21. USE OF CORN-BEAN MIXTURES TO SATISFY PROTEIN AND ENERGY REQUIREMENTS OF PRE-SCHOOL CHILDREN

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Objectives

1. To determine whether pre-school children can fulfil their protein requirements with a diet based on corn and beans.

2. To determine which proportions of corn-and-bean-protein mixtures are better, in the sense that they lead to lower protein requirements and are the proportions spontaneously selected by pre-school children.

3. To determine the energy density of corn-bean diets necessary to fulfil both the protein and energy requirements of pre-school children eating *ad libitum*. (Is bulk a limiting element in corn-bean diets in pre-school children?).

Experimental Details

1. Subjects

Healthy pre-school children, fully recovered from previous oedematous protein-energy malnutrition. Chronological age: 2 to 3 years old; height-age: 1 to 3 years old.

2. Study Environment

Clinical Centre at INCAP.

3. Physical Activity

The children were free to play in the Clinical Centre and surrounding grounds when not undergoing urine and faecal collections. However, they were not encouraged to be active.

4. Duration of the Study and Diets Used

The duration and diet of each study are presented below in "Summary of the Main Results."

5. Indicators and Measurements

a. Anthropometry: body weight, height, and skin-fold thickness.

b. Serum proteins and albumin; creatinine-height index.

c. Nitrogen absorption and retention, as described in other INCAP studies.

Summary of the Main Results

1. A study to test the hypothesis that, with a mixture of corn and beans in the proportions usually eaten, one can obtain sufficiently high concentration and quality of protein (ND p cal %) to satisfy calorie and protein requirements of pre-school children.

Four children between 21 and 28 months of age, with height-ages between 14 and 16 months, were fed a diet in which protein was provided by corn and black beans only, in a proportion of 76 and 24 per cent, respectively. Energy intake was fixed at 100 kcal/kg/day, 20 per cent of which came from vegetable fat. The children received a vitamin supplement. Protein intake was constant for two weeks at each of the following levels (g/kg/day): 1.00, 1.25, 1.50, 1.75, 2.00, and 2.25. Two children followed an ascending and two a descending order of protein intake. Nitrogen balance was measured the last three days of each protein level. The children gained adequate weight and no clear tendency in height changes was detected.

Nitrogen balance is presented in figure 1. Nitrogen retained has been corrected for skin and other losses amounting to 14 mg/kg/day. Intakes of corn-bean protein greater than 1.3 g/kg/day resulted in positive balance in all children. However, two children retained less nitrogen than ideal for maintenance and growth (calculated for children of their height-age to be 20.7 mg/kg/day), although they were very close to that figure (19 and 16 mg/kg/day).

If 1.4 g of protein/kg/day is taken as the safe level of intake and is compared with 1.25 obtained with egg protein, this corn-and-bean mixture has a relative value of 89 per

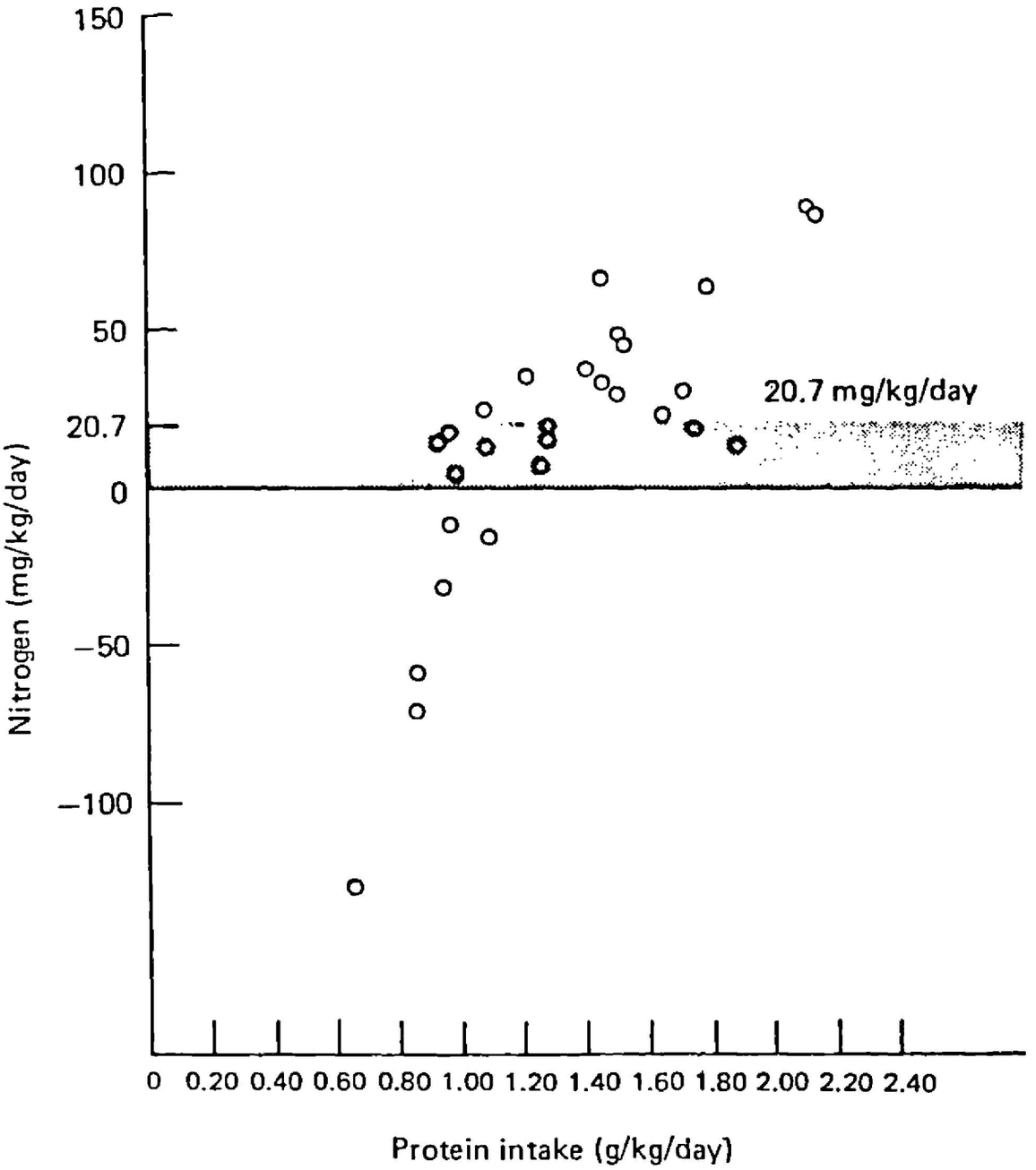

FIG. 1. Nitrogen Retention Necessary for Normal Growth of Children One to Two Years Old (Height-Age of Subjects)

cent protein quality in relation to egg. This is very close to the relative urea:creatinine ratio in urine at different levels of protein intake obtained with the two proteins.

The 95 per cent confidence interval from the nitrogen balance data yields 1.7 g of corn-bean protein/kg/day as needed for all children studied under the above conditions.

2. Based on the results of the previous study (1, above), the following study, consisting of three phases, each of two months' duration, was conducted in four pre-school-age

children. The four children participated in three phases aimed at testing the following hypotheses:

Phase 1: A corn-bean diet that provides 76:24 protein from the respective sources is adequate for pre-school children when fed for two months at a level providing 1.5 g protein/kg/day and 100 kcal/kg/day.

Phase 2: A similar diet, but one providing a 60:40 protein ratio from corn and beans, is superior to that tested in phase 1 under the same conditions.

Phase 3: Children allowed to choose freely from corn-and-bean dishes satisfy their protein and energy needs and select close to a perfect ratio of corn and bean protein.

The diet in phase 1 was homogenized. In the other two phases, familiar corn and bean preparations were given or offered to the children. They were offered food five times per day; at least three of the meals contained beans.

The four children in this study were between 21 and 32 months of age, with height ages betweeen 16 and 19 months. They remained essentially healthy throughout the study.

Nitrogen balance (three days) was performed periodically. In phase 1, four balances were performed in each child (one every two weeks); in phase 2, five balances were performed, except for one child who had only four balances; in phase 3, three balances were performed except for the same child who had only two.

Results are summarized in figure 2. During phase 1, four balances were either marginal or lower than expected, with intakes ranging between 230 and 240 mg N/kg/day. During phase 2, all balances, except for one unexplained case, were satisfactory, with intakes between 260 and 270 mg/kg/day. During phase 3, nitrogen intake (*ad libitum*) was higher (between 330 and 370 mg/kg/day), the selected ratio of corn to bean protein was 49:51, and all nitrogen balances were highly positive.

3. The purpose of this study was to define the necessary energy density of corn-bean diets to ensure that such diets fulfil protein and energy requirements when consumed *ad libitum* by pre-school children.

Four pre-school children, between 21 and 26 months of age (height-ages between 14 and 16 months), were studied. The diets were offered four times a day as follows: First, the children were offered corn and beans in amounts that ensured a protein intake of 1.75 g/kg/day, 50 per cent of the protein coming from each source (corn and beans). Only after the children had consumed this amount of food, given as tortilla and black bean paste, were they offered *ad libitum* extra amounts of these foods plus banana and lemonade. Three levels of energy density were tested (see table 1); these were achieved by adding vegetable oil to the black bean paste. All children received vitamin supplements.

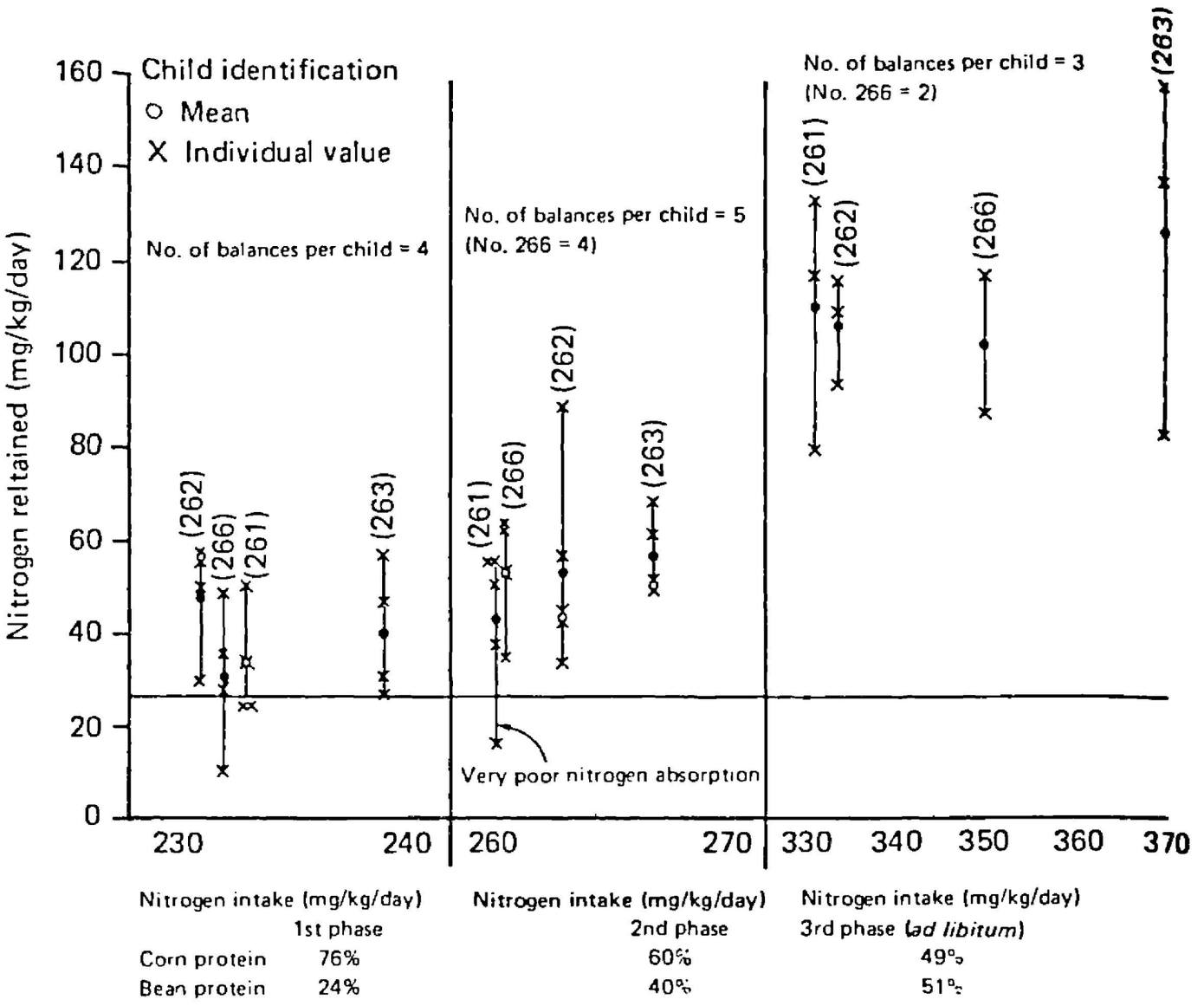

FIG. 2. Nitrogen Retention of Children Receiving Corn-Bean Diets

TABLE 1. Protein, Fat, and Calorie Contents of the Experimental Diets, Excluding Banana and Lemonade

	Caloric density		
	Low	Intermediate	High
Protein (g/100 g dry wt)	12.9	11.9	11.0
Fat (g/100 g dry wt)	4	12	21
Intrinsic fat (%)	100	33	19
Added vegetable fat (%)	0	67	81
Fat calories (% of total)	8	22	35
Caloric density (cal/g dry wt)	4.5	4.9	5.4
Caloric density (cal/g protein)	34.9	41.2	49.1

Two children were given the highest-energy-density diet first and followed a descending design; the other two children followed an ascending design. Each energy-density diet was offered for three weeks. The study lasted nine weeks per child. Nitrogen balance was performed during the last three days on each diet.

Table 2 presents actual energy and protein intakes and changes in body weight in g/day. It is evident that with the lowest energy-density diet (4.5 kcal/g of dry diet, 8 per cent fat calories), weight gain was inadequate. Table 3 attempts to provide mean estimates of energy adequacy, although no actual measurments of energy expenditure were performed. Table 4 presents the nitrogen balance data plus other indicators of protein nutrition. All these parameters were satisfactory. Figure 3 expresses graphically the mean weight gain in relation to that expected for the children's height-age. It is clear that with the lowest energy-density diet children do not grow adequately.

TABLE 2. Total Calorie and Protein Intakes and Weight and Height Increments with the Three Experimental Diets

	Dietary caloric density (cal/g dry wt)		
	4.5	4.9	5.4
Total caloric intake/kg/day	843.3 ± 6.2*	95.7 ± 12.5	102.2 ± 10.4
Total protein intake (g)/kg/day	2.3 ± 0.2	2.3 ± 0.3	2.0 ± 0.2
Change in weight (g/day)	6.5 ± 9.3	14.8 ± 8.7	13.2 ± 9.7
Change in height (mm/day)	0.45 ± 0.39	0.01 ± 0.02	0.37 ± 0.36

TABLE 3. Mean Caloric Expenditures for Children Weighing 10.5 kg

	Cal/kg/day
Basal	59
Activity	24
Growth	6
Total	89
Mean expected weight gain (g/day)	12
Mean expected height gain (mm/day)	0.32

	4%	12%	21%
Dietary caloric density (cal/g dry wt)	4.5	4.9	5.4
Mean caloric intake (% of required)	95	108	115
Mean caloric intake above basal (cal/kg/day)	28	40	46
Mean weight gain (% of expected)	54	123	110
Mean height gain (% of expected)*	117	31	142

* The total height gain is 97 per cent of expected for the total period of the study.

TABLE 4. Nitrogen Retention and Biochemical Indices of Protein Nutrition in Children Consuming Three Corn-and-Bean Experimental Diets with Different Caloric Densities

	Dietary caloric density (cal/g dry wt)		
	4.5	4.9	5.4
Nitrogen retained (mg/kg/day)	187 ± 34*	97 ± 32	140 ± 40
Total serum proteins (g/100 ml)	6.25 ± 0.26	6.33 ± 0.31	6.15 ± 0.34
Serum albumin (g/100 ml)	3.75 ± 0.17	3.85 ± 0.26	3.78 ± 0.13
Non-essential/essential amino acid ratio	1.97 ± 0.21	2.14 ± 0.12	2.10 ± 0.20
Creatinine-height index (%)	+5.8 ± 4.4	-4.5 ± 4.4	+0.8 ± 4.0

* Mean ± S.D.

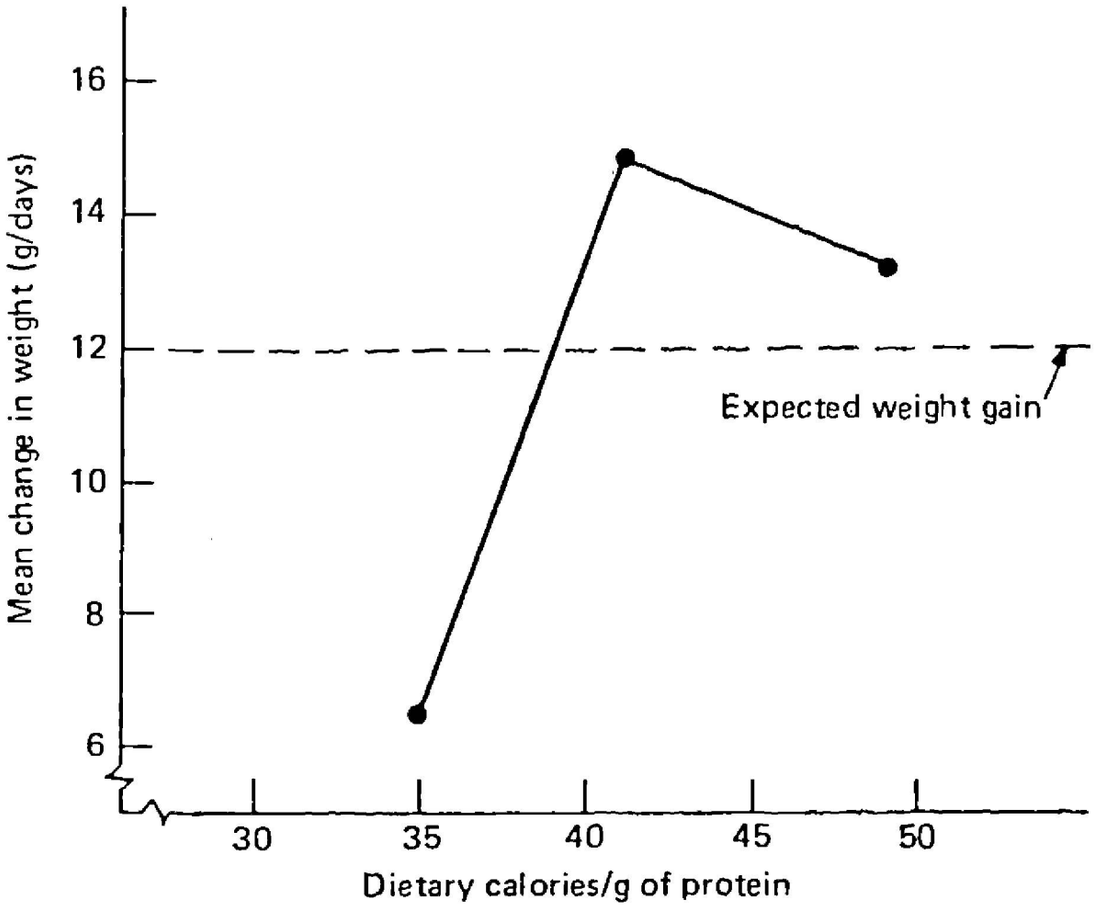

FIG. 3. Mean Weight Gain Relative to That Expected for the Height-Age