Nutritional Evaluation of Basmati Rice (*Oryza sativa* L.) Genotypes

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Growth studies and nutritional evaluation of 'Basmati–370', 'Pusa Basmati–1' and 'Haryana Basmati–1' were carried out in rats. Moisture, crude proteins, ether extractives, crude fibre, mineral matter, carbohydrates and energy of the basmati rice varieties ranged from 11.15 to 11.29; 8.23 to 8.41; 1.17 to 1.21; 0.87 to 0.92; 1.08 to 1.14; 77.14 to 77.32 and 352.5 to 366.0 kcal/100g, respectively. Feed efficiency ratio and protein efficiency ratio values did not differ among rice diets. 'Pusa Basmati–1' appeared to have better apparent protein digestibility, true protein digestibility, biological value, net protein utilization, utilisable protein and liver enzymes.

Keywords : Basmati rice, Proximate composition, Protein efficiency ratio, Amino acids, Biological value, Net protein utilization.

The overall assessment of a foodgrain is determined by its physical, physico–chemical, biochemical, nutritional, milling, cooking, processing and eating qualities besides economic values (Goyal and Sharma 1998). The nutritive value is governed by the levels of nutrients, antinutrients, non–nutrients in combination with biological assays, using laboratory animals, followed by human beings. Any alteration in the nutritive value of foods brought through introduction of new varieties would have significant impact on the nutritional status of population consuming such diets.

Basmati rice is an important cash crop of Haryana, Punjab, and Western Uttar Pradesh, but Haryana is known for best quality of rice and basmati from Haryana accounts for 33% of total export of the country. Scented rice is highly valued in many parts of the world and is preferred over non–scented because after cooking, they become soft, non-sticky, possess pleasant aroma and show linear kernel elongation without significant increase in breadth. The nutritive value of rice and rice diets is basically governed by their chemical composition and bioavailability of nutrients. A few studies on feeding of rice and rice diets were earlier conducted on rats (Srinivasan et al. 1970; Bresseni et al. 1971; Juliano 1990; Kaur and Sekhon 1994), but information on nutritional evaluation of basmati rice is scanty. The present study was designed to assess the nutritional value of 3 varieties of basmati rice.

Materials and Methods

Paddy seeds of 'Pusa Basmati', "Haryana Basmati–1', and 'Basmati 370' were procured from CCS Haryana Agricultural University, Regional Rice Research Station, Kaul (Kaithal) during December 1996. Paddy samples were dehusked and polished uniformly utilising the available local facilities. The rice grains were cleaned off dust, stones, broken seeds and other foreign material and ground to 80 mesh sieve having 0.2 mm particle size using Udytec Cyclone Sample mill. AOAC (1984) methods were followed for determining proximate composition. Wet oxidation chromic acid method as described by O'shea and Maguire (1962) was employed for determining energy value. Tryptophan was estimated after enzymatic hydrolysis as per the procedure of Spices and Chamber (1949). Methionine, tyrosine, cystine and lysine were estimated after acid hydrolysis by using the methods of McCarthy and Paille (1959), Joseph (1957), Leach (1966) and Miyahara and Jikoo (1967), respectively.

Male albino rats weighing between 22 and 58 g obtained from the disease-and germ-free animal house of the University were divided into four groups, consisting 6 rats each in a complete randomised design. The rats were housed individually in aluminium metabolic cages and were kept in an air conditioned room maintained at 22–24°C. Food and water were given *ad libitum*. Rats were fed on nutritionally complete diets of raw basmati rice/casein at 8% protein level, containing salt mixture 3.5%, vitamin mixture 2%, vitaminized groundnut oil 5%, cellulose 5% and corn starch to equal 100%. Diet consumption was monitored daily. The rats were finally weighed after 4 weeks. Feed efficiency ratio (FER) and protein efficiency ratio (PER) were calculated. For biological value determination, the rats were first allowed to acclimatize for 4 days. Urine and faeces were

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collected for 6 days and pooled. Faecal samples were dried at 70°C. A few drops of H_2SO_4 (1N) were added to urine to prevent loss of ammonia. Nitrogen was determined in urine and faeces by micro Kjeldahl method (AOAC 1984). Metabolic faecal nitrogen and endogenous urinary nitrogen have been derived using the method described by Bondi (1987). Biological value (BV), net protein utilization (NPU) and utilizable protein were calculated from the data obtained, Amino acid requirements as reported by Friedman (1996) were used for comparison. After the expiry of 40 days, all the rats were sacrificed after ether anaesthesia and rats were dissected to expose the various vital organs and their respective weights were recorded. Glutamate pyruvate transaminase (GPT), glutamate oxaloacetate transaminase (GOT) in liver were assayed by the method of Sharma (1993) and liver alkaline phosphatase and acid phosphatase by the methods of Jones (1969).

Results and Discussion

Proximate composition : The data on the proximate composition are presented in Table 1. Moisture contents of the 'Basmati' rices varied from 11.15 to 11.29; proteins from 8.23 to 8.41; crude fibre from 0.87 to 0.92; ether extractives from 1.17 to 1.21; mineral matter from 1.08 to 1.14; carbohydrates from 77.14 to 77.32% and energy value from 352.5 to 366.0 kcal/100g. The values reported by different workers (Firmin 1991; Annapure et al. 1998; Chakrabarthy et al. 1972; Narasinga Rao et al. 1995; Oleka et al. 1997) are comparable to the present findings. However, the present values for crude fat, crude ash and crude fibre were different from earlier values of milled rice observed by Pomeranz and Ory (1982) and Barber (1972). This may be due to variations in agroclimatic conditions and genetic factors.

TABLE 1. PROXIMATE AND ESSENTIAL AMINO ACID COMPOSITION OF BASMATI RICE VARIETIES

	'Basmati 370'	'Pusa Basmati-1'	'Haryana Basmati-1'
Moisture, %	11.29 ± 0.05	11.16 ± 0.10	11.28 ± 0.09
Crude proteins, %	8.23 ± 0.02	8.28 ± 0.01	8.41 ± 0.02
Crude fibre, %	0.92 ± 0.03	0.92 ± 0.02	0.87 ± 0.02
Ether extractives, %	1.17 ± 0.01	1.20 ± 0.03	1.21 ± 0.01
Mineral matter, %	1.08 ± 0.01	1.14 ± 0.02	1.11 ± 0.01
Carbo-hydrates, %	77.32 ± 0.03	77.32 ± 0.03	77.14 ± 0.03
Energy, kcal/100g	352.5 ± 3.54	361.0 ± 1.41	366.0 ± 4.24
Tryptophan, g/16g N	0.876 ± 0.001	0.882 ± 0.002	0.884 ± 0.002
Methionine, g/16gN	3.21 ± 0.01	3.35 ± 0.01	3.53 ± 0.02
Tyrosine, g/16gN	2.57 ± 0.02	2.60 ± 0.02	2.60 ± 0.03
Cystine, g/16g N	0.675 ± 0.002	0.699 ± 0.002	0.703 ± 0.002
Cysteine, g/16g N	2.18 ± 0.01	2.16 ± 0.02	2.19 ± 0.02
Lysine, g/16g N	2.82 ± 0.01	2.81 ± 0.01	2.83 ± 0.02

Each value is an average of four estimations

Amino acids composition : Data presented in Table 1 indicate that the evaluated 'Basmati' rice cultivars contained sufficient levels of sulphur amino acids to meet the requirements of all age groups of population, lysine and tryptophan to adults only and tyrosine to 10–12 years age group and adults (Friedman 1996). Higher contents of lysine, total sulphur amino acids and tryptophan in rice were earlier reported (Chatterjee and Abrol 1975; Eggum et al. 1987; Resurrecion et al. 1993). Values for methionine and cysteine previously reported (Juliano 1985; Eggum et al. 1982; Pederson and Eggum 1983) were in line with presently estimated contents, but slightly higher for tryptophan, tyrosine and lysine contents. The possible governing attributes for disagreement of the present data on amino acids with literature could be the differences in rice genotypes selected for evaluation, agroclimatic conditions prevailing in different regions, post-harvest technology employed for processing and techniques chosen for amino acid determinations. However, the contents of essential amino acids fail to take into account the differences in digestibility. Further, the essentiality of amino acids is dependent upon the requirements of the specific species in question.

Biological assay : Table 2 presents data on the food intake, protein consumed, weight gain, feed efficiency ratio, protein efficiency ratio and relative protein efficiency ratio. FER, PER and rPER did not vary much among 'Basmati' rice. 'Pusa Basmati-1' gave better growth of rats, followed by 'Haryana Basmati-1' and 'Basmati 370'. Bressani et al (1971) reported PER values in the range of 1.94 to 2.56 in rats fed at 5% protein level that supported the present findings. The present results are also in agreement with many previous nutritional investigators (Udayasekhara Rao and Sharma 1989; Prakash and Ramanatham 1995). Friedman (1996), who evinced that PER values of above 2.0 indicated

TABLE 2. EFFECT OF FEEDING, CASEIN AND BASMATI RICE ON GROWTH OF RATS

Experimental diets	Food intake g	Protein intake g	Weight gain g	Feed efficiency ratio (PER)	Protein efficiency (PER)	Relative PER (rPER)
'Basmati 370'	184.82 ± 12.38	14.79 ± 0.99	37.33 ± 2.30	0.202 ± 0.001	2.53 ± 0.010	80.13 ± 0.03
'Pusa Bsmati-1'	218.27 ± 38.01	17.46 ± 2.64	44.10 ± 6.67	0.202 ± 0.001	2.53 ± 0.002	80.14 ± 0.05
'Haryana Basmati-1'	198.85 ± 19.30	15.91 ± 1.54	40.17 ± 3.90	0.201 ± 0.001	2.53 ± 0.001	80.14 ± 0.03
Casein	190.27 ± 39.36	15.20 ± 3.14	47.93 ± 8.71	0.252 ± 0.001	3.15 ± 0.017	100.00
CD 5%	NS	NS	7.62	0.001	0.001	

Each value is an average of six replications

TABLE 3. EFFECT OF FEEDING BASMATI RICE TO RATS ON DIGESTIBILITY COEFFICIENT, BIOLOGICAL VALUE AND NET PROTEIN UTILIZATION

Experimental diets	Nitrogen intake, mg/day/rat	Faecal N, mg/day/rat	Metabolic faecal N, mg/day/rat	Urinary N, mg/day/rat	Endogenous urinary N, mg/day/rat	Apparent protein digestibility,	True protein digestibility,	Biological value, %	Net protein utilization, %	Utilizable protein %
'Basmati 370'	46.15 ± 1.68	14.80 ± 0.62	7.99 ± 0.29	11.15 ± 0.57	4.50 ± 0.19	67.94 ± 0.53	85.25 ± 0.52	83.09 ± 1.76	70.82 ± 1.06	5.67 ± 0.09
'Pusa Bsmati-1'	48.75 ± 1.67	14.97 ± 0.50	8.44 ± 0.29	10.74 ± 0.24	4.82 ± 0.27	69.29 ± 0.57	86.07 ± 0.67	85.99 ± 0.66	74.00 ± 0.78	5.92 ± 0.06
'Haryana Basmati-1'	47.13 ± 1.24	15.71 ± 0.17	8.16 ± 0.22	11.48 ± 0.34	4.45 ± 0.13	66.65 ± 0.56	83.95 ± 0.56	82.21 ± 1.08	69.01 ± 1.33	5.52 ± 2.00
Casein	50.05 ± 0.75	14.66 ± 0.11	8.66 ± 0.13	9.80 ± 0.52	4.90 ± 0.49	70.71 ± 0.46	88.01 ± 0.47	88.86 ± 2.27	78.20 ± 2.21	70.85 ± 2.00
CD 5%	2.14	0.45	0.37	0.68	NS	0.82	0.86	2.42	2.23	1.55

Each value is an average of four replications

TABLE 4. INTESTINAL LENGTH AND ORGAN WEIGHTS OF RATS FED ON BASMATI RICE

Experimental diets	Small intestine length, cm	Liver, g	Kidney, g	Brain, g	Testes, g	Spleen g	Heart, g
'Basmati 370'	84.15 ± 06.63	2.92 ± 0.96	0.57 ± 0.06	1.32 ± 0.08	0.42 ± 0.12	0.17 ± 0.03	0.32 ± 0.04
'Pusa Bsmati-1'	93.10 ± 02.32	3.70 ± 0.25	0.89 ± 0.39	1.39 ± 0.22	0.76 ± 0.48	0.32 ± 0.14	0.46 ± 0.16
'Haryana Basmati-1'	83.18 ± 08.60	2.65 ± 0.67	0.57 ± 0.17	1.22 ± 0.16	0.55 ± 0.23	0.18 ± 0.07	0.31 ± 0.02
Casein	86.95 ± 10.41	3.15 ± 1.22	0.79 ± 0.23	1.36 ± 0.20	0.57 ± 0.22	0.25 ± 0.05	0.42 ± 0.17
CD 5%	NS	NS	NS	NS	NS	NS	NS

Each value is an average of six replications

that the proteins are of good to high quality and as such, the presently evaluated rice varieties could be grouped into this category.

Data on nitrogen intake, urinary nitrogen, endogenous urinary nitrogen, endogenous faecal nitrogen, true protein digestibility, biological value, net protein utilization and utilizable protein presented in Table 3 show that 'Basmati' rice had biological value between 82.21 and 85.99% and net protein utilization between 69.01 and 74.00% as compared to the corresponding values of 88.86 and 78.20% for casein. Utilizable protein and true protein digestibility varied from 5.52 to 5.92% and 83.95 to 86.07% as compared to 70.85 and 88.01% for casein diet. 'Pusa Basmati-1', emerged better on the basis of nitrogen balance studies under present conditions. The lower values of APD, TPD, BV, NPU and UP in rice diets as compared to casein diet may be due to interaction with phenolic compounds, phytates, carbohydrates, conformational changes and enhanced nitrogen loss. Similar explanation was also given by Deka (1998). True digestibility, BV, NPU and UP in four rice varieties reported by Sikka et al (1989) lent support to the present results. Biological value is a good index of protein quality and a food protein with 70% biological value is generally considered capable of supporting growth, provided it contains adequate calories (Gruenwedel and Whitaker 1984).

Organ weights : The data relating to organs weight namely liver, kidney, brain, testes, heart and length of intestine and its expression on per cent body weight are given in Tables 4 and 5. The perusal of data revealed that the rats fed on 'Pusa Basmati-1' recorded maximum length of small intestine and weights of all the organs and

TABLE 5. INTESTINAL LENGTH AND ORGAN WEIGHTS (PER CENT BODY WEIGHT) OF RATS FED ON BASMATI RICE

Experimental diets	Small intestine length, cm	Liver, g	Kidney, g	Brain, g	Testes, g	Spleen g	Heart, g
'Basmati 370'	84.9 ± 01.93	2.92 ± 0.79	0.58 ± 0.06	1.34 ± 0.11	0.42 ± 0.11	0.16 ± 0.03	0.32 ± 0.03
'Pusa Bsmati–1'	85.6 ± 04.78	3.40 ± 0.12	0.80 ± 0.30	1.27 ± 0.16	0.68 ± 0.40	0.29 ± 0.10	0.42 ± 0.12
'Haryana Basmati–1'	85.2 ± 05.70	2.70 ± 0.61	0.58 ± 0.16	1.25 ± 0.16	0.57 ± 0.25	0.19 ± 0.26	0.32 ± 0.02
Casein	78.7 ± 10.77	2.81 ± 0.90	0.71 ± 0.18	1.23 ± 0.20	0.51 ± 0.18	0.22 ± 0.05	0.38 ± 0.14

Each value is an average of six replications

TABLE 6. EFFECT OF FEEDING BASMATI RICE ON ACTIVITIES OF LIVER TRANSAMINASES AND PHOSPHATASES IN RATS

Experimental diets	Glutamate pyruvate transaminase (GPT), µ moles pyruvate/ min/g tissue	Glutamate oxalo-acetate transaminase (GOT), µ moles oxalo-acetate/min/g tissue	GPT/ GOT	Acid phosphatase, µ moles P-nitro phenol released/ min/g tissue	Alkaline phosphatase µ moles P-nitro phenol released/ min/g tissue	Acid phosphatase / Alkaline phosphatase
'Basmati 370'	0.885 ± 0.278	0.339 ± 0.089	2.61	0.069 ± 0.018	0.055 ± 0.015	1.25
'Pusa Bsmati–1'	0.705 ± 0.049	0.282 ± 0.020	2.50	0.048 ± 0.004	0.036 ± 0.002	1.33
'Haryana Basmati–1'	0.949 ± 0.297	0.359 ± 0.086	2.64	0.072 ± 0.019	0.058 ± 0.014	1.24
Casein	1.023 ± 0.274	0.378 ± 0.131	2.71	0.098 ± 0.036	0.073 ± 0.027	1.34
CD 5%	NS	NS		0.035	0.026	

Each value is an average of four replications

statistically, there were non-significant differences among experimental diets. The expression of data on per cent body weight revealed the similar trend (Table 5). The differences in organs weights may be due to differences in their mitotic index (Linder 1984). The present data on organs weight are not akin to those of Gupta and Wagle (1988), Kumar (1985) and Agarwal (1984). The possible reasons for differential behaviour of organ weights may be due to differences in diet, protein level and age of the rats under experimentation.

Liver enzymes : Activities of GPT, GOT, acid and alkaline phosphatases in rat liver samples when the animals were fed on 'Basmati' rices and casein diet are given in Table 6. Glutamate pyruvate transaminase activities in livers of rats fed on rice diets ranged from 0.705 to 0.949 as compared to 1.023 µ moles pyruvate/min/g tissue on casein diet. Glutamate oxaloacetate transaminase values were lower than glutamate pyruvate transaminase values and varied from 0.282 to 0.359 on rice diets as compared to 0.378 µ moles oxaloacetate/min/g tissues on casein diet. Acid phosphatase activities were found higher as compared to alkaline phosphatase activities in livers of rats fed on experimental diets (Table 6), but livers of rats on casein diets exhibited maximum levels of both the enzymes. Rat livers showed acid phosphatase and alkaline phosphatase activities from 0.048 to 0.072 and 0.036 to 0.058 µ moles nitrophenol released/ min/g tissues, 'Pusa Basmati–1' feeding resulted in lower ratios of GPT/GOT and higher ratio for acid phosphatase/alkaline phosphatase in rat livers. Glutamate pyruvate transaminase and glutamate oxaloacetate transaminase activities are implicated in the synthesis of non-essential amino acids in cellular proteins and their activities are regulated by glucocortico steroids, glucagon and substrate concentration (Linder 1984). The differential behaviour of GPT and GOT in liver homogenates under present experimental conditions may be due to differences in vitamin B_6 level. Martin et al (1985) held the opinion that equilibrium constant for most of transaminases was close to unity and they functioned in amino acid catabolism and biosynthesis. Many liver diseases are linked with activities of GPT and GOT (Bansal and Bansal 1997). The phorate, triazophos, fenitrothione administration, in general, caused an increase in liver phosphatase levels of rats (Gupta et al. 1981; Agarwal 1984; Kumar 1985). But, the present results depicted decreases in activities of the enzymes studied in rats fed on basmati rice diets. The probable reasons assigned for differential activities of enzymes investigated as compared to standard diet may be due to rapid activation, synthesis, inactivation, presence of inhibitors, activators and variance in their regulation pattern.

It may be concluded from the present studies that though 'Haryana Basmati–1' had better chemical composition, 'Pusa Basmati–1' exhibited higher nutritive value as judged by growth, organs weight and nitrogen balance studies.

References

AOAC (1984) Official Methods of Analysis, 14th edn. Association of Official Analytical Chemists, Washington, DC

Agarwal RAK (1984) Studies of biochemical effects of phorates in rats. MSc Thesis. Haryana Agricultural University, Hisar

Annapure US, Singhal RS, Kulkarni PR (1998) Studies on deep fat fried snacks from some cereals and legumes. J Sci Food Agric 76:377–382

Bansal P, Bansal R (1997) Practical Viva Question Bank, Vishvas Publications Pvt. Ltd., Chandigarh

Barber S (1972) Milled rice and changes during aging. In: Rice Chemistry and Technology, Houston DF (ed.). American Association of Cereal Chemists. St Paul MN

Bondi AA (1987) Animal Nutrition, Wiley Inter Science Publication, New Delhi

Bressani K, Elias LG, Juliano BO (1971) Evaluation of the protein quality and milled rices differing in protein content. J Agri Food Chem 10:1029–1034

Chakraborthy TK, Dwarakanath KR, Prabhakar Bhat B (1972) Studies on physicochemical properties of some varieties of rice. J Food Sci Technol 9:140–143

Chatterjee SR, Abrol YP (1975) Amino acid composition of new varieties of cereals and pulses and nutritional potential for cereal pulse combinations, J Food Sci Technol 12:221–227

Deka SC (1998) Studies on comparative nutritive value of different genotypes of basmati rice (*Oryza sativa* L.). PhD Thesis, CCS Haryana Agricultural University, Hisar

Eggum EO, Juliano BO, Maningat CC (1982) Protein and energy utilization of rice milling fractions by rats. Plant Foods Human Nutri 31:371–376

Eggum EO, Juliano BO, Ibabao MGB, Perez CM, Carangal VR (1987) Protein and energy utilization of boiled cereals in growing rats. Plant Foods Human Nutri 37:237–245

Firmin A (1991) Quality characteristics of fifteen rice varieties grown in the Ivory Coast. Food Chem 39:357–362

Friedman M (1996) Nutritional value of proteins from different food sources. Å Review. J Agric Food Chem 44:6–29

Goyal KC, Sharma ML (1998) Electrophoretic pattern and quality characteristics of some seed varieties of Indian rice (*Oryza sativa* L.) Physiol Mol Bio Plants 4:91–92

Gruenwedal DW, Whitaker JR (1984) Food Analysis– Principles and Techniques, Gruenwedal DW, Whitaker (eds), Marcel Dekker Inc, New York

Gupta K, Wagle DS (1988) Biochemical evaluation of soybean varieties and their effect on growth and intestinal transport of glucose and L-tryptophan in rats. Haryana Agric Univ J Res 18:92–99

Gupta RC, Malik JK, Paul BS (1981) Acute toxicity study: Fenitrothion induced biochemical changes in male rats. Indian J Pharma 13:173–184

Jones KC (1969) Similarities between gibberellins and related compounds in inducing acid phosphatase and reducing sugar release from barley endosperm. Plant Physiol 44:1695–1700

Joseph RS (1957) Colorimetric procedure for tyrosine by phenol reagent method. In: Enzymology. Vol 3 pp 467–468

Juliano BO (1985) Rice chemistry and technology. AACC. St Paul MN

Juliano BO (1990) Rice grain quality: Problems and challenges, Cereal Foods World 35:245:253

Kaur A, Sekhon KS (1994) Evaluation of nutritional quality of parboiled rice. J Food Sci Technol 31:162–164

Kumar S (1985) Studies on the biochemical effects of triazophos on albino rats M.Sc Thesis, Haryana Agricultural University, Hisar

Leach SL (1966) A laboratory Manual of Analytical methods of Protein Chemistry, Alexander P, Landgren HP (eds). Pergaman Press, Oxford

Linder MC (1984) Nutritional Biochemistry and Metabolism with Clinical Applications. Lender MC (ed) Elsevier Science Publishing Co. Inc, New York

Martin DW, Mayes PA, Rodwell VW, Granner DK (1985) Review of Biochemistry, Harper S (ed) Lange Medical Publications, Maruzen Co Ltd, Tokyo, Japan

McCarthy TE, Paille MM (1959) A rapid method of determination of methionine in crude protein. BBA Res Commun 1:29

Miyahara S, Jikoo K (1967) Examination of the method of colorimetric determination of lysine. J Jap Soc Food Sci Technol 14:512–513

Narasinga Rao YG, Deasthale YG, Pant KC (1995) Nutritive Value of Indian Foods, National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, India

Oelka EA, Porter KA, Grombacher RW, Addis PE (1997) Wild rice–new interest in an old crop. Cereal Foods World 42:234–247

O'shea J, Maguire MP (1962) Determination of calorific value of feedstuffs by chronic acid oxidation. J Sci Food Agric 13:530–534

Pederson B, Eggum EO (1983) The influence of milling on the nutritive value of flour from cereal grains IV. Rice. Plant Foods Human Nutri 33:267–278

Pomeranz Y, Ory RL (1982) Rice processing and utilization. CRC Handbook of Processing and Utilization. In: Agriculture Vol II, Wolf IA (ed) CRC Press West Palm Beach, Florida

Prakash J, Ramanatham G (1995) Proximate composition and protein quality of stabilized rice bran. J Food Sci Technol 32:416–426

Resurreccion AP, Li X, Okita TN, Juliano BO (1993) Characterization of poorly digested protein of cooked rice protein bodies. Cereal Chem 70:101–104

Sharma S (1993) Practical Biochemistry, Classic Publishing House, Jaipur, India

Sikka KC, Lodha ML, Mehta SL (1989) Nutritional quality of cereals and grain legume proteins. In: Recent Advances in Plant Biochemistry. Publication and Information Division, Indian Council of Agricultural Research, New Delhi, pp 305–338

Spices UR, Chambers DC (1949) Chemical determination of tryptophan in proteins. Anal Chem 21:1249–1266

Srinivasan KS, Sastry MCS, Indira K, Desikachar HSR (1970) Growth promoting value of some high lysine rice varieties. J Food Sci Technol 7:95–96

Udayasekhara Rao PU, Sharma RD (1989) Effect of fenugreek seeds (*Trigonella foenum* Graecum) supplementation on the protein quality of rice (*Oryza sativum*), wheat (*Triticum aestivum*) and Jowar (*Sorghum vulgare*). Food Chem 11:139–148

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