PB-223 999

IMPROVING PROTEIN QUALITY OF MILLET, SORGHUM, AND MAIZE DIETS BY SUPPLEMENTATION

S. Pushpamma, et al

Kansas State University

Prepared for:

Agency for International Development

1972

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

IMPROVING PROTEIN QUALITY OF MILLET, SORGHUM, AND MAIZE DIETS BY SUPPLEMENTATION[1]

S. Pushpamma,[2] D. B. Parrish and C. W. Deyoe
Food and Feed Grain Institute
Kansas State University
Manhattan, Kansas 66502

ABSTRACT

Nutritive value of the protein of millets (Bajra and Ragi), sorghum, and maize was studied by amino acid analyses, and by growth of rats and calculations of PER using diets containing the grains, unsupplemented or supplemented with lysine, tryptophan, or four protein concentrates. Ragi protein was highest in essential amino acids (EAA) except leucine, and compared to the FAO reference pattern, no amino acid in Ragi was limiting except lysine was marginal. Bajra protein was deficient in lysine; sorghum and maize were deficient in three or more amino acids. On several protein-quality scores, Ragi ranked first and Bajra second; both ranked considerably higher than sorghum or maize. Among unsupplemented diets, Bajra caused greatest weight gain in rats and had the highest PER. Supplementing Bajra and Ragi diets with lysine increased both gains and PER. Lysine improved sorghum and tryptophan improved maize diets; together lysine and tryptophan markedly improved both diets. Fish protein concentrate was the most effective supplement with sorghum and Ragi, dried milk with maize, and isolated soybean protein with Bajra.

INTRODUCTION

Although millets grow and yield well under a variety of conditions and are a principal food of millions of poor people in Asia and Africa, less is known about the nutritive value of millet proteins and effect of supplementing them than about other common cereal proteins. Millets, sorghum and maize are deficient in lysine, and results of supplementing those grains with some amino acids and proteins have been reported (1-4).

---

[1]Contribution no. 134, Department of Biochemistry and no. 776, Department of Grain Science and Industry, Kansas Agricultural Experiment Station, Manhattan. Presented in part at Western Hemisphere Nutrition Congress III, Miami, Fla., Aug. 30-Sept. 2, 1971.

[2]Present address: College of Home Science, Hyderabad, India.

We determined the EAA contents of Ragi or finger millet (Eleusine coracana), Bajra or pearl millet (Pennisetum typhoideum), sorghum (Sorghum vulgare), and maize (Zea Mays) and scored them for nutritional quality. We measured growth of rats and calculated PER values using diets containing the four grains unsupplemented or supplemented with lysine and/or tryptophan, or with nonfat dried milk (DM), fish protein concentrate (FPC), isolated soybean protein (α-P), and dried brewer's yeast (BY).

METHODS

Amino acid contents were determined using the Beckman analyzer, after hydrolyzing the samples with acid and oxidizing sulfur amino acids (5). Tryptophan was determined by the method of Lombard and DeLange (6). Methods for calculating protein quality scores are cited in the tables. The growth data were analyzed statistically (7), and significant differences among groups may be found by using LDS values shown in the tables. Calculations of quantities of amino acids supplied by supplements were based on analytical data, but those data are not shown.

Experiment 1. Female albino rats, 24 days old, four per group, were housed individually in wire-bottom cages in a room at 26-28°.

Table I. Basal Diets for Experiment 1

Ingredients[1]	Diet composition (%)					
	Ragi	Bajra	Sorghum	Maize	Casein	
Grain (or casein)	96.5	96.5	96.5	96.5	5[2]	10[2]
Dicalcium phosphate	1.85	2.18	2.0	1.85	2.34	2.34
Calcium carbonate	.17	.29				
Potassium sulfate					.4	.4
Magnesium carbonate					.15	.15
Protein content of diet	5.4	11.0	9.9	9.4	5	10

[1]Added to all diets: vegetable oil, 1%; sodium chloride, 0.3%; and trace mineral mix, 0.025% (contained in %, Mn, 10; Fe, 10; Ca, 14; Cu, 1: Zn, 5; I, 0.3; Co, 1). Vitamins were added at N.R.C. requirements for growth (8), plus 20 IU vitamin D_3 per 100g. Corn starch was the carrier for vitamins and was added in small quantities to equalize weights of diets.

[2]Percent protein in diet from casein; starch was added as the energy source to make a diet to 100%.

Feed (all ingredients finely ground) and water were provided ad libitum. Feed consumption and weight gains were recorded weekly. The basal diets are shown in Table I. The calcium, phosphorus, potassium, and magnesium additions were to adjust diets to requirements for those nutrients. L-lysine was added so that the supplemented diets contained 0.75% lysine, including that in the grain, as found by analysis. L-tryptophan added was 0.1%; the diets then contained the published tryptophan requirement (8) or more (0.16-0.28%).

Experiment 2. The general plan was as in experiment 1, except that diets were compounded to contain the largest possible uniform quantity of grain (86%), the additional amino acids were supplied by 3% protein from four supplements, and the only minerals added were trace minerals. Otherwise experiment 2 was so similar to experiment 1 that diet compositions are not shown.

RESULTS AND DISCUSSION

The essential amino acid contents of the grain proteins, egg, and FAO patterns are shown in Table II. Based on the FAO reference pattern, Ragi scored as high as egg except for lysine which was marginal. Sulfur amino acids and threonine were adequate, contrary to earlier reports (1). Bajra was deficient in lysine; sorghum and maize were deficient in three or more amino acids.

Table II. Essential Amino Acids (g/16gN) in Grain and Reference Proteins

Amino acid	Millet		Sorghum	Maize	Egg[1]	FAO[2] pattern	Adjusted[3] FAO pattern
	Ragi	Bajra					
Arg	5.8	4.7	4.2	4.3	6.6		
His	2.9	2.2	2.2	2.7	2.4		
Ile	4.7	4.1	4.1	3.2	6.6	4.2	
Leu	10.5	9.5	13.5	12.2	8.8	4.8	
Lys	4.0	3.0	2.5	2.9	6.4	4.2	
S-aa	6.1	4.7	3.6	4.1	5.5	4.2	3.4
Phe-Tyr	10.4	8.0	9.8	8.7	10.1	5.6	
Thr	4.9	3.7	3.5	3.8	5.0	2.8	3.3
Trp	1.8	1.7	1.0	0.6	1.7	1.4	1.1
Val	5.9	5.2	5.0	3.4	7.4	4.2	2.8

[1]See reference 9.
[2]See reference 10.
[3]See reference 11.

Protein quality scores calculated by various methods are shown in Table III. The limiting amino acids in grain and egg proteins (Table IV) were found by comparisons to the FAO pattern and to requirements for human infants and growing rats. In general Ragi protein scored best, followed by Bajra, with sorghum and maize much lower.

Table III. Protein Quality Evaluations Calculated by Various Methods

Grain	E/T[1] ratio	First limiting aa	Chem. score Egg ref.[2]	Chem. score FAO pattern ref.[3]	Protein score[4]	EAA index[5]	B.V. from EAA index[6]
Ragi	3.0	Lys	63	95	68	89	85
Bajra	2.5	Lys	47	71	61	77	72
Sorghum	3.3	Lys	38	58	38	69	64
Maize	2.5	Trp & Lys	39	55[4]	52	66	61

[1]E/T ratio = EAA/g total nitrogen.
[2]Amino acid composition from Orr and Watt (12).
[3]See reference 10. Chem. score of maize 68 on adjusted FAO pattern (11).
[4]See reference 11.
[5]See reference 13.
[6]B.V. = 1.09 (EAA) - 11.73

Table IV. Mg Specific Amino Acid/g Total Essential Amino Acids

Amino acid	Ragi	Bajra	Sorghum	Maize	Egg[1]
Ile	100+#	103*#	78*+#	80*+#	129*
Leu	219	238	257	306	172+
Lys	84*+#	76*+#	46*+#	72*+#	125*+
Phe-Try	210	200	187	219	195
S-aa	127	117*	68*+#	103*#	107*#
Thr	103	92#	66*+#	95#	99
Trp	37*#	43	19*+#	16*+#	31*#
Val	122*	131	95*+#	85*+#	141

[1]Amino acid composition from Orr and Watt (12).
*Limiting compared with FAO ref. pattern (10).
+Limiting compared with requirements for human infant (14).
#Limiting compared with requirements for growing rat (14).

Results of supplementing diets with lysine and tryptophan are given in Table V. Studies in our laboratory (unpublished) have shown that 0.75% lysine, as used in this study, was adequate for growth in diets containing 10-12% protein. Rats grew better when fed unsupplemented Bajra than when fed unsupplemented sorghum or maize, probably reflecting higher lysine, tryptophan, and sulfur amino acid contents, and perhaps the better leucine balance and slightly higher protein content. However, Bajra was somewhat deficient in lysine; when lysine was added the rats grew better than those fed casein. Since Bajra was adequate in tryptophan, adding that amino acid to the diet had no effect on rat growth. Rats grew poorly when fed Ragi diets, because of low total protein, despite good protein quality. Adding lysine, which was marginal in Ragi, improved performance of Ragi diets somewhat. Adding nonspecific nitrogen to Ragi diets (data not shown) improved rat growth provided supplemental lysine also was present, which reflected the good distribution of other EAA. Lysine was deficient in sorghum and addition of lysine increased rat growth markedly, but tryptophan addition was effective only when lysine, the more limiting amino acid, also was added. Both tryptophan and lysine were required to improve maize diets markedly. The PERs of maize diets supplemented with lysine or tryptophan are higher than might be expected from growth data. Apparently supplementation improved protein utilization, even though the second limiting (or co-limiting) amino acid did not allow a corresponding effect on growth. Other PER data generally reflected growth data, except for Ragi and low casein diets, in which the smaller protein intakes were used more efficiently (16). The PER values of unsupplemented diets are higher than many of those reported previously (1,2,4), which might have resulted from strain of rat used, better vitamin or mineral balance of diet, or other experimental conditions.

Table V. Average 5-week Wt. Gain of Weanling Rats and PER. Expt. 1

	Supplement							
Diet	None	Lys	Trp	Lys-Trp	None	Lys	Trp	Lys-Trp
	g				PER			
Ragi	34	76	36	63	1.74	3.00	1.87	2.70
Bajra	85	139	82	135	1.84	2.41	1.83	2.34
Sorghum	51	109	49	123	1.36	2.11	1.32	2.48
Maize	53	49	62	118	1.46	1.65	1.82	2.62
Casein (5%)	45				2.68			
Casein (10%)	108				2.54			

Least significant difference (7), 5%: gain = 8.3; PER = 0.13

Table VI presents results when diets were supplemented with 3% protein. That uniform supplementation made all diets except Ragi contain approximately 12% protein, believed to be a minimum practical test level for evaluating diets for general use in human nutrition. All supplements caused greatest relative improvement in Ragi diets because of the proportion of additional protein supplied. Weight gains of rats fed Ragi diets were in order of increasing total lysine content, regardless of supplement source. All supplemented Bajra diets outperformed the corresponding casein control diet, but no supplement was uniformly the best with all grains. FPC was most effective with Ragi and sorghum, probably because of relatively high lysine content. FPC was ineffective with maize because maize was deficient in tryptophan, in which FPC is relatively low. That reasoning was confirmed by giving additional tryptophan to half the rats fed the FPC-supplemented maize diet at the end of the regular 4-week test. The best supplement to maize was DM, probably because it supplied relatively large quantities of lysine and tryptophan. DM produced poorest gains in rats fed the sorghum diet, apparently because of sulfur amino acid deficiencies in both foodstuffs. Supplementation with BY was less effective than expected from analytical data. That may have resulted from poor digestibility of yeast (15). The poor results in maize and sorghum diets supplemented with α-P could have resulted from imbalances precipitated by the lower quantities of methionine, valine and lysine in α-P. Even though overall growths were restricted, the better PERs of Ragi and 8% casein diets apparently reflected the reasonably good EAA distribution and/or more efficient use of total protein (16).

Table VI. Average 4-week Wt. Gain of Weanling Rats and PER. Expt. 2

	Supplement[1]							
Diet	DM	α-P	FPC	BY	DM	α-P	FPC	BY
	g				PER			
Ragi	83	73	108	77	3.05	2.43	3.35	2.79
Bajra	105	115	97	90	2.22	2.27	2.0	1.97
Sorghum	83	75	113	72	1.89	1.63	2.24	1.59
Maize	98	77	61	80	2.36	1.79	1.57	2.01
Casein (8%)	47				2.49			
Casein (12.5%)	83				2.18			

[1]To supply 3% protein. Total protein contents of diets, in %: Bajra, 12.6; sorghum, 11.8; maize, 11.4; Ragi, 7.8. No protein supplement added to casein diets.

Least significant difference (7), 5%: gain = 5.3; PER = 0.13.

Chemical and protein scores (Table III) based on egg protein as reference correlated better with PER values than did scores based on the FAO reference pattern. Variations in different protein quality scores of sorghum and maize and lack of consistent correlation with nutritive performance also have been noted by others cited in the reviews. Requirements of amino acids and protein for growth and methods to predict how well foodstuffs meet those requirements need further study.[3]

The data show that selection of the best protein supplement for a given grain requires consideration of the amino acid composition of both supplement and grain. The quality of supplemental protein in Ragi diets may be less critical than in maize, sorghum, or several other cereal diets because of the better amino acid distribution in Ragi. Even small additions of lysine in Ragi diets should allow more efficient use of otherwise unutilized portions of other EAA. Since Ragi and Bajra also contain more sulfur amino acids than maize or sorghum, they might be used more extensively in designing diets. If a Ragi protein isolate could be prepared efficiently and economically, it would be a high quality protein supplement.

REFERENCES

1. Swaminathan, M. Newer Methods of Nutritional Biochemistry III, (A. A. Albanese, ed.), Academic Press, Inc., New York 1967 p. 197.

2. Howe, E. E., Jansen, G. R. and Anson, M. L. An Approach Toward the Solution of the World Food Problem with Special Emphasis on Protein Supply. Am. J. Clin. Nutr., 20, 1134 (1967).

3. Kurien, S., Narayanaswamy, D., Daniel, V. A., Swaminathan, M., Rajalakshmi, D. and Parpia, H. A. B. Improvement of Protein Value of Poor Pearl Millet (Pennisetum typhoideum) Diet by Supplementation with Limiting Amino Acids. Nutr. Reports Intern., 3, 357 (1971).

4. Howe, E. E., Jansen, G. R. and Gilfillan, E. W. Amino Acid Supplementation of Cereal Grains as Related to the World Food Supply. Am. J. Clin. Nutr., 16, 315 (1965).

5. Blackburn, S. Amino Acid Determination, Marcel Dekker, Inc., New York 1968.

[3]For further discussion of results see Pushpamma, S. Ph.D. dissertation, Kansas State University. No. 68-1756, obtained from University Microfilms, 300 N. Zeeb Road, Ann Arbor, Michigan 48106.

6. Lombard, J. H. and DeLange, D. J. The Chemical Determination of Tryptophan in Foods and Mixed Diets. Anal. Chem., 10, 260 (1965).

7. Snedecor, G. W. Statistical Methods. Iowa State College Press, Ames, Iowa 1956.

8. National Research Council. Nutrient Requirements of Laboratory Animals. National Academy of Sciences - National Research Council, Washington, D.C., Pub. 990 (1962).

9. Block, R. J. and Bolling, D. The Amino Acid Composition of Proteins and Foods; Analytical Methods and Results. Edition 2. Thomas, Springfield 1951.

10. Food and Agricultural Organization, United Nations. Protein Requirements. FAO Nutritional Studies 16 Rome (1957).

11. Joint FAO/WHO Expert Group. Protein Requirement. FAO Nutrition Meeting Report Series 37, and WHO Technical Report Series 301. Food and Agricultural Organization, United Nations, Rome (1965).

12. Orr, M. L. and Watt, B. K. Amino Acid Content of Foods. Agricultural Research Service, U.S.D.A., Home Economics Research Report No. 4, Washington D.C. (1957).

13. Oser, B. L. Protein and Amino Acid Nutrition (A. A. Albanese, ed.), Academic Press, Inc., New York 1959 p. 281.

14. National Research Council. Evaluation of Protein Quality. National Academy of Sciences - National Research Council, Washington, D.C. Pub. 1100 (1963).

15. Tannenbaum, S. R., Mateles, R. I. and Capco, G. R. World Protein Resources. Advances in Chemistry Series 57, (R. F. Gould, ed.), Am. Chem. Soc., Washington, D.C. 1966 p. 254.

16. McLaughlan, J. M. and Campbell, J. A. Mammalian Protein Metabolism III, (H. M. Munro, ed.), Academic Press, Inc., New York 1969 p. 391.

RECEIVED
NATIONAL TECHNICAL
OCT 3 - 1973
INFORMATION SERVICE

BIBLIOGRAPHIC DATA SHEET	1. Report No. 664.06-P261	2.	PB 223 999

4. Title and Subtitle "Improving Protein Quality of Millet, Sorghum and Maize Diets by Supplementation"	5. Report Date Feb 72 6.
7. Author(s) D. B. Parrish, and C. W. Deyoe.	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Kansas State Univ.	10. Project/Task/Work Unit No. 931-17-560-481 11. Contract/Grant No. AID/csd-1586
12. Sponsoring Organization Name and Address Department of State Agency for International Development Washington, D.C. 20523	13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

Nutritive value of the protein of millets (Bajra and Ragi), sorghum, and maize was studied by amino acid analyses, by growth of rats and calculations of PER using diets containing the grains, unsupplemented or supplemented with lysine, tryptophan, or four protein concentrates. Ragi protein was highest in essential amino acids (EAA) except leucine, and compared to the FAO reference pattern, no amino acid in Ragi was limiting except lysine was marginal. Bajra protein was deficient in lysine; sorghum and maize were deficient in three or more amino acids. On several protein-quality scores, Ragi ranked first and Bajra second; both ranked considerably higher than sorghum or maize. Among unsupplemented diets, Bajra caused greatest weight gain in rats and had the highest PER. Supplementing Bajra and Ragi diets with lysine increased both gains and PER. Lysine improved sorghum and tryptophan improved maize diets; together lysine and tryptophan markedly improved both diets. Fish protein concentrate was the most effective supplement with sorghum and Ragi, dried milk with maize, and isolated soybean protein with Bajra.

17. Key Words and Document Analysis. 17a. Descriptors

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 664

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 9
	20. Security Class (This Page) UNCLASSIFIED	22. Price 3.00