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Nutritional improvement of rice by fortification with synthetic amino acids and vitamins; final research report,1971 to 1975

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9. ABSTRACT
Testing was carried out by the Harvard School of Public Health in 29 villages in Thailand to determine the health benefits of rice fortification with the nutrients most lacking in the diets of Asia. The study was based on the assumption that major health benefits might result if the rice were fortified with amino acids and other nutrients. The results of this study show that the desired health effects were not obtained. During the field study period, August 1971 to January 1975, grains fortified with lysine, threonine, thiamin, riboflavin, vitamin A, and iron were provided to Thai villagers. The testing involved 2400 children from 6 months to 12 years old. Some adults were also part of the study. The fortified grains had no significant effect on the measurements of development and of health status. The study also concluded that poor growth among the villagers does not appear to be related to morbidity or to a lack of available food. It is more probably linked to inadequate caloric consumption or to the high prevalence of enteric parasite infections. As a result of this study, the Thai Ministry of Health is committed to further studies to evaluate health problems so that low-cost practical village nutrition and health programs can be started. Tables present the data collected on winter and summer physical examinations of the children each year from January 1971, detailed morbidity data on all children gathered every 15 days from July 1972 through June 1975, and data on the use of fortified rice. There is a section on nutrition intervention programs and their feasibility in Thai villages. The report observes that day care centers established for the study provide good delivery systems for nutrition and education programs.

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FINAL RESEARCH REPORT

A. 1. Nutritional Improvement of Rice by Fortification with Synthetic Amino Acids, Vitamins, and Iron.

2. Principal Investigator: Stanley Gershoff

Contractor: President and Fellows of Harvard College
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3. Contract Period: June 30, 1971 to December 31, 1975

B. Narrative Summary of Accomplishments and Utilization

1. Provision of rice fortification grains in the full field study of the effects of rice fortification in Thailand was initiated in all test villages during August 1971 and continued until January 1975. A winter and summer physical examination of the children involved in the study were done each year starting in January 1971. From July 1972 through June 1975 RFG use and detailed morbidity data were obtained on all children in the study every 15 days. Analysis of the data to answer the questions asked by AID have been completed. It is clear that the village children studied were retarded in growth. The consumption of rice fortified with lysine, threonine, thiamin, riboflavin, vitamin A, and iron had no significant effect on the measurements of development and health status which were made. The poor growth of the village children does not appear related to morbidity or to a lack of available food.

It is our feeling that the reasons for the poor growth of Thai villagers may be related to their inadequate caloric consumption of the Thai diet which has a very low caloric density or to the high prevalence of enteric parasite infections. We are pleased that, in part as a result of this study, the Thai Ministry of Health has become increasingly concerned about the nutritional and health needs of its children and is committed to doing further studies to evaluate their problems so that low cost practicable village nutrition and health programs can be initiated.

a. General Background

The major staple in the diets of most of the people of Asia is rice. For most of them, it may provide 70-80 percent of their calories. Although rice is a good food, it is low in several nutrients. Partly as a result of this, it is not uncommon to observe protein, thiamin, riboflavin, vitamin A, and iron deficiencies in the rice-eating populations of Asia. Preschool children and pregnant and lactating mothers are at particularly high risk to developing these problems.

Rice contains on the average about 7 percent protein of modest biological value. Lysine and threonine are the two limiting amino acids. The addition of .3 percent lysine and .1 percent threonine in our laboratories to the glutenous rice used exclusively in the villages of Chiang Mai, Thailand has been found to increase the availability of protein in rat assays by about 70 percent.

The present study was initiated in Thai villages because although there was evidence of nutrient deficiencies in the villagers, there was not a marked calorie shortage. Furthermore, the Thai officials of the Ministry of Health were interested and offered their cooperation and technical assistance in carrying out the work.

b. *Statement of Present Project Objectives*

The present study was instituted to determine the health benefits to be derived from the fortification of rice with the nutrients most limiting in the diets of the rice eaters of Asia. Furthermore, because of their potential value as instruments for improving the nutrition and health of preschool children as well as providing educational and custodial usefulness the present study was designed to evaluate the feasibility of developing village day care centers for preschool children.

c. *Continued Relevance of Objectives*

It is our belief that the purpose of AID in funding studies such as this is to obtain information so that programs to improve the health of people in developing countries may be developed. The current study was initiated because of the belief by the Division of Nutrition at AID that major health benefits might be achieved in Asiatic populations consuming diets mainly of rice if their rice was fortified with amino acids and other nutrients thought to be limiting in their diets. The results of this study clearly show that the desired effects were not obtained. It is also clear that serious nutritional problems exist in the population studied. Recently, Dr. Forman pointed out at Harvard that the Nutrition Division at AID had initiated a systems analysis approach to the nutritional problems of the peoples of developing countries and that the first step in such an analysis is an evaluation of the nutritional problems of the people to be helped. It is our conclusion that the data obtained show that our fundamental understanding of the nutritional problems of Thai village children is inadequate and by inference that this also applies

to the populations of many other developing countries. The lack of information makes likely the failure of many types of nutrition programs with the loss of much needed resources. It, therefore, seems that studies such as the one just completed which are designed to gather basic information and field test projected programs are of continuing relevance to the objective of AID.

d. Accomplishments

In January 1971 a study of the effects of rice fortification with lysine, threonine, riboflavin, thiamin, vitamin A, and iron on the health of Thais living in villages near Chiang Mai was started. The design of the study and a description of the baseline data collected have been previously described in detail in the contract and in a paper (Amer. J. Clin. Nutr., 28: 170, 1975). This is a report of the general results of this four year intervention study.

Methods: Briefly, 29 villages with approximately 13,000 people were divided into five groups:

Group 1 - raw control, no intervention provided

Group 2 - placebo control (RFG-3) plus day-care centers for preschool children

Group 3 - vitamin and iron fortification (RFG-2) plus day care centers

Group 4 - vitamin, iron, and amino acid fortification (RFG-1) plus day-care centers

Group 5 - RFG-1, no day care centers

The rice fortification grains (RFG) were added to the rice at the mill at a 1 percent level. When used the levels of nutrients in the RFG were L-lysine HCL 20 percent, L threonine 10 percent, thiamin naphthalene disulfonate 0.0873 percent, riboflavin 0.04 percent, retinol acetate 0.0815 percent and $FePO_4:4H_2O$ 0.8 percent.

Examinations of the population were made twice a year, in Jan-Feb and July-Aug and were directed primarily towards the pre-school children. During the last three years of the study morbidity records and records of use of the RFG were obtained at least once every 15 days. Examinations consisted of measurements of reclining length, weight, head arm and chest circumferences, subscapular and triceps skin folds and a physicial examination primarily directed to clinical signs related to nutritional deficiency. During the winter examination hemoglobins and hematocrits were measured and where possible fecal samples were obtained for parasite examinations. Initially 1265 children between the ages of 6 months and 5 years were examined. Since children once in the study remained in it and new children were constantly added by the end of the study there were approximately 2400 children being examined. At each examination over 99 percent of the children were examined.

Thai Diets: Since the primary purpose of this study was to determine the effects of fortifying rice with lysine and threonine, it was considered important to make sure that these two amino acids were limiting in the diet of the Thais. Although rice makes up the bulk of the Thai diet, they eat many other foods and it was possible that the amino acids of the other foods would make up the deficits in rice. At the start of the study, the food used during one day by 29 families with 145 people in 4 villages was measured. The food was weighed before and after cooking. Waste was also weighed. The amino acid composition of the food consumed was calculated from the HEW-FAO food composition table for use in east Asia and from our amino acid analysis of the glutenous rice used in the villages studied. The adequacy of the protein in the diets consumed were calculated using the 1973 amino acid scoring patterns of FAO-WHO.

In using the food composition tables representive foods were selected which probably contained better proteins than those which were actually consumed. This was done so that errors in estimates of the biological value of the proteins consumed would be on the high side. For example, although most of the meat consumed was fried pork rind, for the purposes of our analysis chicken muscle was used. For fish, sardine analyses were used; for pulses, peanuts, for leafy vegetables, Chinese cabbage; and for other vegetables, beans with pods. The data obtained are presented in Table 1. It can clearly be seen that lysine and threonine are the limiting amino acids in the protein of the diets of the children but not the adults of this study. As indicated the data presented are probably an overestimate of the amino acid score of the Thai dietary protein. Of special importance is the amino acid composition of the rice consumed since 74 percent of the protein eaten came from glutenous rice. The calculations of Table 1 are based on our analyses which indicated 19 percent more lysine and 11 percent more threonine in glutenous rice than the analysis reported in the HEW-FAO food tables.

It can also be seen from this table that the use of the fortification mixture used generally corrected the lysine and threonine deficits in the protein of the Thai diets examined, although in the case of the suggested pattern for 10-12 year olds, the lysine level remained less than desirable. The somewhat low values for the S amino acids are generally considered to be mostly an artifact caused by analytical difficulties.

As the rice fortification study progressed, it was decided to have a closer look at the food intakes of some of the pre-school children. Eight children in each of three villages were studied. Each child was followed for

three days by a nutritionist and an estimate of the quality and amount of all food consumed was made. One of the villages, Harnkaew was selected because the average height and weight of the children in each age-group were high in comparison to the other villages of the study. The children of the other two villages, Sansai and Bantawai were among the lowest in average height and weight. The main difference in the diets of the children of the three villages was in the amount of rice consumed. The children of Harnkaew ate about 30 percent more rice than the children of the other two villages with the result that during the period of observation, the children of Harnkaew obtained the recommended allowances for calories but the children studied in the other two villages only received about 64 percent of their caloric needs.

Anthropometric and Blood Measurements. Table 2 presents a summary of the anthropometric and hemoglobin and hematocrit measurements made in Jan-Feb 1975 on the entire population of children studied according to age and sex. It is of interest that the bone age of the children determined from hand-wrist X-rays indicate considerable retardation in development which reaches about three years by age 9. We view this as being quite significant since we have reported bone maturation similar to that seen in normal American children in middle class Thai children through at least four years. Table 3 shows that there was a significant secular change in the lengths and weights of the study population from Jan 1971 to Jan 1975 in children 1-5 years of age. However, the size of these children was still considerably smaller than the values obtained in 1973 from middle class Bangkok children. These data point up the need to have adequate controls in a study such as this.

Because of the way in which data on the use of the RFG were collected it is possible to divide the population of children not only into users of RFG

and non-users but into groups according to the amount of use. If the intervention had been effective it would have been interesting to compare the effects observed with different levels of usage. Because no significant effects were observed to analyze the data in such a way would generate large numbers of meaningless figures. In Tables 4,5,6, and 7 the effects on children of using RFG-1 or RFG-2 two-thirds or more of the time have been compared to the effects on children who consumed the RFG less than 10 percent of the time. It can be seen that there were no significant changes in the anthropometric measurements or hemoglobin and hematocrit levels with RFG use whether measured over the 1971-1975 period or the 1974-1975 period.

Morbidity. As in the case of other measurements, in Table 8 it can be seen that in 1974 the use of RFG was not associated with any significant change in morbidity. Usually when nutrition intervention field studies in developing countries are negative, it is suggested by their critics that the problem was that the investigators had not been able to control the rampant disease in the population and that it should not be surprising that children with infections do not provide expected responses to nutrients.

Although our original contract did not require it, our concern over the possible effects of disease led us to develop a morbidity data collection system which I believe is unique in studies of this sort. We have morbidity data on each child collectedevery 15 days over a three year period. On the basis of these data it would be very difficult to support the contention that the growth retardation seen in the children studied was caused by disease.

Although, growth retardation in Thai village children is not generally caused by illness, occasional illness may have a short profound effect on growth.

In looking at the 1-5 year old children divided according to tertiles for morbidity, it is clearly shown in Table 9 that in 1974 there were no differences in length or weight changes or in hemoglobins or hematocrits in children related to morbidity. With the exception of children who suffer from grave illness what we have observed in looking at monthly length and weight changes (Last year we collected monthly length and weight data on several hundred children.) is that an abnormal loss in weight or inhibition of growth is usually associated with illness but upon recovery there is catch-up growth over the next couple of months so that the effects of the illness are not seen in yearly growth records.

Interestingly, as can be seen from Table 10 there does not appear to be more illness in children with angular lesions or hookworm than the population as a whole. These two conditions were examined in relationship to morbidity because they are often seen in the population and we expected their occurrence might be associated with increased morbidity.

As might be expected from our experience with school children attendance at a day care center was associated with a higher incidence of infectious disease as is shown in Table 11 . This usually took the form of mild respiratory disease. More than 50 percent of days of illness in Thai children are due to respiratory illness. There is surprisingly little diarrhea. In fact, there was surprisingly little illness in the entire population. These conclusions are confirmed by the data shown in Table 12 for the entire population of children studied. In general, illness was most prevalent during the monsoon season (summer) and in the younger children.

Nutrition Intervention Programs. We feel that having worked in Thai villages for so many years that it would be useful to AID to share some of our

thoughts about fortification and other nutrition programs, their feasibility and chances of acceptance among villagers in Thailand.

To our surprise even though no pressure was exerted there was little initial difficulty in obtaining the cooperation of Thai villagers when we asked them to participate in this study. This appeared to be due to the concern the people had for the health of their children and to the feeling based on their previous experience that the Thai Health Department was interested in them. This latter reason might not apply in some other Thai provinces or in some other Asiatic countries. Most of the people were willing to eat fortified rice as long as the fortificants did not taste too bad. Problems arose concerning the organoleptic properties of the RFG. Many complaints about the smell of RFG-1 and RFG-2 were heard. We believe that this may have been related to their thiamin content. Because of Thai laws prohibiting the import of rice or rice products we were forced to use corn starch as a filler in the RFG instead of rice flour. This clearly had a bad effect on palatability. It was quite clear that the addition of 20 percent lysine and 10 percent threonine to the RFG changed their texture if not their taste in an undesirable way. Probably the biggest acceptance problem had to do with the cooking properties of the RFG. The villagers stated that they did not mind if the RFG were softer than rice after cooking or whether it colored their rice when riboflavin was added. They were particularly against eating RFG which were hard following cooking. Unfortunately, we experienced three periods when the RFG were hard after cooking and lost participants each time. The first occurred three months into the full field study when the Ajinomoto Company was still experimenting with the

coating on the RFG. The second, which was particularly unfortunate coincided with the introduction of riboflavin into the RFG. The Ajinomoto Company changed the RFG covering to keep the colored riboflavin from leaking out during cooking. The third episode occurred in a few villages late in the study because some of the RFG being used had been kept in storage too long by us and apparently its cooking properties had altered. It was somewhat surprising to us and we expressed this many times during the study to people at Ajinomoto that at no time during the study did they make any effort to improve the quality of the RFG or to seriously discuss different delivery systems which might be used during a fortification program.

A major problem developed in the Spring of 1973 when the Thai government over sold its rice supplies and the price of rice increased 50 percent in three months. This was a problem to us because people were shopping in different markets for rice and it was imperative to our program that they obtain rice milled at their village mills. Even when rice became plentiful we continued to have a residue of this problem because the price of milling became unstable and villagers would in some cases take their paddy to cheaper mills outside their villages.

With all of these problems many villagers continued to use the RFG. When we asked them why we were told that it was because they understood that it would help their children. This is particularly encouraging to those of us who are interested in improving the health of children in developing countries.

The pre-school day care centers were a great success. Parents could appreciate their custodial care value immediately. Although for the purposes of this study we were unable to use the day care centers to provide nutritional benefits, we have become very impressed with them as a delivery system for

providing nutrition, health, and education programs. There were a number of reasons why some of the children did not attend the day care centers. One was that a number of children did not wish to leave their mothers or grandmothers who lavish affection on them. We found that if we could get such children to spend three days in the day care center, we would usually keep them. The other important reason had to due to the shape of the villages. Some of the villages are long and narrow. Land for the day care centers was hard to find and often the day care centers were not centrally located. Thus, in some cases parents found that the distance from their homes to the day care center made it inconvenient for them to enroll their children. The success of our day care centers is attested to by the fact that since financial support for their operation was terminated, the villagers have been paying to use them and they have continued to operate.

Dissemination and Utilization of Research Results. Two papers have been published and we eventually expect to publish 4 to 6 others:

Gershoff, S.N., R.B. McGandy, D. Suttapreyasri, A. Nondasuta, U. Pisolyabutra, and P. Tantiwongse. Amino acid fortification of rice studies in Thailand. I. Background and baseline data. Amer. J. Clin. Nutr. 28: 170, 1975.

Blackwell, R.Q., L. Yen, J.T.H. Huang, Y.O. Hung, A. Nondasuta, R. Vachananda, and S. Gershoff. Structural identification of haemoglobin E in a group of Thai subjects. Trop. Geogr. Med. 27: 93, 1975.

We assume that the results of this study and the recent marked increase in the cost of amino acids will discourage the implementation of costly ineffective amino acid fortification programs. On the other hand, the current study demonstrates that fortification of rice is feasible and suggests that villagers in developing countries are amenable to programs which may improve the nutritional status

and health of their children. The current study demonstrates a major gap in our understanding of the etiology of growth retardation in Thai children. This study has resulted in an increased awareness of nutrition among the decision makers in the Thai government. This has been demonstrated in the increased expenditures in the Thai budget for nutrition and in the promotions in rank which Thais associated with this program have received. It is the announced intention of the Thai government to continue these studies so that they can develop programs to improve the nutritional status and health of their children. We hope that we shall be able to serve them in this effort.

Table 1

Effects of Lysine and Threonine Fortification on Amino Acid Patterns of Thai Village Diets

	Isoleucine	*Leucine*	*Lysine*	*Methionine + Cystine*	*Phenylalanine + Tyrosine*	*Threonine*	*Tryptophan*	*Valine*
mg/g protein	37.9	70.0	42.6	29.2	62.7	30.6	20.9	45.6
mg/100g glutenous rice *	220	473	239	193	424	197	174	310
% Suggested FAO/WHO Patterns ( )								
Table 21	95	100	77(108)	83	105	77(103)	209	91
Table 20 - Infants	108	88	82(114)	101	100	70 (94)	246	97
10-12 years	102	125	57 (79)	86	184	70 (94)	454	112
Adults	211	280	194	122	251	235	322	253

*Analyses made using an amino acid analyzer by the Nutrition Division, Thai Department of Health.

Figures in ( ) represent amino acid scores for lysine and threonine if rice fortified with RFG-1 was used.

Table 2

Thai Village Children Anthropometric and Blood Measurement - 1975

MALE

Age	No. of Children	Length cm	Weight Kg	Bone, Age Year	Head Circum,cm	Chest Circum,cm	Arm Circum,cm	Triceps Skinfold,mm	Subscap. Skinfold,mm	HB	Hct
< 1	50	68.5 ± 4.1	7.8 ± 1.2	.73 ± .29	44.0 ± 1.6	44.5 ± 2.6					
1-1.99	115	76.5 ± 4.0	9.3 ± 1.1	1.46 ± .75	46.0 ± 1.3	47.1 ± 1.8	14.1 ± 1.0	8.1 ± 1.6	5.6 ± 1.1	10.9 ± 1.5	37 ± 4
2-2.99	120	83.1 ± 4.3	10.8 ± 1.3	2.05 ± .67	47.3 ± 1.4	49.5 ± 2.1	14.3 ± 1.0	8.7 ± 1.6	5.8 ± 1.2	11.4 ± 1.2	38 ± 3
3-3.99	125	90.6 ± 4.2	12.5 ± 1.4	2.89 ± .77	48.3 ± 1.3	51.0 ± 2.4	14.7 ± 0.8	9.0 ± 1.4	5.5 ± 1.1	11.5 ± 1.3	38 ± 3
4-4.99	137	96.7 ± 4.3	13.8 ± 1.4	3.47 ± .79	48.8 ± 1.3	52.1 ± 2.1	14.8 ± 0.8	8.4 ± 1.5	5.2 ± 1.0	11.6 ± 1.2	39 ± 3
5-5.99	128	102.4 ± 4.7	15.0 ± 1.6	4.25 ± .91	49.3 ± 1.2	52.7 ± 2.1	14.7 ± 1.0	7.2 ± 1.4	4.7 ± 0.8	11.7 ± 1.3	39 ± 3
6-6.99	141	107.8 ± 4.9	16.7 ± 1.9	4.85 ± 1.03	49.6 ± 1.3	54.0 ± 2.4	15.0 ± 0.9	6.6 ± 1.3	4.6 ± 0.8	11.7 ± 1.1	39 ± 3
7-7.99	152	113.1 ± 4.9	18.1 ± 2.1	5.44 ± 1.16	50.0 ± 1.2	55.1 ± 2.2	15.1 ± 1.0	6.1 ± 1.2	4.5 ± 0.7	12.1 ± 1.1	40 ± 3
8-8.99	131	118.0 ± 4.6	20.1 ± 2.2	6.17 ± 1.03	50.3 ± 1.5	57.2 ± 2.4	15.6 ± 0.9	5.8 ± 1.3	4.6 ± 0.8	12.2 ± 1.1	41 ± 3
> 9	22	122.5 ± 4.5	22.2 ± 2.5	6.84 ± .88	51.0 ± 1.4	58.7 ± 2.8	16.1 ± 1.1	6.0 ± 1.5	4.7 ± 0.7	12.3 ± 1.1	40 ± 3

FEMALE

< 1	59	67.1 ± 3.5	7.4 ± 1.0	.68 ± .38	43.0 ± 1.6	43.7 ± 2.3					
1-1.99	133	74.9 ± 4.3	8.8 ± 1.0	1.40 ± .59	45.0 ± 1.2	46.3 ± 2.3	13.6 ± 0.8	8.2 ± 1.4	5.9 ± 1.1	10.8 ± 1.5	37 ± 3
2-2.99	106	83.4 ± 3.5	10.7 ± 1.0	2.16 ± .57	46.5 ± 1.0	48.9 ± 1.9	14.1 ± 0.8	9.2 ± 1.6	6.1 ± 1.2	11.4 ± 1.5	38 ± 3
3-3.99	121	90.2 ± 4.8	12.2 ± 1.4	2.55 ± .67	47.2 ± 1.3	50.2 ± 2.1	14.6 ± 0.9	9.4 ± 1.6	6.0 ± 1.2	11.6 ± 1.4	39 ± 3
4-4.99	107	96.6 ± 4.6	13.6 ± 1.5	3.12 ± .91	48.1 ± 1.2	51.1 ± 2.2	14.9 ± 0.9	8.8 ± 1.6	5.6 ± 1.2	11.6 ± 1.3	39 ± 3
5-5.99	146	102.7 ± 4.5	15.0 ± 1.6	3.82 ± .93	48.5 ± 1.3	52.0 ± 2.3	14.8 ± 0.9	8.2 ± 1.6	5.2 ± 0.9	11.9 ± 1.2	39 ± 3
6-6.99	144	107.0 ± 5.5	16.2 ± 1.8	4.41 ± .95	48.9 ± 1.6	52.3 ± 2.1	15.1 ± 0.8	7.8 ± 1.3	5.2 ± 1.0	11.8 ± 1.5	39 ± 3
7-7.99	129	112.9 ± 4.6	17.9 ± 1.9	4.96 ± .67	49.1 ± 1.1	54.4 ± 2.3	15.4 ± 0.9	7.1 ± 1.5	5.2 ± 1.1	12:2 ± 1.3	39 ± 3
8-8.99	148	117.5 ± 5.5	19.7 ± 2.6	5.36 ± .51	49.5 ± 1.3	55.9 ± 2.6	15.6 ± 1.1	7.1 ± 1.7	5.1 ± 1.2	12.1 ± 1.3	40 ± 3
> 9	16	124.5 ± 6.1	22.5 ± 2.7	5.51 ± .25	50.1 ± 1.0	58.0 ± 2.6	16.3 ± 0.8	7.7 ± 1.4	5.4 ± 0.7	12.3 ± 1.2	41 ± 2

Table 3

Secular Changes in Length and Weight

of Chiang Mai Village Children 1971 to 1975

	Age	.5-.99	1-1.99	2-2.99	3-3.99	4-4.99
Village Children, 1971	Length, cm	66.2	74.7	81.7	89.8	96.0
	Weight, Kg	7.3	8.9	10.6	12.3	13.7
Village Children, 1975	Length, cm	67.7	75.6	83.2	90.4	96.7
	Weight, Kg	7.6	9.0	10.8	12.4	13.7
Middle Class, Bangkok Children, 1973	Length, cm	69.5	78.4	88.3	96.8	102.0
	Weight, Kg	8.1	10.4	11.9	14.2	15.0

Table 4

Effects of RFG on Anthropometric Blood Data

Changes from 1971-75

- Use of RFG-1

Age	*No. of Children*	*Length cm*	*Weight Kg*	*Head Circum,cm*	*Chest Circum,cm*	*Arm Circum,cm*	*Triceps Skinfold,mm*	*Subscap. Skinfold,mm*	*Hb*	*Hct*
4	10	31.2 ± 3.5	6.7 ± 1.1	6.5 ± 1.7	9.7 ± 3.0					
5	30	28.0 ± 3.1	6.0 ± 0.9	3.8 ± 0.9	6.6 ± 2.5	1.2 ± 1.1	0.5 ± 2.0	0.1 ± 1.1	1.1 ± 1.5	1.7 ± 4.3
6	40	24.2 ± 2.3	5.3 ± 0.9	2.6 ± 0.6	4.3 ± 1.8	0.7 ± 0.7	-.9 ± 1.7	-.6 ± 1.2	0.5 ± 1.4	1.1 ± 4.1
7	29	22.4 ± 2.2	5.3 ± 1.2	2.1 ± 0.7	4.1 ± 1.9	0.4 ± 1.1	-1.6 ± 1.5	-.5 ± 1.3	0.3 ± 1.7	0.8 ± 3.5
8	33	21.7 ± 3.0	6.3 ± 1.4	1.9 ± 0.4	5.6 ± 1.8	0.9 ± 0.9	-1.2 ± 1.3	.03 ± 1.3	0.1 ± 1.2	0.8 ± 2.8
9	3	20.4 ± 1.6	5.1 ± 1.6	1.6 ± 0.1	5.7 ± 1.3	1.7 ± 0.7	0 ± 1.0	1.0 ± 1.0	1.7 ± 0.9	4.7 ± 2.1

+ Use of RFG-1

4	11	31.5 ± 2.7	6.8 ± 1.0	5.8 ± 1.1	8.8 ± 2.7					
5	17	27.7 ± 2.2	6.1 ± 1.0	3.8 ± 1.0	6.1 ± 2.2	1.1 ± 1.0	1.4 ± 1.0	-.2 ± 1.1	1.0 ± 1.6	0.3 ± 4.2
6	13	25.2 ± 2.4	5.9 ± 1.1	3.0 ± 0.6	4.8 ± 1.9	0.9 ± 0.9	1.5 ± 0.7	-.5 ± 0.8	0.5 ± 1.4	0.3 ± 4.6
7	13	22.8 ± 1.3	5.9 ± 1.1	2.3 ± 0.6	5.1 ± 1.4	0.8 ± 0.7	2.4 ± 0.8	-.6 ± 0.9	0.2 ± 1.2	0.6 ± 3.2
8	17	21.6 ± 2.0	6.3 ± 1.4	2.0 ± 0.5	6.0 ± 1.7	1.2 ± 0.8	-1.0 ± 1.6	0.3 ± 0.8	0.2 ± 1.5	-.2 ± 4.2
9	3	20.0 ± 1.6	7.1 ± 1.6	1.5 ± 0.6	6.4 ± 0.7	1.3 ± 1.1	-.7 ± 1.1	1.0 ± 1.0	1.2 ± 0.6	0.7 ± 2.3

+, children consumed RFG 2/3 or more of the time.

-, children consumed RFG less than 10% of the time.

Table 5

Effects of RFG on Anthrompometric Blood Data

Changes from 1971-75

Age	No. of Children	Length cm	Weight Kg	Head Circum,cm	Chest Circum,cm	Arm Circum,cm	Triceps Skinfold,mm	Subscap. Skinfold,mm	Hb	Hct
- Use of RFG-2										
4	2	30.6 ± 5.1	5.8 ± 1.3	6.0 ± 1.6	9.4 ± 2.5					
5	5	27.3 ± 4.8	6.0 ± 0.9	3.4 ± 0.7	6.2 ± 2.1	1.4 ± 0.3	0.0 ± 0.7	1.2 ± 1.3	0.9 ± 2.7	-.2 ± 6.7
6	5	23.4 ± 5.6	5.6 ± 1.7	2.7 ± 0.9	5.3 ± 1.3	0.6 ± 0.2	-1.4 ± 1.5	-2.0 ± 1.2	-1.2 ± 1.2	2.0 ± 3.7
7	2	31.8 ±10.0	6.1 ± 1.1	3.8 ± 2.3	5.4 ± 0.1	0.1 ± 0.8	-1.5 ± 0.7	-3.0 ± 2.8	0.5 ± 1.3	1.0 ± 2.8
8	6	21.6 ± 2.3	5.7 ± 1.1	2.2 ± 0.4	5.2 ± 1.6	1.2 ± 0.5	1.2 ± 1.3	-.2 ± 0.7	-.2 ± 1.3	-1.5 ± 2.9
9	3	22.5 ± 1.9	8.3 ± 2.8	1.5 ± 0.5	8.1 ± 1.3	2.0 ± 1.2	0.3 ± 2.0	1.0 ± 1.0	0.9 ± 1.2	1.3 ± 1.5
+ Use of RFG-2										
4	11	32.1 ± 3.6	6.6 ± 1.1	5.7 ± 1.2	7.7 ± 2.0					
5	18	26.7 ± 1.9	5.7 ± 0.7	3.5 ± 0.7	5.7 ± 2.8	1.0 ± 0.5	-.2 ± 1.0	-.06± 0.9	0.9 ± 1.4	1.5 ± 3.9
6	11	24.9 ± 2.0	5.7 ± 1.2	2.6 ± 0.7	4.2 ± 2.8	1.2 ± 1.0	-.7 ± 1.5	-.4 ± 1.6	-.1 ± 1.6	-.5 ± 2.8
7	11	22.4 ± 1.8	5.1 ± 1.0	2.0 ± 0.5	4.4 ± 2.4	0.5 ± 0.7	-2.2 ± 1.2	-.6 ± 0.9	0.2 ± 0.9	0.6 ± 4.0
8	13	22.3 ± 1.7	6.3 ± 1.1	1.7 ± 0.3	5.6 ± 1.7	1.4 ± 1.0	-.8 ± 1.1	0.2 ± 1.2	.05± 1.1	0.5 ± 3.1

+, Children consumed RFG 2/3 or more of the time.

-, Children consumed RFG less than 10% of the time.

Table 6

Effect of RFG Usage on Anthropometric and Blood Value Changes 1974-75

Age	No. of Children	Length cm	Weight kg	Head circum,cm	Chest circum,cm	Arm circum,cm	Triceps skinfold,mm	Subscap. skinfold,mm	Hb	Hct
					- Use of RFG-1					
1	22	10.2 ± 1.5	1.8 ± .6	2.4 ± .8	3.3 ± 1.7					
2	22	8.1 ± 1.3	1.7 ± .6	1.6 ± .7	2.9 ± 1.6	.5 ± .8	.9 ± 1.7	.5 ± 1.1	.1 ± 1.5	3.0 ± 3.5
3	24	6.2 ± 1.3	1.6 ± .5	.8 ± .3	1.6 ± 2.0	.6 ± .5	.5 ± 1.7	-.2 ± .9	-.2 ± 1.5	1.1 ± 3.4
4	18	6.1 ± 1.1	1.2 ± .4	.6 ± .4	1.6 ± 1.0	.3 ± .4	-.4 ± 1.0	-.3 ± .9	-.6 ± 1.2	1.9 ± 2.7
5	29	5.4 ± .9	1.1 ± .5	.4 ± .2	1.3 ± 1.5	.0 ± .5	-1.0 ± 1.1	-.4 ± .8	-.9 ± .9	.7 ± 2.7
6	41	5.3 ± .9	1.5 ± .5	.3 ± .3	1.4 ± 1.0	.3 ± .5	-.5 ± .9	.1 ± .7	-1.1 ± 1.4	.5 ± 2.7
7	29	4.8 ± .8	1.6 ± .5	.3 ± .2	1.5 ± .9	.4 ± .5	-.1 ± .8	.0 ± .6	-1.1 ± 1.4	.8 ± 2.9
8	33	4.5 ± .5	1.9 ± .8	.4 ± .3	1.7 ± 1.0	.5 ± .6	-.1 ± 1.0	.3 ± .8	-1.3 ± 1.4	-1.9 ± 1.5
9	3	4.9 ± 1.0	1.2 ± 1.4	.1 ± .2	2.0 ± .8	.8 ± .2	1.3 ± 1.1	1.0 ± 1.0	.8 ± 2.4	4.0 ± 1.7
					+ Use of RFG-1					
1	3	11.6 ± 3.5	1.8 ± .9	2.8 ± 1.3	2.9 2.0	±				
2	13	8.3 ± 1.3	2.0 ± .3	1.4 ± .4	2.4 1.8	.5 ± .4	.5 ± 1.0	0.0 ± .8	.1 ± 1.5	2.5 ± 2.7
3	11	6.8 ± 1.5	1.5 ± .5	.9 ± .4	1.0 1.1	.7 ± .6	.3 ± 1.3	-.1 ± 1.1	.6 ± .8	.1 ± 2.7
4	17	6.0 ± .9	1.3 ± .5	.6 ± .3	1.5 1.1	.3 ± .5	-1.2 ± 1.4	-.5 ± .9	-.7 ± 1.8	.7 ± 2.2
5	17	5.9 ± .7	1.5 ± .5	.5 ± .3	1.4 1.0	.4 ± .4	-.4 ± .9	-.2 ± .7	-1.3 ± 1.2	1.1 ± 2.0
6	13	5.4 ± .8	1.5 ± .4	.5 ± .3	1.5 .7	.2 ± .5	-.8 ± .7	-.2 ± .6	-.9 ± 1.5	1.8 ± 2.3
7	14	5.0 ± 1.1	1.9 ± .6	.4 ± .2	2.4 .8	.7 ± .5	-.6 ± .6	-.1 ± .8	-.5 ± 1.1	1.1 ± 2.9
8	17	4.8 ± 1.1	1.9 ± .6	.4 ± .3	2.2 1.4	.7 ± .4	-1.0 ± 1.6	.2 ± .4	-1.1 ± 1.1	-.4 ± 2.6
9	3	5.1 ± .3	2.0 ± .8	.0 ± .4	2.0 2.0	.5 ± .5	-.7 ± 1.1	.3 ± .6	.2 ± .4	4.7 ± .6

+, children consumed RFG 2/3 or more of the time.

-, children consumed RFG less than 10% of the time.

Table 7

Effect of RFG Usage on Anthropometric and Blood Value Changes 1974-75

Age	No. of Children	Length cm	Weight cm	Head Circum,cm	Chest Circum,cm	Arm Circum,cm	Triceps Skinfold,mm	Subscap. Skinfold,mm	Hb	Hct
-USE OF RFG 2										
1	7	9.3 ± 1.1	1.9 ± 0.5	2.7 ± 1.1	4.2 ± 1.2					
2	8	8.1 ± 1.9	2.0 ± 0.5	1.8 ± 0.5	3.2 ± 1.7	0.7 ± 0.9	1.4 ± 1.3	0.7 ± 0.7	-.5 ± 1.7	2.6 ± 2.4
3	4	6.1 ± 0.4	1.0 ± 0.1	0.6 ± 0.1	1.7 ± 2.5	0.2 ± 0.4	-1.2 ± 0.9	-1.7 ± 0.9	1.3 ± 0.4	-.7 ± 2.1
4	3	6.1 ± 0.4	1.1 ± 0.5	0.6 ± 0.2	1.5 ± 0.8	0.3 ± 0.4	0.0 ± 0.1	-.3 ± 0.6	-.3 ± 0.5	2.0 ± 1.7
5	5	5.6 ± 0.8	1.3 ± 0.3	0.5 ± 0.1	0.5 ± 0.9	0.3 ± 0.3	-.4 ± 1.9	-.2 ± 1.3	-.9 ± 1.2	2.5 ± 2.1
6	5	5.7 ± 1.1	1.7 ± 0.5	0.3 ± 0.1	1.5 ± 1.1	0.4 ± 0.5	-.4 ± 0.9	0.0 ± 0.0	-1.0 ± 1.7	1.5 ± 3.0
7	2	5.5 ± 1.3	1.0 ± 0.1	0.6 ± 0.2	0.7 ± 1.0	-.2 ± 0.1	-1.0 ± 0.0	0.0 ± 0.0	-1.7 ± .07	2.5 ± 3.5
8	7	4.6 ± 1.0	1.5 ± 0.7	0.5 ± 0.3	1.8 ± 1.0	0.4 ± 0.3	-.3 ± 1.1	.14 ± 0.9	-.8 ± 0.9	1.0 ± 2.3
9	3	5.5 ± 1.5	2.8 ± 2.0	0.3 ± 0.2	3.0 ± 2.0	0.5 ± 0.5	0.7 ± 0.6	0.0 ± 0.0	-.9 ± 2.1	0.7 ± 1.5
+USE OF RFG 2										
1	3	10.9 ± 1.4	2.0 ± 0.6	2.9 ± 1.2	3.2 ± 1.3					
2	4	7.5 ± 1.3	1.6 ± 0.4	0.6 ± 1.6	3.0 ± 1.6	0.4 ± 0.9	1.0 ± 0.8	1.0 ± 0.8	-.3 ± 0.9	5.0 ± 2.6
3	12	6.5 ± 1.5	1.5 ± 0.3	0.9 ± 0.2	1.2 ± 1.2	0.5 ± 0.5	0.1 ± 1.7	0.2 ± 0.6	-.7 ± 0.9	0.2 ± 1.9
4	13	6.0 ± 0.9	1.3 ± 0.2	0.5 ± 0.2	1.7 ± 0.9	0.3 ± 0.3	-.8 ± 0.9	-.5 ± 1.0	-.2 ± 1.2	0.4 ± 2.0
5	18	5.5 ± 0.7	1.3 ± 0.5	0.4 ± 0.2	1.7 ± 2.0	0.3 ± 0.4	-.8 ± 0.9	-.3 ± 0.9	-.8 ± 1.0	0.8 ± 1.7
6	12	5.3 ± 0.8	1.4 ± 0.6	0.4 ± 0.2	1.3 ± 0.9	0.4 ± 0.8	-1.2 ± 1.5	-.5 ± 1.2	-.9 ± 1.3	0.7 ± 2.4
7	11	4.7 ± 0.6	1.5 ± 0.5	0.3 ± 0.3	2.0 ± 1.2	0.3 ± 0.4	-.6 ± 0.5	0.1 ± 0.7	-1.0 ± 0.9	2.1 ± 2.6
8	13	4.8 ± 0.5	2.0 ± 1.1	0.2 ± 0.3	1.4 ± 1.2	0.9 ± 1.0	0.1 ± 0.8	0.5 ± 0.9	-.6 ± 1.0	0.5 ± 1.3

Children consumed RFG 2 3 or more of the time.

Children consumed RFG less than 10% of the time.

Table 8

Effect of RFG Use on Total Morbidity

Group	Use of RFG	MEAN % DAYS ILL IN 1974 Age 1	2	3	4	5
RFG-1	Yes	6.5 (17)	6.8 (11)	6.4 (19)	2.9 (18)	8.9 (16)
	No	4.9 (23)	8.0 (30)	5.1 (22)	3.5 (33)	7.9 (46)
RFG-2	Yes	3.9 (6)	4.1 (11)	2.0 (11)	5.3 (17)	2.2 (10)
	No	4.8 (17)	4.7 (11)	5.4 (8)	3.0 (14)	3.3 (14)
RFG-3	Yes	4.9 (11)	5.2 (16)	6.0 (19)	4.0 (15)	2.5 (20)
	No	5.0 (8)	8.1 (14)	5.4 (14)	3.9 (5)	3.4 (17)

Figures in ( ) = No. of Children

Yes = RFG consumed 2/3 or more of the time
No = RFG consumed less than 10 percent of the time

Table 9

Effects of Morbidity on Development

Male Thai Children

Age	1	2	3	4	5
Morbidity Tertile		*Height Change, cm. (1974-75)*			
1	7.4	6.6	5.8	5.4	5.0
2	7.6	6.2	5.7	5.3	5.2
3	7.3	6.6	5.8	5.4	5.1
		Weight Change, kilo			
1	1.7	1.3	1.3	1.5	1.6
2	1.8	1.4	1.2	1.1	1.4
3	1.6	1.6	1.2	1.3	1.5
		Hemoglobin			
1	11.1	12.0	11.4	11.6	11.6
2	11.7	12.0	11.8	11.8	11.7
3	11.3	11.1	11.7	11.7	11.7
		Hematocrit			
1	38	38	38	39	39
2	39	38	39	39	39
3	38	37	39	39	39

Female Thai Children

		Height Change, cm			
1	7.5	6.5	6.1	5.5	5.2
2	7.9	6.9	6.2	5.7	5.4
3	7.6	6.8	6.2	5.6	5.2
		Weight Change			
1	1.7	1.4	1.2	1.3	1.4
2	1.8	1.5	1.4	1.3	1.5
3	1.6	1.5	1.4	1.3	1.3
		Hemoglobin			
1	11.4	12.0	11.4	11.9	12.0
2	11.5	11.8	11.7	12.0	11.7
3	11.3	11.4	11.5	11.8	11.7
		Hematocrit			
1	39	40	39	40	40
2	38	39	39	39	39
3	38	39	39	39	39

Tertiles of Morbidity 1, 2, 3 (low to high) during 1974.

Table 10

Relationship of Incidence of Hookworm and Angular Lesions to Morbidity in Thai Village Children 1-5 Years of Age - 1974

% of Days Ill	0 - 1	1.1 - 4	> 4
Total Population	18.7	36.7	44.5
With Hookworm	24.8	32.8	42.3
With Angular Lesions	20.5	35.2	44.3

Values given as %. Total population 1163. 7.6% had angular lesions at end of 1974. Approximately 25% were infected with hookworm. Our hookworm figures are underestimates because in a single stool examination the parasite can be missed.

Table 11

Effect of Day Care Centers on Total Morbidity

Group	Use of DCC	MEAN % DAYS ILL IN 1974 Age 1	2	3	4	5
Raw Control	No	6.0 (62)	4.2 (57)	5.1 (54)	4.8 (70)	2.5 (68)
RFG-3 + DCC	Yes	5.3 (8)	5.7 (28)	5.7 (41)	4.2 (27)	2.4 (31)
	No	5.6 (14)	8.5 (8)	2.7 (6)	3.8 (2)	1.1 (8)
RFG-2 + DCC	Yes	3.1 (3)	6.3 (22)	4.8 (25)	4.4 (42)	2.6 (26)
	No	4.4 (37)	2.8 (17)	1.1 (5)	1.1 (6)	2.5 (8)
RFG-1 + DCC	Yes	8.6 (12)	18.2 (22)	10.9 (19)	5.4 (34)	13.9 (24)
	No	5.7 (16)	2.3 (8)	2.8 (8)	2.8 (8)	2.2 (15)
RFG-1 - DCC	No	4.1 (32)	4.5 (52)	4.5 (39)	2.3 (54)	3.1 (51)

Figures in ( ) = No. of Children

Table 12

Morbidity in Thai Village Children

	Mean		Median	
	1973	1974	1973	1974
Total Days Ill	8	16	5	9
U.R.I.	5	9	3	6
Diarrhea	.04	1	-	-