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All-Vegetable Protein Mixtures for Human Feeding

II. THE NUTRITIVE VALUE OF CORN, SORGHUM, RICE AND BUCKWHEAT SUBSTITUTED FOR LIME-TREATED CORN IN INCAP VEGETABLE MIXTURE EIGHT[1]

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The first paper in this series described biological trials in chicks and rats leading to the development of an all-vegetable protein mixture for the supplementary and mixed feeding of young children (Squibb et al., '59b). The formula recommended for clinical trials was designated INCAP Vegetable Mixture 8 and contained corn masa, sesame flour, cottonseed flour, torula yeast and kikuyu leaf meal. Simultaneously with studies in children, additional experiments using this mixture were carried out with chicks, in which the lime-treated corn in the original formula was replaced by raw corn, sorghum, rice or buckwheat.

Although corn is the most important staple food consumed by the rural population in Central America, its production is far below the level needed for human and animal consumption. For this reason other cereal grains are becoming important as substitutes for corn. Grain sorghum is of particular interest since it produces well under environmental conditions which are too dry for high yields of corn (Hillier et al., '54; Pond et al., '58).

Even though rice is not an agricultural product found in surplus quantities in Central America, it is very important in Panama (Sogandares and de Barrios, '55; Sogandares et al., '55) where it replaces corn in most human diets. In this study, rice and grain sorghum are compared with corn in feeding experiments with chicks, as components in all-vegetable protein diets.

Wyld et al. ('58) have recently reported on the nutritive value of buckwheat as a possible component of vegetable protein mixtures. They found that buckwheat was a useful component of the ration used in their chick experiments because it contributed significant amounts of lysine, the amino acid most limiting for chick growth in diets based on sesame meal and cottonseed oil meal. In the present experiments buckwheat was studied to obtain further information on its possible value in areas where protein is in short supply.

MATERIALS AND METHODS

Four-day-old New Hampshire chicks of both sexes were distributed by weight and confined in battery brooders. Temperature was thermostatically controlled as required by the age of the birds. Feed and water were provided ad libitum. The chicks were weighed individually every week for a total of 35 days and weekly records were kept of group diet consumption.

Although the raw materials for the rations used are, with the exception of torula yeast, currently produced in Central America, the sesame and cottonseed flours were imported because these are not as yet locally processed in a form suitable for human consumption. The basic chemical composition including the lysine content of the major constituents of the diets is shown in table 1. The percentage composition of the basal diet, INCAP Vegetable Mixture 8 (Scrimshaw et al., '57; Béhar et al., '58; Squibb et al., '59b), was as follows: sesame flour, 35; cottonseed flour, 9; torula yeast, 3; kikuyu leaf meal, 3; corn masa flour, 50. Each cereal grain tested was substituted completely for 50% of the corn masa flour of the basal diet.

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TABLE 1

Proximate composition of major diet constituents

Ingredient	Moisture	Protein	Ether extract	Crude fiber	Nitrogen-free extract[1]	Ash	Lysine
	%	%	%	%	%	%	%
Sesame meal[2]	7.2	46.3	19.6	7.9	13.4	5.6	0.43
Cottonseed flour[3]	7.4	53.2	5.5	3.0	24.5	6.4	2.10
Torula yeast[4]	6.7	48.3	2.5	2.4	29.9	7.8	3.80
Dehydrated kikuyu leaf meal	6.1	20.7	3.8	24.3	34.2	10.9	0.58
Masa flour	7.5	10.6	3.7	1.6	73.6	3.0	0.26
Yellow corn	13.9	9.2	3.5	2.6	69.6	1.2	0.26
Sorghum	14.2	10.2	2.7	4.0	67.9	1.0	0.29
Rice	17.0	8.0	0.2	0.7	73.8	0.3	0.30
Buckwheat	14.0	9.2	2.4	13.4	53.0	8.4	0.54

[1] Calculated by difference.
[2] American Sesame Products, Inc. Paris, Texas.
[3] Traders Oil Mill Co., Fort Worth, Texas.
[4] Lake States Yeast Corp., Rhinelander, Wisconsin.

TABLE 2

Growth response of chicks to various cereals in all-vegetable protein mixtures

Cereal	Crude protein in diet	Number of chicks initial/ final	Initial weight	Final weight[1]	Feed conversion[2]	Protein efficiency[3]
	%		*gm*	*gm*		
			Experiment 1			
Basal diet (INCAP Vegetable Mixture 8)	21.3	12/12	49	223 ± 31.8	2.68	1.75
Yellow corn	20.8	12/10	49	264 ± 57.5	2.60	1.85
Sorghum	21.1	12/10	49	196 ± 36.1	2.89	1.64
Rice	20.3	12/12	49	237 ± 35.5	2.55	1.93
Buckwheat	20.8	12/12	49	332 ± 34.8[4]	2.40	2.00
			Experiment 2			
Basal diet (INCAP Vegetable Mixture 8)	21.3	12/12	54	240 ± 38.3	2.50	1.88
Yellow corn	20.8	12/12	54	262 ± 57.2	2.74	1.76
Sorghum	21.1	12/12	54	247 ± 47.5	2.92	1.62
Rice	20.3	12/11	54	260 ± 30.7	2.75	1.79
Buckwheat	20.8	12/12	54	341 ± 33.1[4]	2.60	1.85

[1] Final weight ± standard deviation.
[2] Grams of feed per gram of weight gained.
[3] Grams of weight gained per gram of protein consumed.
[4] Highly significant; $P = < 0.01$.

The term "masa" is given to the product obtained by cooking corn in a lime solution and subsequently drying and grinding it (Bressani et al., '58; Bressani and Scrimshaw, '58).

In the first and second feeding trials, the basal diet and the experimental diets containing whole ground yellow corn, whole ground sorghum, ground polished rice, or whole ground buckwheat were fed to groups of 12 birds. The complete diets were diluted with cornstarch to 75% of their original value to give protein concentrations of approximately 21%. In the third trial, 24 chicks per ration were used and the complete diets were diluted with cornstarch to 80% to give a protein concentration of about 22%. The experimental rations used in trial 3 were supplemented with 0.4% L-lysine hydrochloride. One group received a complete chick stock ration[2] containing 22.1% protein.

[2] "Ace-Hi," manufactured by Compañía Riverside, Guatemala.

All of the rations tested contained 3% of a mineral supplement,[3] 0.3% of cod liver oil,[4] and 1 ml of a vitamin solution to provide the following in milligrams per 100 gm of ration: thiamine hydrochloride, 2; riboflavin, 2; niacin, 10; inositol, 10; choline chloride, 160; vitamin K, 5; *p*-aminobenzoic acid, 10; pyridoxine hydrochloride, 2; calcium pantothenate, 6; biotin, 0.04, and vitamin B_{12}, 0.003.

RESULTS

Table 2 summarizes the first and second trials by listing the protein content of the rations, the initial and final weights of the chicks, and the feed conversion and protein efficiency values. From these results, it is evident that buckwheat resulted in better growth, feed conversion and protein efficiency than any of the other cereal grains substituted for part of the corn. Yellow corn and rice were slightly more effective than sorghum and the basal diet of INCAP Vegetable Mixture 8. Feed conversion values for the basal diet were, however, somewhat better than those obtained when yellow corn and rice were utilized. The feed conversion and protein efficiency values of the rations containing sorghum were the lowest. The protein efficiency values of the basal diet, yellow corn and rice were essentially equal.

The results of the third trial are shown in table 3. From these it is evident that when all of the cereal combinations were supplemented with lysine, rice substitution produced the best growth response, feed conversion and protein efficiency. The differences observed were not, however, statistically significant. The growth, feed conversion and protein efficiency values of all the experimental rations were improved by supplementation with 0.4% of lysine when compared with the results of experiments 1 and 2. They also gave better results than the stock ration which contained the recommended amount of animal protein for growing chicks.

DISCUSSION

In the rations used in this study, as in those of Wyld et al. ('58), Squibb and Braham ('55) and Squibb et al. ('59b), lysine was the most limiting amino acid. When the vegetable protein mixtures were supplemented with this amino acid alone, marked gains were observed and the apparent differences among the cereal grains tested disappeared. This is evidence that the formulas tested do not contain sufficient lysine for good growth in chicks although they may still prove useful for the feeding of children. In fact, a preliminary report indicating good results from the feeding of the basal ration, INCAP Vegetable Mixture 8, to young children has already appeared (Scrimshaw et al., '57), and the next paper in this series will de-

[3] Mineral supplement of 33% bone meal, 33% calcium carbonate, 33% iodized salt, and 1% minor elements.

[4] Obtained through the courtesy of Mead Johnson & Co., Evansville, Indiana.

TABLE 3

Growth response of chicks to various cereals in all-vegetable protein mixtures[1]

Experiment 3

Cereals	Crude protein in diet	Number of chicks initial/final	Initial weight	Final weight	Feed conversion[2]	Protein efficiency[3]
	%		*gm*	*gm*		
Basal diet (INCAP Vegetable Mixture 8)	23.1	24/24	52	503 ± 46.4	1.97	2.20
Yellow corn	22.5	24/23	52	537 ± 65.0	1.90	2.33
Sorghum	22.9	24/24	52	524 ± 70.1	1.92	2.27
Rice	22.1	24/24	52	546 ± 56.7	1.82	2.48
Control diet[4]	22.1	24/24	52	520 ± 51.6	2.10	2.16

[1] Supplemented with 0.4% lysine.
[2] Grams of feed per gram of weight gained.
[3] Grams of weight gained per gram of protein consumed.
[4] Ace-Hi. Compañía Riverside, Guatemala.

scribe in detail the supporting clinical data.

It has been shown by several workers (Laguna and Carpenter, '51; Cravioto et al., '52; Squibb et al., '59a) that rats fed raw corn do not gain as much weight as rats fed lime-treated corn. Nevertheless, in chicks the basal diet which contained lime-treated corn produced consistently less growth than when either raw corn or rice was substituted. This has been attributed to differences in the physical suitability of the diets for chick feeding (Squibb et al., '59b). When the cereal grains were not supplemented with lysine, however, slightly better feed conversion values were obtained with the diet containing masa flour than with those containing ground yellow corn, ground sorghum or rice. Furthermore, protein efficiencies of the diets containing masa flour and raw corn were similar. An alternate explanation may lie in the altered dietary amino acid proportions since during the preparation of masa from corn, 18.7% of the arginine, 11.7% of the histidine, 21% of the leucine and 12.5% of the cystine are lost, as well as lower percentages of other amino acids (Bressani and Scrimshaw, '58).

It is significant that grain sorghum is not as effective as corn in promoting growth of chicks, although both their chemical composition and amino acid content are very similar. It would be of practical interest to investigate whether this is the result of poorer amino acid availability in sorghum, a less favorable amino acid pattern, or lower digestibility.

The results obtained in this series of experiments indicate that any of the 4 cereals tested, ground yellow corn, buckwheat, sorghum or rice, could be substituted for all or part of the masa flour (from lime-treated corn) in INCAP Vegetable Mixture 8 if economic and agricultural factors make this desirable. They also provide further evidence that the basic formula contains sufficiently good protein to produce excellent growth in rats and satisfactory growth in chicks, although the latter is improved when lysine is added.

SUMMARY

Baby New Hampshire chicks were used to measure the nutritive value of ground yellow corn, grain sorghum, rice, and whole buckwheat substituted for masa flour (from lime-treated corn) in INCAP Vegetable Mixture 8, a formula designed for the supplementary and mixed feeding of infants and young children and containing corn masa flour, sesame flour, cottonseed flour, torula yeast and kikuyu leaf meal. In two experiments, buckwheat produced significantly better growth and feed conversion than any of the cereal grains. Yellow corn gave the next best growth response, followed by rice and sorghum. Substitution of each of the cereal grains resulted in better growth than with masa flour, though the masa flour produced better feed conversions in most cases. In a third experiment in which all rations were supplemented with 0.4% lysine, equally excellent growth and feed conversion as well as protein efficiency values were obtained with all of the diets tested. These were equal or superior to those obtained with a complete stock ration for growing chicks which contained animal protein. The results obtained in this series of experiments indicate that any of the 4 cereals tested, ground yellow corn, buckwheat, sorghum or rice, could be substituted for all or part of the masa flour (from lime-treated corn) in INCAP Vegetable Mixture 8 if factors of economy and agriculture make this desirable.

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