PROTEIN SUPPLEMENTATION

Relative Nutritive Values of Proteins in Whole Wheat And Whole Rye and Effect of Amino Acid Supplements

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The nutritive values of the proteins in whole rye flour were found to be markedly superior to those of whole wheat flour when fed to albino rats at 9, 8, and 5% protein levels, during an experimental period of 10 weeks, as evidenced by gains in body weight and efficiency of proteins. There were marked growth responses to the additions of L-lysine, DL-valine in the presence of lysine, and DL-threonine in the presence of lysine as supplements to the basal ration of whole hard wheat flour on an 8% protein level. There was, however, little growth response to addition of lysine and threonine to the basal ration containing 8% proteins in whole rye flour. Addition of 0.2% threonine in the presence of 0.25% lysine produced significant increase in growth and protein efficiency. Addition of 0.5% valine alone produced greatest response in growth when used as a supplement to the proteins in whole rye flour. Rye is more productive than other cereal grains on infertile, sandy, or acid soils. There are in this country millions of acres of wastelands which perhaps could be converted to rye cultivation and thus provide plant proteins of good quality for man and farm animals.

OF THE TOTAL PROTEIN in the human dietary in the United States, close to one third is supplied by cereal grains, chiefly wheat, corn, and oats. Rice, rye, and barley are of relatively minor importance in this country.

Numerous nutritional studies have been conducted by feeding experiments on the relative nutritive value of the proteins in cereal grains. In 1948 Jones, Caldwell, and Widness (*2*) reviewed such literature and reported results of their own findings. Because of lack of uniformity in experimental procedures, variations in composition of basal diets, and inadequacy of vitamin supplements and mineral content of rations, the literature in this field is conflicting. The early investigators on the nutritional value of the proteins in cereal grains concluded that wheat, rye, corn, barley, and oats vary very little with respect to the nutritive value of their proteins (*1*, *3*, *6*, *7*). Jones and associates (*2*) were the first to report evidence of the superior value of the proteins in whole rye to those of whole wheat. However, while qualitatively the results of the present study are in agreement with theirs, the authors do not consider Jones's figures as conclusive. There is no assurance from their data that the mineral content of their rations was adequate, as they used only 2% of a synthetic salt mixture and they depended on cereal grains for the rest of the essential mineral ingredients. The data of Sure and House (*11*) on the relative biological value of the proteins in cereal grains, determined by the nitrogen-retention method, should be considered preliminary but not conclusive, because in order to investigate the protein efficiency of rice of low nitrogen content, their study had to be conducted on 5% protein levels, which affords little waste in metabolism during the short experimental period of one week; hence, such procedure yielded high biological values for all the whole cereal grains (*5*).

It was, therefore, considered essential to reinvestigate the relative biological values of the proteins in whole wheat and whole rye at several levels of protein intake for a period of 10 weeks and also to study the influence of various amino acid additions on their nutritive efficiency.

This investigation was carried out on the Wistar strain albino rat. Each group on the basal rations containing the cereal grains as only sources of proteins contained 24 animals. The groups that received amino acid additions contained 12 animals. The sexes were equally divided in all groups. The animals were about 30 days old when started on experiments and weighed 50 to 54 grams each. The whole wheat flour and whole rye flour furnished the only sources of protein in the rations and were fed to incorporate the necessary protein levels. The composition of the rest of the rations was 4% of Sure's salt mixture No. 1 (*9*), 7% hydrogenated vegetable shortening, 2% cod liver and 1% wheat germ oil as sources of vitamins A, D, and E, and the rest glucose (Cerelose). The following crystalline components of the vitamin B complex were administered daily to each animal separately from the ration six times a week, with a double dose on Saturdays: 25 γ each of thiamine, riboflavin, pyridoxine, and niacin; 150 γ of calcium pantothenate, 3 mg. of *p*-aminobenzoic acid, 6 mg. of choline chloride, and 1 mg. of inositol. Folic acid was not added to the rations, because under the dietary regime followed this vitamin is synthesized in the intestinal tract of the rat. The possible role of vitamin B_{12} as a supplement to the proteins in cereal grains, in the presence of

Table I. Relative Nutritive Values of Proteins in Whole Wheat and Whole Rye Flour

(12 males and 12 females in each experiment. 10 weeks' growth. Average results per animal)

Type of Ration	Protein in Ration, %	Gains in Body Weight G.	Gains in Body Weight %	Total Food Intake, G.	Protein Intake, G.	Protein Efficiency Ratio[a]	Protein Efficiency Increase, %
Whole wheat flour	9	56.1 ± 7.1[b]	...	594.7	53.5	1.05 ± 0.03[c]	...
Whole rye flour	9	78.2 ± 7.3	39.4	587.0	52.8	1.48 ± 0.03	40.9
Whole wheat flour	8	43.8 ± 9.1	...	593.2	47.5	0.92 ± 0.04	...
Whole rye flour	8	71.6 ± 8.5	63.5	638.7	51.1	1.40 ± 0.03	52.2
Whole wheat flour	5	19.5 ± 9.5	...	438.1	21.9	0.89 ± 0.07	...
Whole rye flour	5	54.1 ± 10.5	177.4	556.8	27.8	1.95 ± 0.08	119.1

[a] Expressed as gains in body weight per gram of protein intake.
[b] Standard deviation
[c] Standard deviation of means.

certain amino acids, was not considered in this study, but was investigated later (*8*).

The whole hard wheat flour and whole rye (pumpernickel) flour, obtained from General Mills, Minneapolis, had a protein content of 14.7% for the wheat and 9.44% for the rye. These were studied at 8 and 5% levels. A whole rye grown locally, which had a 10.1% protein content, was ground into flour, and was studied at a 9% protein level, was compared with the General Mills whole wheat flour on the same protein intake.

The results of this study are presented in summarized form in Tables I, II, and III. It will be noted from Table I that on all levels of protein intake the animals on the proteins in whole rye flour made considerably more growth and showed much greater increases in protein efficiency than the rats on the proteins in whole wheat flour. On the 9% protein level there were 39.4% increased growth and 40.9% increase in protein efficiency ratio in favor of the proteins in whole rye. On the 8% protein level there were 63.5% increased growth and 52.2% increase in protein efficiency ratio; and on the 5% protein intake there were 177.4% increased growth and 119.1% increase in protein efficiency ratio on the whole rye compared with the proteins in whole wheat.

Paired Feeding Experiments

Two groups of animals, 12 in each group, sexes equally divided, were fed rations containing 8% proteins in whole wheat flour and 8% proteins in whole rye flour. This study was conducted with animals in pairs. One animal on the rye flour ration was given the same amount of food consumed 24 hours previously by the litter mate of the same sex which was fed the wheat flour ration. The experiment was conducted for 35 days. The average gain per animal on the wheat flour was 24.0 grams and on the rye flour 40.9 grams. In other words, on the same amount of food and on the same amount of protein daily the animals on the rye flour gained 70.4% more in body weight than those on the wheat flour.

Chemical Composition Of Body Gains

In order to determine the chemical nature of the body gains, controlled feeding was conducted on two groups of male rats, 12 in each group. The daily food intake was limited to 7 grams to each animal on ration 1, containing 8% proteins in whole wheat, and to 7 grams to each animal daily on ration 6, containing 8% proteins in whole rye. After an experimental period of 30 days the animals were sacrificed, and protein, fat, and ash were determined (*10*). During this 30-day period each animal on ration 6, containing the proteins in rye flour, gained 14.5 grams of fat, 14.9 grams of protein, and 3.7 grams of minerals (ash), while each animal on ration 1, containing the proteins in wheat flour, gained only 4.5 grams of fat, 5.1 grams of protein, and 1.8 grams of minerals. This establishes conclusively the superior efficiency of the proteins in whole rye to those in whole wheat.

Table II. Improvement in Nutritive Value of Proteins in Whole Wheat Flour with Lysine, Valine, and Threonine

(Fed at 8% protein level for 8 weeks. Average results per animal)

Ration No.	Type of Ration	Gains in Body Weight G.	Gains in Body Weight %	Total Food Intake, G.	Protein Intake, G.	Protein Efficiency Ratio[a]	Protein Efficiency Increase, %	Nitrogen Intake, G.	Gains in Body Weight per G. Nitrogen Intake G.	Gains in Body Weight per G. Nitrogen Intake %
1	WWF	36.5 ± 9.7[b]	...	452.8	36.2	1.01 ± 0.04[c]	...	6.21	5.88	...
2	WWF + 0.25% L-lysine	66.5 ± 11.3	82.2	518.9	41.5	1.60 ± 0.05	58.4	7.32	9.09	54.6
3	WWF + 0.25% L-lysine + 0.2% DL-threonine	108.6 ± 14.6	197.0	612.7	49.0	2.22 ± 0.08	119.8	8.69	12.49	112.4
4	WWF + 0.25% L-lysine + 0.5% DL-valine	76.5 ± 11.0	109.6	495.6	39.6	1.93 ± 0.05	91.9	7.00	10.91	85.5
5	WWF + 0.25% L-lysine + 0.5% DL-valine + 0.2% DL-threonine	106.4 ± 14.9	191.3	596.5	47.7	2.23 ± 0.09	120.8	8.44	12.60	114.3

[a] Expressed as gains in body weight per gram of protein intake.
[b] Standard deviation.
[c] Standard deviation of means.

Influence of Lysine, Valine, and Threonine

From Table II it is evident that the addition of 0.25% L-lysine to ration 1, which contained 8% proteins in whole hard wheat flour, was followed by 82.2% increased growth and 58.4% increase in protein efficiency ratio. The further fortification of ration 2 with 0.5% DL-valine produced 109.6% increased growth and 91.9% increase in protein efficiency ratio. The addition of 0.25% L-lysine and 0.2% DL-threonine to basal ration 1 was accompanied by 197% increased growth and 119.8% increase in protein efficiency ratio. This demonstrates that the proteins in hard whole wheat flour can be markedly improved by addition of lysine and threonine. There was a response to valine in the presence of lysine, but no response to valine in the presence of lysine and threonine. However, there was a response to valine in the presence of lysine and threonine in the case of whole soft wheat proteins (*8*), for reasons not apparent at present.

From Table III it is apparent that in the case of whole rye flour, the growth response to the addition of either 0.25% L-lysine or 0.2% DL-threonine alone as supplements to ration 6, containing whole rye flour, was rather small, resulting in only 11.1 and 16.0% increased growth, respectively. However, there was a significant growth response to 0.2% DL-threonine in the presence of 0.25% L-lysine—i.e., 51.6% increased growth and 31.4% increase in protein efficiency ratio. The addition of 0.5% DL-valine alone to basal ration 6 produced the most marked response—i.e., 89.4% increased growth and 44.0% increase in protein efficiency ratio. No beneficial effect of lysine is evident in the presence of valine, and the addition of lysine and threonine seems to have produced an imbalance of amino acids in the presence of valine (ration 12).

Discussion

These findings may have practical applications in agriculture. In 1952 the annual production of rye in this country was only 15,910,000 bushels compared with 1,291,247,000 bushels of wheat, which constitutes about 12% of the wheat crop (*12*). The leading countries in rye production are Russia (U.S.S.R.), Germany, Poland, Czechoslovakia, France, and Hungary (*4*). Rye can be grown in all states of the Union, but the chief acreage is in the northern and eastern states. The highest yields of rye are obtained on rich, well-drained loam soils, but rye is more productive than other cereal grains on infertile, sandy, or acid soils. Rye usually yields less grain than winter wheat under conditions favorable for wheat, because of its shorter growing period and heavier straw growth. However, rye usually is sown on poorer soils and with poorer seed bed preparation than is wheat (*4*). There are in this country millions of acres of wastelands which perhaps could be converted to rye cultivation (*12*) and thus provide plant proteins of good quality for man and farm animals.

Table III. Influence of Additions of Lysine, Valine, and Threonine on Nutritive Value of Proteins in Whole Rye Flour

(Fed at 8% protein level for 8 weeks. Average results per animal)

Ration No.	Type of Ration	Gains in Body G.	Gains in Weight %	Total Food Intake, G.	Protein Intake, G.	Protein Efficiency Ratio[a]	Protein Efficiency Increase, %	Nitrogen Intake, G.	Gains in Body Weight per G. Nitrogen Intake G.	Gains in Body Weight per G. Nitrogen Intake %
6	WRF	63.6 ± 11.5[b]	...	500.6	40.0	1.59 ± 0.05[c]	...	6.86	9.27	...
7	WRF + 0.25% L-lysine	70.7 ± 13.4	11.1	508.5	40.7	1.74 ± 0.08	9.4	7.17	9.85	6.2
8	WRF + 0.2% DL-threonine	73.8 ± 11.9	16.0	539.9	43.2	1.71 ± 0.05	7.6	7.47	9.87	6.4
9	WRF + 0.25% L-lysine + 0.2% DL-threonine	96.4 ± 9.2	51.6	579.3	46.3	2.09 ± 0.04	31.4	8.26	11.66	25.8
10	WRF + 0.5% DL-valine	120.3 ± 9.7	89.4	657.8	52.6	2.29 ± 0.04	44.0	9.27	13.00	40.2
11	WRF + 0.5% DL-valine + 0.25% L-lysine	110.6 ± 11.4	73.9	612.7	49.0	2.29 ± 0.07	44.0	8.80	12.55	37.3
12	WRF + 0.5% DL-valine + 0.25% L-lysine + 0.2% DL-threonine	95.1 ± 14.6	49.5	603.4	48.2	1.97 ± 0.09	23.9	8.74	10.88	17.4

[a] Expressed as gains in body weight per gram of protein intake.
[b] Standard deviation.
[c] Standard deviation of means.

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