., Chauhan, B. M., & Punia, D. (1989). Antinutrients and protein digestibility (*in vitro*) of mungbean as affected by domestic processing and cooking. *Food Chemistry, 32*, 9.

Kaur, D., & Kapoor, A. C. (1991). Nutrient composition and antinutritional factors of rice bean (*Vigna umbellata*). *Food Chemistry, 43*, 119–124.

Kay, D. E. (1979). Rice bean (*Vigna umbellata*) 348:354. In *Crop and Products. Digest no. 3. Food legumes. London: Tropical Products Institutes.*

Khalil, J. E., Sawaya, W. N., & Al-Mohammad, H. M. (1986). Effects of experimental cooking on the yield and proximate composition of three selected legunes. *Journal of Food Science, 51*, 233.

Khokhar, S., & Chauhan, B. M. (1986). Antinutritional factors in mothbean (*Vigna acenitifolia*): varietal difference and effects of methods of domestic processing and cooking. *Journal of Food Science, 51*, 591–594.

Liener, I. E. (1980). *Toxic constituents of plant food stuffs* (2nd ed.) New York: Academic Press.

Lin, M. J. Y., Humbert, E. S., & Sosulski, I. W. (1974). Certain functional properties of sunflower meal products. *Journal of Food Science, 39*, 368.

Lolas, G. M., & Merkakis, P. (1975). Phytic acid and other phosphorus compounds of beans (*Phaseolus vulgeris* L.). *Journal of Agricultural and Food Chemistry, 23*, 13.

Meiners, C. R., Derise, M. L., Lau, H. C., Crews, M. G., Ritchey, S. J., & Murphy, E. W. (1976). The content of nine mineral elements in raw and cooked matured dry legumes. *Journal of Agriculture and Food Chemistry, 2A 6*, 1126.

Monorama, R., & Sarojini, G. (1982). Effect of different heat treatments on the trypsin inhibitor activity of soybean. *Ind. J. Nutr. Diet, 19*, 8.

Mosely, G., & Griffiths, B. W. (1979). Varietal variation in the antinutritive effects of field bean (*Vicia faba*) when fed to rats. *Journal of the Science of Food and Agriculture, 30*, 772–778.

Mukherjee, A. K., Roquib, M. A., & Chatterjee, B. N. (1980). Rice bean K-1 for the scarcity period. *Indian Farming, 29*, (12), 19–26.

Narasimha, H. V., & Desi Kachar, H. S. R. (1978). Objective methods for studying cookability of tur pulse (*Cajanus cajan*) and factors affecting varietal differences in cooking. *Journal of Food Science and Technology, 15*, 47.

Ologhobo, A. D., & Fetuga, B. L. (1983). Trypsin inhibitor activity in some lima bean (*P. lunatus*) varieties as affected by different processing methods. *Nutr. Rep. Int., 27*, 41.

Onayemi, O., Osibogun, O. A., & Obembe, O. (1986). Effect of different storage and cooking methods on some biochemical, nutritional and sensory characteristics of cow pea (*Vigna unguiculata* L. Walp). *Journal of Food Sciemce, 51*, 153.

Rao, P. V., & Deosthale, Y. G. (1982). Tannin content of pulses: varietal differences and effect of germination and cooking. *Journal of the Science of Food and Agriculture, 33*, 1013–1016.

Reddy, N. R., Sathe, S. K., & Salunkhe, D. K. (1982). Phytates in legumes and cereals. *Adv. Fd. Res., 28*, 1.

Shakib, L. A. E., Zouil, M. E., Yousef, M. M., & Mohammad, M. S. (1985). Effect of cooking on the chemical camposition of lentils, rice and their blend (Koshary). *Food Chemistry, 18*, 169.

Singh, S. P., Mishra, B. K., Chandel, K. P. S., & Pant, K. C. (1980). Major food constituent of rice bean (*Viqna umbellata*). *Journal of Food Science and Technology, 17*, 238–240.

Snedecor, G. W., & Cochran, G. W. (1967). *Statistical methods*. Ames, IA: The Iowa State University Press.

Thompson, D. B., & Erdman, J. W. (1982). Phytic acid determination in soybean. *Journal of Food Science, 47*, 513.

Verma, P., & Mehta, U. (1988). Study of physical characteristics, sensory evaluation and the sprouting, cooking and dehulling on the antinutritional factors of rice bean (*Vigna umbellata*). *Journal of Food Science and Technology, 25*, 197.

Vimala, V., & Pushpamma, P. (1987). Changes in cookability of pulses from three regions of Andhra Pradesh. *Journal of Food Science Technology, 24*, 155.

Wong, S. Y. (1928). The calorimetric determination of iron. *Journal of Biological Chemistry, 77*, 409.

Yem, E. W., & Wills, A. J. (1954). The estimation of carbohydrates in plant extracts by anthrone. *Biochemical Journal, 57*, 508.