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With the Compliments of the Author(s)

Nutritive Value of Some Improved Varieties of Legumes

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The nutritional quality of some improved varieties of chick peas (*Cicer arietinum*), mash beans (*Phaseolus mungo*), mung beans (*Phaseolus aureus*) and cow peas (*Vigna sinensis*), grown in Pakistan, was measured chemically (including amino acid analyses) and biologically in N-balance experiments with growing rats. Lysine and total sulphur amino acids were lowered in varieties with a higher content of protein. The true protein digestibility (TD), biological value (BV) and net protein utilisation (NPU) of different varieties of chick peas, mung beans and cow peas varied between 85–89, 83–85 and 87–92%, 62–69, 54–56 and 55–59% and 55–60, 45–48 and 50–51%, respectively. The TD of protein was highest (89%) in chick peas, 6560 having a higher protein content (29.4%) while its BV was lowest (62%) as compared to the other varieties of chick peas. There was a significant correlation ($r = 0.97$) between BV and the total sulphur containing amino acids and BV could be predicted from the regression equation: BV (%) $= 33.03 + 10.56 \times$ methionine + cystine (g per 16 g N). This indicates that methionine + cystine are the first limiting amino acids in these varieties. Tannin content does not seem to affect the TD of mash and mung beans.

1. Introduction

Despite the importance of legumes in the diets of people with low incomes in the developing countries, lack of availability and consequent high price reduce the frequency of their consumption. The nutritional contribution of legumes could be raised by increasing yields and by improving the quality and quantity of the seed protein.

The relationship between yield, protein and amino acids contents have been studied by various workers. In most cases a negative correlation between yield and protein content[1] and between protein and sulphur content[2] was observed and a positive correlation was obtained between nitrogen and lysine content.[3]

Differences in chemical composition have been attributed to soil, climate, strain and fertiliser treatment.[4] Reports from other investigators[5–7] using different approaches for the protein evaluation of legume foods, found differences between species as well as between varieties of the same species.

This paper is an account of our investigations into chemical and biological evaluation of some improved varieties of legumes grown in Pakistan.

2. Experimental

2.1. Animal and diets

The experimental procedure has been described by Eggum.[8] Groups of five Wistar male rats each weighing approximately 75 g were used. The preliminary period lasted for 4 days and the balance period for 5 days. The rats were weighed at the beginning of the experiments and divided into groups

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of five such that the average weights of the groups differed by no more than ±0.5 g. Weighing was repeated at the end of the preliminary and balance periods: access to feed and water was prevented 3 h before weighing. Each animal received 150 mg N and 10 g dry matter daily throughout the preliminary and balance periods. The N content of the diet was adjusted using a basal diet consisting of an N-free mixture (Table 1). The rats were housed in individual metabolic cages. During the balance period, urine and faeces were collected in separate flasks containing 5% H_2SO_4. At the end of the experiment the animals were weighed and killed with chloroform. Any feed left in the feed container was also weighed. A 5-day sample of urine and faeces was collected from each of the rats. Faeces were homogenised in a blender. Urine and faeces were diluted to volume with distilled water and nitrogen was determined by the Kjeldahl method.

Table 1. Composition (parts by weight) of the nitrogen-free mixture

Potato starch (autoclaved)	767
Sucrose	90
Cellulose powder	52
Soya-bean oil	52
Mineral mixture[a]	40
Vitamin mixture[b] (mixed with autoclaved potato starch)	20

[a] To provide per kg diet: $CaCO_3$, 2.74 g; calcium citrate, $Ca_3C_{12}H_{10}O_{14}\cdot 4H_2O$, 12.33 g; $CaHPO_4\cdot 2H_2O$, 4.51 g; K_2HPO_4, 8.75 g; KCl, 4.99 g; NaCl, 3.08 g; $MgSO_4$, 1.53 g; $MgCO_3$, 1.41 g; ammonium ferric citrate (20.5–22.5% Fe), 0.61 g; $MnSO_4\cdot H_2O$, 8.0 mg; $CuSO_4\cdot 5H_2O$, 3.1 mg; KI, 1.6 mg; NaF, 20.3 mg; $AlNH_4(SO_4)_2\cdot 12H_2O$, 3.6 mg.

[b] To provide per kg diet: retinol equivalent, 1.2 mg; cholecalciferol, 7.4 μg; thiamin, 0.8 mg, riboflavin, 2 mg; nicotinamide, 8 mg; pantothenic acid, 2 mg; α-tocopherol, 0.4 mg; pyridoxine, 0.2 mg.

2.2. Processing methods

Different varieties of chick peas (*Cicer arietinum*), mash beans (*Phaseolus mungo*), mung beans (*Phaseolus aureus*) and cow peas (*Vigna sinensis*) were obtained from the University of Agriculture and Punjab Agricultural Research Institute, Faisalabad, Pakistan. All the varieties were soaked in water for 12–15 h. The chick peas, mash and mung beans were cooked for 20 min and cow peas for 10 min at 121°C (103.5 kPa). All the samples were freeze-dried, ground and incorporated into the test diet (Table 1) at the expense of autoclaved potato starch, to be measured in the N-balance experiments with rats.

2.3. Analytical methods

The chemical composition of the samples was determined according to standard methods.[9] Available carbohydrates were estimated according to the method of Macrae and Armstrong.[10] Acid hydrolysis followed by ether extraction was used for the estimation of fat according to the method of Stoldt.[11] Tannin was estimated as described by Eggum and Christensen[12] and amino acid analyses were carried out according to Weidner and Eggum[13] and Eggum.[14] All the assays were performed in duplicate.

3. Results

3.1. Chemical composition

The average values for the chemical composition of different strains of chick peas, mash beans, mung beans and cow peas are given in Table 2.

The protein content in chick peas ranged from 21.4 to 29.4, in mung beans from 24.5 to 25.8

Table 2. Chemical composition (dry basis) of some varieties of cooked legumes

		g per 100 g						mg per 100 g			
		Protein (N × 5.7)	Fat	Available carbohydrate	Crude fibre	Ash	Tannin	Ca	P	S	Fe
Chick peas	C 727	22.9	5.4	39.8	13.8	2.4	0.85	260	310	46.3	13.0
Chick peas	6227	23.1	5.2	37.2	11.5	2.6	0.67	300	250	44.1	12.0
Chick peas	6501	22.3	4.8	37.8	12.8	2.6	0.51	320	280	50.7	14.0
Chick peas	6560	29.4	6.3	33.5	13.7	2.8	0.61	250	370	58.1	7.3
Chick peas	6576	21.4	5.7	38.8	14.3	2.3	0.75	280	230	45.1	13.0
Mash beans	133	24.2	1.9	41.8	5.7	3.8	1.69	180	390	67.4	6.8
Mung beans	MgI	25.4	2.4	46.8	5.3	4.0	1.55	170	460	91.9	5.3
Mung beans	588	25.8	2.4	45.6	5.7	3.9	1.32	140	450	85.2	4.8
Mung beans	6601	24.5	2.5	46.8	5.1	3.9	1.37	140	430	93.6	5.4
Cow peas	Local	27.4	3.5	48.3	6.1	3.0	0.76	140	530	35.5	5.8
Cow peas	382	25.7	3.3	52.4	4.8	3.3	0.46	140	520	38.1	6.0
Cow peas	411	26.4	3.1	49.4	5.7	3.3	0.60	160	540	36.6	6.9

and in cow peas from 25.7 to 27.4%. The fat content of chick peas appears to lie between 4.8 and 6.3% and for cow peas between 3.1 and 3.5%. A low level of fat (1.9%) was found in mash beans and was fairly uniform in mung beans. The available carbohydrate content in chick peas varies from 33.5 to 39.8% and in cow peas from 48.3 to 52.4%. The fibre content was highest (11.5–14.3%) in chick peas and the range in cow peas from 4.8 to 6.1% was estimated. The ash content was almost uniform in all the varieties and was highest in mash (3.8%) and mung beans (4.0%). The calcium content was highest in chick peas (250–320 mg per 100 g) and was low in mash and mung beans and cow peas. Phosphorus (mg per 100 g) was found in the largest amount in cow peas (520–540), then mung beans (430–460), then mash beans (390) and finally chick peas (230–370). The sulphur content (mg per 100 g) ranked in the following order: mung beans (85.2–93.6), mash beans (67.4), chick peas (44.1–58.1) and cow peas (35.5–38.1).

The concentration of iron was found to be the highest in chick peas (7.3–14.0 mg per 100 g). Nevertheless, very little is known about the availability of these nutrients to the body. Tannin content was highest in mash beans (1.69%) and in mung beans ranged from 1.32 to 1.55, in chick peas from 0.51 to 0.85 and in cow peas from 0.46 to 0.76%. When the chemical composition of these improved varieties was compared to their original varieties,[15,16] the protein content (chick peas 6560, all the varieties of mung beans and cow peas), fat, crude fibre, Ca, P, and Fe were found to be significantly higher but available carbohydrates were lower in all the improved varieties of legumes tested in this study.

3.2. Protein quality

The amino acid composition of all the varieties (Table 3) was uniform. The highest lysine and methionine + cystine content was found in mung beans (MgI) and chick peas (C 727), respectively, and the lowest lysine, methionine + cystine and tryptophan levels per 16 g N were found in sample chick peas (6560) which had the highest protein content.

Table 4 presents the calculated protein scores for different varieties of legumes based upon the FAO scoring pattern. Methionine + cystine are the first limiting amino acids in all the varieties of cow peas, mung beans, mash beans and chick peas (6560) except chick peas strain Nos C 727, 6227, 6501 and 6576, where threonine is the first limiting amino acid. Threonine is the second limiting amino acid in case of cow peas, mung beans, mash beans and chick peas (6560) and valine is the second limiting amino acid in chick peas C 727, 6227, 6501 and 6576. Valine is the third limiting amino acid in the case of cow peas where as it is tryptophan in all varieties of mung beans, mash beans and chick peas (6560), methionine + cystine are third limiting amino acids in chick peas C 727, 6227, 6501 and 6576.

The true protein digestibility (TD), biological value (BV) and net protein utilisation (NPU)

Table 3. Amino acid composition (g per 16 g N), true digestibility (%), biological value (%) and net protein utilisation (%) of different varieties of cooked chick peas, mash beans, mung beans and cow peas

	Variety											
	Chick peas					Mash beans	Mung beans			Cow peas		
Amino acid	C 727	6227	6501	6560	6576	133	MgI	588	6601	Local	382	411
Aspartic acid	11.6	11.2	11.9	11.4	11.6	12.0	11.4	11.2	12.5	11.1	11.1	11.0
Threonine	3.4	3.3	3.5	3.1	3.5	3.2	3.1	3.0	2.9	3.4	3.6	3.3
Serine	4.8	4.4	4.8	4.8	4.7	5.0	4.8	4.6	4.4	4.9	4.7	4.4
Glutamic acid	17.8	17.6	18.2	17.6	17.6	21.0	18.5	18.3	18.9	18.1	18.6	18.3
Proline	4.3	4.2	4.3	4.2	4.3	4.2	4.2	4.2	4.3	4.1	4.1	4.2
Glycine	3.9	3.9	3.9	3.7	3.9	4.0	3.7	3.7	3.6	3.8	3.8	3.6
Alanine	4.1	4.1	4.2	4.0	4.2	4.3	4.2	4.1	4.3	4.1	4.2	4.1
Valine	4.3	4.3	4.4	4.1	4.3	5.3	5.0	4.9	5.1	4.7	4.8	4.8
Isoleucine	4.6	4.5	4.6	4.4	4.6	4.7	4.5	4.4	4.5	4.2	4.4	4.3
Leucine	7.6	7.5	7.7	7.2	7.6	8.3	7.7	7.7	7.9	7.6	7.7	7.8
Tyrosine	2.8	2.7	2.9	2.5	2.9	3.3	2.9	2.9	2.9	3.2	3.3	3.2
Phenylalanine	5.5	5.3	5.6	5.4	5.4	5.8	5.7	5.6	5.5	5.3	5.5	5.4
Lysine	6.1	6.0	6.3	5.8	6.1	6.1	6.4	6.3	6.2	6.1	6.3	6.2
Histidine	2.4	2.3	2.5	2.3	2.5	2.4	2.7	2.6	2.5	3.0	3.0	2.9
Arginine	9.1	9.4	9.4	11.5	8.9	6.2	6.8	6.8	6.7	8.2	7.5	7.5
Methionine	1.7	1.7	1.7	1.5	1.7	1.9	1.4	1.4	1.5	1.5	1.6	1.6
Cystine	1.6	1.5	1.4	1.2	1.5	0.7	0.6	0.7	0.6	0.7	0.8	0.8
Tryptophan	1.0	1.2	1.2	0.8	1.1	1.0	1.0	1.0	1.0	1.1	1.1	1.1
True digestibility	87.0	86.0	86.0	89.0	85.0	83.0	84.0	83.0	85.0	89.0	92.0	87.0
	(1.3)	(1.5)	(0.4)	(1.6)	(0.7)	(0.9)	(1.5)	(0.8)	(0.7)	(1.1)	(1.5)	(0.7)
Biological value	69.0	67.0	65.0	62.0	66.0	62.0	55.0	54.0	56.0	57.0	55.0	59.0
	(0.8)	(0.8)	(0.6)	(0.8)	(1.1)	(0.6)	(1.1)	(1.3)	(1.0)	(0.5)	(1.1)	(0.6)
Net protein utilisation	60.0	58.0	56.0	55.0	56.0	51.0	46.0	45.0	48.0	51.0	50.0	51.0
	(1.0)	(1.2)	(0.6)	(1.0)	(1.1)	(0.6)	(1.1)	(1.1)	(0.9)	(0.7)	(1.0)	(0. 6)

Figures in parentheses indicate s.d.

Table 4. Protein score and limiting amino acids of the cooked legumes under study

Legume	Varieties	Protein score[a]	Limiting amino acids: First	Second	Third
Chick peas	C 727	79	Threonine	Valine	Methionine + cystine
Chick peas	6227	79	Threonine	Valine	Methionine + cystine
Chick peas	6501	80	Threonine	Valine	Methionine + cystine
Chick peas	6560	76	Methionine + cystine	Threonine	Tryptophan
Chick peas	6576	81	Threonine	Valine	Methionine + cystine
Mash bean	133	65	Methionine + cystine	Threonine	Tryptophan
Mung bean	MgI	55	Methionine + cystine	Threonine	Tryptophan
Mung bean	588	56	Methionine + cystine	Threonine	Tryptophan
Mung bean	6601	58	Methionine + cystine	Threonine	Tryptophan
Cow peas	local	61	Methionine + cystine	Threonine	Valine
Cow peas	382	63	Methionine + cystine	Threonine	Valine
Cow peas	411	63	Methionine + cystine	Threonine	Valine

[a] Based on the FAO/WHO 1973 scoring pattern.

of different varieties of legumes are presented in Table 3. The TD of chick peas, 6560 was highest (89%) and was significantly ($P < 0.001$) but only slightly better than all the other varieties of chick peas whereas the TD of C 727 was slightly superior ($P < 0.05$) to that of chick pea 6576. Mung bean 6601 was significantly ($P < 0.01$) but slightly more digestible than mung bean 588. The TD of cow peas, local and 411 was lower ($P < 0.01$ and $P < 0.001$ respectively) than the TD of cow pea 382. The BV of chick pea 6560 was significantly ($P<0.001$) lower than all the varieties of chick peas. The BV of mung bean 6601 was significantly ($P<0.05$) higher than that of 588. The BV of cow peas local and 382 was lower ($P<0.01$ and $P<0.001$ respectively), than cow pea 411 but the differences were small. The NPU, a derived factor, ranged from 55 to 60% in chick peas, from 45 to 48% in mung beans and from 50 to 51% in cow peas. The BV of the samples was highly correlated with the total methionine+cystine content. The relationship is given in the following regression equation: BV (%) = 33.03 + 10.56 × methionine + cystine (g per 16 g N). The following values were obtained: $r=0.97$; $s=1.4$; $s_b=0.89$; where s is the deviation from regression and s_b is the deviation of the regression coefficient. The regression coefficient differed significantly from zero ($P<0.001$). The results are illustrated in Figure 1.

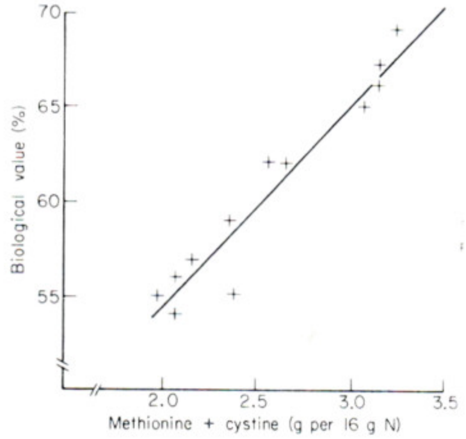

Figure 1. Relationship of total sulphur amino acids and biological value.

4. Discussion

According to Bressani and Elias[17] the protein quality of grain legumes depends on the presence of anti-physiological substances, tertiary structures, protein complexing substances and is limited by the sulphur-containing amino acids.

The heat treatment applied to legume foods improves their texture, palatability and nutritive value by destroying or inactivating heat-labile toxic compounds and other enzyme inhibitors.[5–7,18] Bressani *et al.*[19] reported that cooking black beans for 10–30 min at 121°C improved their protein utilisation as compared to raw beans. Longer cooking, however, caused a drop in the nutritive value of the beans.

In the present experiment the different varieties of legumes were cooked for 10–20 min at 121°C. This procedure seems to be sufficient to destroy the anti-nutritional factors as indicated by the highly significant positive correlation ($r=0.97$) between BV and the total methionine+cystine (Figure 1), which are the first limiting amino acids in these varieties. Consequently the protein quality of the processed legumes in the present study, according to rat assay, was determined by their contents of sulphur amino acids. On comparison with the FAO scoring pattern these four varieties of legumes are limited, for man, by threonine.

In conclusion, grain legumes are still under-exploited sources of edible protein. Greater attention needs to be given to their genetic diversity to improve amino acid profiles particularly the sulphur containing ones and to eliminate antinutritional factors. The cooking quality and consumer acceptance of the new varieties should also be taken into account. Breeding for improved nutritional quality should not be undertaken at the expense of all those factors that contribute to improved yield.

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