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The Nutritional Quality of some Pakistani Wheat Varieties

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The nutritional quality of some improved wheat varieties grown in Pakistan was measured chemically (including amino acid analyses) and biologically in N-balance experiments with growing rats. The protein content ranged from 12.3 to 16.7%. Lysine per 100 g protein varied between 2.46 and 2.90%. The protein of Chenab-70, Punjab-76 and Barani-70 contained 16–18% more lysine than the SA-75 having highest content of protein. Iron content was highest in PARI-73. The true protein digestibility (TD), biological value (BV), net protein utilisation (NPU) and net dietary protein calorie percent (NDP cal%) varied between 91–94%, 58–69%, 54–63% and 7.4–8.8%, respectively. Available carbohydrate, lysine and biological value were lowered in varieties with a higher content of protein.

1. Introduction

Cereal grains are the main source of calories and protein for an estimated two-thirds of the world's population. It has been suggested that if people in the developing countries had enough to eat in the form of their traditional diet of food grains, the protein and energy requirement could be met to a large extent.[1] Wheat is the most popular food species among the cereals. The protein content of wheat varies from 6 to as much as 22% depending on the production environment especially soil fertility, water and grain yield.[2] Wheat protein lacks the balance of essential amino acids required for its complete biological utilisation. Khan and Eggum[1] reported that the order of limiting amino acids in wheat protein is lysine, threonine and valine. Mixed human diets based on wheat have been shown to be deficient in lysine and threonine.[3]

Genetic variations for lysine in wheat is much less than would be required to bring lysine into balance with other essential amino acids. Lysine per unit protein ranges from 2.2 to 4.2% among World Collection wheat and a lysine level of 4% has been suggested to bring it into reasonably good balance with other essential amino acids.[4] The relationship between protein content and lysine level (g per 16 g N) in wheat grain is curvilinear.[5] Between 8 and 15% of protein, the relationship is strongly negative. As protein increases above 15% its effect on lysine diminishes and finally disappears. In work with the protein-rich Mexican varieties, Eggum[6] found lower BV-values than in a common Danish wheat variety.

The investigations reported here were designed to assess the nutritive value of some improved varieties of wheat grown in Pakistan, in terms of both chemical analyses (including amino acid estimation) and biological evaluation in N-balance experiments with growing rats.

2. Experimental

2.1. Animal and diets

The experimental procedure has been described by Eggum.[7] Groups of five Wistar male rats each weighing approximately 75 g were used. The preliminary period lasted for 4 days and the balance

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period for 5 days. The rats were weighed at the beginning of the experiment and divided into groups of five so 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 required N content of the diet was adjusted using a basal diet consisting of an N-free mixture (Table 1).

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; $CaHPO_4.2H_2O$, 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; $MnSO_4.H_2O$, 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.

The experimental diets were weighed out into plastic boxes with tightly fitting lids for each of the preliminary and balance periods. The feed was weighed each day from these boxes in four daily allowances in the preliminary period and five during the balance period. Any remaining feed was weighed and taken into consideration in the calculation of the experimental results. Endogenous urinary-N and metabolic faecal-N were determined in rats fed 4% freeze-dried, ether-extracted egg protein.[7]

2.2. Material

The wheat varieties tested in this study were collected from the University of Agriculture and the Punjab Agricultural Research Institute, Faisalabad, Pakistan. All the varieties were ground to whole flour and incorporated into the test diet (Table 1) at the expense of autoclaved potato starch to be measured in N-balance experiments with rats.

2.3. Analytical methods

The chemical composition was determined according to standard methods.[8] Available carbohydrates were estimated according to the method of MacRae and Armstrong.[9] Acid hydrolysis followed by ether extraction was used for the estimation of fat.[10] The caloric value of the diets was determined in IKA-Calorimeter and amino acid analyses were carried out according to Weidner and Eggum[11] and Eggum.[12] All the assays were performed in duplicate.

3. Results

3.1. Chemical composition

From Table 2 it can be seen that the protein content ($N \times 6.25$) was highest in SA-75 (16.7) and PARI-73 (16.2%) and that the range in the rest of the varieties was from 12.3 to 13.9%. The fat

Table 2. Chemical composition (dry basis) of some Pakistani wheat varieties

	g per 100 g						mg per 100 g		
	Protein (N × 6.25)	Fat	Available carbohydrate	Crude fibre	Ash	Total (cal per 100 g)	Ca	P	Fe
Wheat LU-26	13.3	2.9	70.2	2.6	1.7	440	42.7	348.2	5.2
Wheat LU-31	13.1	2.6	69.5	2.8	1.7	438	41.7	359.4	5.2
Wheat LU-60	13.3	2.8	69.9	2.6	1.9	438	45.7	380.2	5.6
Wheat LU-61	13.9	2.7	72.0	2.6	1.6	440	38.5	336.8	5.1
Wheat LU-71	13.6	2.7	70.8	2.4	1.7	436	43.3	348.2	5.1
Wheat PARI-73	16.2	2.5	68.5	2.8	2.0	439	45.1	392.4	6.7
Wheat SA-42	12.7	2.9	71.6	2.9	2.0	436	41.9	401.3	6.0
Wheat SA-75	16.7	2.9	66.1	2.9	1.7	442	38.0	358.3	5.9
Wheat Chenab-70	13.6	3.1	70.0	2.8	1.6	438	47.9	315.1	3.9
Wheat Barani-70	12.9	3.0	68.9	2.9	1.9	439	50.3	367.5	4.9
Wheat Punjab-76	12.3	2.8	71.2	2.8	1.7	438	42.4	327.7	4.2

content appeared to lie between 2.5 and 3.1% while available carbohydrate was highest in LU-61 (72.0%) and lowest in SA-75 (66.1%). The fibre content ranged from 2.4 to 2.9% while the ash content was almost uniform in all varieties. The calcium content varied from 38.0 to 50.3 mg per 100 g and phosphorus from 315 to 401 mg per 100 g. The concentration of iron varied considerably with the highest value of 6.7 and the lowest of 3.9 mg per 100 g.

The protein concentration of the samples were negatively correlated with the available carbohydrate (Figure 1). The relationship is given in the following regression equation:

$$\text{Available carbohydrate } (\%) = 82.00 - 0.88 \times \text{protein } (\%).\ \text{r.s.d.} = 1.2;\ \text{s.e.} = 0.27;\ r = -0.74$$

where r.s.d. is the deviation from regression and s.e. is the deviation of the regression coefficient. The regression coefficient differed significantly from zero ($P < 0.05$).

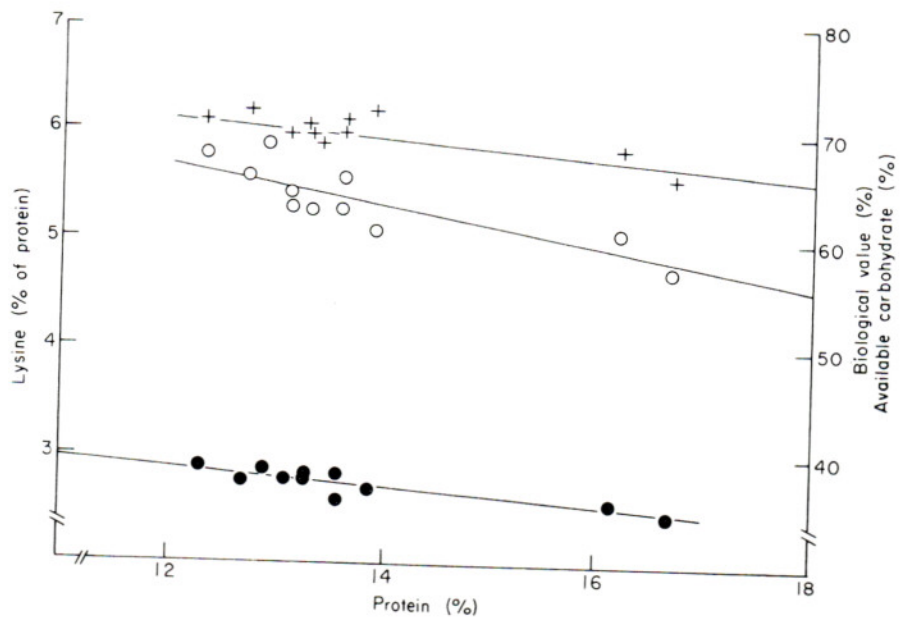

Figure 1. Lysine content (+) biological value (○) and available carbohydrate (●) in relation to protein content in wheat.

3.2. Protein quality

The amino acid content of wheat varieties are presented in Table 3. Lysine per 100 g protein ranged from 2.46 to 2.90% with a mean of 2.72%. The proline and glutamic acid contents were highest while the levels of lysine, valine and alanine were lowest in SA-75 having highest content (16.7%) of protein. The lowest concentration (13.3%) of protein in Punjab-76 resulted in an increase in lysine, threonine and glycine but in a simultaneous decrease in proline when expressed in g per 16 g N. Highest contents (4.52 g per 16 g N) of methionine and cystine in variety SA-42 and lowest (3.81 g per 16 g N) in PARI-73 were found. LU-26 contained highest (1.45 g per 16 g N) and PARI-73 had lowest (1.01 g per 16 g N) concentration of tryptophan.

Table 3. Amino acid composition (g per 16 g N) of some Pakistani wheat varieties

Wheat varieties	LU-26	LU-31	LU-60	LU-61	LU-71	PARI-73	SA-42	SA-75	Chenab-70	Barani-70	Punjab-76
Aspartic acid	4.96	4.98	5.13	5.01	4.63	4.95	4.96	4.63	5.37	5.34	5.20
Threonine	2.74	2.81	2.88	2.77	2.58	2.62	2.81	2.70	2.95	2.96	3.04
Serine	3.93	4.19	4.34	4.17	3.87	3.96	3.93	4.11	4.23	4.43	4.40
Glutamic acid	27.67	27.50	27.48	27.85	27.54	28.64	26.88	29.58	27.84	27.43	27.22
Proline	8.98	9.00	8.84	8.98	8.87	8.99	8.76	9.36	8.58	8.65	8.55
Glycine	4.00	4.08	4.03	4.00	3.68	3.86	3.78	3.83	3.98	3.93	4.17
Alanine	3.49	3.50	3.50	3.42	3.34	3.37	3.50	3.28	3.61	3.60	3.59
Valine	4.32	4.26	4.32	4.23	4.16	4.22	4.28	4.14	4.34	4.34	4.26
Isoleucine	3.44	3.40	2.99	3.40	3.34	3.37	3.37	3.43	3.52	3.38	3.34
Leucine	6.37	6.47	6.02	6.38	6.25	6.31	6.42	6.37	6.46	6.54	6.42
Tyrosine	2.60	2.78	2.74	2.75	2.59	2.59	2.51	2.65	2.66	2.56	2.72
Phenylalanine	3.89	3.90	4.04	3.93	3.82	3.95	3.76	3.97	3.90	3.79	3.74
Lysine	2.77	2.77	2.77	2.68	2.56	2.56	2.78	2.46	2.85	2.90	2.86
Histidine	2.12	2.14	2.23	2.23	2.08	2.17	2.10	2.13	2.20	2.21	2.19
Arginine	5.04	4.95	4.93	5.05	4.59	4.86	4.74	4.64	4.88	4.95	5.11
Methionine	1.69	1.71	1.67	1.66	1.70	1.63	1.75	1.65	1.69	1.70	1.78
Cystine	2.22	2.28	2.20	2.27	2.31	2.18	2.77	2.34	2.33	2.31	2.43
Tryptophan	1.45	1.24	1.15	1.27	1.31	1.01	1.16	1.06	1.09	1.28	1.18

The lysine content (g per 16 g N) in wheat varieties can be seen from Figure 1 to be negatively correlated ($P<0.05$) with protein concentration. The relationship is given in the following regression equation:

$$\text{Lysine (g per 16 g N)} = 3.89 - 0.08 \times \text{protein (\%)}$$

$$\text{r.s.d.} = 0.08;\ \text{s.e.}_b = 0.02;\ r = -0.84$$

Results obtained on true protein digestibility (TD), biological value (BV), net protein utilisation (NPU) and net dietary protein calorie percent (NDP cal%) of the wheat component are summarised in Table 4.

The TD was highest (94%) in LU-31 and SA-75 and the lowest value (91%) was found in LU-71 and Barani-70. The BV and NPU ranged from 58 to 69% and from 54 to 63%, respectively. The NDP cal% was calculated according to Miller and Payne[13] and the values lie between 7.4 and 8.8%. A negative correlation ($r=-0.81$) between BV and protein concentration as shown in the following regression equation was found:

$$\text{BV (\%)} = 89.67 - 1.88 \times \text{protein (\%)}$$

$$\text{r.s.d.} = 2.0;\ \text{s.e.}_b = 0.5;\ r = -0.81$$

The regression coefficient differed significantly ($P<0.05$) from zero and the relationship is illustrated in Figure 1.

Table 4. Protein quality of some Pakistani wheat varieties

	True digestibility		Biological value		Net protein utilisation		Net dietary protein calorie	
	(%)	(s.d.)	(%)	(s.d.)	(%)	(s.d.)	(%)	(s.d.)
Wheat LU-26	93.0	1.3	63.0	0.6	58.0	0.7	7.4	0.7
Wheat LU-31	94.0	1.2	63.0	0.9	59.0	1.4	7.4	1.4
Wheat LU-60	93.0	0.4	64.0	1.2	59.0	1.3	7.6	1.3
Wheat LU-61	93.0	0.7	61.0	0.7	56.0	0.9	7.4	0.9
Wheat LU-71	91.0	0.6	63.0	0.6	57.0	0.8	7.5	0.8
Wheat PARI-73	93.0	1.1	61.0	1.1	57.0	0.5	8.8	0.5
Wheat SA-42	93.0	1.3	66.0	0.9	62.0	1.2	7.6	1.2
Wheat SA-75	94.0	0.9	58.0	1.0	54.0	1.2	8.6	1.2
Wheat Chenab-70	92.0	0.7	66.0	1.2	61.0	1.0	8.0	1.0
Wheat Barani-70	91.0	0.8	69.0	0.7	63.0	0.5	7.8	0.5
Wheat Punjab-76	93.0	1.0	68.0	0.9	62.0	0.9	7.4	0.9

4. Discussion

The protein content in SA-75 was slightly higher than in PARI-73 but it contains more protein and less available carbohydrate than other varieties. The protein of Chenab-70, Punjab-76 and Barani-70 contains 16–18% more total lysine than the protein of the SA-75 variety. PARI-73 had iron content slightly higher than SA-42 and SA-75, on comparing with other varieties it had 20–72% more iron. Even if the absorption of iron in cereals is only 10%, an adequate amount of these varieties, if consumed, may meet the daily iron requirement of 10–20 mg for adult men and women.[14]

The present results indicate that wheat with high-protein content had a low lysine content in the protein. Consequently, the BV was lower than in wheat low in protein. A similar relationship was reported by Lindner[15] and Larsen and Nielsen;[16] increasing levels of N-fertilisation resulted in an increase in the non-essential amino acids proline and glutamic acid but a simultaneous decrease in lysine and arginine. Brune *et al.*[17] found that protein quality in wheat was considerably reduced with increasing N-fertilisation. Similar results have also been reported by Eggum.[6]

The lysine content (Figure 1) is negatively correlated with protein concentration. This is probably due to the fact that environmentally-induced increases in nitrogen are stored chiefly in the prolamin fraction which is poor in lysine[18] but rich in glutamic acid and proline.[19] As lysine is the first limiting amino acid in wheat protein, a decrease in this amino acid must result in a reduction in BV. This relationship is also illustrated in Figure 1. BV shows a linear decrease with increase in protein concentration due to the lower lysine content in wheat high in protein.

According to FAO[20] the protein allowances for different age groups in terms of NDP cal% are 8.0, 7.8, 5.9, 8.4, 4.6 and 9.5 for infant, toddler, child (4–9 years), adolescent, adult and lactating mothers, respectively. The NDP cal% of the PARI-73 and SA-75 is 8.8 and 8.6, respectively and can meet the given levels of all the groups except lactating mothers. The NDP cal% of the rest of the varieties lies between 7.4 and 8.0 and are suitable only for toddler, children and adults, if consumed in adequate amounts.

The most desirable objective, especially in the developing countries where wheat is needed for child feeding, should be to increase the content of protein, lysine and possibly threonine.

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