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NUTRITIONAL VALUE OF CEREALS IN RELATION TO HUMAN NEED

M. Akmal Khan*

ABSTRACT: The nutritive value of wheat, maize, rice, barley, millet, triticale and sorghum was determined chemically and biologically in N-balance experiments with growing rats. Theoretical estimate of cereal proteins for human needs has been discussed. The available carbohydrates were the highest in rice (90 percent) and the lowest in barley (64.9 percent). Protein was highest (14.4 percent) in barley, while sorghum contained only 6.9 percent. An appreciable amount of iron was found in sorghum, millet and barley. All cereals were deficient in lysine. In addition, maize was deficient in tryptophan and ... rest lacked threonine. The concentration of sulphur containing amino acids was quite high (3.6 – 4.9 g/16 gN). The true protein digestibility (TD), biological value (BV), net protein utilisation (NPU) and net dietary protein calorie percent (NDpCal percent) varied between 56–100, 55–91, 55–71 and 3.3 – 8.3 percent, respectively. Higher content of tannin does affect the TD. The protein needs of infants could not be met with cereals, however, cereal proteins sufficed for growing children and adults, as indicated by NDpCal percent values.

INTRODUCTION

In Pakistan, cereals constitute the main staple of diet providing, respectively, 76 and 72 percent of the per capita in-take of calories and protein per day (Planning Commission, 1978-79). The cereal-based diets are reported to be inadequate to satisfy the protein requirements of the different age groups (Khan and Eggum, 1978). The current research was therefore, undertaken to ascertain the nutritive value of different cereals with a view to determine their adequacy in meeting protein requirements in human diets.

MATERIALS AND METHODS

The study was conducted in the Department of Nutrition, University of Agriculture, Faisalabad, during 1979. The nutritive value of different cereal grains was determined chemically and biologically. For biological studies conducted as described by Eggum (1973), 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 of five such that the average weight 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 hours 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 by using a basal diet consisting of a N-free mixture. The wheat, maize, rice, barley, millet ('bajra'), triticale and sorghum grains were ground to whole meal flours and incorporated into the test diets (Table I), at the expense of autoclaved potato starch.

The chemical composition of the diets was determined according to the standard methods (AOAC, 1970). The caloric value of the diets was determined in IKA-calorimeter (Adiabatic). Metabolizable energy (ME) of the diets was calculated according to Miller and Payne (1959). The methods for the estimation of fatty acids, amino acids and tannin were as described by Khan and Eggum (1979).

* Department of Nutrition, University of Agriculture, Faisalabad, Pakistan.

Table 1. Composition of the nitrogen-free mixture

Ingredient	Parts by weight
Potato starch (autoclaved)	767
Sucrose	90
Cellulose pow[illegible]	52
Soybean 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, $Ca_3C_{12}H_{10}O_{14}$, $4H_2O$, 12.33 g; $CaHPO_4 \cdot 2H_2O$, 4.51 g; K_2HPO_4, 8.75 g; KCl, 4.999; 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; $MnSO_4H_2O$, 8.0 mg; $CuSO_4$, $5H_2O$, 3.1 mg; KI, 1.6 mg; NaF, 20.3 mg; $AlNH_4(SO_4)_2$, $12H_2O$, 3.6 mg.

b To provide per kg diet: Retionl equivalent, 1.2 mg; Cholecalciferol, 7.5mg; Thiamin, 8.8 mg; Riboflavin, 2 mg; Nicotinamide, 8 mg; Pantothenic acid, 2 mg; a-tocopherol, 0.4 mg; Pyridoxine, 0.2 mg.

RESULTS AND DISCUSSION

Chemical Composition

Chemical composition of wheat, maize, rice, barley, millet ('Bajra'), triticale and sorghum is given in Table 2 and 3.

The available carbohydrates were highest in rice (90.1 percent) and the lowest in barley (64.9 percent). The protein content (N x 5.7), was highest (14.4 percent) in barley, whereas, sorghum contained only 6.9 percent. The fat content was relatively low, with the highest value for maize (5.7 percent) and the lowest for rice (1.4 percent). Due to low fat content the cereal grains have a low energy density (average 4.3 Cal/g), which might cause a problem in infant feeding. The crude fibre content was (4.8 percent) in sorghum and was lowest (0.7 percent) in rice. All cereals contained appreciable amounts of calcium, phosphorus, sulphur and iron. The concentration of calcium and iron was highest i.e., 62.4 and 10.1 mg/100 g, respectively, in barley and sorghum. The value of these minerals is partly discounted by the presence of phytic acid, which may interfere with their absorption. The tannin contents ranged from 0.48 to 1.90 percent, being highest (1.90 percent) in sorghum. Wheat contained the maximum linoleic acid, whereas, barley and triticale had the highest concentration of linolenic acid (Table 3).

The total amino acid composition in various cereal grains is shown in Table 4.

Table 2. Chemical composition of various cereal grains in Pakistan

(dry matter basis)

	g/100 g					Calories/100 g		mg/100 g				g/100 g
	Protein (Nx5.7)	Fat	Available carbohyd-rate	Crude fibre	Ash	Total	ME*	Ca	P	S	Fe	Tannin
Wheat	11.2	2.2	81.1	1.2	1.6	436	414	31.4	395.4	38.4	5.1	0.50
Maize	10.4	5.7	74.0	2.3	1.6	461	438	16.8	330.3	29.6	4.2	0.48
Rice	8.1	1.4	90.1	0.7	0.6	432	410	12.5	125.5	31.9	2.9	0.11
Barley	14.4	3.9	64.9	4.3	2.2	454	431	62.4	374.3	29.5	7.0	0.81
Millet	12.2	5.5	73.7	1.8	1.8	459	436	22.5	338.2	33.8	8.1	0.72
Triticale	14.1	2.6	67.4	2.7	2.0	442	420	44.4	399.6	31.1	2.9	0.70
Sorghum	6.9	4.5	67.4	4.8	3.0	447	425	44.8	313.9	25.9	10.1	1.90

*ME = Metabolizable energy.

Table 3. Fatty acid composition of cereal grains in Pakistan

(g/100 g measured F.A.)

Fatty acids	Wheat	Maize	Rice	Barley	Millet	Triticale	Sorghum
Lauric acid	0	0	0.1	0	0	0	0
Myristic acid	0.2	0.1	1.9	0.8	0.1	0.2	0.1
Palmitic acid	23.6	15.8	39.9	25.7	20.1	18.6	17.4
Palmitoleic acid	0	0.4	0	0	0.6	0	0.9
Stearic acid	1.0	2.4	3.5	1.1	2.9	0.9	1.4
Oleic acid	9.9	33.0	22.4	12.1	25.5	15.0	35.4
Linoleic acid	60.7	45.9	30.1	54.3	45.8	59.3	43.3
Linolenic acid	4.7	2.3	2.2	6.0	5.0	6.0	1.5

The lysine content ranged from 2.3 to 3.4 g/ 16 g N and was highest (3.4 g/16 gN) in rice. The concentration of sulphur containing amino acids was quite high with values from 3.6 to 4.9 g/16 gN. Protein score, based on FAO scoring pattern (Table 5) indicated that the lysine was the first limiting amino acid in all the cereals, and threonine was the second one except maize, which was deficient in tryptophane. Isoleucine was the third limiting amino acid in rice, barley, millet and sorghum; valine in wheat and triticale; and threonine in maize.

Table 4. Amino acid composition of cereal grains in Pakistan

(g/16gN)

Amino acid	Wheat	Maize	Rice	Barley	Millet	Triticale	Sorghum
Aspartic acid	4.6	5.5	8.3	5.1	6.7	5.9	6.5
Threonine	2.8	3.2	3.4	2.9	3.2	2.9	3.3
Serine	4.8	4.4	4.6	3.7	4.4	4.0	4.3
Glutamic acid	34.9	19.0	18.1	26.2	23.5	27.3	18.9
Proline	10.7	8.5	4.3	10.7	7.0	8.6	7.5
Glycine	3.7	3.4	4.2	3.6	3.3	4.1	3.8
Alanine	3.2	7.2	5.3	3.7	6.2	3.7	8.0
Valine	3.8	4.5	5.4	4.6	4.8	4.2	4.7
Isoleucine	3.4	3.4	4.0	3.5	3.8	3.4	3.6
Leucine	6.9	12.7	7.7	6.7	8.9	6.4	11.2
Tyrosine	3.0	4.0	4.6	3.0	3.0	2.8	3.6
Phenylalanine	4.7	4.5	4.8	4.9	4.5	4.2	4.4
Lysine	2.3	2.5	3.4	3.2	2.7	2.9	2.7
Histidine	2.1	2.7	2.1	2.0	2.1	2.2	2.2
Arginine	4.2	4.4	7.6	4.7	4.5	5.4	4.6
Methionine	1.6	2.1	2.9	1.7	2.2	1.7	2.3
Cystine	2.0	2.0	2.0	2.0	1.9	2.0	2.2
Tryptophan	1.0	0.6	1.1	1.1	1.3	1.1	1.0

Biological Efficiency

The true protein digestibility (TD), biological value (BV), net protein utilisation (NUP) and net dietary protein calorie percent (NDpCal percent) of various cereals are presented in Table 6.

The TD varied between 56 percent for sorghum to 100 percent for rice. The low TD for sorghum can partly be explained by its crude fibre concentration (4.8 percent) and the high tannin content (1.9 percent). Higher content of crude fibre and tannin in the diets had a negative effect on the protein digestibility (Just et al., 1976; and Eggum and Christensen, 1975). Rice on the other hand, had a very low content of both crude fibre and tannin, which might explain the very high digestibility of rice protein.

As the BV is directly dependent on the concentration of the first limiting amino acid (lysine), the highest BV (91 percent) was obtained in sorghum and the lowest in wheat (55 percent).

The NPU values varied from 51 to 71 percent : in other words 49 to 29 percent of the ingested nitrogen was excreted in urine and faeces. This loss of nitrogen could be saved by increasing lysine and threonine content in the cereal grains through genetic manipulation.

According to FAO (1965), the protein allowance for different age groups in terms of NDpCal% is 8.0, 7.8, 5.9, 8.4, 4.6 and 9.5 for infants, toddler, child (4–9 years), adolescent, adult and lactating mothers, respectively. The NDpCal% of wheat, maize and rice ranged from 5.5 to 5.7 and could meet the protein requirement of adult only, if consumed in adequate amount. Millet protein was suitable for children (4–9 years) and adults. The protein value of barley and triticale was adequate for all different age groups except adolescents and lactating mothers.

Table 5. Protein score and the limiting amino acids in various cereal grains in Pakistan

Grain	Protein score[a]	Limiting amino acids		
		First	Second	Third
Wheat	49	lysine	threonine	valine
Maize	41	lysine	tryptophan	threonine
Rice	58	lysine	threonine	isoleucine
Barley	63	lysine	threonine	isoleucine
Millet	49	lysine	threonine	isoleucine
Triticale	61	lysine	threonine	valine
Sorghum	46	lysine	threonine	isoleucine

a = Based on FAO/WHO – 1973 scoring pattern.

Table 6. Protein quality of various cereal grains in Pakistan

	True digestibility %	Biological value %	Net protein utilization %	Net dietary protein calorie %
Wheat	96.0	55.0	53.0	5.7
Maize	95.0	61.0	58.0	5.5
Rice	100.0	71.0	71.0	5.6
Barley	88.0	70.0	62.0	8.3
Millet	93.0	60.0	56.0	6.3
Triticale	93.0	66.0	61.0	8.2
Sorghum	56.0	91.0	51.0	3.3

The ability of cereal grains to meet protein requirements of different age groups is shown in Table 7.

The safe level of reference protein proposed by FAO/WHO (1973) is given in column 3 (Table 7). The reference protein was corrected for protein quality (NPU) of the various cereals. It appeared that a six-month old infant weighing 7.6 kg, would require 238 g of wheat flour to meet his

Table 7. Relative ability of cereal grains to meet protein requirements

Group	Age	Protein requirements (g/kg/day)							
		Reference protein*	Wheat	Maize	Rice	Barley	Millet	Triticale	Sorghum
Infant	0—3 months	2.40	4.5	4.1	3.4	3.9	4.3	3.9	4.7
	3—6 months	1.85	3.5	3.2	2.6	3.0	3.3	3.0	3.6
	6—9 months	1.62	3.1	2.8	2.3	2.6	2.9	2.7	3.2
	9—11 months	1.44	2.7	2.5	2.0	2.3	2.6	2.4	2.8
Children	1 year	1.27	2.4	2.2	1.8	2.0	2.3	2.1	2.5
	2 year	1.19	2.2	2.1	1.6	1.9	2.1	1.9	2.3
	5 year	1.01	1.9	1.7	1.4	1.6	1.8	1.6	1.9
	11 year	0.76	1.4	1.3	1.1	1.2	1.4	1.2	1.5
Adolescent male	17 year	0.61	1.2	1.1	0.9	1.0	1.1	1.0	1.2
Adolescent female	17 year	0.57	1.1	0.9	0.8	0.9	1.0	0.9	1.1
Adult male	25 year	0.57	1.1	0.9	0.8	0.9	1.0	0.9	1.1
Adult female	25 year	0.52	0.9	0.8	0.7	0.8	0.9	0.9	1.0

* FAO/WHO (1973)

protein needs. This quantity may not be stomached. The cereals as a total diet would not meet the protein needs of infants, since the infants probably cannot consume sufficient calories from cereals alone. If the infant need about 15 percent of the calories as fat, products based upon cereals alone would be even less adequate since the addition of fat would decrease the total intake. The school children, by and large, grow at normal rates or near normal rates on high cereal diets in the developing countries. The NDpCal% values in the present study, indicated that millet, barley, and triticale could meet the protein need of the growing children. Widdowson and McCane (1954) showed that undernourished children grew at above-normal rates, when fed diets very high in wheat flour. On the other hand, cereal grains were adequate in protein for adults. Walker (1958) reported that high cereal diet could meet the requirements in case of high physical labour, as well as during pregnancy and lactation. There is also evidence from all parts of the world indicating to do hard physical labour and even satisfactory pregnancy and lactation on high cereal diets (Walker, 1958).

The estimates of wheat and rice protein needed to meet protein requirement in adults are given in Table 8. The reference protein requirements were converted to needs of wheat and rice proteins by using 53 and 71 percent as NPU values for wheat and rice protein, respectively. The average body

Table 8. Estimates of adult requirement of wheat and rice protein

	Body weight (kg)	Reference protein requirement*	Wheat required			Rice required		
			Protein g/day	As flour g/day	As flour Cal/day	Protein g/day	As flour g/day	As flour Cal/day
Adult man with mo activity	55	0.57	59.2	529	2306	44.2	546	2359
Adult woman with moderate activity	46	0.52	45.1	403	1757	33.7	416	1797

* FAO/WHO (1973).

weight of 55 and 46 kg for Pakistani adult man and woman, respectively, have been used (Khan, 1980). Both the amount of protein required as well as the total calories that would have to be consumed to reach this protein intake are of interest. Thus, 529 g of wheat flour, would theoretically be adequate to meet the energy and protein requirements of adult man. These estimates agree with the findings of Hegsted (1957, 1964).

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