APPENDIX V-

PN-AAS-567

Evaluation of the Protein Quality and Digestibility of Sorghum in the Diet of Infants: Supplementary Report

TO:

Dr. Samuel G. Kahn
Science Research Officer
Office of Nutrition
Agency for International Development
Washington, D.C. 20523

FROM:

Instituto de Investigacion Nutricional
Apartado 55
Miraflores (Lima), Peru
and
William C. MacLean, Jr., M.D.,
George G. Graham, M.D.
615 North Wolfe Street
Baltimore, Maryland 21205

SUBJECT:

Progress Report - March 19, 1980
Research Contract AID/ta-C-1286
Clinical Assay of High Protein Foods

During the past several years we have been carrying out studies to evaluate the protein quality and the digestibility of four varieties of whole grain sorghum flour made available by Purdue University. In an initial report (April, 1979) the results of studies in nine children were reported. The conclusion reached at that time was that the protein digestibility and apparent protein quality of whole grain sorghum flour was lower than any food or food blend studied in the unit during the previous 17 years. This conclusion was somewhat tentative because of the fact that sufficient numbers of studies had not been carried out with two of the varieties, 954063 and IS11758. To be certain that there were no significant differences among varieties that would contradict the conclusion, further studies have been carried out with these two varieties during the past year. These studies are summarized in this report. They confirm our previous impression of whole grain sorghum flour as a food that should be expected to have little nutritional benefit and a real potential for harm when added to the diets of infants or small children.

MATERIALS AND METHODS

The methods for these studies were previously reported on in detail and will not be elaborated on here.

Patients. The descriptive characteristics of the additional patients studied are shown in Table 1. Four Peruvian Mestizo male infants participated in the studies with the consent of their parents. Ages ranged from 8 to 30 months. Heights ranged from 61 to 74.2 cm, weights from 5850 g to 3950 g. All children were well past the acute phase of recuperation from malnutrition and were remaining in hospital

to consolidate recovery. Serum albumin concentrations were within the normal range at the beginning of the study.

Diets. The diets used in these studies were the same as those used in the original studies and are detailed in Table 2 of the previous report, a copy of which is attached. Most nitrogen balance studies in our unit are carried out with protein providing 6.0 to 6.4% of energy. During the previously reported studies the amount of sorghum protein was increased to 8% of energy when the early nitrogen retention results were analyzed. All of the present studies were carried out with the control diet providing 6.4% of energy and sorghum protein providing 8% of energy. By so doing, a tendency to underestimate the difference between the two diets was introduced.

Cooking time for the sorghum was 60 minutes in the current studies. In one of the previous and one of the present studies the sorghum was cooked in a pressure cooker in an attempt to improve digestibility.

Protocol. The protocol for these studies paralleled that of the previous nine studies. Basically each study began with a nine-day control period during which the child consumed a diet based on casein, a blend of soybean and cottonseed oil, sucrose and dextrimaltose. This was then followed by one or two dietary periods with a sorghum-based diet and a final control period. Metabolic balances were carried out during the last six days of each dietary period using methods standard for the unit. Methods of analysis for urinary and stool nitrogen, stool fat, and stool energy were standard for the unit (1, 2).

RESULTS

Table 2 summarizes the results of individual patient studies. Patient #587 had an uneventful initial control period; the rate of weight gain and nitrogen retention were adequate. During the dietary period with IS11758 weight loss ensued. Nitrogen absorption and retention were extremely low. The dietary period was discontinued after eight days because of marked loss of appetite and refusal to eat. For this reason rather than go directly to the second sorghum dietary period, an intervening control period was used. During that nine-day period the child gained weight rapidly and again had adequate nitrogen absorption and retention. During the dietary period that followed with 954063 the rate of weight gain slowed again almost to zero. Nitrogen absorption and retention also dropped. Stool weights and energy losses increased dramatically. The final dietary period in this patient, a control period, showed a return to rapid weight gain and an apparent rebound in nitrogen retention.

Patient #589 completed the four dietary period study as planned. During the sorghum dietary periods the slowing of the rate of weight gain was not as impressive as in the previous patient. The poor absorption of nitrogen and the very low nitrogen retention were more marked. For example, during the second dietary period, with 954063, nitrogen retention during the six days that it was studied was zero. The final control period in this patient was marked by an apparent increase in nitrogen retention above the initial control value, again most likely indicating compensatory or rebound retention following a diet inadequate in available nitrogen.

Patient #594 had an uneventful first control period. The initial dietary period with sorghum, IS11758, resulted in a dramatic slowing of weight gain and very poor nitrogen retention. The second sorghum dietary period, 954063, was stopped after four days because of profound weight loss and dehydration. This phenomenon was reversed immediately after changing to a normal diet.

Patient #596 completed a four dietary period study. Of the four infants studied, this patient did the best with the sorghum diets although nitrogen absorption and retention from sorghum were expectedly inferior to those from casein. Because the quantity of IS11758 was insufficient to complete an additional study, this patient had an additional study done with P721-OP9. The rate of weight gain, nitrogen absorption and nitrogen retention during this period although inferior were acceptable.

The results of the studies with 954063 and IS11758 as well as their corresponding casein control periods are summarized in Table 3. In Table 4 the mean values for all studies to date with all four varieties of sorghum are summarized. The picture is quite consistent and shows little variation among varieties. Consumption of sorghum was characterized by a dramatic slowing in the rate of weight gain in virtually all cases. Nitrogen absorption decreased to approximately 50% of that from casein. Nitrogen retention was 33 to 66% of that from the initial casein control period. A rebound retention of nitrogen during the following casein control period further suggested the marked inadequacy of the protein quality of sorghum. Stool wet weights were exceedingly high as were stool energy losses. There were no consistent diet related changes of serum albumin concentration.

DISCUSSION

The present studies bring to a total of 26 the number of individual dietary studies with sorghum. This represents a very large experience with the food, almost as large as we have for this type of study with any of the staple foods. There are no significant differences among the four varieties studied and the picture of sorghum derived is quite consistent. Whole grain sorghum flour is an extremely bulky and poor source of dietary energy for children. The poor absorption and retention of nitrogen from sorghum in this form make it unacceptable as a supplement of dietary protein to the diets of infants or children. Both of the previous statements hold true regardless of how sorghum is prepared. At different times during our studies, the cooking time for sorghum was varied between 15 and 60 minutes. During several studies a pressure cooker was used in an effort to try to improve the digestibility through additional cooking. We were unable to influence the outcome of studies by any of these changes.

In the initial report concerning sorghum we compared it with the other major staple foods, wheat, rice, potato and maize. This table has been updated to include the current studies and is found as Table 5 of this report. It is quite clear that all of the other major staples are substantially superior to sorghum as sources of both protein and energy. Experience in the past with sorghum as a component of a blended food, Thriposha, was favorable. The sorghum used in Thriposha was pearled and processed by extrusion cooking as part of a blend. The absorption and retention of nitrogen from the blend were excellent, suggesting no adverse effect of the sorghum. In earlier studies from

India, the partial replacement of rice with whole grain sorghum flour in the diet of school-age children produced a dramatic decrease in nitrogen absorption and retention (3). Used in an unprocessed form as a dietary supplement, however, its consumption by children is not recommended. There is no nutritional justification for the use of whole grain sorghum flour in AID sponsored feeding programs when the possibility of using any of the other major staple foods exists.

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Table 1

Additional patients studied

Pt. No.	Hosp. Day	Age mos.	Ht. cm	Height Age mos.	Weight g	Weight Age mos.	[Albumin] g/dl
587	140	8	61.0	3.3	5850	3.3	4.17
589	78	15	73.8	11.3	6680	4.7	4.17
594	66	30	74.2	11.5	8950	8.8	3.99
596	48	8	66.0	6.0	6140	3.7	3.38

Table 2

Individual patient summaries of additional studies with sorghum

Pt. No.	Diet	Kcal	% Prot Kcal	No. Days	Apparent N Balance Δ Wt g/kg/d	On Days	Abs %	Ret %	STOOL Wet Wt	Dry Wt	Fat % Int	Energy Kcal/d	% Int	Serum Albumin Final g/dl	Δ
587	Casein	150	6.4	11	4.2	6-11	82	48	130	14.25	7.5	59	6.1	3.29	-0.88
	IS11758	150	8.0	8†	-3.8	4- 6	36	21	193	48.61	42.7	221	23.0	3.80	+0.51
	Casein	150	6.4	9	7.6	4- 9	83	52	112	13.43	5.7	53	5.3	3.95	+0.15
	954063	150	8.0	12	0.3	4-12	48	25	200	38.69	8.8	176	16.9	3.80	-0.15
	Casein	150	6.4	9	5.7	4- 9	83	61	155	15.72	7.7	64	6.2	3.97	+0.17
589	Casein	125	6.4	11	5.9	6-11	80	28	64	17.03	10.2	62	6.7	4.05	-0.12
	954063	125	8.0	10	2.3	5-10	26	0	177	37.02	10.2	168	17.3	--	--
	IS11758	125	8.0	7	4.5	2- 7	15	4	208	46.9	15.6	218	22.4	3.30	-0.75
	Casein	125	6.4	9	3.2	4- 9	75	42	99	17.6	10.1	68	6.4	3.68	+0.38
594	Casein	110	6.4	11	4.3	6-11	79	32	102	18.6	8.3	71	6.1	4.06	+0.07
	IS11758	110	8.0	9	0.5	4- 9	33	2	271	55.6	20.8	261	23.2	4.08	+0.02
	954063	110	8.0	4o	-10.3	2- 3	41	13	409	60.4	23.4	--	--	--	--
596	Casein	125	6.4	9	5.2	4- 9	85	42	85	12.8	14.1	59	7.4	3.67	+0.29
	954063*	125	8.0	9	0.2	4- 9	52	20	222	29.7	11.6	129	16.4	3.29	-0.38
	P721-OPO	125	8.0	10	4.4	2-10	56	25	237	31.4	9.9	129	15.4	2.91	-0.38
	Casein	125	6.4	13	6.5	8-13	82	41	117	15.6	15.6	71	7.9	3.44	+0.53

* Pressure cooked

† Discontinued for anorexia

o Stopped for weight loss and dehydration

Table 3

Summary of additional studies with 954063 and IS11758

Diet	n	Δ Wt	Abs %	Ret %	Stool Weight Wet	Stool Weight Dry	Fat %	Stool Energy Kcal/D	Stool Energy %	Serum Albumin Final	Serum Albumin Δ
Casein-Pre	4	4.7 ±0.8	82 ± 2.6	38 ± 9	95 ± 28	15.7 ± 2.6	10.0 ±2.9	63 ± 6	6.6 ±0.6	3.77 ±0.37	-0.19 ±0.49
954063	4	-1.9 ±5.7	42 ±11	15 ±11	252 ±106	41.5 ±13.2	13.5 ±6.7	158* ±25	16.9 ±0.5	3.54 (n=2)	-0.27 (n=2)
IS11758	3	0.4	28	9	226	50.3	26.4	233	22.9	3.73	-0.07
Casein-Post	4	5.8 ±1.9	81 ± 4	49 ± 9	121 ± 24	15.6 ± 1.7	9.8 ±4.3	64 ± 8	6.5 ±1.1	3.76 ±0.25	+0.31 ±0.18

Table 4

Summary of mean values for all studies with sorghum

Diet	n	Δ Wt	Abs %	Ret %	Stool Weight		Fat %	Stool Energy		Serum Albumin	
					Wet	Dry		Kcal/D	%	Final	Δ
Casein-Pre	15	5.1	82	38	94	15.9	12.3	67	7.3	3.85	-0.09
954114	9	0.5	46	12	205	38.0	17.0	201	19.8	3.52	-0.30
P721-OP9	7	2.8	54	16	232	34.9	11.6	153	12.7	3.50	-0.09
954063	5	-0.4	47	18	238	39.7	12.5	151	15.2	3.56†	-0.19†
IS11758	5	0.8	35	11	232	45.2	18.7	224*	20.8*	3.78	-0.10
Casein-Post	9	6.7	81	51	132	17.8	11.0	76	6.9	3.75	+0.14

* One patient - no data.

† n = 3.

Table 5

Comparison of various results of sorghum studies with corresponding data from other staple foods

	Apparent N Balance		Stool Weight		Stool Energy
	Abs %	Ret %	Wet g/d	Dry g/d	Kcal/d
Sorghum[1]	46	14	223	38.9	183
Wheat[2]	81	20	95	13.3	60
Rice[3]	66	26	67	11.6	58
Potato[4]	66	34	165	20.3	78
Maize[5]	73	27	133	28.6	117
Casein[6]	81	38	94	16.0	69

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1 Mean values of all 26 sorghum periods.

2 Studies of all-wheat pasta, J. Nutr. 109:1290, 1979.

3 Data from studies of two varieties of rice, J. Nutr. 108,1740, 1978.

4 Data from 9 balance studies with potato, report under review.

5 Data from 6 studies with whole kernel normal maize, J. Nutr., in press.

6 Data from the 11 preceding casein control periods of these studies.

12