PROTEIN-ENERGY INTAKES IN A MALNOURISHED POPULATION AFTER INCREASING THE SUPPLY OF THE DIETARY STAPLES

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This paper examines the extent to which food intake in malnourished populations is affected by increasing the availability of the dietary staples. Free amounts of corn and beans were supplied to 47 families in a rural Guatemalan community during eight weeks. Relative to a six-week baseline period, adults increased their intakes by about 400 kcal (1.68 MJ) and 15 g of protein per day. The average changes for pre-school children were 198 kcl (0.83 MJ) and 5.8 g of protein per day. The findings suggest that it is possible for adults to satisfy their energy and protein needs by consuming more corn and beans. In children, bulk may be a limiting factor and it may be necessary to resort to additional measures, such as increasing the energy density of the diet, to satisfy needs.

KEY WORDS: Protein-energy malnutrition, beans, staple foods, dietary intakes, corn.

INTRODUCTION

The nutritional adequacy of diets has been the subject of intensive study in developing nations since the first descriptions of protein-energy malnutrition (PEM) appeared in the scientific literature some 40 years ago (Williams, 1933). Though deficiencies in many nutrients were soon identified, most of the early research indicated that the lack of good quality protein was the principal dietary problem. This position has been reassessed in recent years and the view that prevails now is that protein deficiency is secondary to energy deficits in most of the world (Sukhatme and Margen, 1978). Nonetheless, there is still considerable controversy among nutrition experts over the relative importance of protein and energy deficiencies in the diets of developing nations (Scrimshaw, 1977). The protein-calorie debate is more than academic for its resolution involves a selection of corrective measures among alternatives which may vary widely in terms of cost and feasibility and which may imply marked shifts in the food production policies of developing countries.

In a sense, it would be desirable if the current view stressing energy rather than protein were correct because the proposed solutions would not necessarily involve the introduction of novel foods, a procedure which would face considerable cultural and economic barriers. For instance, Gopalan *et al.* (1973) claim that in India, energy and protein needs may be met simply by eating more of the cereal-based diet. If true, this indication would also apply to many other areas where the staples include a cereal and a legume.

The proposition that malnourished populations will in fact eat more of the basic diet if more food is made available to them needs to be tested. It is certainly possible, particularly in the case of children, that consumption of cereal-based diets, with their low energy density, is limited by bulk. The monotony of the diet may also be a factor in explaining the low intakes. Recently, Mata *et al.* (1977) suggested that the high prevalence of infectious disease in developing countries, through its effects on appetite and other mechanisms, may be as important a cause of low intakes as food availability. For a variety of noneconomic reasons therefore, people may simply not be able or willing to eat more of the usual diet.

The food staples of much of Central America and Mexico, are corn and beans. In rural Guatemala, these foods provide 75 percent of the energy intake (INCAP, 1969). Whereas the ratio of corn to beans usually consumed approaches 91/10 (dry weight), maximal protein quality, as determined in animal studies, is provided by a mixture of 72 percent corn and 28 percent beans (Bressani, Valiente, and Tejada, 1962). Such a mixture was utilized in a study of two- and three-year-old children in a metabolic ward. The experimental diet supplied 1.74 g of protein and 100 kcal (0.42 MJ) per kilogram of body weight and was supplemented with liberal amounts of vitamins and minerals. It was found that the children in the corn/bean diet exhibited nitrogen retention rates judged adequate for maintenance and normal growth (Arroyave, 1973).

The present study represents a practical test of the potential of corn and beans for correcting protein-energy deficiencies in free living populations. The study was carried out in a rural Guatemalan community and involved the distribution of corn and beans and the measurement of the resulting dietary impact. Specifically, the field nutrition experiment was guided by the following questions:

a) To what extent are adults and children able to consume more corn and beans?

b) Does the increased consumption, if any, affect consumption of other foods?

c) Is the ratio of corn to beans affected?

d) What is the net effect on protein and energy intakes for adults and children?

MATERIAL AND METHODS

The study was conducted in a small coffee plantation located in the mountain slopes facing the Pacific Coast of Guatemala, an area known to have high prevalences of protein-energy malnutrition. The settlement was permanent, the heads of household being salaried agricultural workers employed throughout the year. Most of the inhabitants of the community were Indian, though all spoke Spanish reasonably well. Families did not cultivate their own corn but instead purchased it from the landlord every two weeks at below market prices. The quantity that a family could purchase was a function of the family's size and age composition. Beans and other foods were bought by the families in nearby markets.

There were two phases to the study, a baseline (six weeks) and an intervention (eight weeks) phase. During both phases, dietary intakes of fathers, mothers, and children six years or younger were estimated from 24-hour recall dietary surveys. All reports were provided by the mothers. The food composition tables for Central America (Flores *et al.*, 1960) were utilized to convert amounts of foods consumed to nutrients. As dietary surveys were carried out every week, a maximum of six and eight surveys respectively were available per individual during baseline and intervention phases.

All families received free amounts of corn and beans during the intervention phase of the study. The foods provided were distributed every two weeks at the same time the families picked up their regular supply of corn. Each family received 100 g of beans and 90 g of corn per day per individual, amounts which provided 653 calories (2.74 MJ) and 30.1 g of protein per capita. These quantities exceeded the estimated average energy deficits (INCAP, 1969). This was purposely done for the following reasons. It was expected that upon receiving free beans, the families would not have purchased the customary amounts and hence the large quantity of beans provided. In addition, an abundant supply of beans were provided in order to find out whether families would increase bean consumption relative to corn. As the corn was obtained from the plantation, the quantity of corn normally received by the family was not expected to vary. However, because the families were to be told that the distribution was to last for only two months, it was anticipated, though not investigated, that some of the corn and beans provided would be stored for later use.

At least four dietary surveys were collected on each individual for each of the two phases of the study. These data provided estimates of the mean intake of individuals during each of the phases. The average of the mean intakes of individuals during the first and second phases were then compared to detect changes resulting from the intervention. The comparisons were carried out for fathers, mothers, and for three age groups in children: less than 24 months, children 24–47 months, and children 48–72 months of age.

TABLE I

Protein and energy intakes ($\bar{X} \pm$ S.D.) before and during the intervention

Group	n	Energy (kcal/day) Before	Energy (kcal/day) After	Energy (kcal/day) Change	Energy (MJ/day) Before	Energy (MJ/day) After	Energy (MJ/day) Change	Protein (g/day) Before	Protein (g/day) After	Protein (g/day) Change
Adults										
Fathers[a]	45	2656 ± 656	3080 ± 646	424[e]	11.16 ± 2.76	12.94 ± 2.71	1.78	80.4 ± 18.4	96.5 ± 18.1	16.1[e]
Mothers	47	1773 ± 340	2177 ± 426	404[e]	7.45 ± 1.43	9.14 ± 1.79	1.69	53.7 ± 11.5	67.5 ± 13.4	13.8[e]
Children (months)										
0–23	15	428 ± 374	663 ± 424	235[d]	1.80 ± 1.57	2.78 ± 1.78	0.98	13.1 ± 13.9	18.4 ± 12.8	5.3
24–47	12	736 ± 235	837 ± 245	101	3.09 ± 0.99	3.52 ± 1.03	0.42	20.2 ± 6.6	24.6 ± 6.6	4.4[c]
48–72	13	1094 ± 402	1339 ± 426	245[d]	4.59 ± 1.69	5.62 ± 1.79	1.04	30.5 ± 9.0	38.3 ± 11.4	7.8[c]
Total[b]	40	737 ± 349	935 ± 380	198[e]	3.10 ± 1.47	3.93 ± 1.60	0.83	20.9 ± 10.6	26.7 ± 10.8	5.8[e]

[a] Fathers were not present in two of the families.
[b] Weighted means and standard deviations.
[c d e] Paired t-test significant at 5, 1, and 0.1 percent respectively.

RESULTS

The mean energy and protein intake of fathers, mothers, and young children is given in Table I for the baseline and intervention phases of the study. Relative to intakes during the baseline period, adults increased their intakes by about 400 kcal (1.68 MJ) and 15 g of protein per day. The average changes for all preschool children were 198 kcal (0.81 MJ) and 5.8 g of protein per day.

The effect on dietary intakes appears to have been more pronounced in those adults with poorer diets during the baseline period. This is suggested by data in Table II, where it is observed that the estimated change in intake is always greater for the lowest and always smallest for the highest tercile of initial energy and protein intake. For example, the energy intake of fathers in the lowest tercile during the baseline period increased from 2017 kcal (8.47 MJ) to 2711 kcal (11.39 MJ) per day, a change of 694 kcal (2.91 MJ) per day. The intake of the middle tercile changed by 486 kcal (2.04 MJ) and that for the highest changed the least, 141 kcal (0.59 MJ) per day.

Consumption of the staples increased in all groups during the period of food distribution as shown in Table III. Adults appear to have increased their intake of corn by 74 g and of beans by 29 g. The changes in children were of lesser magnitude, 32 g of corn and 9 g of beans.

Indirect estimates of the extent to which the increased consumption of corn and beans affected consumption of other foods is shown in Table IV for energy and Table V for protein intake. The first column shows the observed increment in energy or protein intake as already shown in Table I. In the next three columns the energy or the protein value of the reported increment in consumption of corn and beans (Table III) are shown. The difference between the energy or the protein provided by the

TABLE II

Energy and protein intake ($\bar{X} \pm$ S.D.) before and during the intervention by terciles of initial intake[a]

Group	Tercile	n	Energy (kcal/day) Before	Energy (kcal/day) After	Energy (kcal/day) Change	Energy (MJ/day) Before	Energy (MJ/day) After	Energy (MJ/day) Change	Protein (g/day) Before	Protein (g/day) After	Protein (g/day) Change
Fathers	Lower	15	2017 ± 226	2711 ± 276	694	8.47 ± 1.12	11.39 ± 1.16	2.91	65.7 ± 8.6	88.3 ± 7.9	22.6
	Middle	15	2557 ± 164	3043 ± 609	486	10.74 ± 0.69	12.78 ± 2.56	2.04	76.2 ± 9.2	94.0 ± 17.5	17.8
	Upper	15	3346 ± 537	3487 ± 733	141	14.05 ± 2.26	14.64 ± 3.08	0.59	98.8 ± 17.7	107.1 ± 21.3	8.3
Mothers	Lower	16	1455 ± 100	2110 ± 387	655	6.11 ± 0.42	8.86 ± 1.63	2.75	43.9 ± 4.3	65.2 ± 13.7	21.3
	Middle	15	1726 ± 92	2090 ± 538	364	7.25 ± 0.39	8.78 ± 2.26	1.53	53.5 ± 9.6	64.6 ± 15.6	11.1
	Upper	16	2108 ± 239	2335 ± 301	227	8.85 ± 1.00	9.81 ± 1.26	0.95	62.9 ± 8.8	72.7 ± 9.0	9.8

[a] Terciles for energy and protein intake were defined separately.

TABLE III

Corn and bean consumption ($\bar{X}$ ± S.D.) before and during the intervention

Group	n	Corn (g/day) Before	After	Change	Beans (g/day) Before	After	Change
Adults							
Fathers	45	425 ± 132	503 ± 161	78[d]	28 ± 14	62 ± 23	34[d]
Mothers	47	272 ± 68	342 ± 90	69[d]	20 ± 11	43 ± 15	23[d]
Children (months)							
0–23	15	44 ± 55	75 ± 65	31[c]	3 ± 5	9 ± 10	6[b]
24–47	12	87 ± 49	108 ± 73	21	8 ± 8	17 ± 9	9[b]
48–72	13	155 ± 88	198 ± 110	43[c]	10 ± 3	23 ± 8	13[d]
Total[a]	40	93 ± 66	125 ± 84	32[d]	7 ± 5	16 ± 9	9[d]

[a] Weighted means and standard deviations.
[b c d] Paired t-test significant at 5, 1, and 0.1 percent respectively.

TABLE IV

The contribution of corn and beans to the observed increment in daily energy intake[a]

Group	n	Net caloric increment (N) kcal	MJ	Calories from additional corn consumed (C) kcal	MJ	Calories from additional beans consumed (B) kcal	MJ	Calories from additional corn and beans (T = C + B) kcal	MJ	Unexplained calories (U = N − T) kcal	MJ	Ratio of corn and bean calories to net caloric increment (R = T/N)
Adults												
Fathers	45	424	1.78	268	1.13	117	0.49	385	1.62	39	0.16	0.91
Mothers	47	404	1.70	237	1.00	79	0.33	316	1.33	88	0.37	0.78
Children (months)												
0–23	15	235	0.99	107	0.45	21	0.09	128	0.54	107	0.45	0.54
24–47	12	101	0.42	72	0.30	31	0.13	103	0.43	−2	−0.01	1.02
48–72	13	245	1.03	148	0.62	45	0.19	193	0.81	52	0.21	0.79
Total	40	198	0.83	111	0.47	31	0.13	142	0.60	56	0.24	0.72

[a] The energy value of 100 g of corn and 100 g of beans is 344 kcal (1.44 MJ) and 343 kcal (1.44 MJ) respectively (Flores *et al.*, 1960).

TABLE V

The contribution of corn and beans to the observed increment in protein intake (g/day)[a]

Group	n	Net protein increment (N)	Protein from additional corn consumed (C)	Protein from additional beans consumed (B)	Protein from additional corn and beans (T=C+B)	Unexplained protein (U=N−T)	Ratio of corn and bean calories to net caloric increment (R=T/N)
Adults							
Fathers	45	16.1	6.4	7.7	14.1	2.0	0.88
Mothers	47	13.8	5.7	5.2	10.9	2.9	0.79
Children (months)							
0–23	15	5.3	2.5	1.4	3.9	1.4	0.74
24–47	12	4.4	1.7	2.0	3.7	0.7	0.84
48–72	13	7.8	3.5	3.0	6.5	1.3	0.83
Total	40	5.8	2.6	2.0	4.6	1.2	0.79

[a] The protein content of 100 g of corn and 100 g of beans is 8.2 g and 22.7 g respectively (Flores *et al.*, 1960).

additional amounts of corn and beans (T) and the net increment in intake (N) provide a measure of the unexplained energy or protein (U = N − T). Negative values would indicate the extent to which corn and beans may have replaced other foods in the diet while positive values would indicate the degree to which the intervention may have actually caused increased consumption of such foods. The last column shows the ratio between energy or protein derived from corn and beans and the net energy or protein increment (R = T/N). The results indicate that corn and beans contributed the bulk of the observed changes in intake, about 85 percent in adults and 75 percent in children. The percent contribution was lowest for children 0–23 months in age, 54 percent for calories, and 74 percent for protein. There is no indication that corn and beans led to decreases in the consumption of other foods. Rather, increased consumption of the staples appears to have led to modest increases in other foods as well.

TABLE VI

Corn/bean ratios (dry weight) during baseline and intervention phases

Group	Baseline Corn	Baseline Beans	Intervention Corn	Intervention Beans
Adults				
Fathers	94	6	89	11
Mothers	93	7	89	11
Children (months)				
0–23	94	6	87	13
24–27	92	8	88	12
48–72	94	6	90	10
All adults and children	93	7	89	11

Finally, the corn/bean ratio was moderately improved as suggested by the data in Table VI. For all groups, the corn/bean ratio was altered from 93/7 to 89/11 in the intervention phase. This, however, was not reflected in measurable changes in protein quality. For instance, the NDpCal percent of the diets of all groups was 7.4 ± 1.3 in the initial phase and 7.5 ± 0.9 in the intervention phase.

DISCUSSION

The findings strongly suggest that it is possible to correct protein-energy intake deficiencies in the case of adults by distributing additional quantities of the dietary staples, in this case corn and beans. Apparently, bulk and other factors do not appear to be major limiting factors in the case of adults for intakes increased during the intervention period by 424 kcal (1.78 MJ) per day in men and by 404 kcal (1.69 MJ) per day in women largely as a result of increased consumption of corn and beans. Similarly, protein increased by 16.1 g and 13.8 g for men and women respectively. The magnitude of the impact appears to have been greatest for those whose baseline diets were lowest in either protein or energy.

The increments in mean dietary intakes were not only statistically but biologically significant as well. According to the WHO/FAO report on protein and energy requirements the daily needs for a 60 kg male, the approximate weight of men in the study area, are 2760 kcal (11.59 MJ) if moderately active and 3230 kcal (13.5 MJ) if very active (WHO, 1973). The energy requirements for a moderately active 47 kg woman are 1880 kcal (8.40 MJ). Pregnancy and the first six months of lactation require an additional 285 kcal (1.19 MJ) and 550 kcal (2.31 MJ) respectively (WHO), 1973). Thus, energy intakes for adult males reached requirement levels during the intervention while for women, such may have been the case except for the period of lactation (Table I). Protein intakes, on the other hand, exceeded the safe level of intake even before the intervention and after adjusting for quality. Other studies carried out in Guatemala have shown that supplementation during pregnancy with over 20,000 kcal (84.00 MJ) during the last six months of pregnancy, or 111 kcal (0.47 MJ) per day, decreased the prevalence of low birth weight babies by 50 percent (Lechtig *et al.*, 1975). Similarly, there is evidence indicating that agricultural workers in Guatemala limit their physical activity because of poor energy intakes; these studies also suggest that a supplement providing 500 kcal (2.10 MJ) and 11 g of protein per day significantly improved work output (Viteri and Torún, 1975). Therefore, the dietary impact measured in this study would be expected to result in an improvement in nutritional status and function.

Greater energy and protein intakes during the intervention phase were also observed in children. A special case is presented by children less than two years of age in that only 50 percent of the increased energy intake was due to corn and beans. A breakdown by foods showed that increases in rice and sugar accounted for the rest of the caloric increment. However, for older children, increased consumption of corn and beans explained most of the increased energy and protein intake. As a summary statement, the mean changes observed in children 0 to 6 years of age were 198 kcal (0.83 MJ) and 5.8 g of protein. These are important biological effects. Other studies in rural Guatemala have estimated that preschool children have diets that are primarily deficient in energy. Two-year-olds, for example, were found to consume 76 kcal/kg/day (Martorell *et al.,* 1978), and needs according to FAO/WHO are 100 kcal (0.42 MJ)/kg/day (WHO, 1973). Assuming a weight of 9.5 kg at two years of age, the estimated deficit, without allowing for catch-up growth, would be 228 kcal (0.96 MJ) per day. If, however, allowances are made for catch-up growth by utilizing ideal rather than actual weights as suggested by FAO/WHO (1973), the energy deficit would be 354 kcal (1.49 MJ). An increment of 198 kcal (0.83 MJ) represents, therefore, 56 percent of the energy deficit. Perhaps bulk does impose physiological constraints in children and other alternatives, such as increasing the number of meals and raising the energy density of the diet through the use of oil and sugar, should be given consideration.

Results from similar investigations in young children from India are conflicting. Pereira *et al.* (1973) reports that children fed a rice-based diet fortified with lysine and threonine were not able to consume enough to meet energy needs. On the other hand, Pasricha (1973) and Parvathi Rau *et al.* (1970) suggest that an adequate distribution of total energy over frequent meals will allow children to eat the necessary quantities of their basic diet to satisfy energy needs.

The findings presented in this paper are provocative and undoubtedly point out that increasing the availability of corn and beans, as a basic strategy to improve diets of rural populations in Guatemala and in other areas of Central America, is a promising approach. However, it must be pointed out that the findings are tentative. The study was conducted over a short period of time, two months, and it remains to be seen how populations would behave over a longer period. Sample sizes were small, particularly for children. In spite of the fact that both baseline and intervention phases were conducted before the coffee harvest, an event known to interfere with dietary patterns, seasonal effects cannot be ruled out. Similarly, one cannot rule out bias in reporting on the part of the study subjects. Though the dietary intake methodology used in this study has been shown to be reliable for estimating the dietary intake of groups in other communities in the area, checks for accuracy against other methods such as the direct weighing technique were not carried out during the course of the study just described. The findings must, therefore, be confirmed in larger long-term studies. Tentative as the results are, however, they do highlight that increasing the availability of the staples is a strategy that may prove effective for improving dietary intakes.

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