THE EFFICIENCY OF FOOD EXPENDITURE AMONG CERTAIN WORKING-CLASS FAMILIES IN COLOMBIA

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY
CECILIA A. FLORENCIO

1967

This is to certify that the

thesis entitled

THE EFFICIENCY OF FOOD EXPENDITURE AMONG

CERTAIN WORKING-CLASS FAMILIES IN COLOMBIA

presented by

CECILIA A. FLORENCIO

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Foods and Nutrition

Victor E. Smith
Dena Cederquist
Major professor

Date July 25, 1967

O-169

ABSTRACT

THE EFFICIENCY OF FOOD EXPENDITURE AMONG CERTAIN WORKING-CLASS FAMILIES IN COLOMBIA

by Cecilia A. Florencio

The study was designed to investigate how efficiently certain working-class families in Colombia bought their nutrition and how inexpensively they could have bought their nutrition. Linear programming was used to solve the problem of finding least-cost diets that would meet the following levels of nutritional allowances: the estimated actual level of nutritional intake, the minimum dietary standard, the more generous Colombian dietary standard and the additional nutrients necessary to raise the nutritional content of the actual diet to the level specified in each of the two dietary standards. Protein allowances were set at two levels. One level was appropriate for a mixed diet with a biological value of sixty (and where the source of protein was left unspecified) while the other was appropriate for a mixed diet with a biological value of eighty (and where one-third of the

total daily protein allowance must be obtained from animal sources).

The most efficient family is the one that spends the smallest fraction of its food peso for "non-nutritional" objectives. In less efficient families, the cost of the "non-nutritional" component accounts for larger fractions of the total expenditure for food. The average Colombian family in this sample spent 59 percent for buying nutrients and 41 percent for other objectives. The most efficient family spent 77 percent of its actual food expenditure for nutrition while the least efficient family spent only 37 percent.

The primary difference between the actual diets and the least-cost diets that would have provided the same level of nutritional intake was the change in the percentage cost contribution of milk and meat. The milk cost contribution increased from 3.73 percent in the actual diet to 33.15 percent in the least-cost diet, while the meat cost contribution decreased from 30.50 percent to 0.15 percent. Among the other changes were an 8.93 percentage point increase in the expenditure for cereals and a tenfold increase in the expenditure for fruits in the least-cost diets.

It was found that the least-cost diets which required animal protein cost from one to seven centavos less than the least-cost diets which did not require animal protein. In general, the major responsibility of providing for the protein in the diet, instead of being shared by milk, corn and/or beans (as in the least-cost diets where the source of protein was not specified) was shifted largely (in the least-cost diets which required animal protein) to whole milk with a decrease in the contribution of corn and legumes.

Using the marginal costs of nutrients obtained as a routine part of the linear programming solution to the least-cost diet problem, the marginal efficiency of a list of commodities, including INCAPARINA, was computed. A food is 100 percent efficient if the aggregate monetary value of its nutrients is equal to its market price. The four foods - milk, corn, vegetable oil and whole orange which were present in nearly all of the least-cost diets each had a marginal efficiency of 100 percent.

THE EFFICIENCY OF FOOD EXPENDITURE AMONG CERTAIN WORKING-CLASS FAMILIES IN COLOMBIA

By

Cecilia A. Florencio

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Foods and Nutrition

1967

47090
12-20-67

ACKNOWLEDGEMENTS

The author wishes to express her most sincere gratitude to Dr. Victor Smith for two years of challenge, enlightenment and guidance and to Dr. Dena Cederquist and Dr. Dorothy Arata for their understanding.

The author is indebted to Miss Fe Sunga for her help and her encouragement.

The author also wishes to express her gratitude to Dr. Arnold E. Schaefer, Executive Director of the Interdepartmental Committee on Nutrition for National Defense, for the use of the original food consumption records of the Colombian families.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

Efforts to solve the problem of hunger have been directed largely towards studying the possibilities of increasing food production. These efforts, however, may fall short of the goal of improving the nutrition of the world unless corresponding improvements are made in the patterns of food consumption. If an intelligent estimate of future food needs is to be made, it is important to understand thoroughly the existing dietary patterns. There is a need to study which foods, among those variously consumed, are most efficient in terms of providing for the nutrient needs of a group of people. Perhaps more basic than asking how much more to produce is the question of what best to produce. And if significant improvements can be made in peoples' attitudes towards food selection, then estimates of how much additional food is needed may not be as large as are now indicated (1). More food does not necessarily mean better nutrition. Freedom from undernutrition and/or malnutrition will come only when enough of the right kinds of food is consumed.

Many families spend enough for food but do not obtain an adequate diet. At any given income level, there is a wide range in food expenditures even among families of the same size and composition. The quality of the diet depends on how wisely the food money is invested. Where food supply is less than adequate to meet food needs, it is doubly important that people attain a certain degree of efficiency in the purchase of their nutrition. "Efficiency in the purchase of nutrition" is used here to mean obtaining nutrients in the least costly way. A family is efficient to the degree that it chooses the least expensive combination of foods that will provide a certain level of nutritional intake.

For a long time, dietitians and others have helped families plan low-cost food budgets based on rules of thumb. Since the introduction of the simplex method of linear programming (2), this method has also been used to compute least-cost diets for adequate nutrition. However, there has been no study on how efficiently or how inexpensively any given family buys its nutrition. There have been numerous investigations concerning the varied factors which influence one's expenditure for food. None of these, however, has quantified the magnitude of the components of total food expenditure.

This pilot study was designed to investigate two things: "how efficiently did certain working-class families in Colombia buy their nutrition" and "how inexpensively could they have bought their nutrition". It is also the purpose of this study to look into the "nutritional" and "non-nutritional" components of expenditures on food. Knowing the most efficient foods for a particular group of people and the least costly way of meeting their nutritional needs will be useful in providing a guide for the coordination of agriculture and nutrition.

CHAPTER I

THE NUTRITIONAL MODEL

The problem of finding least-cost diets that will meet specified levels of nutritional allowances can be solved by linear programming. The method involves making an optimal selection from a group of foods, each of which provides nutrients in specified fixed proportions, and each of which involves a cost for the optimizing agent (3). The solution is made subject to restrictions, the most common of which are minimum requirements for certain nutrients. Let Z be the total expenditure on foods, p_j the unit price of food j, x_j the quantity of food j to be consumed, b_i the allowance for nutrient i and a_{ij} the amount of nutrient i provided by one unit of food j. The problem can be expressed as follows:

Minimize	$Z = \sum_j p_j x_j \quad, j=1,2,\ldots,n$	Make Z, the total expenditure on foods as small as possible subject to the following restrictions:

subject to:

(1)	$x_j \geq 0$	No negative quantities of foods may be purchased.

(2)

(3)

(4)

(5)

(6)

(7)

(8)

(9)

(10)

Altho

has b

are b

studi

1

fat,

acid.

(2) $\sum_{i=1}^{8} a_{ij}x_j \geq b_i$ — The total quantity of each of eight nutrients shall equal or exceed the required amount for each.[1]

(3) $\sum_j a_{9,j}x_j - x_{n+1} = 0$ — The total Calories in the diet shall equal the Calories for which certain B-vitamins must be provided.

(4) $\sum_j a_{10,j}x_j - x_{n+2} = 0$

(5) $\sum_j a_{11,j}x_j - x_{n+3} = 0$

(6) $\sum_j a_{12,j}x_j - x_{n+4} = 0$

The total thiamine (10), riboflavin (11) and niacin (12) shall equal the thiamine, riboflavin and niacin (respectively) needed to go with the total Calories in the diet.

(7) $x_{n+1} \geq b_{n+1}$ — The total Calories for which certain B-vitamins must be provided shall equal or exceed the minimum caloric allowance.

(8) $-k_{n+2}x_{n+1} + x_{n+2} \geq 0$

(9) $-k_{n+3}x_{n+1} + x_{n+3} \geq 0$

(10) $-k_{n+4}x_{n+1} + x_{n+4} \geq 0$

The quantity x_{n+2}, the thiamine needed to go with the Calories in the diet, shall be equal to or greater than a specified proportion, k_{n+2}, of the Calories in the diet. Similarly for x_{n+3}, riboflavin and x_{n+4}, niacin.

Although not explicitly stated in the model, palatability has been considered indirectly since these least-cost diets are based only on foods commonly consumed by the families studied.

---

[1] These nutrients are total protein, animal protein, fat, calcium, phosphorus, iron, vitamin A and ascorbic acid.

leas

ance

of a

nutr

ing n

were c

consum

were o

Nutrit

survey

each o

familie

study c

of each

waste w

From the

ily was

Sources of Information

Three kinds of information are needed to obtain least-cost diets: a statement of the nutritional allowances appropriate for the people being studied, a list of available foods and the price of each food, and the nutrient composition of each food.

Least-cost diets that will meet each of the following nutritional levels were computed:

1. The existing level of nutrient intake
2. A minimum standard
3. The Colombian standard
4. The additions to (1.) required to raise it to the levels specified in (2.) or (3.). These are the least-cost supplementary diets.

Data for the existing or actual nutrient intake were calculated from the original records of actual foods consumed by forty working-class families. These records were obtained by the Interdepartmental Committee on Nutrition and National Defense (ICNND) in its nutrition survey of Colombia from May to August of 1960 (4). At each of the eight cities studied, from three to thirteen families were selected at random for detailed dietary study of one or two days duration. The edible portion of each food consumed was weighed after preparation waste was discarded, but before the food was cooked. From these data the actual nutrient intake of each family was calculated, using the <u>Tabla de Composicion de</u>

los Alimentos Colombianos published by the Colombian Institute of Nutrition (5). The difference between the actual nutrient intake and the recommended nutrient allowances formed the basis for calculating the least-cost supplementary diets. Possible errors in recording the foods actually consumed and inaccuracies in the food composition data preclude knowing the exact nutritional intake of the families. For convenience and as a means of differentiating from the least-cost diets obtained by linear programming, the calculated nutritional intake based on the food consumption records will be called the actual or existing level of nutritional intake.

The Minimum and Colombian standards will be discussed in the next chapter.

Prices for some thirty-five of the foods most commonly consumed by working-class Colombian families at the time of the survey were provided by the Departamento Administrativo Nacional de Estadistica in Colombia (6).

Comparison of Least-Cost diets Obtained by Linear Programming and the Usual Low Cost Diets

Even before the linear programming technique for computing least-cost diets was developed, dietitians and others helped families plan low cost food budgets. There has long been an interest in providing the nutrients for an adequate diet with the least costly combinations of food. However, while in linear programming a mathematical model is first formulated, in the conventional method used by dietitians, the starting point for the low cost food plans is the average quantities of foods purchased by low income families, as shown in dietary studies. These quantities are then checked for nutritional adequacy and adjusted for greater amounts of what have been labeled the "cheaper" foods - in the United States these are thought to be potatoes, dry beans, peas, flour and cereals.

Since, in the conventional method, the low-cost dietary plan is developed from an existing dietary pattern, the low-cost diets provide not only for the cost of nutrition but also for customary food habits and taste preferences. Unless non-nutritional restraints are explicitly stated, the diets computed by linear programming fulfill only one criterion, that of nutritional adequacy; so it is with the least-cost diets in this study.

It is well known that palatability plays a role in food selection. However, since the magnitude of the components of total food expenditure has not been measured, the extent of the influence of palatability is not known. Comparing least-cost diets based on a purely nutritional model with the actual diets gives one an insight into the relative importance of nutritional and non-nutritional objectives in the purchase of food.

The actual cost to a family of the foods in the least-cost diets obtained by linear programming depends upon nutritional needs and market conditions. Diets will differ as the nutrient needs decrease or increase from one family to another. They will also differ when the prices of commodities and/or the list of commonly available foods changes from one market to the next. The set of commodities available for use will affect the cost of the diet and the kinds of foods that will make up the diet. Since only those foods that were commonly available in the local market being studied were considered in the computation of least-cost diets for the Colombian working-class families, the costs of the diets obtained might have been still lower if some less common foods had been included.[2] Each of the least-cost diets ob-

---

[2]For example, in this study, the least-cost diets (obtained by linear programming) which would provide the actual level of nutrient intake of two families cost more than their actual expenditure for food. These families had exceedingly high intakes of vitamin A resulting from their consumption of beef liver. The least-cost diets had to provide as much vitamin A as was consumed. However, liver, being an uncommon food item, was not included in the commodity list from which foods in the least-cost diets were chosen. As a consequence, the unusually large amounts of vitamin A in the computed least-cost diets had to be obtained from other foods which turned out to be more expensive sources of the vitamin than liver.

tained is appropriate only for a specific family confronted with a given market situation.

CHAPTER II

DIETARY STANDARDS

The first expression of a dietary standard is sometimes credited to Dr. Edward Smith, who, in 1862 at the request of the Privy Council of the United Kingdom, recommended 4300 grams of carbon and 200 grams of nitrogen daily as the minimum allowance to maintain health (7). Since that time, other scientists like Voit (8) and Lusk (9) and scientific groups such as the Canadian Council on Nutrition (10), the British Medical Association (11), the National Research Council of the United States (12) and many others have proposed dietary allowances.

Two sets of dietary standards were used in assessing the nutritional adequacy of the food consumption of working-class families in Colombia. Practical considerations and economic necessity may rule out the immediate attainment of the generous allowances provided by the Colombian *Instituto Nacional de Nutricion*. The restricted minimum level, which is appropriate for subsistence diets may be a more readily attainable primary goal.

The Minimum Allowance

The dietary standard developed by the author is stated in terms of a minimum allowance (see Tables 1a and 1b). This is defined as the level of nutrient intake presumed to be sufficient to meet the normal physiological needs of healthy individuals representative of each of the various categories into which a population is divided for dietary purposes. These categories take into account differences in age, sex and physiological status. The specific allowances are adequate in the sense of a maintenance level or a minimum below which the normal physiological needs of average individuals can not be sufficiently covered. Since this standard is set to represent the needs of the average person in the population, some individuals will require more than the minimum allowances and others will require less. A complex of factors makes it extremely difficult to define with precision terms like "minimum", "optimum" or "maximum" allowance. The concept of an exact nutrient allowance, whether minimum or maximum, is an illusion.

TABLE 1a. DAILY MINIMUM NUTRIENT ALLOWANCES
(FOR 30°C AREA)

Groups	Age (years)	Weight (kg)	Calories	Protein (BV = 80) Total (gm)	Protein (BV = 80) Animal	Protein (BV = 60) Total (gm)	Protein (BV = 60) Animal	Fat (gm)
Infants	0-1		800	20*	20	20*	20	9
Children								
Both sexes	1-3	13	1100	25	8	35	--	12
Both sexes	4-6	18	1260	30	10	32	--	14
Both sexes	7-9	24	1440	40	13	48	--	16
Male	10-12	33	1650	50	17	60	--	18
Female	10-12	33	1550	50	17	60	--	17
Adolescents								
Male	13-15	45	1960	65	22	82	--	22
Male	16-19	60	2420	60	20	75	--	27
Female	13-15	47	1860	60	20	70	--	21
Female	16-19	53	1760	55	18	70	--	20
Adults								
Male	20-29	65	2600	50	17	68	--	29
	30-39	65	2550	50	17	68	--	28
	40-49	65	2350	50	17	68	--	26
	50-59	65	2250	50	17	68	--	25
	60-69	65	2000	50	17	68	--	22
Female	20-29	55	1750	40	13	60	--	19
	30-39	55	1650	40	13	60	--	18
	40-49	55	1600	40	13	60	--	18
	50-59	55	1500	40	13	60	--	17
	60-69	55	1400	40	13	60	--	16
Pregnant women	16-19		1960	67	22	73	--	22
	20-29		1950	52	17	72	--	22
	30-39		1850	52	17	72	--	21
	40-49		1800	52	17	72	--	20
	50-59		1700	52	17	72	--	19
Lactating women	16-19		2560	73	24	79	--	28
	20-29		2550	58	19	78	--	28
	30-39		2450	58	19	78	--	27
	40-49		2400	58	19	78	--	27
	50-59		2300	58	19	78	--	26

*The biological value is actually greater than 80 (or 60) because the total protein allowance for infants is to be derived solely from animal protein.

TABLE 1a--Continued

Calcium (mg)	Phosphorus (mg)	Iron (mg)	Vitamin A (I.U.)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic Acid (mg)
500	500	4	1300	0.24	0.4	2.4	20
400	400	5	800	0.30	0.6	3.0	15
400	400	5	1100	0.40	0.6	4.0	15
400	400	5	1500	0.40	0.7	4.0	20
600	600	10	2000	0.50	0.8	5.0	25
600	600	10	2000	0.50	0.8	5.0	25
600	600	12	2700	0.60	1.0	6.0	30
500	500	10	3600	0.70	1.2	7.0	30
600	600	12	2000	0.60	0.9	6.0	30
500	500	12	3000	0.50	0.9	5.0	30
400	400	6	3000	0.80	1.3	8.0	20
400	400	6	3000	0.80	1.3	8.0	20
400	400	6	3000	0.70	1.2	7.0	20
400	400	6	3000	0.70	1.1	7.0	20
400	400	6	3300	0.60	1.0	6.0	20
400	400	10	3300	0.50	0.9	5.0	20
400	400	10	3300	0.50	0.8	5.0	20
400	400	10	3300	0.50	0.8	5.0	20
400	400	10	3300	0.50	0.8	5.0	20
400	400	8	3300	0.40	0.7	4.0	20
800	800	15	4200	0.70	1.2	7.0	40
800	800	13	4300	0.70	1.2	7.0	40
800	800	13	4300	0.70	1.1	7.0	40
800	800	13	4300	0.70	1.1	7.0	40
800	800	13	4300	0.70	1.1	7.0	40
1000	1000	15	5200	0.90	1.3	11.0	50
900	900	13	5300	0.90	1.3	11.0	50
900	900	13	5300	0.90	1.2	11.0	50
900	900	13	5300	0.90	1.2	11.0	50
900	900	13	5300	0.90	1.2	11.0	50

TABLE 1b. DAILY MINIMUM NUTRIENT ALLOWANCES [a]
(FOR 30°C AREA)

Groups	Age (years)	Weight (kg)	Calories	Fat (gm)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)
Infants	0-1		785	9	0.24	0.4	2.4
Children							
Both sexes	1-3	13	1080	12	0.30	0.5	3.0
Both sexes	4-6	18	1275	14	0.40	0.6	4.0
Both sexes	7-9	24	1410	16	0.40	0.7	4.0
Male	10-12	33	1615	18	0.50	0.8	5.0
Female	10-12	33	1520	17	0.50	0.8	5.0
Adolescents							
Male	13-15	45	1920	21	0.60	1.0	6.0
Male	16-19	60	2370	26	0.70	1.2	7.0
Female	13-15	47	1825	20	0.50	0.9	5.0
Female	16-19	53	1725	19	0.50	0.9	5.0
Adults							
Male	20-29	65	2550	28	0.80	1.3	8.0
	30-39	65	2500	28	0.80	1.3	8.0
	40-49	65	2305	26	0.70	1.2	7.0
	50-59	65	2205	25	0.70	1.1	7.0
	60-69	65	1960	22	0.60	1.0	6.0
Female	20-29	55	1715	19	0.50	0.9	5.0
	30-39	55	1615	18	0.50	0.8	5.0
	40-49	55	1570	17	0.50	0.8	5.0
	50-59	55	1470	16	0.40	0.7	4.0
	60-69	55	1370	15	0.40	0.7	4.0
Pregnant women	16-19		1925	21	0.70	1.2	7.0
	20-29		1915	21	0.70	1.2	7.0
	30-39		1815	20	0.70	1.1	7.0
	40-49		1770	20	0.70	1.1	7.0
	50-59		1670	19	0.60	1.0	6.0
Lactating women	16-19		2525	28	0.90	1.3	11.0
	20-29		2515	28	0.90	1.3	11.0
	30-39		2415	27	0.90	1.2	11.0
	40-49		2370	26	0.90	1.2	11.0
	50-59		2370	25	0.80	1.1	10.0

[a] The minimum allowances for nutrients other than Calories, fat, thiamine, riboflavin and niacin are the same as in Table 1a.

Calories[3]

The caloric allowances determined by the ICNND in its 1960 nutrition survey of Colombia were used for all the categories of individuals except for adults (4). A comparison of dietary standards from different countries by Young (13) showed that South Africa has the lowest caloric allowance for a reference male and a reference female. For adults, the South African caloric recommendation was adopted, making the necessary corrections for differences in environmental temperature and body size (14).

Protein

Protein allowances were set at two levels, one appropriate for a mixed diet with a biological value of sixty and the other appropriate for a mixed diet with a biological value of eighty. In the model that used the former level, there was no restriction set on the kind of protein in the diet (except for small amounts of animal protein to provide for the protein needs of an infant in a family where there is no lactating woman). In the model that used the latter level, it was specified that one-third

---

[3]The ICNND selected mean environmental temperatures of 20°C. and 30°C. to correct for climatic differences in different areas of Colombia. Two sets of caloric allowances were formulated, the one for the 30°C. areas being 2 percent less than that for the 20°C. areas.

of the total daily protein allowance must be obtained from animal sources.[4]

Animal protein was specified in one of the models as a way of insuring a diet of high protein quality. It is recognized that another way of achieving the same purpose is with a proper mixture of vegetable proteins. Experience with least-cost diets obtained by linear programming indicates, however, that the diets may contain only four or five foods and the chance of having a variety of vegetable protein sources for proper supplementation may be small. It may well turn out that the least-cost diet will rely heavily on one or two foods in meeting the protein requirement. If this food happens to be corn, then one is faced with the problem of poor protein utilization.

One has no way of knowing in advance the least expensive way of meeting protein needs, i.e., whether it is less costly to consume all vegetable protein, all animal protein or a combination of animal and vegetable proteins. By using the two models one can compare the

---

[4]This notation will be used: MS and CS for Minimum Standard and Colombian Standard with protein source unspecified, respectively, and MS(AP) and CS (AP) for Minimum Standard and Colombian Standard with animal protein required, respectively.

costs of diets meeting nutritional needs with or without an allowance for animal protein.

Another way out of this "protein-source" dilemma is to establish protein allowances in terms of specific amino acids. This refinement in methodology was precluded at the time of this study not only by the paucity of data regarding the amino acid requirements of man but also by the fact that the requirements which have been established are not known with particular accuracy. Relatively few subjects have been studied and the periods of observation have been rather short. Then, too, several groups of workers differ in their interpretation of what constitutes nitrogen equilibrium.

The allowances indicated for protein were based on the calculated minimal protein requirements of humans proposed by the National Research Council (NRC) in its Evaluation of Protein Nutrition (15). The approach used by the NRC is to estimate separately all the components of protein needs at each age and physiological state and to express the sum of these estimates in terms of a provisional protein of a certain biological value.[5] This factorial approach in assessing protein needs takes into account the obligatory nitrogen losses and the in-

---

[5]Biological value is an index of protein quality. It expresses the proportion of absorbed nitrogen that is retained.

crea

in g

cent

tion

Mine

world

of ca

day (

adult

izati

use.

of 5 t

balanc

intake

The al

by the

an adul

Vitamin

V

(19).

ternati

creased protein need for the formation of new tissues in growing children, for the growth of the fetus, placenta and membranes in pregnant women and for the secretion of milk during lactation.

Minerals

Most apparently healthy people throughout the world develop and live satisfactorily on a dietary intake of calcium which lies between 300 mg and over 1000 mg a day (16). The calcium allowance of 400 mg per day for adults as recommended by the Food and Agriculture Organization of the United Nations (FAO) was adopted for our use.

Dubach et al. (17) estimated that a daily intake of 5 to 10 mg of iron is adequate for an adult male while balance studies on young women have established that an intake of 10 to 12 mg was adequate to cover all losses (18). The allowance for iron was patterned after that proposed by the Canadian Council on Nutrition - 6 mg per day for an adult male and 10 mg per day for an adult female (10).

Vitamins A and C

Vitamin A needs appear to be related to body weight (19). This is usually expressed as between 25 and 55 International Units (I.U.) of vitamin A per kilogram of actual body weight or double that for β-carotene. Because a mixed diet is usually eaten, the amount of vitamin A needed daily is customarily given as a mixture of vitamin A and carotene. In this standard, the vitamin A figure was based on an allowance of 60 I.U. per kilogram of body weight per day (assuming that one-third is present as the preformed vitamin A and the rest as the vitamin precursors). This allowance approximated that given for a reference adult male in the South African standard.

In no other dietary essential has there been greater disagreement with respect to human requirements than in the case of ascorbic acid. Studies made in the United Kingdom revealed that 10 mg of vitamin C daily both prevented the appearance of signs of scurvy in adults and caused their disappearance when added to a deficient diet (11). The NRC allowance of 70 mg daily was based on a maintenance of a level of saturation in the blood (12). Whether as high a level as this is beneficial remains to be seen. The British Medical Association's Committee on Nutrition considered 20 mg an adequate allowance for an adult. This recommendation was adopted here.

B - Vitamins

Thiamine, riboflavin and niacin function in part as co-enzymes in tissue respiration. The quantitative allowance for these three nutrients is expressed in relation to caloric expenditure in the following manner: thiamine = 0.3 mg per 1000 Calories, riboflavin = 0.5 mg per 1000 Calories and niacin = 3 mg per 1000 Calories. These three ratios are those indicated in the Canadian Standard (10). As with the other nutrients, added allowances for pregnancy and lactation were made in setting up the allowances for these three vitamins.

Fats and Phosphorus

Fats and phosphorus are known to be essential nutrients. The present state of knowledge does not permit setting a specific minimum allowance for either of them. Nevertheless, both nutrients were included in formulating the dietary standards because, in finding least-cost diets by linear programming, the more nutrient restraints are included, the greater the variety in the diets obtained and the closer the least-cost diets come to the actual food consumption patterns of the families.

The fat value suggested was based on the existing dietary pattern in Colombia, as shown by nutrition surveys (4, page 89). It was set at 10 percent of the total caloric allowance.

In ordinary diets, the phosphorus intake by adults is approximately 1 to $1\frac{1}{2}$ times that of calcium (20). The allowance for phosphorus was set equal to the recommended allowance for calcium.

Since these allowances for fat and phosphorus were not based on clinical and experimental studies, there is no reason for suggesting that the attainment of the recommended amounts is a desirable goal nor that failure to include the recommended amounts in the diet will be detrimental. Cross-cultural comparison of food consumption patterns indicates that a wide range of intake of these nutrients is compatible with good health (21).

The Colombian Recommended Allowance

The second set of dietary standard which was used to assess the nutritional adequacy of the diets of the forty working-class families was established by the Institute of Nutrition in Colombia (22). It was formulated after a careful study and revision of the existing dietary standards in different countries. The recommended amounts include a safety factor above the theoretical minimum requirements in order to cover individual variations adequately.[6] Unlike the minimum standard, which was

---

[6]The theoretical minimum requirement for each of the nutrients considered was not stated explicitly.

designed for the average person in the population, the Colombian allowances are adequate for the majority in the population.

The Colombian recommended allowances for iron, vitamin A, thiamine, riboflavin and niacin were taken from the dietary standard formulated by the National Research Council (NRC) of the United States. This standard had its beginning when a committee was assigned to recommend amounts of various nutrients that should be provided in the diet. A survey was made of all research reports regarding the requirement for any nutrient. A tentative set of values was formulated and sent to a large group of nutrition workers throughout the country for evaluation. The revised set was adopted in 1941 (23). Since then, revisions have been made as new knowledge became available. The NRC allowances are not minimal requirements. They provide a margin of safety (also called, margin of sufficiency) above the minimum requirements.

The Colombian recommended set of allowances is reproduced in Appendices 1a and 1b with some modifications. As in the minimum standard, allowances for fat, phosphorus, animal protein and for a total protein level suitable for a mixed diet with a biological value of 60 were added so that both standards provide for the same number of nutrients.

Estimation of Nutrient Allowances of a Family

The daily nutritional allowance of a family was computed as the sum of the individual allowances of the average number of persons eating per day. Since the meals were not equal in nutritive value, a relative weight was assigned to each meal - 0.20 for breakfast, 0.35 for lunch and 0.45 for dinner. Adjustments were made for absent members of the family and for visitors at family meals. See Appendix 2. Where the average number of persons eating per day exceeded the family size, the additional person or persons were taken to be a reference male (unless there was an indication to the contrary). Conversely, where the average number of persons eating was less than the family size, the missing person or persons, when not specified in the food consumption record, was assumed to be a reference male. Where there were an infant and a lactating mother and where an allowance for the lactation of the mother was provided, the infant allowance was omitted.

CHAPTER III

NUTRITIONAL ADEQUACY OF ACTUAL DIETS

One way of assessing the nutritional status of a population group is by comparing the nutrients in the foods actually consumed with some given dietary standard. However, the fact that the intake of certain nutrients falls below a given recommended level does not by itself justify the conclusion that a group of people is suffering from malnutrition. The possible presence of malnutrition may be inferred, but the dietary survey *per se* provides no conclusive evidence of its existence.

Dietary Study

Comparison of Actual Nutrient Intake with the Minimum Standard

Since the minimum standard against which the nutritional adequacy of the actual diets was first assessed was formulated in the sense of a minimum below which the normal physiological needs of an average person can not be sufficiently covered, it is desirable that

100 percent of the minimum recommended amount be consumed.[7]

Table 2 shows that more than one-half of the forty families had less than 100 percent of the allowance for calcium (38 families), vitamin A (33), riboflavin (30), animal protein (26), total protein (23) and Calories (23). On the other hand, only two to eight families failed to meet the minimum allowance for iron, thiamine, niacin, ascorbic acid, fat or phosphorus. On the average, six of the twelve nutrients for which minimum allowances were established were consumed in amounts less than 100 percent of the standard. These nutrients were calcium, vitamin A, riboflavin, animal protein and Calories. The other six nutrients (fat, iron, ascorbic acid, thiamine, niacin and phosphorus) were present in the diet in amounts which far exceeded the minima set for them.

The average daily intake, expressed as a percentage of the minimum standard, was 46 percent for calcium and 59 percent for vitamin A.[8] Average intakes of total protein, riboflavin, animal protein and Calories were 82, 83, 86 and 93 percent of the standard, respectively.

---

[7]This is not true for fats and phosphorus, the allowances for which were based on the existing dietary patterns and not on clinical and experimental studies. There is no reason for believing that failure to include the recommended amounts of these two nutrients in the diet will be detrimental.

[8]The average intake, expressed as a percentage of the minimum standard, was obtained by using the formula:

$$\frac{\Sigma \text{actual intake of a nutrient by all families}}{\Sigma \text{minimum allowance for a nutrient for all families}} \times 100$$

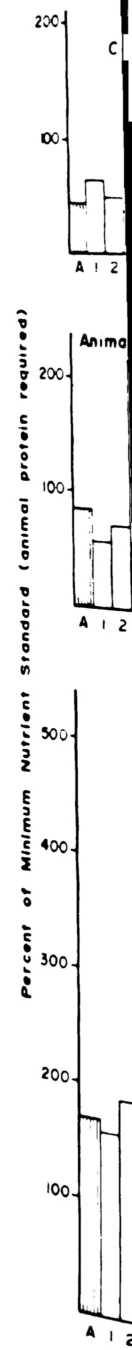
TABLE 2. PERCENT OF FAMILIES INGESTING LESS THAN 100% OF THE MINIMUM NUTRIENT STANDARD (ANIMAL PROTEIN REQUIRED)

Nutrient	Families with < 100% of standard	
	Number	Percent
Calcium	38	95
Vitamin A	33	85
Riboflavin	30	75
Animal protein	26	65
Total protein	23	58
Calories	23	58
Fat	8	20
Iron	5	13
Ascorbic acid	4	10
Thiamine	3	8
Niacin	2	5
Phosphorus	2	5

Figure 1 and Table 3 present a more detailed picture of the nutritional adequacy of the diets. On the average, the families in each of the eight cities had inadequate intakes of calcium. Only the families in Medellín met 100 percent of the allowance for vitamin A and only those in Villavicencio had sufficient riboflavin. The caloric intake was more than 100 percent of the minimum allowance for those families studied in Cali, Cartagena, Ibagué and Medellín. The intake of total protein was more than adequate for the families in Cartagena and Ibagué. The families in every one of the cities had an actual ascorbic acid intake which exceeded the minimum allowance.

Not one of the forty families met 100 percent of the minimum allowance for all nutrients, including fat and phosphorus. Based on the total number of nutrient deficiencies in the diets which were evaluated by using the minimum standard (animal protein required), the families can be distributed as follows:

No. of nutrient deficiencies	No. of families
12	1
11	0
10	1
9	2
8	1
7	3
6	9
5	5
4	3
3	9
2	4
1	2



200
C
100
A 1 2
Anima
200
100
A 1 2
Percent of Minimum Nutrient Standard (animal protein required)
500
400
300
200
100
A 1 2

A. Colom

1. B

2. C

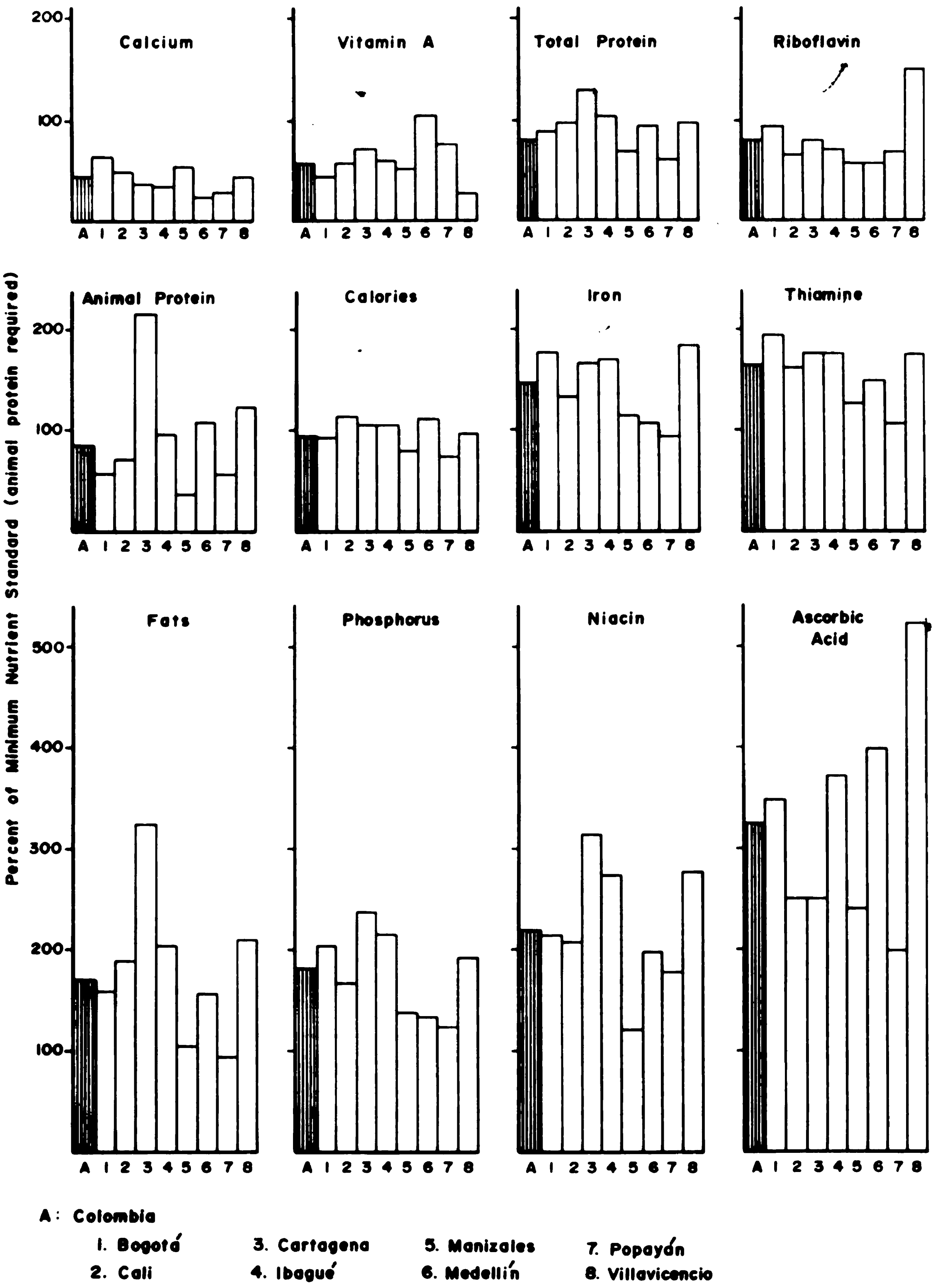


FIGURE 1.--ACTUAL NUTRIENT INTAKE AS A PERCENTAGE OF THE MINIMUM NUTRIENT STANDARD (ANIMAL PROTEIN REQUIRED)

TABLE 3. ACTUAL NUTRIENT INTAKE AS A PERCENTAGE OF THE MINIMUM NUTRIENT STANDARD
(ANIMAL PROTEIN DELETED)

	Calcium	Vitamin A	Total protein	Riboflavin	Animal protein	Calories	Iron	Thiamine	Fat	Phosphorus	Niacin	Ascorbic acid
Colombia	46	50	82	83	86	93	140	162	171	178	220	326
Bogotá	64	44	92	95	58	90	170	192	162	203	217	347
Cali	50	58	90	66	68	115	135	161	188	167	212	240
Cartagena	38	73	130	80	217	106	166	177	325	237	313	250
Ibagué	35	60	101	72	98	106	170	176	204	213	275	377
Manizales	52	57	63	56	77	80	118	124	108	138	120	240
Medellín	20	104	94	56	100	110	107	152	158	133	108	400
Popayán	28	78	62	63	58	67	95	101	93	121	174	190
Villavicencio	42	31	99	148	126	96	186	175	211	180	277	525

The me

defici

the av

Least

Most d

Compar
with t

appear

was ev

by the

margin

requir

allowa

Thus,

calciu

milarl

and ph

famili

The mean and median for the group was five nutrient deficiencies.

The cities can be arranged as follows, based on the average number of nutrient deficiencies per family:

	City	No. of nutrients
Least deficient	Cartagena	3.75
	Medellín	4.00
	Ibagué	4.20
	Villavicencio	4.50
	Cali	4.67
	Bogotá	5.08
	Manizales	6.66
Most deficient	Popayán	6.75

Comparison of Actual Nutrient Intake with the Colombian Standard

The nutritional inadequacy of the Colombian diets appeared more pronounced when the actual nutrient intake was evaluated against the higher allowances recommended by the Institute of Nutrition in Colombia. Since the margin of safety added to the theoretical physiological requirement is different for each nutrient, the recommended allowances are not uniformly related to minimal needs. Thus, an intake of only 60 percent of the allowance for calcium or iron has a different implication than do similarly low intakes of protein, vitamin A or Calories.

Table 4 shows that, except for ascorbic acid, fat and phosphorus, more than one-half (23 to 39) of all the families had less than 100 percent of the Colombian allow-

TABLE 4. PERCENTAGE OF FAMILIES INGESTING VARIOUS PROPORTIONS OF THE COLOMBIAN RECOMMENDED ALLOWANCE (ANIMAL PROTEIN REQUIRED)

Nutrient	Below 25%	25-49.9%	50-74.9%	75-99.9%	100% or more	Families with < 100% of standard No.	%	Actual intake as a percentage of the allowance
Calcium	37.50	45.00	12.50	2.50	2.50	39	97.5	71
Vitamin A	37.50	35.00	17.50	5.00	5.00	38	95.0	40
Riboflavin	2.50	45.00	27.50	12.50	12.50	35	87.5	58
Fat	---	7.50	12.50	10.00	70.00	12	30.0	138
Animal protein	22.50	27.50	15.00	7.50	27.50	29	72.5	67
Total protein	---	22.50	25.00	35.00	17.50	33	82.5	71
Calories	---	12.50	32.50	30.00	25.00	30	75.0	75
Thiamine	---	10.00	35.00	30.00	25.00	30	75.0	90
Phosphorus	---	2.50	7.50	20.00	70.00	12	30.0	120
Niacin	---	12.50	25.00	37.50	25.00	30	75.0	84
Iron	---	2.50	25.00	30.00	42.50	23	57.5	93
Ascorbic acid	---	5.00	5.00	10.00	80.00	8	20.0	167

ances.
which
amount
intake
Only 5
75 per
percen
allowa

Ta
of the
of the
of cal
of int
allowa
to 92
mine.
tal pr

The
per fa
twelve
the mi
categor
as the

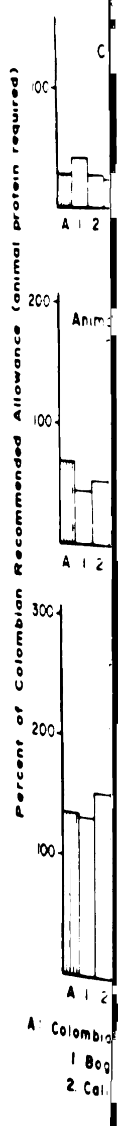
ances. On the average, nine of the twelve nutrients for which allowances have been recommended were consumed in amounts less than 100 percent of the standard. Only the intake of fat, phosphorus and ascorbic acid was adequate. Only 5 percent of all the families had calcium intakes of 75 percent or more of the recommended allowance. Ninety percent of the families consumed 75 percent or more of the allowance for ascorbic acid.

Table 5 and Figure 2 show the actual nutrient intake of the families, city by city. The families in every one of the eight cities had less than sufficient quantities of calcium, vitamin A, Calories and thiamine. The range of intake for these nutrients was 19 to 63 percent of the allowance for calcium, 18 to 55 percent for vitamin A, 54 to 92 percent for Calories and 52 to 98 percent for thiamine. Only the families studied in Cartagena met the total protein and animal protein allowances.

There was an average of eight nutrient deficiencies per family. While only one family was deficient in all twelve nutrients when the diets were assessed against the minimum standard, there were seven families in this category when the Colombian set of allowances was used as the yardstick.

TABLE 5. ACTUAL NUTRIENT INTAKE AS A PERCENTAGE OF THE COLOMBIAN RECOMMENDED ALLOWANCE
(ANIMAL PROTEIN [illegible])

	Calcium	Vitamin A	Riboflavin	Animal protein	Total protein	Calories	Thiamine	Niacin	Iron	Phosphorus	Fat	Ascorbic acid
Colombia	31	40	58	67	71	75	80	94	93	120	138	167
Bogotá	44	27	67	45	71	74	98	85	100	130	134	188
Cali	32	32	45	55	70	92	70	78	81	107	153	114
Cartagena	26	45	56	171	103	86	90	123	105	163	264	129
Ibagué	24	30	52	75	78	80	90	110	116	147	171	194
Manizales	36	33	34	22	50	62	57	42	77	95	83	131
Medellín	63	55	37	80	77	84	70	70	66	84	120	200
Popayán	10	40	43	46	40	54	52	67	61	83	75	104
Villavicencio	28	18	103	90	78	78	87	106	114	125	172	240


Percent of Colombian Recommended Allowance (animal protein required)
100
200
100
300
200
100
A 1 2

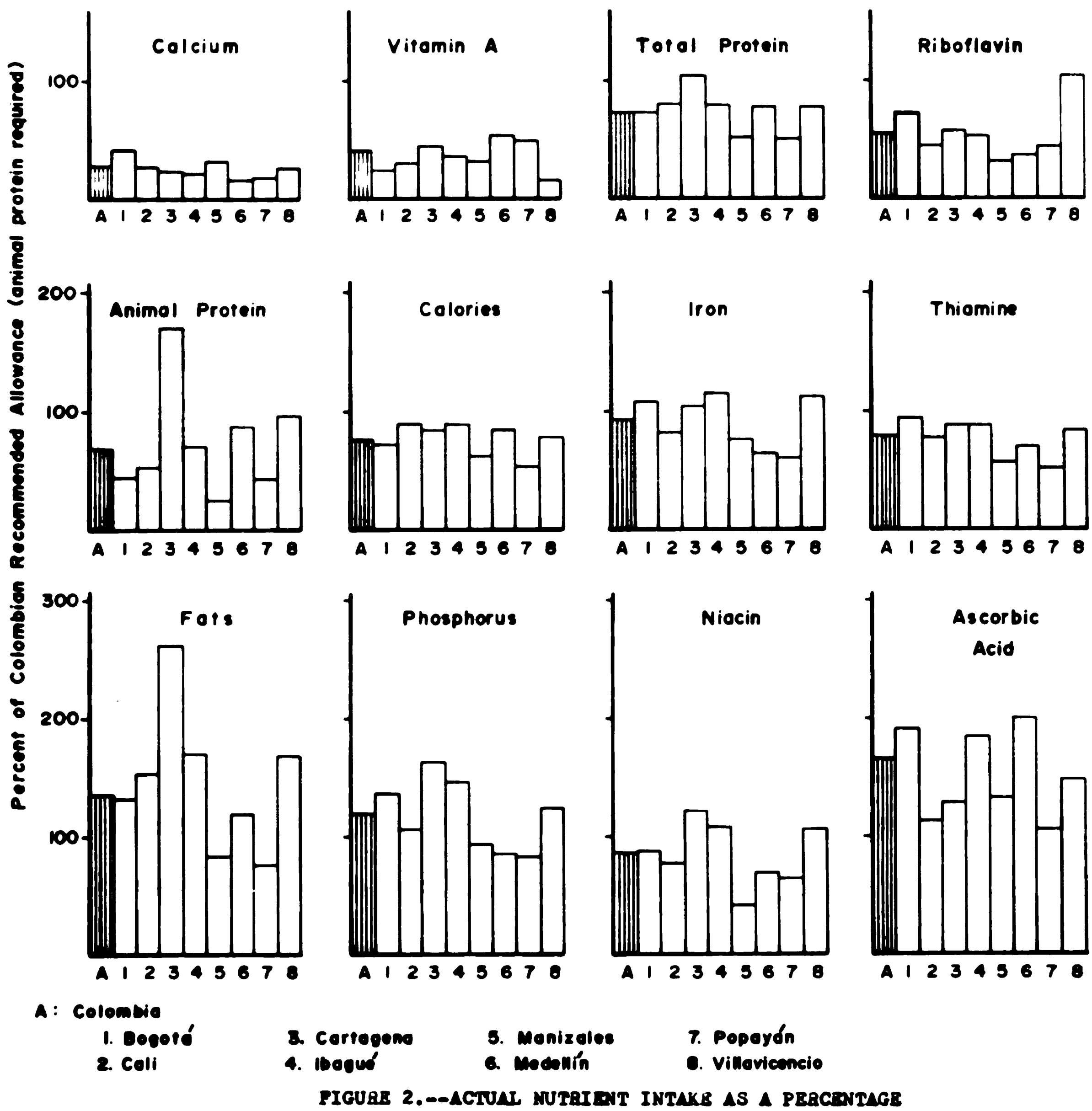


FIGURE 2.--ACTUAL NUTRIENT INTAKE AS A PERCENTAGE OF THE COLOMBIAN RECOMMENDED ALLOWANCE (ANIMAL PROTEIN REQUIRED)

Ot

divid

requi

indica

clusic

assess

clinic

and u

becaus

plus t

tempo

dicate

Althou

they

bioch

tissu

varie

store

of as

the p

of vit

spite

tamin

under

Other Methods of Evaluating Nutritional Status

Wide variations in the nutritional needs of individuals, uncertainties regarding human nutritional requirements and inaccuracies in food composition data indicate that prudence must be used in drawing conclusions from dietary findings. Two other methods of assessing the nutritional status of a population are the clinical method and the biochemical analysis of blood and urine. Agreement among these three may be limited because of the inherent sources of errors in each method plus the fact that these approaches measure different temporal aspects of nutriture. The dietary survey indicates the nutrient intakes at the time of the survey. Although the measured intakes may be satisfactory then, they may not have been so in the past or *vice versa*. The biochemical results reflect the nutrient stored in the tissues in the relatively recent past. This interval varies for different nutrients. For example, the body stores of ascorbic acid are small, so that concentrations of ascorbic acid in the blood reflect the intake during the preceeding weeks (24). On the other hand, the level of vitamin A in the tissues may remain satisfactory despite two years or more of restricted intake of this vitamin (25). For the development of clinical findings of undernutrition or malnutrition, an even longer period is requ

limi

nutr

plet

of p

fort

and

repo

give

page

by l

pect

A.

from

urine

inte

grou

and

by th

guide

activ

weigh

required to exhaust body stores. In spite of these limitations, however, all three methods of assessing nutritional status are necessary for properly and completely understanding the state of nutrition of a group of people.

In addition to the detailed dietary study of forty working-class families, the ICNND made biochemical and clinical examinations of Colombian civilians. A report of the ICNND nutrition survey of Colombia (4) gives the biochemical findings by location (Table 28, page 122) and the percent prevalence of clinical findings by location (Tables 49 and 50, pages 174 and 176, respectively).

A. Biochemical Study

The ICNND obtained specimens of blood and urine from Colombian civilians. There were 647 blood and 448 urine samples. In the absence of a standard guide for the interpretation of biochemical findings on population groups, the "Suggested Guide to Interpretation of Blood and Urine Data", formulated by the ICNND (26) was used by this author to evaluate the Colombian findings. This guide applies to a reference man, namely, a physically active 35-year-old adult male, 170 centimeters in height, weighing 65 kilograms, living in a temperate climate and

cons
blood
or de

plasm
and l
globi

ment
dex o
found
some
Nutri
have s
Popula
show e
(29).
satory
albumi
total
would
intake

B. Cl

consuming a varied diet. Levels of nutrients in the blood were interpreted as either high, acceptable, low or deficient.

The biochemical findings indicated high total plasma protein and ascorbic acid, acceptable vitamin A, and low red cell riboflavin, serum albumin and hemoglobin. See Appendix 3.

Current evidence suggests that the simple measurement of total plasma concentration is an unreliable index of protein nutriture. Keys _et al_. (27), for example, found only a slight decrease in the plasma proteins of some 34 men maintained on a famine diet for six months. Nutrition surveys of some malnourished population groups have shown normal values of total plasma protein (28). Populations consuming inadequate protein may actually show elevated rather than depressed plasma protein levels (29). In most instances, this is a result of a compensatory increase in gamma-globulin with an actual fall in albumin. Thus, even if the Colombian samples have high total plasma protein, the low level of serum albumin would indicate the probability of a deficient protein intake.

B. Clinical Study

Clinical examination is an essential part of a

nutrition survey because it provides visible evidence reflecting the nutritional status of the population studied.

A single lesion may be caused by a deficiency in more than one nutrient. To illustrate this point, glossitis may be seen in niacin, folic acid, and/or vitamin B deficiency. The occurrence of a syndrome, on the other hand, may be a more valid evidence of a deficiency. Thus, the combination of Bitot's spots with keratotic lesions has greater diagnostic significance than either sign alone. The ICNND report only recorded the percentage prevalence of clinical symptoms of nutritional deficiencies by location. The interpretation of these findings was made by this investigator, using the guide for interpreting clinical findings on the association of signs which was proposed by the World Health Organization (30). This guide presents a group of signs which together constitute clinical patterns of malnutrition which are frequently seen. See Appendix 4 for the clinical findings.

A total of 4818 individuals, exclusive of the group seen by the pediatric team, was examined in 14 areas of Colombia. The pre-school and school age groups accounted for almost 90 percent of the sample. Pregnant or lactating women made up 10 percent of the total female sample. These are groups of special interest because of

thei
velo

C

quac
rabl
urem
cula
othe
obse
used
Unit
idea
not
refe
ativ
tuar
grou
in th
weig
samp
Medel
ard w
inees

their increased nutritional demands for growth and development.

Calories and Protein

Height-weight data provide a measure of the adequacy of caloric intake. Ideally, standards of desirable height and weight should be constructed from measurements of apparently healthy subjects for the particular population. Unfortunately, Colombia, like most other countries, has no standard based on locally made observations. For purposes of comparison, the ICNND used a set of height-weight data tables developed for the United States population (31). While not necessarily ideal even for the American population, and certainly not necessarily applicable to other populations, these references allow an evaluation and comparison of data relative to some fixed point. Using the U.S. Medico-Actuarial Tables and the Baldwin-Wood Tables, the ICNND group found 267 persons or 13 percent of the total sample in the eight cities below 90 percent of the standard weight for their height. An average of 8 percent of the sample in the 20°C. areas (Bogotá, Ibagué, Manizales, Medellín and Popayán) were below 90 percent of the standard weight, while an average of 27 percent of the examinees in the 30°C. areas (Cali, Cartagena and Villavicencio)

stan

"bel

meas

unde

kor,

was

dren

grou

tain

Stat

asso

as b

pluc

in c

curr

appr

and

perc

defi
of t
that

cio) were found with body weights 90 percent below the standard. It remains to be seen whether, for Colombians, "below 90 percent of the U.S. standard weight" is a good measure of the adequacy of their caloric intake.

The pediatric study showed 17 chidren with severe undernutrition. Four were diagnosed as having kwashiorkor, the others marasmus.[9] The most persistent finding was that both the height and weight of Colombian children were considerably below those of corresponding age groups in the United States. Colombian infants maintained height and weight very similar to those of United States infants until six months of age. Physical signs associated with the syndrome of protein deficiency, such as bilateral edema, depigmentation, sparse or "easily pluckable" hair and skin lesions were commonly observed in children less than four years of age. Diarrhea, either current or recent (within the past month) occurred in approximately 40 percent of all the cases examined.

According to the ICNND, the prevalence rate of frank and severe undernutrition in the sample examined was 1.34 percent. The committee suggested that on the basis of

---

[9]Kwashiorkor is a syndrome produced by severe protein deficiency, with characteristic changes in pigmentation of the skin and hair. Marasmus is a form of starvation that is less specifically related to a shortage of protein.

expa

ten

derr

epis

come

seer

cent

bic

and

cier

A de

the

Colc

unde

vita

mine

low

phos

experience in several parts of the world, approximately ten times this number are suffering from borderline undernutrition which requires only the occurrence of an episode of diarrhea or other infectious disease to become clinically evident.

Vitamins

Syndromes reflecting vitamin deficiencies were seen in 3 percent of the sample for vitamin A, 0.8 percent for niacin and 0.2 percent for riboflavin and ascorbic acid.

It appears from the clinical data that caloric and protein undernutrition far outweigh vitamin deficiencies. Of the latter, only the prevalence of vitamin A deficiency may be of some importance.

Summary

Biochemical and/or clinical findings supported the observation from the dietary study that among the Colombian civilians studied there was a caloric-protein undernutrition, an inadequate intake of riboflavin and vitamin A and an adequate intake of ascorbic acid, thiamine and niacin. The dietary survey also indicated a low intake of calcium and adequate levels of fat and phosphorus. There were no biochemical nor clinical tests made to measure calcium nor fat or phosphorus nutrition.

The dietary study showed an adequate iron intake but hemoglobin values corrected for altitude were found to be in the low range. This discrepancy may be explained by one or a combination of the following: an inadequate intake of other nutrients, the existence of infection and parasitism and the biological availability of iron in foods.

As indicated in the ICNND report (4, page 80), the nutritional problems summarized above might be expected to be more prevalent among the Colombians studied than in the population as a whole, since the intent of the ICNND was to study groups in which, because of economic, social or other conditions, the nutritional status might be generally poor.

CHAPTER IV

COMPARISON OF ACTUAL DIETS AND LEAST-COST DIETS WHICH WOULD PROVIDE THE ACTUAL NUTRIENT INTAKE

Some families are undernourished and/or malnourished not because the quantity of food available is limited, nor because their purchasing power is small, but because they do not buy their nutrition efficiently. In some cases, the problem is not having too little to spend but spending unwisely what one can afford to spend.

A comparison of actual food expenditures with the costs of the least-cost diets which meet dietary standards for an average person in each of the eight cities is shown in Table 6 and Figure 3[10]. The actual expenditure for food was computed by multiplying the as purchased weight of each of the foods consumed, as reported in the food composition record of each of the families, by the price of the food. The cost of the least-cost diets obtained by linear programming was the product of

[10] The actual food expenditure and cost of the least-cost diet which would meet dietary standards for an average person was obtained using the formula:
Σ Actual food expenditures (or costs of least-cost diets) for all families/number of persons eating

TABLE 6. COST OF ACTUAL AND LEAST-COST DIETS IN EACH OF THE EIGHT CITIES
(COST IN PESOS PER PERSON PER DAY)

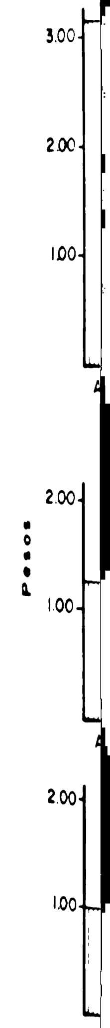
Cities (1)	Actual food expenditure* (2)	Cost of least-cost diets meeti			
		Actual nutrient intake (3)	MS[a] (4)	MS(AP)[b] (5)	CS[c] (6)
Bogotá	1.30	0.66	0.67	0.64	0.80
Cali	1.18	0.56	0.51	0.49	0.73
Cartagena	3.11	2.15	0.95	1.02	1.40
Ibagué	1.89	0.93	0.77	0.76	1.04
Manizales	1.04	0.53	0.71	0.70	1.03
Medellín	1.26	0.90	0.83	0.76	1.16
Popayán	0.90	0.53	0.81	0.75	1.13
Villavicencio	1.36	0.89	0.82	0.79	1.13
Average	1.51	0.89	0.76	0.74	1.08

[a]Minimum Standard.
[b]Minimum Standard (animal protein required).
[c]Colombian Standard
[d]Colombian Standard (animal protein required).
[e]The most efficient city (ranked 1) spent the greatest part of its total food expenditure for nutritional objectives.

*At the time of the survey, one Colombian peso ($1.00) was equivalent to 15 cents in the United States.

TABLE 6--Continued

diets meeting		% excess of (2) over (5)	"Nutritional" cost as % of total food expenditure	Efficiency of cities: rank[c]
CS[a] (6)	CS(AP)[a] (7)	(8)	(9)	(10)
0.89	0.85	97	51	5.5
0.73	0.70	111	47	8.0
1.49	1.52	45	60	2.0
1.04	1.01	103	49	7.0
1.03	1.03	96	51	5.5
1.16	1.09	40	72	1.0
1.13	1.07	70	59	4.0
1.13	1.11	53	65	3.0
1.08	1.05	77	59	---


3.00
2.00
1.00
Pesos
2.00
1.00
2.00
1.00

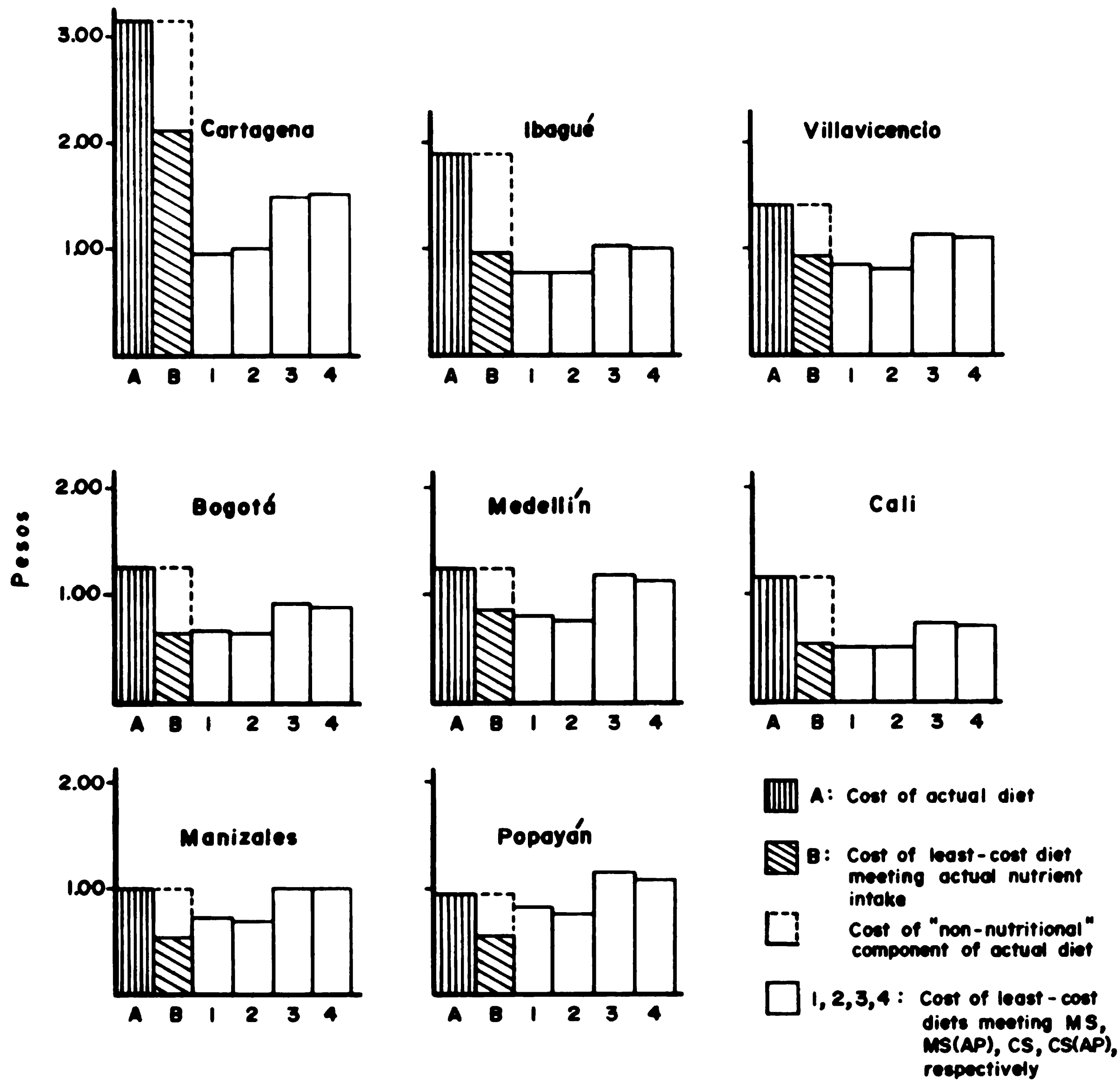


FIGURE 3.--COST OF ACTUAL AND LEAST-COST DIETS IN EACH OF THE EIGHT CITIES (COST IN PESOS PER PERSON PER DAY)

multiplying the quantity of each of the foods in the optimal solution times the price of the food. Prices were obtained primarily from the list of some thirty-five foods commonly consumed by working-class families at the time of the survey. This list was provided by the Departamento Administrativo Nacional de Nutricion (DANE) in Colombia. The prices of foods eaten but which were not in the DANE list were estimated, using price information given in the dietary questionnaire completed by the families. Appendix 5 lists for each city the percentage of the total food expenditure which was estimated. The range of the estimates was from 4.05 percent in Villavicencio to 14.74 percent in Manizales.

Figure 3 and Table 6 show that in every one of the eight cities, the actual expenditure for food exceeded the amount necessary to obtain the actual nutritional intake. The families studied in Bogotá, Cali, Ibagué and Manizales had an actual food expenditure which was around 100 percent more than the least-cost diets that would have provided the existing level of nutritional intake. In Cartagena, Medellín, Popayán and Villavicencio, the families studied spent about forty to seventy percent more than necessary if nutrition were their only objective in buying foods. There was an average percentage excess of expenditure of seventy-seven.

Except for two, all forty families had an actual food expenditure which was more than the cost of meeting their nutritional needs. The range of this excess was from 30.02 to 168.70 percent. Appendix 6 gives the per capita costs of the actual and least-cost diets in each of the thirty-eight families.

For two families, one in Popayán and another in Villavicencio, the actual food expenditure was less than the cost of the least-cost diet obtained by linear programming. Both families consumed beef liver in their actual diets and thus obtained exceedingly high intakes of vitamin A. The least-cost diet had to provide as much vitamin A as was in the actual diet but, since liver was not a common food in Colombian diets, it was excluded from the commodity list; as a consequence, vitamin A in the computed least-cost diet had to be obtained from other foods, which turned out to be more expensive sources of the vitamin. This points out the fact that the set of commodities available for use in linear programming will affect the cost of the diet and the kinds of foods that make up the diet. Since interest was centered only in those diets containing foods that were commonly eaten in the particular city being studied, it was decided to exclude these two diets in the further analysis of the data. Average figures for Popayán, Villa-

vicencio or for the whole of Colombia do not include data from these diets.

Cost of "Nutritional" and "Non-Nutritional" Components of the Total Expenditure for Food

It is evident from the comparison of dietary costs that among these Colombian working-class families, the total expenditure for food exceeded the least cost of a diet chosen solely for its nutritional content. There are varied reasons why people eat what they eat. Food has acquired a significance in human society beyond that of simply providing nourishment for the body. It is closely associated with feelings of security and prestige. It is linked with religious beliefs, superstition and prejudices. There are many studies which describe qualitatively the role of various motives behind food selection (32,33,34). None, however, has quantified the magnitude of the components of the total expenditure for food.

Dr. Smith (3) uses the terms "nutritional" and "non-nutritional" or "cultural" to denote the two basic components of total expenditure for food. The method used in this study for separating the total food expenditure into its component parts is based on Stigler's work (35). The "nutritional" component is the least cost of achieving the nutritional level actually attained, with no consideration given to palatability or taste preferences other than limiting the list of foods to be considered to those commonly eaten in the area. The "non-nutritional" component is what remains after the nutritional component is subtracted from the total expenditure on food. The cost of this non-nutritional component can be called the Stigler gap, in honor of George Stigler, who first suggested that the physiological and cultural components of low-cost diets should be distinguished (35, page 314). The Stigler gap is the difference between the least cost of a diet chosen solely to attain certain levels of nutrition and the cost of a diet chosen for reasons of culture and food preference as well (3, page 123).

Computing least-cost diets based on a purely nutritional model enables the investigator to attach a cost to each of the two fractions and to gain an understanding of their magnitude. In Figure 3, the "nutritional" fraction is the part of bar B with diagonal hatching while the "non-nutritional" fraction is the part of bar B outlined with broken lines. These two parts together add up to the total expenditure indicated by bar A.

Table 6 and Figure 3 show that the families studied in Bogotá, Cali, Ibagué and Manizales spent about as much for "non-nutritional" as for "nutritional" purposes. About 30 to 40 percent of the total food expenditure was spent for "cultural" reasons among the families studied in Cartagena, Medellín, Popayán and Villavicencio. The average Colombian family in the sample spent 59 percent of the food peso for buying nutrients and 41 percent for other objectives.

"Efficiency in the purchase of nutrition" was earlier defined as the ability to obtain the necessary nutrients in the least costly way. A family or a city is efficient to the degree that it chooses the least expensive combination of foods that will provide a certain level of nutritional intake. Using the measure of the cost of the "nutritional" and "non-nutritional" components of total food expenditure, the most efficient family is the one that allocates the greatest part of its total food expenditure to meeting nutritional needs. In less efficient families, the cost of the "non-nutritional" component accounts for larger fractions of the total expenditure for food.

The most efficient family spent 77 percent of its actual food expenditure for nutrition while the least efficient family spent only 37 percent. Of the ten most efficient families (average expenditure for nutrition, 70 percent), four were from Medellín, three from Villa-

vicencio, two from Cartagena and one from Ibagué. Five of the ten least efficient families (average expenditure for nutrition, 44 percent) came from Bogotá, two from Cali, two from Manizales and one from Ibagué. There was no relationship between family efficiency in the purchase of nutrition and variables such as family size or the amount of the total expenditure for food.

The frequency distribution of nutritional efficiency of the families is as follows:

Percent of nutritional efficiency	Number of families
35 - 40	2
41 - 45	3
46 - 50	5
51 - 55	4
56 - 60	10
61 - 65	5
66 - 70	6
71 - 75	1
76 - 80	2

The median and model class was 56 to 60 percent while the mean was 59 percent.

The cities arranged from the one where the average per capita expenditure on food was most efficient to the one where it was least are: Medellín, Cartagena, Villavicencio, Popayán, Manizales, Bogotá, Ibagué and Cali (see Table 6). Medellín and Cartagena were the two cities which had the smallest average number of nutrient deficiencies per family when the actual dietary intake was evaluated against the minimum standard. Popayán, the

fourth most efficient city, however, was the city with the most nutrient deficiencies.

Not one of the forty families met 100 percent of the minimum allowance for all nutrients. And yet, given the actual amounts spent for food, if the families had selected the least-cost diets, thirty-two of them could have obtained adequate nutrition not only at the minimum but also at the higher Colombian level.

The magnitude of the "non-nutritional" component of food expenditure or the significance of the "inefficiency" of the families in obtaining the necessary nutrients may be better understood if one employs the concept of a standard family[11]. If the families were efficient purchasers of their nutrition, that is, if they obtained all of their nutrient needs at least cost, the money they actually spent for food would have been sufficient to provide 100 percent of the minimum allowance for all nutrients not only for all thirty-eight of the families but also for 47.26 hypothetical standard families (see Table 7). This means that each of the families, after meeting its own minimum needs, could have provided adequately for 1.24 standard families. Expressing the

---

[11]The standard family for Colombia used in this study is made up of a 30 to 39 year-old male, a pregnant female 20 to 29 years of age and four children with ages ranging from one to nine years.

TABLE 7. NUMBER OF STANDARD FAMILIES WHICH COULD BE PROVIDED WITH 100% OF THE MS(AP)[a] FROM THE DIFFERENCE BETWEEN ACTUAL FOOD EXPENDITURE AND THE COST OF THE LEAST-COST DIET MEETING MS(AP)

Cities (1)	Number of families (2)	Total actual food expenditure (3)	Total cost of least-cost diets meeting MS(AP) (4)	Difference (3) - (4) (5)	Cost of least-cost diet meeting MS(AP) for a standard family (6)	Number of standard families the difference would support (7)
Bogotá	13	$108.60	$53.61	$54.99	$3.54	15.53
Cali	3	27.10	11.23	15.87	4.04	3.93
Cartagena	4	69.71	22.88	46.83	3.52	13.30
Ibagué	5	44.55	17.98	26.57	4.63	5.74
Manizales	3	23.81	16.08	7.73	3.80	2.03
Medellín	4	35.05	21.20	13.85	4.59	3.02
Popayán	3	27.15	22.53	4.62	3.11	1.49
Villavicencio	3	28.34	16.53	11.81	5.31	2.22
	38					47.26

[a]Minimum standard (animal protein required).

implication of the "cultural" cost of food expenditure this way provides a tool for making a comparison of efficiency of food expenditure not only between families and cities but also across countries. Thus, a country where an average family has a "non-nutritional" expenditure which is adequate to provide for the minimum needs of one standard family is more efficient than one where the "cultural" cost is sufficient to give two standard families adequate nutrition at the minimum level. The Food and Agriculture Organization of the United Nations has done an extensive cross-country comparison of levels, patterns and trends of food consumption, extent of hunger and malnutrition and the size of future food needs (36). However, it has not looked into the relative efficiency of these countries with respect to food expenditure perhaps because of the absence of a usable yardstick.

Food Selection in Actual and Least-Cost Diets Providing Existing Levels of Nutrient Intake

The ICNND, in its final analysis of the findings of the Colombian survey concluded that "the problem of nutrition, as far as this segment of the population is concerned, is low food intake due mainly to low family incomes" (4, page 102). It is evident, however, from the comparison of dietary costs, that these Colombian working-class families spent sufficient money to buy adequate

nutrition but failed to obtain the needed nutrients because a significant fraction of their food peso was spent for "non-nutritional" objectives. It is generally assumed that poor diets are more prevalent among the lower income groups than among the higher. However, merely increasing income may not guarantee that their diets will be more adequate. Proper food selection is important at whatever level of food expenditure one can afford.

Table 8 shows the least expensive combinations of foods that would provide the amounts of nutrients present in the actual diets of the families. Nineteen of the forty families had food consumption records for two days, the rest had a record for one day. There was a total of fifty-seven diets (excluding the two diets with total food expenditure less than the cost of the least-cost diets). There were twenty-three foods which appeared in the optimal solutions of the least-cost diets. These foods (and the frequency of their occurrence in both the least-cost and actual diets) are given in Table 9.

Either milk (raw or pasteurized) or cheese was present in all fifty-seven least-cost diets. Some kind of corn[12] was in all diets, vegetable oil in forty-four diets

---

[12]In the various cities, different kinds of corn were available to the Colombian families studied.

Table 8. [illegible]

City	Milk or cheese	Whole grains	Vegetable oil	Corn	Corn flour	Arracacha	Potato	Green plantain	Cassava	Brown sugar	Panela	Rice	Carrots	Cabbage	Dry lentils	Black beans	Dry peas	Beef
Bogotá	*	*		*c						+	+		+					
Bogotá	*	*		*c							+		+				+	
Bogotá	*	*		*c			+						+					
Bogotá	*	*	*	*c		+							+					
Bogotá	*	*	*	*c									+					
Bogotá	*	*		*c			+						+					+
Bogotá	*	*	*	*c			+				+		+					+
Bogotá	*	*	*	*c							+		+					+
Bogotá	*	*	*	*c		+	+				+		+					
Bogotá	*	*	*	*c		+					+		+					
Bogotá	*	*	*	*c		+					+							
Bogotá	*	*	*	*c		+												
Bogotá	*	*		*c														+
Bogotá	*	*	*	*c														
Bogotá	*	*		*c						+	+							
Bogotá	*	*		*c						+								
Bogotá	*	*	*	*c							+							+
Bogotá	*	*	*	*c							+		+					

TABLE 8--Continued

Cali	*[b]	*	*	*[d]		x											
Cali	*[b]	*	*	*[d]		x							x				
Cali	*[b]	*	*	*[d]													
Cali	*[b]	*	*	*[d]						x							
Cali	*[b]	*		*[d]		x				x							
Cali	*	*	*	*[d]		x				x							
Cartagena	*		*				x	x				x				x	
Ibagué	*	*	*		*	x											
Ibagué	*	*	*	*[e]	*	x				x							
Ibagué	*	*	*		*	x				x							
Ibagué	*	*	*	*[c]	*	x				x							
Manizales	*[b]		*	*[d]		x			x	x				x			
Manizales	*[b]		*	*[d]										x			
Manizales	*[b]			*[d]						x				x			
Medellín	*[b]	*	*	*[f]	*	x				x			x				
Medellín	*[b]		*	*[e]	*	x				x							
Popayán	*	*	*	*[c]		x				x					x		
Popayán	*	*	*	*[c]						x					x		
Popayán	*	*	*	*[c]	*	x				x					x		
Popayán	*		*	*[e]		x				x		x			x		
Popayán	*		*	*[e]		x				x					x		
Villavicencio	*		*		*	x	x		x								
Villavicencio	*		*		*	x	x										

[a]Foods in the "core" group are represented by an * mark and additions to the "core" group, by an x mark.

[b]Cheese.

[c]Yellow corn from Bogotá.

[d]Yellow corn from Caldas.

[e]Degermed yellow corn.

[f]Degermed white corn.

TABLE 9. FOODS IN THE ACTUAL AND LEAST-COST DIETS AND THEIR FREQUENCY OF APPEARANCE

Foods	Frequency of appearance in Least-cost diets	Actual diets
Milk and milk products		
Cow's milk, whole, raw	41	24
Soft cheese, without cream	12	2
Cow's milk, pasteurized	4	4
Fruits		
Orange, whole	43	2
Vegetables		
Carrots	12	9
Cabbage	3	16
Meat		
Beef	6	37
Legumes		
Dry lentils	6	1
Black beans	4	1
Dry peas	3	8
Cereals		
Yellow corn from Bogotá[a]	25	10
Barley	16	3
Yellow corn flour	13	10
Yellow corn from Caldas	9	7
Yellow corn, degermed	9	2
Rice	5	47
White corn, degermed	4	13
Tubers and plantain		
Arracacha	28	6
Potato	11	40
Green plantain	4	18
Cassava	3	20
Fats		
Vegetable oil	44	46
Sugar		
Brown sugar	22	45

[a]There were two kinds of yellow corn in the Colombian diet. Because of problems in transportation and distribution, the corn eaten by the people in a city is characteristic of the corn grown in the surrounding area. We have assumed that yellow corn from Bogotá was the variety consumed by the Bogotá families, and yellow corn "from Caldas", by the rest of the families studied. Yellow corn "from Caldas" has ten times as much vitamin A as yellow corn from Bogotá. One of the possible explanation for the difference may be because the two varieties are grown at different altitudes and also because each variety requires a different maturation period.

and whole oranges in forty-three diets. These foods - milk, corn, vegetable oil and oranges formed what may be called the "core" group of foods. Although the actual diets differed from family to family within a city and from city to city, this "core" group of foods was common to nearly all of the diets. Among the common supplements to this "core" group were vegetables (carrots and cabbage), legumes (black beans, dry peas and dry lentils) or beef. Beef was in the cheapest combination of foods only for Bogotá. In some of the least-cost diets, other cereals (barley and rice), tubers (potatoes, cassava and arracacha) and plantain were added to corn, the main staple food in all the cities except Cartagena. There, potatoes, rice and plantain formed the bulk of the diet.

Panela (unrefined brown sugar cake) was present in twenty-two of the least-cost diets. It is a common item in the actual diets of the Colombians, being consumed between meals and with meals as agua de panela (panela dissolved in water) or panela in milk (used widely as a

---

Yellow corn was either the Bogotá or Caldas variety; the latter has ten times as much vitamin A as the former. Because of problems in transportation and distribution, yellow corn from Bogotá may have been available only in Bogotá and yellow corn from Caldas, in the rest of the cities. Corn, both yellow and white, were consumed either as whole corn, degermed corn or as corn flour. The degermed corn called "maiz trillado", has less iron, thiamine, riboflavin and niacin than either whole corn or corn flour.

food for infants).

There were a total of 101 different food items in the actual diets of the families. Of these, however, twenty-seven appeared no more than once in any of the diets and thirty-six in only two to nine of the diets. Sixty-three of the 101 food items in the actual diets then were not generally consumed by these working-class families. Beef was in thirty-seven actual diets but was included in only six of the least-cost diets. Thirty families had milk (or cheese) in their actual diets. Vegetable oil was in forty-six of the actual diets and in forty-four of the least-cost diets.

Table 10 and Figures 4a and 4b give a comparison of the percentage contributions of the various food groups to the total costs of the actual diets and of the least-cost diets that would provide for each family the nutrients it actually consumed. The total cost of the actual diet of an average Colombian working-class family was divided among the different food groups as follows: 30.50 percent from meat, 26.12 from cereals, 19.73 from tubers and plantain, 9.23 from fats, 5.01 from legumes, 3.73 from milk, 3.14 from miscellaneous foods, 2.27 from vegetables and 0.27 from fruits. On the other hand, the total cost of the least-cost diets that would have provided the same nutrients as the actual diet was apportioned

TABLE 10. PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL COSTS OF THE ACTUAL DIETS AND OF THE LEAST-COST DIETS PROVIDING THE ACTUAL LEVELS OF NUTRIENT INTAKE

	Milk	Fruits	Vegetables	Meat	Legumes	Cereals	Tubers and plantain	Fats	Miscellaneous
I. Actual diets									
Bogotá	8.17	---	2.97	13.08	4.90	27.34	24.52	15.90	3.12
Cali	6.40	---	1.43	20.75	4.54	33.15	18.22	11.02	2.73
Cartagena	2.44	1.37	3.58	54.27	1.22	17.27	7.55	4.12	8.27
Ibagué	0.89	---	2.07	37.81	3.60	26.88	17.73	9.31	1.62
Manizales	6.06	0.14	1.69	19.30	13.52	29.91	18.17	10.14	1.07
Medellín	---	---	1.05	43.01	5.56	16.54	23.31	10.08	0.45
Popayán	3.48	0.67	1.87	25.57	1.74	32.66	23.83	5.22	4.95
Villavicencio	2.31	---	3.52	30.18	4.93	24.14	24.40	8.05	2.41
Colombia	3.73	0.27	2.27	30.50	5.01	26.12	19.73	9.23	3.14

TABLE 10--Continued

II. Least-cost diets providing the actual nutrient intake levels

Bogotá	29.83	9.31	1.19	1.19	0.48	40.40	4.06	4.53	---
Cali	23.04	3.00	---	---	---	53.00	8.06	12.90	---
Cartagena	50.70	---	---	---	1.82	31.40	8.37	7.71	---
Ibagué	33.71	2.28	---	---	---	37.36	18.91	7.74	---
Manizales	17.01	---	10.70	---	---	50.75	12.19	8.46	---
Medellín	31.64	6.36	2.86	---	---	28.14	20.99	10.02	---
Popayán	31.07	0.99	5.95	---	10.08	19.01	23.80	6.45	2.64
Villavicencio	47.28	---	---	---	---	11.37	40.04	1.31	---
Colombia	33.15	2.74	2.59	0.15	1.55	35.05	17.05	7.39	0.33

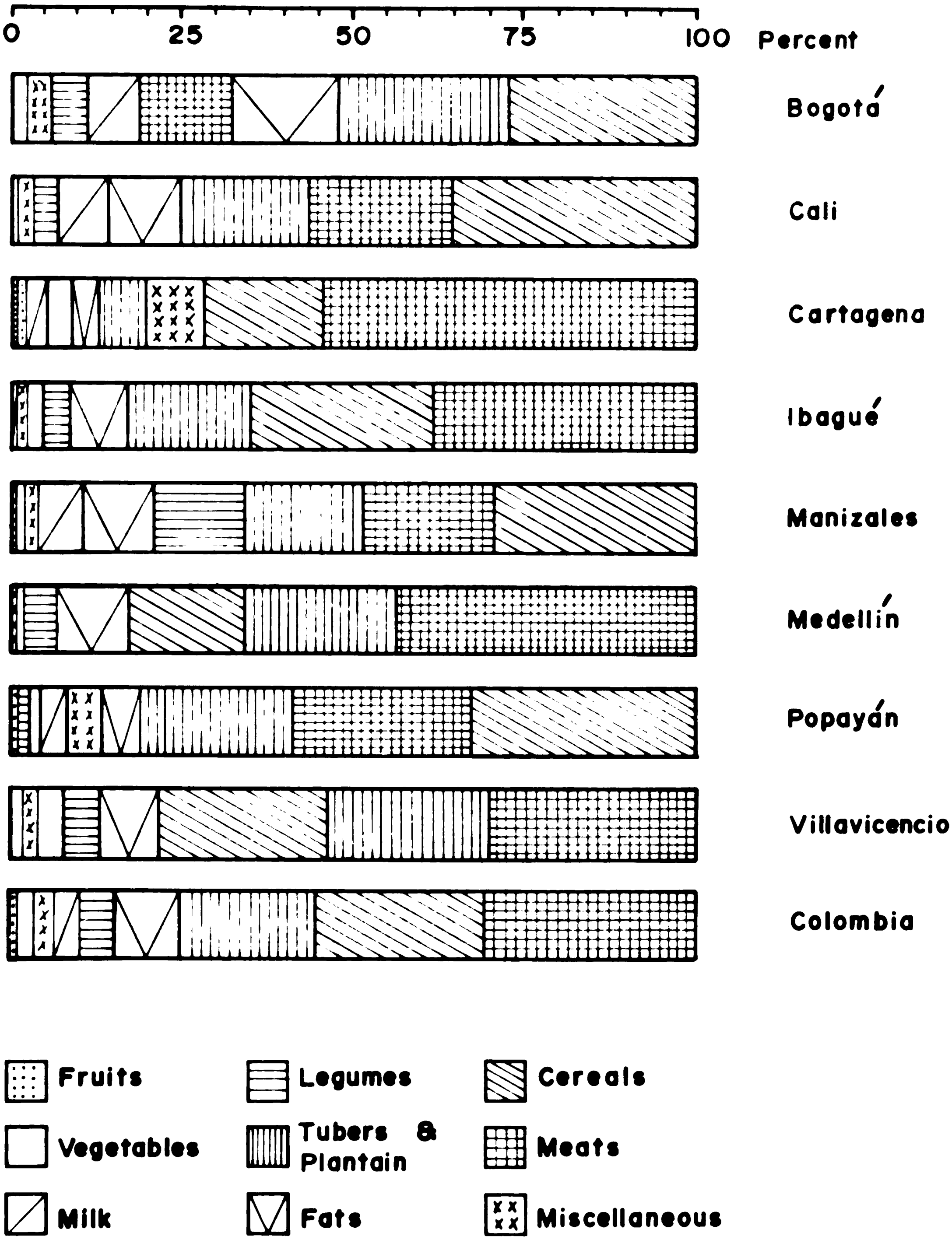


FIGURE 4a.--PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL COSTS OF THE ACTUAL DIETS

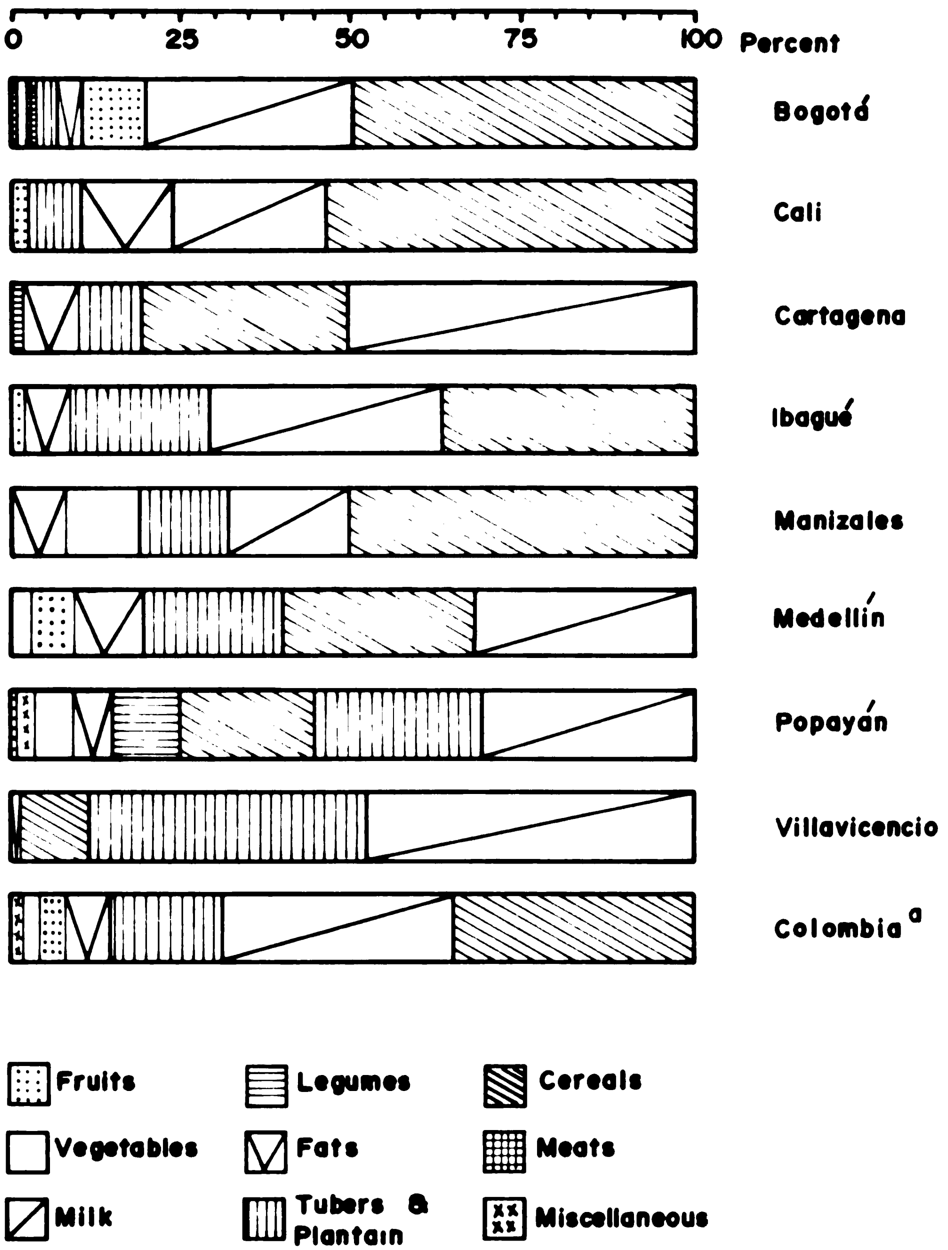


FIGURE 4b.--PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL COSTS OF THE LEAST-COST DIETS THAT WOULD PROVIDE THE ACTUAL LEVELS OF NUTRIENT INTAKE

[a]Because the contribution of meats, legumes and miscellaneous food groups is very small, the percentage values have been added and represented as [symbol].

thus: 35.05 percent from cereals, 33.15 from milk, 17.05 from tubers and plantain, 7.39 from fats, 2.74 from fruits, 2.59 from vegetables, 1.55 from legumes, 0.33 from miscellaneous foods and 0.15 from meat. Cereals, tubers and plantain together account for the major part of the total food expenditure in both diets. Meat had the biggest percentage contribution to the total food expenditure in the actual diet but the smallest in the least-cost diet.

The primary difference between the two types of diets is the change in the percentage contribution of milk and meat. Together the two account for about 33 to 34 percent of the total expenditure for food in both the actual and least-cost diets. However, for the country as a whole, the milk cost contribution increased from 3.73 percent in the actual diet to 33.15 percent in the least-cost diet, while the meat cost contribution decreased from 30.50 percent to 0.15 percent. In none of the least-cost diets was money allocated for the purchase of meat except in the city of Bogotá. Among the other changes from the actual diets to the least-cost diets were an 8.93 percentage point increase in cereals accompanied by a 2.68 percentage point decrease in tubers and plantain and a tenfold increase in the expenditure for fruits. Since the model for finding least-cost diets did not explicitly consider palatability and taste preferences, the expenditure for miscellaneous items in these diets was only 0.33 percent as against 3.14 percent in the actual diet. The "miscellaneous" item in the least-cost diet is unrefined brown sugar.

Tables 11 and Figures 5a and 5b indicate the percentage contributions of the various food groups to the total Calories in the actual diets and in the least-cost diets that would provide the actual nutrient intake. Cereals were the major source of Calories in both diets, 39 percent of the total caloric intake in the actual diets and 61 percent in the least-cost diets. Compared with the actual diets, there was a decrease in the least-cost diets of the percentage contribution to total Calories of four food groups: tubers and plantain - from 35.37 to 19.77 percent, fats - from 10.71 to 7.76 percent, meats - from 6.96 to 0.02 percent and miscellaneous foods-from 1.63 to 0.03 percent. However, the caloric contribution of milk rose from 1.61 to 10.10 percent.

The cereal foods in the least-cost diets were corn (present in 60 diets), barley (16) and rice (5). The actual diets had rice (47), corn (42) and barley (3) and in addition, bread (32), noodles (15), wheat (2) and oats (1).

TABLE 11. PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL CALORIES IN THE ACTUAL DIETS AND IN THE LEAST-COST DIETS PROVIDING THE ACTUAL LEVELS OF NUTRIENT INTAKE

	Milk	Fruits	Vegetables	Meat	Legumes	Cereals	Tubers and plantain	Fats	Miscellaneous
I. Actual diets									
Bogotá	4.42	---	0.55	2.57	4.46	40.65	29.00	16.28	1.21
Cali	2.05	---	0.26	3.45	2.30	46.02	31.04	9.12	4.18
Cartagena	3.08	0.70	0.40	16.84	3.47	36.04	22.73	11.56	4.18
Ibagué	0.56	---	0.35	6.80	2.37	40.53	33.54	12.77	0.99
Manizales	2.26	0.02	0.33	2.04	8.18	34.72	41.65	9.00	0.04
Medellín	---	---	0.07	9.01	3.16	39.92	41.23	6.26	0.29
Popayán	1.08	0.48	0.60	5.07	2.10	43.82	38.40	6.20	0.25
Villavicencio	1.61	---	0.40	8.01	4.47	26.60	43.51	14.02	0.42
Colombia	2.00	0.16	0.37	6.96	3.81	39.00	35.37	10.71	1.63

TABLE 11--*Continued*

II. Least-cost diets providing the actual nutrient intake levels

Bogotá	10.36	2.25	0.17	0.18	0.28	80.43	3.12	3.21	---
Cali	3.14	1.02	---	---	---	82.24	5.95	7.65	---
Cartagena	21.74	---	---	---	3.24	50.04	11.26	13.73	---
Ibagué	12.63	0.84	---	---	---	54.84	25.12	6.57	---
Manizales	2.29	---	1.68	---	---	74.75	16.27	5.00	---
Medellín	4.00	1.86	0.46	---	---	48.04	33.02	9.03	---
Popayán	14.07	0.59	1.41	---	4.87	37.20	35.68	5.98	0.22
Villavicencio	12.57	0.24	---	---	---	50.39	26.82	9.08	---
Colombia	10.10	0.85	0.47	0.02	1.05	61.10	19.77	7.76	0.03

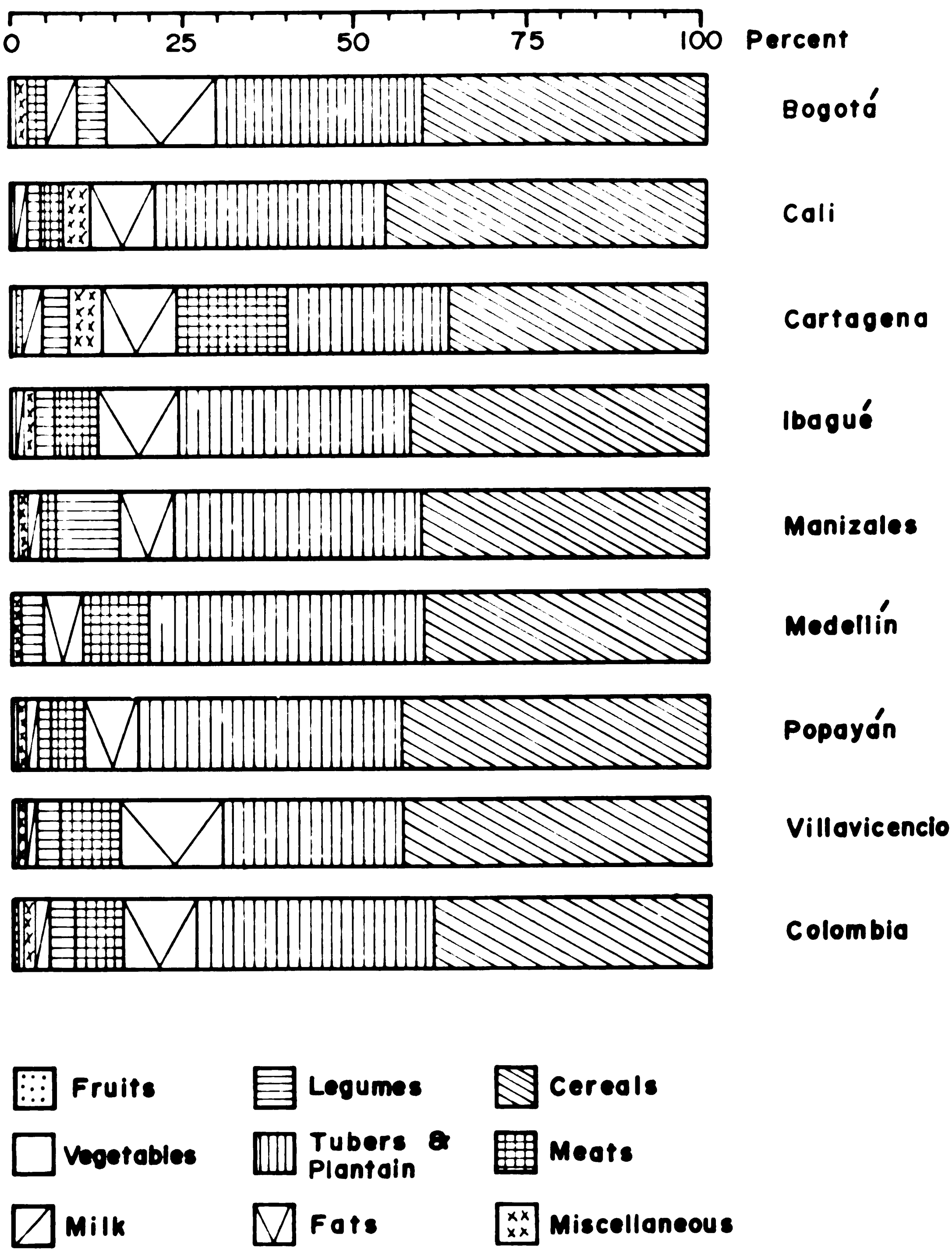


FIGURE 5a.--PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL CALORIES IN THE ACTUAL DIETS

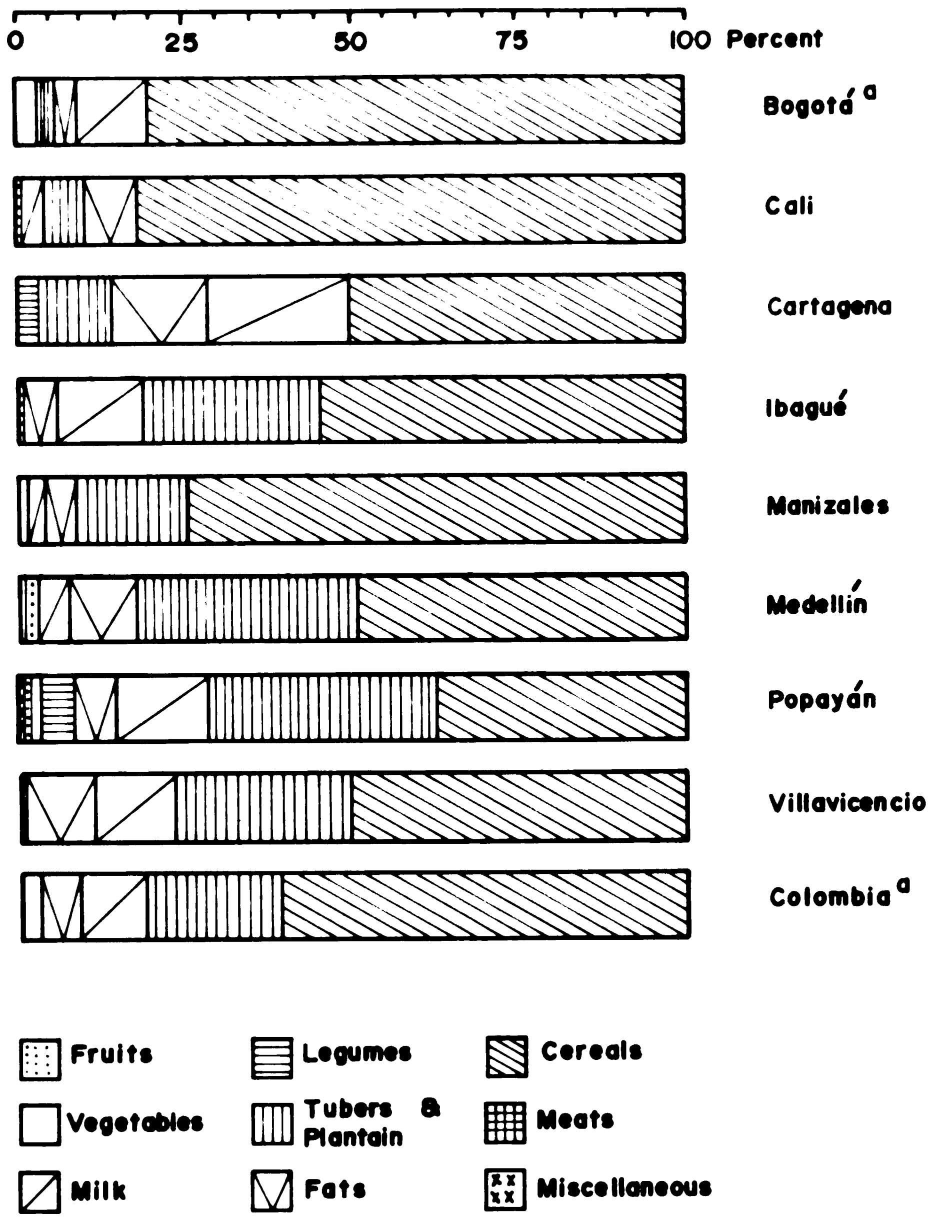


FIGURE 5b.--PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL CALORIES IN THE LEAST-COST DIETS THAT WOULD PROVIDE THE ACTUAL LEVELS OF NUTRIENT INTAKE

[a]Because the contribution of vegetables, meats, legumes, fruits and miscellaneous foods is very small, the percentage values for these five groups have been added and represented as ☐ .

The main tuber in the least-cost diet was arracacha (which was present in 28 diets); other tubers were potatoes (11) and cassava (3). The tubers in the actual diets were potato (40), cassava (20), and arracacha (6). Plantain was in five least-cost diets and sixteen actual diets. Other tubers in the actual but not in the least-cost diets were yam (3) and sweet potato (1).

Table 12 and Figures 6a and 6b show the percentage contributions of the various food groups to the total protein in the actual diet and the least-cost diets which would provide the actual nutrient intake of an average family. In both diets, cereals were the major source of protein. They accounted for 44.44 percent of the total protein in the actual diet and 62.08 percent in the least-cost diets. Meat and milk together account for about 28 percent of the total protein in both the actual and least-cost diets. Meat decreased in importance as a protein source in the least-cost diets, making up only 0.04 percent of the total protein (but providing 23.02 percent in the actual diet). The change from actual to least-cost diets was also characterized by an increase in the protein derived from milk (4.95 to 28.62 percent), a decrease in protein from legumes (11.78 to 2.89 percent) and a decrease in tubers and plantain as sources of protein (12.40 to 4.87 percent).

TABLE 12. PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL PROTEIN IN THE ACTUAL DIETS AND THE LEAST-COST DIETS PROVIDING THE ACTUAL LEVELS OF NUTRIENT INTAKE

	Milk	Meat	Legumes	Cereals	Tubers and plantain	Others
I Actual diets						
Bogotá	10.65	8.51	14.47	45.22	16.23	4.92
Cali	5.80	13.37	6.08	57.12	8.98	8.65
Cartagena	5.97	43.08	7.95	32.02	6.98	3.29
Ibagué	1.49	23.35	8.20	49.33	15.20	2.42
Manizales	6.19	11.33	26.26	42.46	10.40	3.26
Medellín	---	28.72	10.18	47.32	12.10	1.67
Popayán	5.74	21.11	6.81	53.31	11.10	1.93
Villavicencio	3.74	33.80	13.36	28.75	19.24	1.11
Colombia	4.95	23.02	11.78	44.44	12.40	3.41
II Least-cost diets providing the actual nutrient intake levels						
Bogotá	18.48	0.30	0.69	78.14	0.95	1.43
Cali	18.64	---	---	79.43	1.22	0.71
Cartagena	46.93	---	6.88	40.07	6.12	---
Ibagué	30.00	---	---	64.14	5.20	0.66
Manizales	16.62	---	---	77.98	1.57	3.84
Medellín	38.50	---	---	54.83	4.78	1.89
Popayán	34.18	---	15.58	39.91	6.97	3.35
Villavicencio	25.48	---	---	62.17	12.15	0.20
Colombia	28.62	0.04	2.89	62.08	4.87	1.51

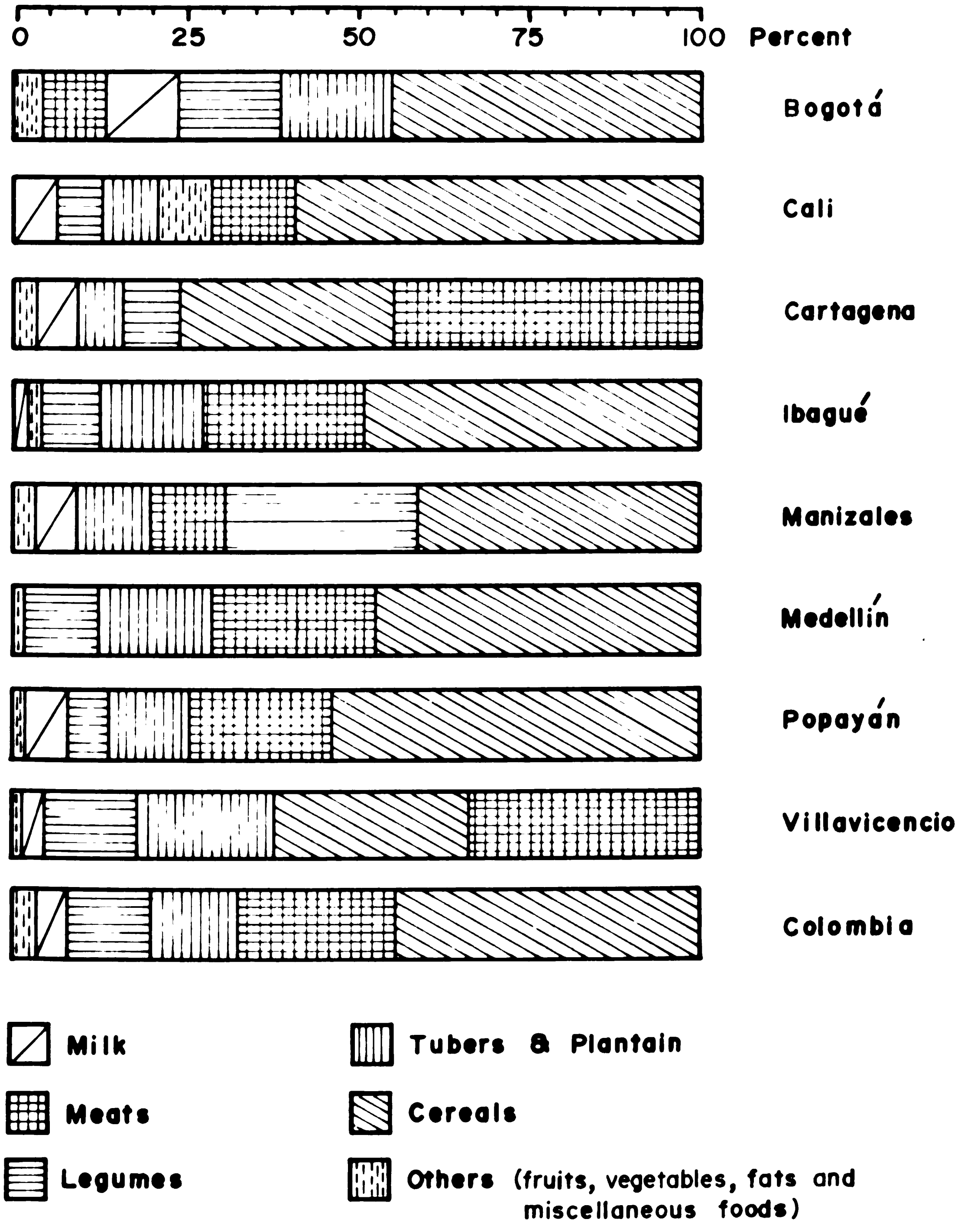


FIGURE 6a.--PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL PROTEIN IN THE ACTUAL DIETS

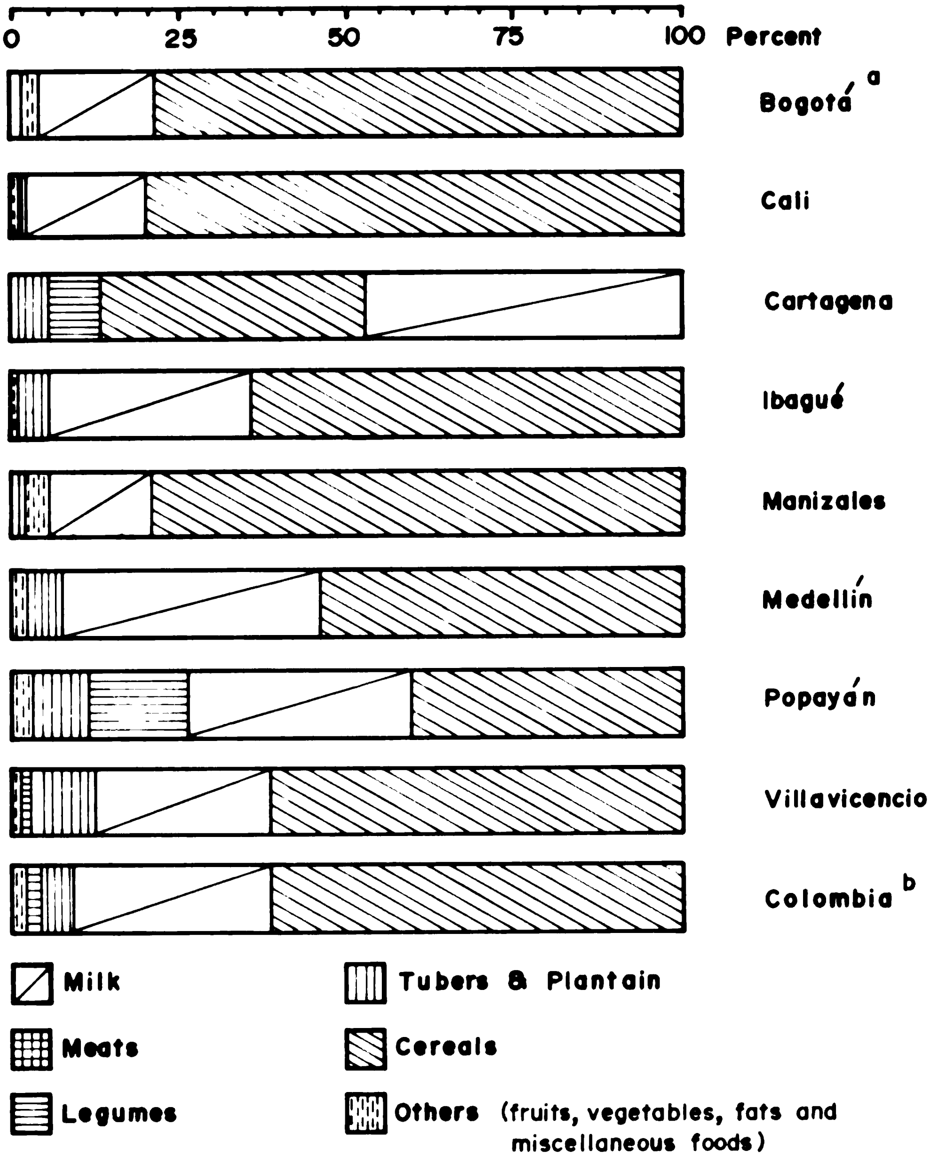


FIGURE 6b.--PERCENTAGE CONTRIBUTIONS OF THE VARIOUS FOOD GROUPS TO THE TOTAL PROTEIN IN THE LEAST-COST DIETS THAT WOULD PROVIDE THE ACTUAL LEVELS OF NUTRIENT INTAKE

[a]Because the contribution of meats, legumes and tubers and plantain is very small, the percentage values for these three groups have been added and expressed as ☐ .

[b]The contributions of meats and others have been added and expressed as ▒.

Although food habits are far from unchangeable, a specific change may be more easily brought about if the existing dietary patterns of the people are not changed substantially. Since all the foods in the least-cost diets were in the list of those commonly consumed by Colombian working-class families, those who may choose these diets would not be faced with making major changes in their patterns of food consumption. The change involved is not one of accepting a new food but of changing the relative proportions of the different foods to be eaten. This would mean allocating the food peso among the different foods differently. Among the Colombian families studied, this would mean spending less for meat, tubers and plantain and more for milk and cereals and doing away with essentially all miscellaneous food items (except unrefined brown sugar).

The least-cost diets based on a purely nutritional model will not be acceptable to all the people involved. This does not mean, however, that they are of little practical use. Knowing the most efficient foods for a particular group of people will be useful in providing a guide for agricultural policies and for indicating where the emphasis must be placed with regard to nutrition education. Minimum cost subsistence diets provide a measure of the capacity of a country to feed itself. A useful

measure of the extent of the food problem in any country would be the ratio of the production actually available to the production that would be required to provide everyone a least-cost subsistence diet (3, page 6).

One of the criticisms against least-cost diets obtained by linear programming and based on a purely nutritional model is the lack of variety or monotony. Time once remarked that "a computer can live cheaper than a human being because it has no taste buds" (37). Some individuals and families willingly sacrifice nutrition and economy for the sake of palatability. Variety in meals is one of the guidelines for dietitians when planning menus. They look at it as one way of insuring an adequate intake of certain nutrients known to be essential to the body, but for which levels of recommended intake are not known as yet. And yet, in spite of all the importance attached to variety in meals, there really is no measure of monotony or its absence when describing diets. When is a diet monotonous and when is it not? How many food items must there be in a diet before it can be considered a "varied diet"? It is meaningful at this point to ask the question raised by D. Lee at a symposium on Nutrition and Behaviour (38). "Is eating monotony peculiar to the economy of plenty?" Is the desire for a whole array of foods in the diet a particular expression of an affluent society's broader tendency to seek, sooner or later, variations in an activity? One can readily find instances of ethnic groups subsisting upon essentially repetitive or "monotonous" diets. These are societies where what may be valued is sameness, not variety; where monotony is good and sought. Does it matter as much that a diet contains only four to eight foods (as is true with the least-cost diets obtained in this study) as the fact that the diet, in spite of the limited foods it contains, provides the necessary nutrients? Dr. Porter[13] calls the emphasis on "variety in foods" among most Westerners a "fetish"; the investigator regards it as a luxury few can afford. Most people in Asia are lucky and content if they can have something to eat.

It may be a little pessimistic but certainly not out of line to think that some day man cannot choose his foods as he is now able to do. He will only be concerned with getting whatever available food he needs in order to survive, not with what he prefers to eat. Least-cost diets based on a purely nutritional model provide one with a list of the least expensive and most efficient combinations of foods for meeting nutrient needs. These

---

[13]Personal communication with Dr. Thelma Porter, former Dean of the College of Home Economics at Michigan State University in East Lansing, Michigan.

are the appropriate foods that must be made available at a time when free choice of food is no more any man's privilege. That these combinations of foods will be accepted in the long-run is not impossible. The general acceptance in England of potato as a food (where for some two hundred years it was regarded with suspicion and reputed to be poisonous) is convincing proof that the prejudices of a nation, however deeply rooted, are by no means unconquerable. Mckenzie, in discussing the dynamics of accomplished change (39), suggests that the more likely explanations for this can be found in: (a) a growing need for staples with a high yield as the result of a rapidly growing population and, at the same time, a declining proportion of the population working on the land; (b) the favorable soil and climate in areas of growing population; (c) a crop which was easy to store. Thus the gradual operation of economic and social incentives within the community may have persuaded the farmer to change his crops and the consumer to change his choice of foods. Incentives within the community rather than abrupt pressure from outside for change may have brought about the desired effect. What was it in history that made other food changes internally and externally consistent with the beliefs of people and what conditioning brought about the agreement to change?

Of course, it is an oversimplification of the problem to think that all will be well once people are made aware of the relative value of the different foods. One only has to refer to recent attempts to stop people from smoking to realize the complexity of the problem. This is not to say that education will not modify attitudes but merely to emphasize the need for considerable research to see under what circumstances nutrition education can become successful and which teaching techniques are the most effective.

CHAPTER V

LEAST-COST STANDARD AND SUPPLEMENTARY DIETS

This study used linear programming to compute least-cost diets that would provide each of the families with the recommended nutrient allowances, both at the restricted minimum level and at the more generous Colombian level. As with the least-cost diets which provided the existing level of nutritional intake for the Colombians studied, the diets for these standards were based on a purely nutritional model. The foods in the least-cost diets that would provide each family with the specified nutritional needs are presented in Appendix 7. There was much less variation in dietary patterns among these least-cost diets than among the least-cost diets which would have provided the actual nutrients consumed by the families studied. There were nineteen different combinations of foods in the least-cost minimum-standard diets (seventeen for the least-cost Colombian-standard diets) and fifty-six in the least-cost diets providing the actual nutrient intakes (see Table 8). In Bogotá, for example, all of the twenty-five least-cost diets which provided the Colombian nutrient allowances were composed of the same five foods - whole milk, oranges, carrots, corn and barley. The twenty-five least-cost diets which provided the level of nutrients in the actual diets exhibited twenty different combinations of some ten foods, almost one pattern for each of the daily diets. This wide variation in dietary pattern reflected the considerable differences in actual nutrient intake between families.

The foods and the frequency of their appearance in both the least-cost minimum-standard and Colombian-standard diets are presented in Table 13. The same foods appeared in both sets of diets except for the addition of rice and barley in the Colombian-standard diets. The foods in the "core" group are milk, corn and oranges. These foods appeared in most of the least-cost diets despite differences in family composition and differences in prices of commodities between cities. In some diets, both milk and cheese were present. In others, too, more than one kind of corn appeared in the diets. Supplements to the "core" group included the addition of vegetables (carrots and cabbage), legumes (dry lentils and black beans), tubers (arracacha, potato and cassava) and green plantain, vegetable oil or unrefined brown sugar.

Table 6 (page 45) and Figure 3 (page 47) give the daily per capita cost of the least-cost minimum and stand-

TABLE 13. FOODS IN THE LEAST-COST DIETS:
MINIMUM AND COLOMBIAN STANDARDS
(ANIMAL PROTEIN REQUIRED)

Foods	Frequency of appearance in Minimum-standard diets	Colombian-standard diets
Milk and milk products		
Cow's milk, whole, raw	40	40
Soft cheese, without cream	13	13
Cow's milk, pasteurized	8	8
Fruits		
Orange, whole	45	33
Vegetables		
Carrots	36	38
Cabbage	0	2
Legumes		
Dry lentils	7	6
Black beans	4	4
Cereals		
Yellow corn from Bogotá	25	25
Yellow corn, degermed	16	16
Yellow corn flour	13	22
Yellow corn from Caldas	0	0
White corn, degermed	7	4
Barley	0	25
Rice	0	4
Tubers and plantain		
Green plantain	14	15
Arracacha	8	28
Potato	3	2
Cassava	1	4
Fats		
Vegetable oil	33	10
Sugar		
Brown sugar	22	24

ard diets. In each of the cities, the per person cost of the least-cost diets was less than the cost of the actual diets consumed. For Colombia as a whole, the average actual food expenditure per person per day was $1.51, seventy-seven centavos more than the average cost of the least-cost minimum-standard diet (with an allowance for animal protein) and forty-six centavos more than the average cost of the least-cost Colombian-standard diet (animal protein required).

Figure 3 also shows that for the least-cost standard diets, whether minimum or Colombian, the least cost of providing for the nutritional needs is less when animal protein is required in the diet than when the source of protein is left unspecified. It was pointed out earlier that since there was no way of knowing in advance whether it would be less expensive to meet protein needs by consuming all vegetable protein, all animal protein or a combination of both, protein allowances were set at two levels. One level was appropriate for a mixed diet with a biological value of sixty and the other was appropriate for a mixed diet with a biological value of eighty. In the model that used the former level, there was no restriction set on the kind of protein in the diet (except for small amounts of animal protein to provide for the protein needs of an infant in a family where there was no lactating woman). In the model that used the latter level, it was specified that one-third of the total daily protein allowance must be obtained from animal sources. The notations MS and CS were used for the minimum and Colombian standards, with protein source unspecified, and MS(AP) and CS(AP) for minimum and Colombian standards with animal protein required. Table 6 indicates that for each of the cities (except Cartagena), the least-cost MS(AP) diets cost from one to seven centavos less than the least-cost MS diets while the costs of the CS(AP) diets were either equal to or less than the costs of the CS diets by two to seven centavos. On the average, the per capita cost of the MS(AP) diet was two centavos less than the MS diets while the per capita cost of the CS(AP) diets was three centavos less than the CS diets. In forty-four of the fifty-seven least-cost minimum-standard diets, the MS(AP) diets cost less than the MS diets. Although the savings that might accrue from consuming foods in the MS(AP) diets instead of those in the MS diets may be small, the cost comparison made between the two types of diets pointed out the fallacy in believing that diets which require animal sources of protein are more expensive than those which do not.

Table 14 lists the foods (and their amounts) in the least-cost minimum-standard diets, with and without an allowance for animal protein for the families studied. Analysis of the data for Bogotá reveals the difference between the MS and MS(AP) diets. Both types of diets had whole milk, oranges, carrots and yellow corn from Bogotá. However, the MS(AP) diets (which were less expensive than the MS diets for ten families) contained whole milk (an average increase per family of 480 grams), more yellow corn (an average increase per family of 230 grams), and no dry beans.

The same kind of analysis of basic changes from the MS to the MS(AP) diets in other cities reveals the following:

a) In Cali, there was an increase in milk, and a decrease in yellow corn from Caldas.

b) In Ibagué, there was an increase in milk and a decrease in crushed yellow corn and yellow corn flour.

c) In Manizales, the amount of milk in the diet was increased.

d) In Medellín, there was an increase in cheese and a decrease in crushed white corn and yellow corn flour.

e) In Popayán, milk was increased while dry lentils and crushed yellow corn decreased.

f) In Villavicencio, there was more milk and less yellow corn flour.

TABLE 14. COMPARISON OF FOODS IN IBAGUÉ-BOGOTÁ MS AND MS(AP) DIETS
(QUANTITY OF FOODS IN KG)

	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)
Ibagué	1		2		3*		4*		5	
Milk	1.40	1.62	1.040	0.96	1.51	2.120	2.10	3.120	1.33	2.18
Whole orange	0.01	---	0.060	0.02	0.04	---	0.10	---	---	---
Dry peas	0.21	---	----	---	0.14	---	0.18	---	0.30	---
Corn	0.02	0.68	0.280	0.25	1.40	1.270	2.00	2.000	0.79	0.90
Corn flour	0.54	0.58	0.610	0.47	1.07	0.410	1.60	0.570	1.17	0.72
Green plantain	0.50	0.59	0.100	0.22	0.37	0.980	0.41	1.060	0.66	0.82
Brown sugar	---	0.35	0.008	0.16	---	0.660	---	0.070	---	0.43
Vegetable oil	---	---	----	---	---	0.004	---	0.008	---	---
Bogotá	1		2		3		4		5	
Milk	1.82	2.42	1.60	1.70	2.70	3.10	1.71	1.80	1.77	2.46
Whole orange	0.14	0.13	0.12	0.12	0.18	0.17	0.10	0.10	0.16	0.15
Carrots	0.14	0.13	0.07	0.08	0.18	0.17	0.15	0.15	0.17	0.16
Dry peas	0.31	---	0.24	---	0.19	---	0.77	---	0.52	---
Corn	2.41	2.60	1.46	1.53	3.14	3.27	1.90	2.03	1.88	2.24
Brown sugar	---	---	---	0.16	---	---	---	---	---	---
Bogotá	6		7*		8		9		10	
Milk	1.82	2.13	2.82	4.34	2.58	3.04	2.52	2.62	2.22	2.50
Whole orange	0.13	0.14	0.22	0.18	0.19	0.16	0.19	0.20	0.17	0.17
Carrots	0.12	0.12	0.33	0.31	0.25	0.23	0.11	0.12	0.15	0.15
Dry peas	0.37	---	0.42	---	0.42	---	0.43	---	0.30	---
Corn	1.71	2.00	5.18	5.31	3.46	3.65	2.00	2.33	2.24	2.56
Brown sugar	---	---	---	---	---	---	---	0.05	---	---
Bogotá	11		12*		13*					
Milk	1.36	1.88	2.66	4.04	2.86	4.05				
Whole orange	0.11	0.10	0.21	0.17	1.18	1.15				
Carrots	0.18	0.17	0.34	0.32	0.35	0.33				

TABLE 14.

	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)
Dry peas	0.29	---	0.27	---	0.25	---				
Corn	2.21	2.39	5.31	5.32	5.14	5.16				
Brown sugar	---	---	---	---	---	---				
Cartagena	1*		2*		3*		4*			
Milk	1.46	2.29	1.46	1.860	2.24	2.78	2.65	3.200		
Black beans	0.65	0.44	0.27	0.310	0.53	0.51	0.57	0.280		
Rice	---	---	---	---	---	---	0.13	---		
Corn	1.41	1.62	1.15	1.250	2.01	2.08	2.17	2.010		
Corn flour	---	---	---	---	---	---	---	0.780		
Cassava	---	---	---	0.060	---	---	---	---		
Green plantain	1.33	1.11	0.50	0.300	1.04	0.92	1.70	1.200		
Brown sugar	---	---	0.17	---	---	---	---	---		
Vegetable oil	0.04	0.02	0.02	0.009	0.03	0.02	0.04	0.006		
Medellín	1		2		3		4			
Milk	0.68	0.61	3.05	1.76	1.59	1.26	1.100	1.23		
Cheese	0.09	0.08	0.03	0.38	0.20	0.22	---	0.07		
Whole orange	---	0.10	---	0.40	---	0.24	---	0.05		
Carrots	0.01	0.04	0.15	0.25	0.01	0.08	0.070	0.11		
Cabbage	0.20	---	0.71	---	0.46	---	0.180	---		
Corn	0.79	0.57	3.32	1.07	1.60	1.20	1.230	0.90		
Corn flour	0.79	0.50	2.70	1.80	1.77	1.19	0.560	0.20		
Arracacha	---	---	---	---	---	---	---	0.07		
Brown sugar	---	0.39	---	1.10	---	0.80	---	0.64		
Vegetable oil	---	0.01	---	0.05	---	0.03	0.006	0.03		
Cali	1		2		3					
Milk	0.45	0.730	0.69	0.53	0.47	0.54				
Cheese	0.33	0.250	0.32	0.34	0.22	0.20				
Whole orange	0.21	0.190	0.22	0.22	0.15	0.14				
Corn	3.31	2.920	4.09	3.57	2.76	2.65				
Brown sugar	0.14	0.520	---	0.14	0.04	0.14				
Vegetable oil	---	0.002	---	---	---	---				

TABLE 14.

	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)	MS	MS(AP)
Manizales	1		2*		3					
Milk	0.23	0.30	0.52	0.09	---	0.500				
Cheese	0.48	0.44	0.17	0.28	0.76	0.640				
Cabbage	0.05	---	0.21	---	0.67	---				
Corn	4.50	4.42	2.42	2.52	5.70	5.210				
Potato	0.65	0.72	---	0.38	---	0.006				
Green plantain	---	---	---	0.04	---	1.670				
Brown sugar	---	---	0.18	---	---	---				
Popayán	1		2		3					
Milk	5.05	6.640	2.09	3.59	2.86	3.04				
Whole orange	0.47	0.210	0.27	0.10	0.13	---				
Carrots	0.21	0.240	0.14	0.16	0.15	0.17				
Dry lentils	1.00	0.530	0.55	0.25	0.28	0.02				
Corn	5.84	4.000	3.31	2.29	3.31	2.45				
Arracacha	---	0.300	---	0.22	---	0.22				
Brown sugar	---	1.850	0.01	1.21	0.21	1.24				
Vegetable oil	0.04	0.008	0.03	0.02	0.03	0.03				
Villavicencio	1		2*		3					
Milk	2.33	3.37	2.20	2.27	1.68	2.000				
Whole orange	0.23	---	0.19	---	0.13	---				
Corn	1.13	0.80	1.00	1.76	0.82	1.130				
Corn flour	3.09	1.76	2.76	0.56	1.83	0.500				
Green plantain	---	0.74	---	1.43	---	0.880				
Brown sugar	---	0.32	---	0.82	---	0.600				
Vegetable oil	---	---	---	0.01	---	0.005				

*Cost of MS diet < cost of MS(AP) diet.

In general, the major responsibility of providing for the protein in the diet, instead of being shared by milk, corn and/or beans (as in the least-cost minimum-standard diets where the source of protein was not specified) was shifted largely to whole milk with a decrease in the contribution of corn and legumes in the least-cost minimum standard diets which required animal protein. While it is not possible to generalize for the whole country from the peculiarities observed in certain sections of that country, it would seem, at least for the sample studied, that milk should have been an important food in the diets of the families studied - in both the nutritional and economic sense. This observation suggests that although all of the efforts to improve the quality of mixtures low in protein content are very useful, present interest in vegetable protein sources should not detract from the recognition that milk is a good and less expensive source of protein than is commonly believed and that its production must be considered of prime importance.

It has usually been assumed that protein from animal sources is more expensive than vegetable proteins. Certainly, in this study eggs, meat or meat products were not in any of the least-cost standard diets. However, as seen from the comparison of the MS and MS(AP) diets, and contrary to popular opinion, milk in the right combination with other foods was a less expensive source of protein than legumes. This reminds us again of the importance of relating the nutritional worth of a food to its market price. The present concept of "costliness" of foods has been more or less arbitrarily based. The next chapter considers an appropriate basis for comparing the monetary and nutritional values of foodstuffs.

Least-Cost Supplementary Diets

Once the nutritional adequacy or inadequacy of actual diets has been established, the next step is to determine the most efficient way of overcoming their inadequacy. Linear programming was used, not only to obtain least-cost diets that would provide the actual level of nutrient intake of the families and least-cost diets that would meet the recommended allowances, but also to determine the least expensive way of supplementing the actual diets so that their nutrient content would be at least equal to the level set by the dietary standards. The nutrients in the supplementary diets then were those needed to close the gap between the actual nutrient intake and the recommended allowance. As with the other types of least-cost diets, a purely nutritional model was used.

For those who are skeptical about people changing their dietary pattern, perhaps the most meaningful and realistic approach to the problem of providing for adequate nutrition is supplementation of the actual diets. The question is not how inexpensively these families could have provided their existing level of nutritional intake nor how inexpensively they could obtain the set of recommended nutrient allowances but rather, given the actual diet, how they could supplement it in the least costly way. What one measures then is the essential minimum increase in expenditure needed to make up the nutritional shortage by adding foods to an existing diet which remains otherwise unchanged.

Table 15 shows the least-cost supplementary diets for the families in Bogotá. It gives the least expensive combination of foods that would provide enough nutrients to make the actual diet nutritionally adequate according to the minimum standard (animal protein required). For the whole group of families, the daily per capita cost of the supplementary diets is 25 centavos in order to meet the MS(AP) needs (this is 18 percent of the per capita total expenditure for food) and 39 centavos in order to reach the level set by the CS(AP) standard (this is 30 percent of the actual per capita expenditure for food, $1.30). The families differed widely in the

TABLE 15. LEAST-COST SUPPLEMENTARY DIETS FOR FAMILIES IN BOGOTÁ

(1) [illegible]	(2) [illegible]	(3) [illegible]	(4) [illegible]	Nutrient deficiencies	
				Nutrient	Amount
1	$ 9.62	$0.10	1	Vitamin A	3746.6
2	16.45	0.67	4	Vitamin A	9822.0
				Calories	1031.0
3	7.70	1.38	18	Vitamin A	7210.0
				Animal protein	62.0
				Calcium	718.8
4	9.02	1.46	16	Vitamin A	471.5
				Animal protein	74.1
				Calcium	881.0
5	10.46	0.77	7	Vitamin A	1752.0
				Animal protein	9.5
				Calcium	959.0
6	13.63	1.07	8	Vitamin A	16072.0
				Calories	2068.0
				Animal protein	9.6
				Calcium	985.0
7	10.16	1.60	16	Vitamin A	11614.8
				Calories	2760.5
				Animal protein	54.1
				Calcium	1722.2
				Riboflavin	1.3
8	6.23	1.90	30	Vitamin A	2824.5
				Calories	58.4
				Animal protein	88.5
				Calcium	1347.5
				Riboflavin	1.3
				Total protein	83.1
9	6.50	0.93	14	Vitamin A	403.5
				Calories	870.0
				Animal protein	38.8

TABLE 15--*Continued*

[illegible]	Foods in least-cost supplementary diets (in kg)					
	[illegible]	[illegible]	Carrots	[illegible]	[illegible]	[illegible]
33	0.09		0.050			
57 18		0.58	0.160	0.13		
49 64 23	1.23	0.14	0.080			
3 81 25	2.18					
13 12 32	1.11		0.020			
78 15 8 27	0.38		0.270	0.56		
53 18 49 55 17	1.59	0.57	0.150			
19 1 100 40 24 31	2.61	0.19	0.020			
3 19 62	1.14	0.15	0.002			

TABLE 15.

(1) Family	(2) Total actual food expenditure	(3) Total cost of least-cost supplementary diet	(4) (3) as a % of (2)	Nutrient deficiencies: Nutrient	Nutrient deficiencies: Amount[a]
				Calcium	914.0
				Riboflavin	0.8
				Total protein	31.9
10	$ 6.82	$2.96	43	Vitamin A	20082.0
				Calories	7067.6
				Animal protein	76.1
				Calcium	2065.0
				Riboflavin	2.3
				Total protein	146.6
				Fat	24.2
11	5.12	1.80	35	Vitamin A	11538.5
				Calories	1470.0
				Animal protein	49.4
				Calcium	1741.5
				Riboflavin	2.0
				Total protein	109.5
				Fat	23.8
				Ascorbic acid	5.5
12	2.70	2.27	84	Vitamin A	13487.0
				Calories	3803.8
				Animal protein	66.1
				Calcium	1630.2
				Riboflavin	2.5
				Total protein	147.9
				Fat	33.1
				Ascorbic acid	49.5
				Iron	9.0

[a]The units used for the nutrients are: Calories for Calories, grams for animal protein, total protein and fat, milligrams for calcium, phosphorus, iron, ascorbic acid, thiamine, riboflavin and niacin, and International Units for vitamin A.

[b]Minimum standard animal protein required.

TABLE 15--Continued

[illegible] % of MDR (AP)	Foods in least-cost supplementary diets (in kg)					
	[illegible] milk, whole, raw	Yellow corn, [illegible]	Carrots	[illegible]	[illegible], whole	Dry [illegible]
47						
18						
17						
80	2.24	1.74	0.260			
44						
62						
58						
28						
40						
13						
97	1.87	0.56	0.140		0.0001	0.02
10						
68						
68						
50						
50						
27						
5						
95	2.07	1.02	0.170		0.0600	
45						
86						
64						
57						
61						
35						
37						
20						

adequacy of their actual diets and, therefore, in the kind of supplementary diets they needed. The number of nutrient deficiencies for the Bogotá families ranges from one for Family 1 to nine for Family 12. Three foods appeared in most of the diets - whole milk, yellow corn and carrots. In addition, one or two families had brown sugar, oranges or dry peas.

The least costly way for Family 1 to eliminate its 33 percent deficiency in vitamin A would be to spend an extra ten centavos, 1 percent of its actual food expenditure, for 0.09 kg of milk and 0.05 kg of carrots. Family 2, which was deficient in vitamin A by 57 percent and in Calories by 18 percent must spend an extra sixty-seven centavos (adding four percent to the total family expenditure for food) to procure 0.58 kg of yellow corn, 0.16 kg of carrots and 0.13 kg of brown sugar. Families 3, 4 and 5 were deficient in the same nutrients (although in different degrees) but differed in the foods needed to eliminate the deficiencies most efficiently. Family 4 needed only milk; Family 5 needed milk and carrots, while Family 3 needed milk, carrots and yellow corn. Family 12, the most deficient among the Bogotá families, could have an adequate diet if it added 2.07 kg of whole milk, 1.02 kg of yellow corn, 0.17 kg of carrots and 0.06 kg of whole orange to its actual diet; this would mean spending an extra $2.27 or 84 percent more than the actual food expenditure.

This study presents two alternative ways of providing for adequate nutrition among the families studied. One way is to alter the existing dietary patterns by imposing upon the families the least-cost diets which would provide either the minimum or Colombian set of nutrient allowances. The other way is to retain the actual diets and make up for the deficit in nutritional intake by supplementing the actual diets in the least costly way. The following presents the economics involved in these two approaches, using data from the families in Bogotá.

I. Supplementation of actual diets

A. Average actual daily per capita expenditure on food - $1.30
Average daily per capita cost of supplementing the actual diet to meet the MS(AP) allowances $0.24
$1.54

B. Average actual daily per capita expenditure on food - $1.30
Average daily per capita cost of supplementing the actual diet to meet the CS(AP) allowances $0.39
$1.69

II. Least-cost minimum and Colombian-standard diets

A. Average daily per capita cost of MS(AP) diet - $0.64
B. Average daily per capita cost of CS(AP) diet - $0.85

The average total cost involved in not changing the existing dietary patterns and making up the nutrient shortage by supplementation is $1.54 if the objective is to meet the minimum set of allowances ($1.69, using the

Colombian set of allowances). The alternative way is to spend $0.64 for the foods in the least-cost diets that will provide the nutrients as specified in MS(AP) or $0.88 for those in CS(AP). This latter approach means spending $0.90 less (IA - IIA) or $0.84 less (IB- IIB). It also means an extra expenditure to educate families to accept a new combination of common foods. Whether, in the long run, one method is less expensive and more efficient than the other remains to be proven. This study provides policy makers with a means of evaluating the two approaches. A quantitative measure of the relative merits of one or the other is important to those who are involved in food production and nutrition education programs.

CHAPTER VI

MARGINAL COSTS OF NUTRIENTS

People usually think in terms of money when they buy food. There are different ways of relating the nutritional worth of a food with its market price. One way is to consider the food that gives the greatest amount of a single nutrient A for every peso spent on the food as the most economical source of nutrient A. Thus it is said that milk is an economical source of calcium, carrots of vitamin A, oranges of ascorbic acid and so on. However, knowing the least expensive source of one nutrient does not necessarily mean knowing the least expensive food. If sugar, for example, costs five centavos per 1000 Calories and tomatoes, one dollar and fifty centavos, are tomatoes then thirty times as expensive as sugar? The method is unfair because foods usually contain more than just one nutrient and in addition, while one food may be an inexpensive source of one nutrient, it may not be of all the others. To determine whether one food is more economical than another with respect to all nutrients requires that weights be assigned to each nutrient so that one can compute some average measure of the efficiency of spending a peso on any food. Sherman and Gilette were the first to attempt to give a weight to the various nutrients (40). They assigned to a list of common foods a composite value obtained by scoring five nutritional elements - Calories, protein, calcium, phosphorus and iron. The values used were forty for Calories and fifteen for each of the other four elements. The weights were chosen arbitrarily, and there is no way at present of evaluating them. According to their calculations, based on the 1915 price level, meat and fish, fatty foods and fruits were the expensive foods, whereas milk, cereal, sweets and vegetables were relatively low in price. Although better than the method in which only one nutrient is taken into consideration, this second method is still unsatisfactory because the weights ascribed were arbitrary and may not have been at all in line with the real need for the nutrients. There is a need to determine weights for the nutrients which would actually represent man's need for each of them. Only when there is a solution to this problem will an analysis of food expenditure and food economy have a real meaning.

Until the development of linear programming, there has been no satisfactory method of determining what part of the price of a certain food is to be regarded as the cost of each of the nutrients contained in the food. It is interesting that as a routine part of the linear programming solution to the least-cost diet problem, one obtains the least cost of adding one unit of a particular nutrient to a diet with a specific set of nutritional objectives. This cost will be called the net marginal cost of a nutrient. The addition is made in such a way that the diet continues to satisfy all the other restrictions in the diet model. For example, the marginal cost of protein in a least-cost diet that provides 1000 Calories, 70 gm of protein and 400 mg of calcium is the cost of adding one more unit of protein to the diet (if one unit of protein is equal to 1 gm, the total protein content of the diet is then increased to 71 gm), without changing the levels of Calories and calcium. This is done by buying a little more of some commodities and a little less of the others with the quantity of foods being so chosen so as not to change the level of the nutrient allowances which were exactly fulfilled, except for that one nutrient which is to be increased by one unit. The marginal costs reflect the extra expenditure needed to obtain a small increase in the quantity of a specific nutrient in the diet. They are the costs of obtaining nutrients through the market and are therefore sensitive to changes in the market prices of foods that are in the least-cost diets. They are also the costs of providing for a specified set of nutritional allowances and as such reflect the particular dietary standard and may change when the standard changes. They are appropriate to use in finding an index for choosing the least expensive foods and the most economical diets.

The marginal costs of nutrients take into account the fact that although all the nutrients for which allowances have been formulated in the dietary standard are equally important, not all of them are equally costly. Some nutrients are difficult to obtain from foods commonly sold in the market while others are relatively abundant in foods, selling at low prices. The marginal cost values measure the difficulty of obtaining each nutrient through the market. Nutrients that are hard to come by and for which the dietary allowances are met only at the minimum level are called the "scarce" nutrients. Some nutrients may be costless in the sense that one need not add to the cost of the least-cost diet in order to obtain them in adequate amounts. For example, in the course of providing the recommended amounts of calcium, riboflavin and Calories, the least-cost minimum-standard diet may incidentally provide more than the recommended amounts of carbohydrate, iron, phosphorus and fat. The first three nutrients are the "scarce" nutrients while the last four are "costless". The cost of the least-cost diet will not be decreased by reducing the allowances for the costless nutrients nor will it be increased if the allowances for them were increased by less than the amount of the excess. Suppose a least-cost diet obtained by linear programming provided exactly the minimum allowances for Calories, calcium and riboflavin. Suppose also that in the course of providing these "scarce" nutrients the diet also provided 5 mg more than the minimum allowance for iron and 10 mg more than the minimum allowance for niacin. If the cost of this least-cost diet were fifty centavos, increasing the minimum allowance for iron by adding less than 5 mg or for niacin, by adding less than 10 mg would not increase the cost of the diet.

The net marginal cost of nutrients is expressed in Table 16 as the cost in pesos of providing ten percent of the minimum standard allowance for each nutrient.[14] The marginal costs were obtained from the optimal solutions of the least-cost minimum-standard diets for the standard family in each of the eight cities. The concept of a standard family was used to facilitate the description and comparison of diets between cities. The hypo-

---

[14] There are two marginal cost values for Calories, one is the cost of adding Calories only and the other is the cost of adding Calories and the B-vitamins associated with it, according to the ratios specified in the model. The B-vitamins are thiamine, riboflavin and niacin.

thetical family was composed of a 31 to 39 year old male, a pregnant female 20 to 29 years of age and four chidren with ages ranging from one to nine years. The minimum and Colombian standard allowances per day for the standard family are:

Nutrient	MS(AP) allowance		CS(AP) allowance	
Calories	9740		12000	
Total protein	237	gm	293	gm
Animal protein	78	gm	97	gm
Fat	108	gm	132	gm
Calcium	2800	mg	4400	mg
Phosphorus	2800	mg	4400	mg
Iron	39	mg	70	mg
Vitamin A	13100	IU	22500	IU
Ascorbic acid	130	mg	275	mg
Thiamine	3	mg	6.1	mg
Riboflavin	5.1	mg	7.2	mg
Niacin	30	mg	79.9	mg

Since the composition of the standard family stays constant in all cities, the difference in the marginal cost of the same nutrient from one city to another reflects the differences in market conditions in these cities, i.e., the foods commonly available and the prices of these foods.

As shown in Table 16 there was a marginal cost for Calories and animal protein in all cities. Calories were the most expensive of the nutrient elements to obtain from the market except in Manizales and Popayán. The nutrients with the highest marginal cost for these two cities were riboflavin and total protein, respectively. Animal protein

TABLE 16. MARGINAL COSTS OF NUTRIENTS IN LEAST-COST MS(AP) DIETS OF THE STANDARD FAMILY
(COSTS IN PESOS OF PROVIDING TEN PERCENT OF THE MS(AP) ALLOWANCES)

Nutrient	Marginal cost							
	Bogotá	Cali	Cartagena	Ibagué	Manizales	Medellín	Popayán	Villavicencio
Calories[a]	$0.21	$0.17	$0.19	$0.19	$0.08	$0.11	$0.02	$0.24
Total protein	---	---	---	0.04	---	0.09	0.14	0.03
Animal protein	0.12	0.09	0.10	0.13	0.02	0.10	0.06	0.13
Fat	---	---	0.03	---	---	0.04	0.05	---
Calcium	---	---	---	---	0.04	---	---	---
Phosphorus	---	---	---	---	---	---	---	---
Iron	---	---	0.07	0.03	---	0.05	0.07	0.01
Vitamin A	0.02	---	0.05	0.03	---	0.02	0.01	0.04
Ascorbic acid	0.01	---	---	---	---	0.01	---	---
Thiamine	---	---	---	---	---	---	---	---
Riboflavin	---	0.05	---	---	0.20	0.02	---	---
Niacin	---	---	---	---	---	0.02	0.02	---
Calories with associated B-vitamins[b]	0.21	0.22	0.19	0.19	0.28	0.15	0.04	0.24

[a] Marginal cost of Calories only.

[b] Marginal cost of Calories and the B-vitamins (thiamine, riboflavin and niacin) that must go with the Calories, according to the ratio specified in the model.

was usually the second most costly nutrient in the diet. On the average, in the eight cities the cost of adding ten percent of the minimum standard allowance for Calories (974 Calories) and animal protein (7.8 gm) was 15 centavos for the former and 11 centavos for the latter.

In the course of providing the minimum allowances for Calories, animal protein, vitamin A and ascorbic acid, the foods in the least-cost diet for the standard family in Bogotá incidentally provided more than the recommended amounts of total protein, fat, calcium, phosphorus, iron, thiamine, riboflavin and niacin. In this particular case, eight of the twelve nutrients were costless at the margin. This means that the cost of the least-cost diet would not be increased if the allowances for these nutrients were increased by less than the amount of the excess. In general, about five to six out of the twelve nutrients (nine for Medellín and seven for Popayán) had a marginal cost and were, therefore, the nutrients which were hard to obtain from the foods commonly bought in the market. These nutrients differed for the same standard family in different cities. In all eight cities, thiamine and phosphorus were costless.

Since the marginal costs reflect a specific set of nutritional objective, they will differ as the dietary standard used differs. For example, on the average, 1000 Calories cost 16 centavos in the standard family's MS(AP) diet and 10 centavos in the CS(AP) diet. Table 17 shows the marginal costs of nutrients in the least-cost Colombian-standard diet for the standard family in the different cities.[15] Calories and calcium were the most expensive nutrient in 3 cities, niacin in 1 city and iron in another. The standard family in every city faced a marginal cost for Calories, niacin and vitamin A. On the average, in the eight cities, the marginal costs of providing ten percent of the allowance for Calories (1200 Calories), niacin (8 mg) and vitamin A (2250 IU) were 13, 9 and 4 centavos, respectively. Phosphorus was costless in every city. Depending upon which level of nutritional allowances was imposed, there was a difference in the set of nutritional elements which had marginal costs and/or the cost of providing ten percent of the allowance for the expensive nutrients. These comparisons between cities and between dietary standards point out the fact that the marginal costs reflect both changes in the price of commodities and in the set of nutritional allowances used. They also indicate that the same nutritional needs are more costly to satisfy in some places than in others.

---

[15] As in Table 16, there are two marginal cost values for Calories, one for Calories only and another for Calories with the associated B-vitamins.

TABLE 17. MARGINAL COSTS OF NUTRIENTS IN LEAST-COST CS(AP) DIETS OF THE STANDARD FAMILY
(COSTS IN PESOS OF PROVIDING TEN PERCENT OF THE CS(AP) ALLOWANCES)

Nutrient	Marginal cost							
	Bogotá	Cali	Cartagena	Ibagué	Manizales	Medellín	Popayán	Villavicencio
Calories[a]	$0.12	$0.09	$0.10	$0.24	$0.08	$0.14	$0.04	$0.10
Total protein	---	0.03	---	0.02	---	0.11	0.07	---
Animal protein	---	---	0.06	0.16	---	0.13	0.08	0.07
Fat	---	0.02	0.05	---	---	0.05	0.06	---
Calcium	0.21	0.19	0.24	---	0.10	---	---	0.16
Phosphorus	---	---	---	---	---	---	---	---
Iron	---	---	0.05	0.04	---	0.09	0.12	---
Vitamin A	0.02	0.02	0.10	0.05	0.02	0.03	0.02	0.09
Ascorbic acid	0.02	---	---	---	---	0.02	---	---
Thiamine	---	---	---	---	---	---	0.11	---
Riboflavin	---	---	---	---	0.31	0.03	---	---
Niacin	0.12	0.09	0.23	0.04	0.02	0.05	0.05	0.15
Calories with associated B-vitamins[b]	0.24	0.18	0.33	0.28	0.41	0.27	0.20	0.34

[a]Marginal cost of Calories only.
[b]Marginal cost of Calories and the B-vitamins (thiamine, riboflavin and niacin) that must go with the Calories, according to the ratio specified in the model.

The marginal cost figures computed from a purely nutritional model provide a consistent allocation of the total expenditure for food among the several nutritional objectives. Thus, in the least-cost minimum-standard diet for the standard family in Bogotá, the 9740 Calories required, at 22 centavos per thousand Calories, represented a total cost of $2.10. The next most costly allowance to fulfill was the one for animal protein. At 15 centavos for every ten gm, the 78 gm required had a total cost of $1.20. Vitamin A was the third most expensive nutrient, with a total cost of $0.20 for 13100 IU, at one centavo per one thousand IU of the vitamin. The cost of 130 mg of ascorbic acid was $0.10 at $0.008 per 10 mg. Where the objective is purely nutritional, as in this study, the total cost of the least-cost diet is equal to the sum of the costs of the individual nutrients. For example, the cost to the standard family in Bogotá of obtaining 100 percent of all the recommended minimum nutrient allowances was $3.60 - this was the sum of the costs allocated to the different expensive nutrients, $2.10 for Calories, $1.20 for animal protein, $0.20 for vitamin A and $0.10 for ascorbic acid. These allocations of total nutrient costs are the appropriate indications of the relative difficulty of providing the different nutrients through the purchase of ordinary foods. They are more meaningful than expressing marginal cost per unit of nutrient, for the units in which nutrients are ordinarily measured are arbitrary.

The Marginal Efficiency of Foods

The marginal costs of nutrients are the proper measures to use in valuing each of the nutrients contained in a food. When the quantity of each nutrient is multiplied by the marginal cost of that nutrient, the sum of these products gives the aggregate monetary value of the nutrients obtained. Dr. Smith (3, page 122) defines the marginal efficiency of any food as the result of dividing its market price into the aggregate monetary value of its nutrients.

The least-cost diet which would provide the standard family in Bogotá with all of the recommended Colombian-standard nutrient allowances was made up of 3.36 kg of whole cow's milk, 0.35 kg of whole orange, 0.26 kg of carrots, 0.15 kg of barley and 2.88 kg of yellow corn from Bogotá. This least-cost diet gave a marginal cost for Calories, calcium, vitamin A, ascorbic acid and niacin. The other nutrients were adequately provided in the course of providing the five "scarce" nutrients. An example of the computation made to measure the marginal

efficiency of whole cow's milk is as follows:

Nutrient	Composition of cow's milk (per kg)	Marginal cost	Aggregate value of nutrients
Calories	600 Calories	$0.104/1000	$0.062
Calcium	1200 mg	0.047/100 mg	0.564
Ascorbic acid	20 mg	0.006/10 mg	0.012
Vitamin A	1500 IU	0.001/100 IU	0.015
Niacin	1 mg	0.015/mg	0.015
			$0.668

The marginal efficiency of milk is 100 percent. This was obtained by dividing the aggregate monetary value of the nutrients in a kilogram of milk ($0.67) by its market price ($0.67 per kg) and multiplying the quotient by 100.

Since milk was also present in the optimal solution to the least-cost diet problem which would provide the standard family with the MS(AP) allowances, one can also use the marginal costs of nutrients obtained in this diet to show that milk has a percentage efficiency of 100. The computation is shown below.

Nutrient	Composition of cow's milk (per kg)	Marginal cost	Aggregate value of nutrients
Calories	600 Calories	$0.217/1000	$0.130
Animal protein	34 gm	0.149/10 gm	0.507
Vitamin A	1500 IU	0.001/100 IU	0.015
Ascorbic acid	20 mg	0.008/10 mg	0.016
			$0.668

Dividing the aggregate monetary value of the nutrients in one kg of milk ($0.67) by its market price ($0.67 per kg) and multiplying the quotient by 100 gives a marginal efficiency of 100 percent for milk.

Both the least-cost MS(AP) and CS(AP) diets gave positive marginal costs for Calories, vitamin A and ascorbic acid. The major contributor to the aggregate monetary value of the nutrients in milk, based on the marginal costs obtained in the MS(AP) diet was animal protein and calcium, based on the marginal costs obtained in the CS(AP) diet. The high marginal efficiency of milk in the MS(AP) diet can be explained by the large monetary value of animal protein, while the large monetary worth of calcium explains the high marginal efficiency of milk in the CS(AP) diet.

The marginal efficiency of a food assigns a high value to nutrients that are difficult to obtain through the market (the "scarce" nutrients) and zero value to nutrients (the "costless" nutrients) which are provided in the course of providing the scarce nutrients. In a diet model that has purely nutritional objectives, the aggregate monetary value of the nutrients in each food in the least-cost diet equals the price of the food, giving each one a marginal efficiency of 100 percent. If a food is not sufficiently economical to be included in the diet, the sum of the value of its nutrients is less than its price. It is characteristic of an optimal solution to a linear programming model that all the foods in the least-cost diet have an efficiency of 100 percent. Every food that does not belong in the least-cost diet has a lower percentage efficiency than every other food that does belong. The marginal efficiencies of foods form a useful index of the relative desirability of foods as economical sources of nutrients.

Those foods that are not in the optimal solution of the least-cost diets have marginal efficiencies less than 100 percent. This means that the expenditure for one of these commodities is greater than the monetary value of the nutrients it contains. The difference between the price of the commodity and the value of the nutrients in the food is called the Stigler gap by Dr. Smith (3, page 123). It measures a non-nutritional objective; it is the price paid to satisfy taste preferences and other "cultural" factors. The marginal efficiency of a food and the Stigler gap measure the contribution of the nutritional and non-nutritional components of the expenditure for a food. The Stigler gap is expressed in centavos per kg and marginal efficiency is expressed as a percentage of the money spent on a food.

Table 18 lists the marginal efficiency and the Stigler gap for each of the foods in the commodity list used in computing the solution to the least-cost Colombian

TABLE 18. MARGINAL EFFICIENCIES AND THE STIGLER GAP: FOODS IN THE COLOMBIAN-STANDARD DIET FOR THE STANDARD FAMILY IN BOGOTÁ

Foods	Price (¢ per kg)	Marginal efficiency (% of price)	Stigler gap[b] (¢ per kg)
Cow's milk, whole, raw	0.67	100	---
Yellow Bogotá corn	0.71	100	---
Barley	1.47	100	---
Carrots	0.83	100	---
Whole orange	0.48	100	---
Arracacha	0.83	94	0.05
Yellow corn flour	1.00	78	0.22
Brown sugar	0.97	78	0.21
Potato	0.54	70	0.16
Cassava	0.65	68	0.21
Rice	1.79	66	0.61
Green plantain	0.47	66	0.16
Cheese, without cream	6.56	60	2.61
Cheese, with cream	6.56	56	2.86
White sugar	1.01	51	0.50
Ripe plantain	0.47	49	0.24
Dry beans	2.30	47	1.21
Banana	0.69	30	0.48
Lima beans	1.56	29	1.11
Red beans	3.78	28	2.70
White bread	2.37	28	1.69
Tomato	1.09	28	0.79
Coffee	3.71	22	2.88
Chocolate	3.68	20	2.93
Vegetable oil	4.67	19	3.77
Noodles	3.60	16	3.02
Butter	11.29	12	9.93
Beef, 14-20% fat	5.32	11	4.73
Beef, 20-30% fat	5.32	10	4.79
Whole egg	7.36	7	6.87

[a] Animal protein required in the diet.
[b] Also, the net marginal cost of substitution.

standard diet problem for the standard family in Bogotá. Five foods each had a marginal efficiency of 100 percent. These were whole cow's milk, yellow Bogotá corn, barley, carrots and whole orange. The zero Stigler gap for these foods meant that every centavo spent on each of the five foods was exchanged for nutrients of equal monetary value. The food with the next highest marginal efficiency was arracacha (94 percent). Among the foods with a marginal efficiency between 50 and 80 percent were: yellow corn flour, 78 percent; brown sugar, 78 percent; potato, 70 percent; cassava, 69 percent; rice, 66 percent; green plantain, 66 percent; cheese, 58 percent (an average for the two kinds of cheese) and white sugar, 51 percent. One-half of all the foods in the list each had a marginal efficiency of less than 50 percent. Among the foods with the lowest marginal efficiencies were coffee, chocolate, butter, beef and whole egg.

That milk is an efficient food and should have been included in the diets of each of the families studied was adequately shown in this study. However, as has been pointed out, the marginal efficiency of any food will vary as the price of the food varies. It becomes meaningful then to ask up to what point milk will remain an efficient food. How much could its price rise before it leaves the solution to the problem in favor of another commodity? There are two ways of finding an answer to this question. One is by linear programming and another is by the simple, though less accurate method described below.

The "scarce" nutrients in milk, using the marginal cost figures from the least-cost Colombian-standard diet for the standard family in Bogotá, are Calories, calcium, vitamin A, ascorbic acid and niacin. The computation of the marginal efficiency of milk, shown on page 113, indicates that of the "scarce" nutrients, calcium is the major contributor to the aggregate monetary value of the nutrients in milk. The monetary worth of calcium ($0.564) constitutes 84 percent of the total price of milk per kg. This means that the food that is most likely to replace milk in the least-cost diet is the one which contains a significantly large amount of calcium. Scanning down the list of commodities given in Table 18, an educated first guess as to what this food may be is cheese. Cheese enters the least-cost diet in place of milk when the ratio of the monetary value of the nutrients in milk to the monetary value of the nutrients in cheese changes. This ratio is $0.67/$3.95. At $6.56 per kg, cheese, which has a nutritional value of $3.95, has a marginal efficiency of only 60 percent. Cheese will replace milk if the price of cheese were reduced by 40 percent or by the amount of

the Stigler gap which is $2.61. At a market price of $3.95 per kg ($6.56 - $2.61), cheese becomes 100 percent efficient. Conversely, milk leaves the least-cost diet, in favor of cheese, if the price of milk were increased by two-thirds of its present price of $0.67 per kg. It ceases to be an efficient food the moment its price is increased by 40 centavos or more; at $1.07 per kg, milk becomes only 60 percent efficient ($0.67/$1.07 x 100). It is interesting to note that milk remains an efficient food even for a relatively wide range of price increase.

The marginal efficiency of Incaparina[16] was computed using the marginal costs of nutrients obtained from the least-cost minimum and Colombian-standard diets for the standard family in each of the eight cities (refer to Tables 16 and 17 for the marginal costs). Based on the MS(AP) set of nutritional objectives, Incaparina was an efficient food for the standard family in four of eight cities and in all but one city when the CS(AP) set of

---

[16] Incaparina is a high protein food developed by the Institute of Nutrition for Central America and Panama and is produced by Quaker Oats in Cali, Colombia. The principal ingredients of this product are corn flour, soya flour and cotton seed flour, as well as calcium carbonate and a vitamin mixture. In April, 1965, its price was $1.75 for 500 gm. The nutrient composition of 100 gm of Incaparina is as follows: 370 Calories, 27.5 gm protein, 4.2 gmfats, 53.8 gm carbohydrate, 4500 IU vitamin A. 2.3 mg thiamine, 1.2 mg riboflavin, 7.8 mg niacin, 898 mg phosphorus, 8.4 mg iron and 656 mg calcium.

dietary allowances was used. These results indicate that the use of Incaparina could have been recommended for the standard family in some cities but not in others. They also suggest that the efficiency of a food is not absolute but that it reflects both the market situation and the nutritional objectives. It would be unjustifiable to recommend an "efficient" food or foods for the country as a whole. Such a generalization is unfounded because every section of the country has its own peculiarities relating to the nutritional needs of its people and the prices of the commodities available in the local market.

City	Marginal efficiency of Incaparina using the marginal costs of nutrients in the least-cost diets	
	MS(AP)	CS(AP)
Bogotá	36 percent	140 percent
Cali	52	131
Cartagena	117	243
Ibagué	76	77
Manizales	180	206
Medellín	117	100
Popayán	130	217
Villavicencio	82	180

It is by no means the investigator's purpose to suggest the imposition of the comsumption of the foods in the least-cost diets here obtained. It is not for her to insist that people give up the pleasures of eating. Surely, for some families, the combinations of foods in these diets are unusual and unacceptable. Nevertheless, it is important to know, even from a purely theoretical point of view, which foods are the most efficient in terms of providing the nutritional needs of a group of people and the savings that could accrue to the consumer who is willing to select foods on the basis of their nutritional worth.

Assume that the standard family in Bogotá consumes the foods provided in the least-cost Colombian-standard diet obtained by linear programming. Suppose that at one time or another this family chooses to alter the diet by introducing one unit of a food other than the ones in the diet. What expenditure is involved in making this change?

Also as a part of the linear programming solution to the least-cost diet problem, one obtains what Dr. Smith calls the marginal cost of substitution (3, page 127). This is defined as the cost of introducing one unit of a new food into the diet without changing the levels of the nutrients that are exactly fulfilled in the diet. It is the change in the cost of the least-cost diet that would occur if the restraint that there be one unit of a new food were added to the model without changing the other restraints specified.

Suppose that the linear programming solution to finding the least-cost diet that will provide 1000 Calories, 70 gm of protein and 40 gm of fat is to spend $0.50 for 500 gm of whole milk, 250 gm of yellow corn and 50 gm of vegetable oil. Suppose also that one wishes to introduce into the diet 100 gm of plantain, a food that is not in the least-cost diet and which therefore has a marginal efficiency of less than 100 percent. The cost of adding this less efficient food to the diet without changing the level of any of the three nutrients required is the marginal cost of substitution of plantain.

The marginal cost of substitution is usually less than the market price of the commodity because the new food brings with it some nutrients and therefore some of the foods already in the diet can be reduced in quantity or replaced. The foods already in the diet provide the greatest nutrient value obtainable for the money spent under the restrictions imposed in the model. Any substitution involves replacing some of these foods by another that provides the nutrients required at somewhat higher prices. In a purely nutritional model such as the one used in this study, the net marginal cost of substitution is also the Stigler gap. Thus, in Table 18 the cost of the Stigler gap for each of the commodities is also the marginal cost of substitution.

As indicated earlier, the least-cost Colombian-standard diet for the standard family in Bogotá was made up of whole orange, yellow Bogotá corn, whole milk, barley and carrots. Table 18 shows what additional expenditure would be incurred by the family if it chooses to add one kg of a new food into the diet. The size of the marginal cost of substitution ranges from five centavos for a kg of arracacha to $9.92 for a kg of butter.

Linear programming of least-cost diets provides a tool not only for properly valuing the nutrients contained in a food but also for measuring the marginal efficiency of a food and the marginal cost of substitution. At once, one recognizes the usefulness of these measures to a student concerned with adequate nutrition and economy in food expenditure.

SUMMARY

The purpose of this study was to investigate how efficiently certain working-class families in Colombia bought their nutrition and how inexpensively they could have bought their nutrition. Knowing the most efficient foods and the least costly way of meeting nutritional needs becomes doubly important at a time when food resources are less than adequate to meet food needs.

Linear programming was used to solve the problem of finding least-cost diets that would meet specified levels of nutritional allowances. The objective was to make the total expenditure on foods as small as possible, subject to the restriction that the minimum allowances for certain nutrients were met. The mathematical model formulated was purely nutritional, although, by limiting the list of foods to only those commonly eaten in the cities studied, palatability and taste preferences have been indirectly considered.

Least-cost diets were computed to provide for the actual level of nutritional intake, the minimum nutritional allowances, the more generous Colombian allowances and the additional nutrients necessary to raise the nutritional content of the actual diet to the level speci-

fied in each of the two dietary standards. Since there was no way of knowing in advance the least expensive way of meeting protein needs, protein allowances were set at two levels in both the minimum and Colombian dietary standards. One level was appropriate for a mixed diet with a biological value of sixty and another was appropriate for a mixed diet with a biological value of eighty. In the model that used the former level, there was no restriction set on the kind of protein in the diet. In the model that used the latter level, it was specified that one-third of the total daily protein allowance must be obtained from animal sources. The notations MS and CS were used for the minimum and Colombian standards, with protein source unspecified, and MS(AP) and CS(AP) for minimum and Colombian standards with animal protein required.

Data for estimating the actual nutritional intake of the families studied were taken from the original food consumption records obtained by the Interdepartmental Committee on Nutrition and National Defense in its nutrition survey of Colombia in 1960. On the average, the families consumed less than 100 percent of the minimum allowances for calcium, vitamin A, riboflavin, animal protein and Calories. The average intake of the other six nutrients (fat, iron, ascorbic acid, thiamine, niacin and phosphorus) far exceeded the minima set for them.

There have been numerous investigations concerning the various factors which influence one's expenditure for food. Unlike the present study, however, none has quantified the magnitude of the "nutritional" and "non-nutritional" components of total food expenditure. The total expenditure on food can be divided into two parts. The "nutritional" component is the least cost of achieving the nutritional level actually attained, with no explicit consideration given to palatability and taste preference. The "non-nutritional" or "cultural" component of expenditure is what remains after the nutritional component is subtracted from the total expenditure on food. Using this measure of the cost of the "nutritional" and "cultural" components of total food expenditure, the most efficient family is the one that spends the smallest fraction of its food peso for "non-nutritional" objectives. In less efficient families, the cost of the "non-nutritional" component accounts for larger fractions of the total expenditure for food.

One-half of the families studied spent about as much for the "non-nutritional" as for the "nutritional" component of food expenditure. In the rest of the fam-

ilies, about 30 to 40 percent of the total food expenditure was spent for "cultural" reasons. The most efficient family spent 77 percent of its actual food expenditure for nutrition while the least efficient family spent only 37 percent. The average Colombian family in this sample spent 59 percent of the food peso for buying nutrients and 41 percent for other objectives.

Not one of the forty families met 100 percent of the minimum allowance for all nutrients. And yet, given the actual amounts spent for food, if the families had selected the least-cost diets, 32 of them could have obtained adequate nutrition not only at the minimum but also at the higher Colombian level. The 41 percent of the total food expenditure which was spent for "non-nutritional" objectives would have been sufficient to provide 100 percent of the minimum allowance for all nutrients, not only for the families studied but also for 47.26 hypothetical standard families. It is evident that the working-class families spent sufficient money to buy adequate nutrition but failed to obtain the necessary nutrients because a significant fraction of their food peso was spent for "non-nutritional" objectives. Now that there is a yardstick to use, it would be interesting to make an inter-country comparison of the efficiency of food expenditure and to relate this measure of efficiency with measures of the nutritional adequacy of the diets consumed.

The primary difference between the actual diets and the least-cost diets that would have provided the same level of nutritional intake was the change in the percentage cost contribution of milk and meat. These two foods together accounted for about 33 to 34 percent of the total expenditure for food in both types of diets. However, the milk cost contribution increased from 3.73 percent in the actual diet to 33.15 percent in the least-cost diet, while the meat cost contribution decreased from 30.50 percent to 0.15 percent. Among the other changes from the actual diets to the least-cost diets were an 8.93 percentage point increase in the expenditure for cereals accompanied by a 2.68 percentage point decrease in the cost contribution of tubers and plantain and a tenfold increase in the expenditure for fruits. Cereals were the major source of Calories in both diets, 39 percent of the total caloric intake in the actual diets and 61 percent in the least-cost diets. In both diets, cereals were also the major source of protein. They accounted for 44.44 percent of the total protein in the actual diet and 62.08 percent in the least-cost diets. Meat decreased in importance as a protein source in the least-cost diets making up only 0.04 percent of the total protein (but providing 23.02 percent in the actual diet). The protein derived from milk increased from 4.95 percent in the actual diets to 28.62 percent in the least-cost diets. The protein contribution of legumes decreased from 11.78 percent in the actual diets to 2.89 percent in the least-cost diets.

For each of the cities (except Cartagena), the least-cost MS(AP) diets cost from one to seven centavos less than the least-cost MS diets while the costs of the CS(AP) diets were either equal to or less than the costs of the CS diets by two to seven centavos. Although the savings that might accrue from consuming foods in the MS(AP) or CS(AP) diets instead of those in the MS or CS diets may be small, the cost comparison made between the two types of diets pointed out the fallacy in believing that diets which require animal sources of protein are more expensive than those which do not. In general, the major responsibility of providing for the protein in the diet, instead of being shared by milk, corn and/or beans (as in the least-cost diets where the source of protein was not specified) was shifted largely (in the least-cost diets which required animal protein) to whole milk with a decrease in the contribution of corn and legumes.

It has usually been assumed that protein from animal sources is more expensive than vegetable proteins.

Certainly, in this study eggs, meat or meat products were not in any of the least-cost standard diets. However, as seen from the comparison of the MS or CS and the MS(AP) or CS(AP) diets, and contrary to popular opinion, milk in the right combination with other foods was a less expensive source of protein than legumes. This reminds one again of the importance of relating the nutritional worth of a food to its market price. The present concept of "costliness" of foods has been more or less arbitrarily based.

It is easy to determine the most economical source of one nutrient. However, knowing the least expensive source of one nutrient does not necessarily mean knowing the least expensive food. To determine whether one food is more economical than another with respect to all nutrients requires that weights be assigned to each nutrient so that one can compute some average measure of the efficiency of spending a peso on any food.

It is interesting that as a routine part of the linear programming solution to the least-cost diet problem, one obtains the least cost of adding one unit of a particular nutrient to a diet with a specific set of nutritional objectives. This cost is called the net marginal cost of a nutrient. It is the cost of obtaining nutrients through the market and is therefore sensitive

to changes in the market prices of foods that are in the least-cost diets. It is also the cost of providing for a specified set of nutritional allowances and as such reflects the particular dietary standard and may change when the standard changes.

The marginal costs of nutrients take into account the fact that although all the nutrients for which allowances have been formulated in the dietary standard are equally important, not all of them are equally costly. Some nutrients are difficult to obtain from foods commonly sold in the market while others are relatively abundant in foods selling at low prices. Nutrients that are hard to come by and for which the dietary allowances are met only at the minimum level are called "scarce" nutrients. Nutrients which are present in the diet in excess of the dietary allowance and which are provided in the course of providing the "scarce" nutrients are called "costless" nutrients. Based on the least-cost MS(AP) diet, for the standard family in all of the eight cities Calories and animal protein were the "scarce" nutrients while thiamine and phosphorus were "costless". Except for two cities, Calories were the most expensive nutrient element to obtain from the market. Animal protein was usually the second most costly nutrient in the diet. On the average, in the eight cities the cost of adding ten percent of the minimum standard allowance for Calories (974 Calories) and animal protein (7.8 gm) was 15 centavos for the former and 11 centavos for the latter.

The marginal costs of nutrients are the proper measures to use in valuing each of the nutrients contained in a food. When the quantity of each nutrient is multiplied by the marginal cost of that nutrient, the sum of these products gives the aggregate monetary value of the nutrients obtained. By dividing the market price of a food into the aggregate monetary value of its nutrients one obtains the marginal efficiency of a food. The marginal efficiency assigns a high value to nutrients that are "scarce" and zero value to nutrients which are "costless". It is characteristic of an optimal solution to a linear programming model that all the foods in the least cost solution have an efficiency of 100 percent. Thus, the four foods - milk, corn, vegetable oil and whole orange which were present in nearly all of the least-cost diets each had a marginal efficiency of 100 percent. If a food is not sufficiently economical to be included in the least-cost diet, the sum of the value of its nutrients is less than its price.

One of the consistent findings of this study is the high marginal efficiency of milk. While it is not possible to generalize for the whole country from the peculiarities observed in certain sections of that country, it would seem, at least for the sample studied, that milk should have been an important food in the diets of the Colombian families. This observation suggests that although all of the efforts to improve the quality of mixtures low in protein content are very useful, present interest in vegetable protein sources should not detract from the recognition that milk is a good and less expensive source of protein than is commonly believed and that its production must be considered of prime importance.

Since only those foods which are commonly consumed were considered, the families who may choose the least-cost diets obtained will not be faced with the problem of learning to like a whole new set of foods. The adjustment to be made is one of changing the allocation of the food peso among the different foods. For the families studied, this means spending less for meat, tubers and plantain and more for milk and cereals.

It is by no means the investigator's purpose to suggest the imposition of the least-cost diets obtained. Certainly for some of the Colombian families, least-cost

diets based on a purely nutritional model would not be acceptable. Still, knowing the most efficient foods for a particular group of people can be useful in providing a guide for agricultural policies and for indicating where the emphasis must be placed with regard to nutrition education. The efficient foods are the appropriate ones that must be made available if and when the time comes when man can not choose his foods as freely as he is now able to do. That the combinations of foods obtained by linear programming may be accepted in the long-run is not impossible. One needs only to refer back to instances in the past when certain food changes, initially met with resistance, eventually became consistent with the beliefs and food habits of the people.

One of the criticisms against least-cost diets obtained by linear programming and based on a purely nutritional model is the lack of variety or monotony. The investigator raised the point that in spite of all the importance attached to variety in meals, there is at present, really no quantitative measure of monotony or its absence when describing diets. It was pointed out that perhaps in some societies what is valued is sameness, not variety.

Nutrition and economics go hand in hand. Students interested in both these allied fields have long asked

questions for which the answers given were more or less arbitrary. This study does not pretend to have given answers to all the questions. It has, however, tried to look into the questions more intensively and extensively than has been done before. The study is limited by the small sample size. Nevertheless, it provides some interesting clues to the solution of problems commonly faced by those involved in food production and nutrition education programs.

APPENDIX 1a. COLOMBIAN DAILY RECOMMENDED ALLOWANCES
(FOR 20°C AREA)

Groups	Age (years)	Weight (kg)	Calories	Protein Total (gm)	(BV = 80) Animal[a]	Protein Total[a] (gm)	(BV = 60) Animal[a]	Fat[a] (gm)
Infants	0-1		900	27[b]	27	27[b]	27	10
Children								
Both sexes	1-3	13	1300	31	10	39	--	14
Both sexes	4-6	18	1600	36	12	50	--	18
Both sexes	7-9	24	2100	43	14	59	--	23
Male	10-12	33	2400	61	20	72	--	27
Female	10-12	33	2300	60	20	72	--	26
Adolescents								
Male	13-15	45	3100	78	26	94	--	34
Male	16-19	60	3300	78	26	90	--	37
Female	13-15	47	2700	73	24	90	--	30
Female	16-19	53	2400	65	22	80	--	27
Adults								
Male	20-29	65	2850	68	23	86	--	32
	30-39	65	2800	68	23	86	--	31
	40-49	65	2600	68	23	86	--	29
	50-59	65	2500	68	23	86	--	28
	60-69	65	2250	68	23	86	--	25
Female	20-29	55	1900	60	20	78	--	21
	30-39	55	1800	60	20	78	--	20
	40-49	55	1750	60	20	78	--	19
	50-59	55	1650	60	20	78	--	18
	60-69	55	1500	60	20	78	--	17
Pregnant women	16-19		2600	77	25	92	--	29
	20-29		2100	72	24	90	--	23
	30-39		2000	72	24	90	--	22
	40-49		1950	72	24	90	--	22
	50-59		1850	72	24	90	--	21
Lactating women	16-19		3200	83	28	98	--	36
	20-29		2700	78	26	96	--	30
	30-39		2600	78	26	96	--	29
	40-49		2550	78	26	96	--	28
	50-59		2450	78	26	96	--	27

[a]Allowances for these nutrients were not in the original standard established by the Colombian Institute of Nutrition but were added by this investigator.

APPENDIX 1a--Continued

Calcium (mg)	Phosphorus[c] (mg)	Iron (mg)	Vitamin A (I.U.)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid (mg)
600	600	7	1500	0.5	0.5	6.0	40
700	700	8	2000	0.7	0.8	8.5	40
700	700	10	2500	0.8	0.9	10.5	40
800	800	12	3500	1.0	1.2	14.0	40
800	800	15	4500	1.2	1.4	16.0	40
800	800	15	4500	1.1	1.3	15.0	40
800	800	15	5000	1.5	1.8	20.4	40
800	800	15	5000	1.7	2.0	22.0	40
800	800	15	5000	1.4	1.6	17.8	40
800	800	15	5000	1.2	1.4	16.0	40
500	500	10	5000	1.4	1.7	18.8	50
500	500	10	5000	1.4	1.7	18.4	50
500	500	10	5000	1.3	1.5	17.0	50
500	500	10	4500	1.2	1.5	16.5	50
500	500	10	4500	1.1	1.3	14.8	50
500	500	15	5000	1.0	1.1	12.5	50
500	500	15	5000	0.9	1.1	11.8	50
500	500	15	5000	0.8	1.0	11.5	50
500	500	12	4500	0.8	1.0	10.8	50
500	500	12	4500	0.8	0.9	9.9	50
1200	1200	18	6000	1.4	1.8	18.0	55
900	900	18	6000	1.2	1.4	14.5	65
900	900	18	6000	1.1	1.4	13.8	65
900	900	18	6000	1.0	1.3	13.5	65
900	900	15	5500	1.0	1.3	12.8	65
1300	1300	18	7000	1.6	1.8	22.0	55
1000	1000	18	7000	1.4	1.5	18.5	65
1000	1000	18	7000	1.3	1.5	17.8	65
1000	1000	18	7000	1.2	1.4	17.5	65
1000	1000	15	6500	1.2	1.4	16.8	65

[b]The biological value is actually greater than 80 (or 60) because the total protein allowance for infants is to be derived solely from animal protein.

APPENDIX 1b. COLOMBIAN DAILY RECOMMENDED ALLOWANCES[a] (FOR 30°C AREA)

Groups	Age (years)	Weight (kg)	Calories	Fat (gm)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)
Infants	0-1		880	10	4	5	5.8
Children							
Both sexes	1-3	13	1270	14	6	7	8.3
Both sexes	4-6	18	1570	17	8	9	10.3
Both sexes	7-9	24	2050	23	10	12	13.5
Male	10-12	33	2345	26	11	14	15.4
Female	10-12	33	2250	25	11	13	15.0
Adolescents							
Male	13-15	45	3030	34	15	18	19.9
Male	16-19	60	3220	36	16	19	21.2
Female	13-15	47	2640	29	13	16	17.4
Female	16-19	53	2340	26	11	14	15.4
Adults							
Male	20-29	65	2790	31	14	17	18.4
	30-39	65	2700	30	14	16	17.8
	40-49	65	2550	29	13	15	16.9
	50-59	65	2420	27	13	14	15.9
	60-69	65	2200	24	11	13	14.5
Female	20-29	55	1860	21	9	11	12.2
	30-39	55	1800	20	9	10	11.8
	40-49	55	1710	19	9	10	11.2
	50-59	55	1620	18	8	10	10.6
	60-69	55	1480	16	8	9	9.8
Pregnant women	16-19		2540	28	13	17	17.4
	20-29		2060	23	11	14	14.2
	30-39		2000	22	11	13	13.8
	40-49		1910	21	11	13	13.2
	50-59		1820	20	10	13	12.6
Lactating women	16-19		3140	35	15	19	21.4
	20-29		2660	30	13	16	18.2
	30-39		2600	29	13	15	17.8
	40-49		2510	28	13	15	17.2
	50-59		2420	27	12	15	16.6

[a]The nutrient allowances for nutrients other than Calories, fat, thiamine, riboflavin and niacin are the same as in Appendix 1a.

APPENDIX 2. ESTIMATION OF FAMILY COMPOSITION FOR SETTING UP TOTAL DAILY NUTRIENT ALLOWANCE FOR A FAMILY (AN EXAMPLE)

City: Ibagué   Family: Cespedes

Meals	Weight of meals	Number of persons eating	Weighted number of persons eating
Breakfast	0.20	5	1.00
Lunch	0.35	5	1.75
Dinner	0.45	5	2.25
		Total:	5
		Family size:	4
		Adjustment factor:	+1 reference adult male

APPENDIX E. RESULTS OF BIOCHEMICAL STUDIES OF COLOMBIAN CIVILIANS[a]

	Total plasma protein (gm/100 ml)	Serum albumin (gm/100 ml)	Hemoglobin (gm/100 ml)
Bogotá			
Sample size	72.	44.	26.
Mean	7.1	3.55	15.1
Interpretation[b]	High	Acceptable	High
Cali			
Sample size	12.	72.	2.
Mean	6.9	3.27	13.6
Interpretation	Acceptable	Low	Low
Cartagena			
Sample size	[illegible]		7.
Mean	[illegible]		11.6
Interpretation	High		Deficient
Ibagué			
Sample size	11.	5.	3.
Mean	7.5	3.28	13.2
Interpretation	High	Low	Low
Manizales			
Sample size	10.		3.
Mean	7.4		14.6
Interpretation	High		Acceptable
Medellín			
Sample size	24.		9.
Mean	7.2		13.8
Interpretation	High		Low
Popayán			
Sample size	12.	12.	20.
Mean	[illegible]	3.55	14.4
Interpretation	High	Acceptable	Acceptable
Villavicencio			
Sample size	10.	14.	
Mean	6.9	2.79	
Interpretation	Acceptable	Low	
For all cities studied			
Sample size	225.	105.	70.
Mean[c]	7.4	3.23	13.8
Interpretation	High	Low	Low

[a]Based on Tables 28 and 29 (pages 123 and 124, respectively) of the ICNND report on the Colombian survey (4).

[b]Interpretation of the biochemical findings was based on the guide suggested by the Interdepartmental Committee on Nutrition and National Defense (26).

APPENDIX 7--Continued

Plasma ascorbic acid (mg/100 ml)	Plasma vitamin A (mcg/100 ml)	Plasma carotene (mcg/100 ml)	Red cell riboflavin (mcg/100 ml)
15. 0.88 High	23. 35.7 Acceptable	23. 90.0 Acceptable	25. 13.7 Low
2. 0.34 Acceptable	2. 18.5 Low	2. 14.5 High	2. 14.6 Low
7. 0.32 Acceptable	7. 27.3 Acceptable	7. 64.0 Acceptable	7. 14.2 Low
3. 0.64 High	3. 27.2 Acceptable	3. 105.0 High	3. 15.0 Acceptable
3. 0.64 High	3. 11.8 Low	3. 78.0 Acceptable	3. 14.0 Low
9. 0.68 High	9. 27.3 Acceptable	9. 66.0 Acceptable	9. 12.6 Low
4. 0.54 High	5. 30.1 Acceptable	5. 77.0 Acceptable	14. 15.2 Acceptable
43. 0.62 High	52. 25.4 Acceptable	52. 94.0 Acceptable	62. 14.2 Low

[c]The mean value for the cities studied was obtained by dividing the sum of the mean values for each city by the total number of cities in which the test was made (and not by 8 throughout).

APPENDIX 4. PERCENTAGE PREVALENCE OF CLINICAL FINDINGS BY LOCATION[a]

	% for all eight cities	Bogotá	Cali
Total sample	2948.	1042.	300.
Adults	355.	112.	28.
Children	2403.	930.	281.
Pregnant or lactating women	173.	61.	20.
Calories:			
% of sample below 90% of standard weight	12.78	6.72	32.61
Protein:	0.44	0.12	1.12
Bilateral edema	0.24	0.10	0.65
Sparse hair	0.40	0.08	0.95
Easily pluckable hair	0.30	0.10	0.96
Depigmentation	0.63	0.20	1.92
Vitamin A:	3.02	5.13	0.32
Bitots spots	0.10	0.28	---
Follicular hyperkeratosis	6.07	0.97	0.64
Riboflavin:	0.19	0.26	0.08
Angular lesions	0.38	0.55	---
Angular scars	0.17	0.18	0.32
Cheilosis	0.18	0.30	---
Scrotal dermatitis	0.04	---	---
Niacin:	0.80	0.64	0.08
Filliform papillary atrophy	1.01	1.03	---
Glossitis	1.51	1.14	0.31
Magenta tongue	0.36	0.20	---
Pellagrous dermatitis	0.28	0.20	---
Vitamin C:	0.24	0.48	---
Swollen red interdental papillae (diffuse)	0.24	0.48	---

[a] Based on Tables 49 and 50 (pages 174 and 176, respectively) of the ICNND report on the Colombian survey (3).

APPENDIX 4--Continued

Cartagena	Ibagué	Manizales	Medellín	Popayán	Villavicencio
286.	253.	277.	204.	238.	140.
44.	24.	35.	55.	57.	---
242.	229.	242.	232.	181.	140.
21.	12.	10.	28.	21.	---
20.48	10.11	6.00	10.74	4.02	20.19
1.05	0.70	---	0.86	0.11	---
0.70	0.38	---	0.35	---	---
1.32	0.80	---	1.03	0.42	---
0.36	0.80	---	1.03	---	---
1.74	0.80	---	1.03	---	---
0.87	0.58	1.27	1.52	0.63	13.47
---	---	---	---	---	---
1.74	1.16	2.53	3.03	1.25	26.94
0.09	0.09	0.09	0.44	---	0.16
0.36	0.38	0.36	0.35	---	0.65
---	0.38	---	0.35	---	---
---	---	---	0.70	---	---
---	---	---	0.35	---	---
0.45	1.38	2.24	1.12	0.43	0.33
0.72	0.38	3.56	1.02	0.85	0.65
0.35	4.36	4.32	1.04	0.85	0.65
0.72	0.78	0.73	0.69	---	---
---	---	0.34	1.71	---	---
---	---	0.36	---	0.41	---
---	---	0.36	---	0.41	---

APPENDIX 5. PERCENTAGE OF THE TOTAL FOOD EXPENDITURE WHICH WAS ESTIMATED

City	Percent of total expenditure estimated
Villavicencio	4.05
Popayán	5.50
Cali	6.55
Bogotá	8.22
Cartagena	8.76
Ibagué	12.27
Medellín	12.75
Manizales	14.74

APPENDIX 6. COST OF ACTUAL AND LEAST-COST DIETS FOR EACH OF THE SIXTEEN [illegible] FAMILIES
(COST IN PESOS PER PERSON PER DAY)

Cities (1)	Average number of persons eating (2)	Total food expenditure per family (3)	Actual food expenditure per person (4)	Cost per person of least-cost diets meeting: Actual nutrient intake (5)	NR[c] (6)	NR(AP)[c] (7)	RD[c] (8)	RD(AP)[c] (9)	% excess of (4) over (5) (10)	"Nutritional" cost as % of total food expenditure[e] (11)
Bogotá										
1	6.33	6.27	0.98	0.62	0.65	0.63	0.88	0.83	57.90	63
2	5.28	9.62	1.82	1.02	0.62	0.56	0.94	0.91	78.38	56
3	8.43	6.32	0.81	0.47	0.63	0.68	0.91	0.88	70.16	59
4	7.15	7.70	1.08	0.69	0.59	0.57	0.79	0.76	55.02	64
5	6.08	16.45	2.71	1.01	0.67	0.64	0.90	0.83	168.70	37
6	6.00	13.63	1.98	0.85	0.70	0.72	1.07	1.01	132.50	43
7	7.18	9.02	1.26	0.75	0.63	0.54	0.96	0.82	68.03	60
8	4.63	2.70	0.58	0.33	0.82	0.72	1.04	0.96	77.30	56
9	6.35	10.46	1.65	0.82	0.62	0.54	0.80	0.74	100.96	50
10	4.03	5.12	1.04	0.43	0.70	0.62	0.93	0.83	142.08	41
11	4.90	6.50	1.33	0.61	0.67	0.62	0.88	0.80	116.13	46
12	7.88	10.16	1.29	0.65	0.67	0.60	0.89	0.86	97.85	51
13	7.27	4.19	0.58	0.29	0.73	0.74	0.92	0.89	98.10	51
Cali										
1	7.95	11.82	1.49	0.68	0.49	0.47	0.71	0.69	118.50	46
2	7.93	7.15	0.90	0.39	0.56	0.52	0.77	0.73	133.66	43
3	7.05	8.13	1.15	0.63	0.48	0.48	0.69	0.67	82.58	55

APPENDIX 6--Continued

Cartagena									
1	5.00	20.57	4.11	3.16	0.95	1.06	1.48	1.60	30.02	77
2	4.25	7.61	1.72	1.15	0.84	0.91	1.33	1.35	55.62	64
3	6.80	25.93	3.81	2.36	0.86	0.92	1.42	1.41	61.35	62
4	6.35	15.60	2.45	1.81	1.11	1.18	1.07	1.70	75.77	74
Ibagué										
1	4.00	5.48	1.37	0.80	0.77	0.72	1.05	0.96	71.78	58
2	2.00	4.18	2.09	1.38	0.87	0.83	1.15	1.11	52.00	66
3	5.00	7.52	1.50	0.90	0.76	0.78	1.02	1.07	[illegible]	60
4	7.60	22.82	3.00	1.16	0.74	0.75	1.00	1.00	153.14	70
5	5.00	4.55	0.91	0.55	0.79	0.77	1.06	1.03	66.05	60
Manizales										
1	8.00	6.40	0.81	0.38	0.71	0.71	1.04	1.03	111.40	47
2	4.95	8.02	1.62	0.79	0.64	0.65	0.91	0.91	105.64	40
3	10.00	9.30	0.93	0.51	0.74	0.72	1.00	1.10	82.37	55
Medellín										
1	4.45	5.47	1.23	0.87	0.66	0.50	0.90	0.90	42.07	70
2	10.00	13.00	1.31	1.00	1.01	0.95	1.35	1.31	70.37	77
3	9.20	10.13	1.10	0.76	0.72	0.65	1.06	0.97	45.54	60
4	4.15	6.36	1.53	1.02	0.79	0.74	1.11	1.03	50.00	69
Popayán										
1	14.55	8.32	0.57	0.32	0.82	0.77	1.15	1.02	76.53	59
2	8.00	9.97	1.25	0.74	0.82	0.75	1.11	1.06	68.41	50
3	7.60	8.86	1.17	0.70	0.80	0.71	1.12	1.03	65.60	60
Villavicencio										
1	6.80	12.00	1.76	1.16	0.98	0.91	1.20	1.20	51.70	66
2	8.00	11.24	1.41	0.91	0.75	0.76	1.07	1.05	54.82	65
3	6.00	5.10	0.85	0.57	0.72	0.71	1.03	0.99	49.12	67

[a] Minimum Standard.
[b] Minimum Standard (animal protein required).
[c] Colombian standard.
[d] Colombian standard (animal protein required)
[e] This is equivalent to (5) / (4) x 100.

APPENDIX 7. "MENU PATTERNS"[a] CHARACTERISTIC OF STANDARD LEAST-COST DIETS MEETING MS(AP) AND CS(AP)

	Milk	Cheese	[illegible]	Vegetable oil	Corn	Corn flour	Arracacha	Potato	Green plantain	Cassava	Brown sugar	Barley	Rice	Carrots	Cabbage	Dry lentils	Black beans	City
A: Foods in least-cost minimum standard diets (animal protein required)	*		*		*[b]									x				Bogotá
	*		*		*[b]						x			x				Bogotá
	*	x	*		*[c]						x							Cali
	*	x	*	*	*[c]						x							Cali
	*	x	*		*[c]													Cali
	*			*	*[d]				x								x	Cartagena
	*			*	*[d]				x	x							x	Cartagena
	*			*	*[d]	*			x								x	Cartagena
	*				*[d]	*			x		x							Ibagué
	*		*		*[d]	*			x		x							Ibagué
	*			*	*[d]	*			x		x							Ibagué
	*	x			*[c]			x	x									Manizales
	*	x			*[c]			x										Manizales
	*	x	*	*	*[c]	*					x			x				Medellín
	*	x	*	*	*[c]	*	x				x			x				Medellín
	*		*	*	*[b]		x				x			x		x		Popayán
	*			*	*[b]		x				x			x		x		Popayán
	*				*[c]	*			x		x							Villavicencio
	*			*	*[c]	*			x		x							Villavicencio

APPENDIX 7--Continued

B: Foods in least-cost Colombian standard diets (animal protein required)[a]

*		*		* [b]							x		x				Bogotá
*		*		* [c]		x				x			x				Cali
*				* [c]		x				x			x				Cali
*				* [b]	*			x				x				x	Cartagena
*			*	* [b]				x	x			x				x	Cartagena
*				* [b]	*			x	x			x				x	Cartagena
*				* [b]	*	x		x		x							Ibagué
*	x			* [c]		x	x	x									Manizales
*	x			* [c]		x		x		x							Manizales
*	x			* [c]	*	x				x			x	x			Medellín
*	x	*	*	* [e]	*	x				x			x				Medellín
*	x		*	* [e]	*	x				x			x				Medellín
*			*	* [d]	*	x				x			x		x		Popayán
*		*		* [d]	*	x				x			x				Popayán
*					*	x		x	x								Villavicencio
*					*	x		x									Villavicencio
*					*	x		x	x	x							Villavicencio

[a]Foods in the "core" group are represented by an * mark and additions to the "core" group by an x mark.

[b]Yellow corn from Bogotá.

[c]Yellow corn from Caldas.

[d]Degermed yellow corn.

[e]Degermed white corn.

LIST OF REFERENCES

(1) Food and Agriculture Organization of the United Nations. Six Billions to Feed. World Food Problems No. 4 (Rome, 1962).

(2) Dorfman, R., Samuelson, P. and Hayes, P. Linear Programming and Economic Analysis. New York: McGraw-Hill Book, Co., Inc., 1958.

(3) Smith, V. Electronic Computation of Human Diets. MSU Business Studies, 1963. Bureau of Business and Economic Research, Graduate School of Business Administration, Michigan State University, East Lansing, Michigan.

(4) Interdepartmental Committee on Nutrition for National Defense. Colombia: Nutrition Survey, May-August, 1960. A Report by the Interdepartmental Committee on Nutrition for National Defense, 1961.

(5) Ministerio de Salud Publica, Instituto Nacional de Nutricion. Tabla de Composicion de Alimentos Colombianos. Bogota, Colombia, 1959.

(6) Departamento Administrativo Nacional de Estadistica. Boletin Mensual de Estadistica. Bogota, Colombia, 1961.

(7) Leitch, I. "The Evolution of Dietary Standards: Historical Outline," Nutr. Abstr. Rev., 11:509 (1942).

(8) Lewis, H. "Fifty Years of Study of the Role of Protein in Nutrition," J. Am. Dietet. Assoc., 28: 701 (1952).

(9) Lusk, G. "The Fundamental Requirements of Energy for Proper Nutrition," J. Am. Med. Assoc., 70: 821 (1918).

(10) Canadian Council on Nutrition. "A Dietary Standard for Canada," Can. Bull. Nutr., 6: 1, (1964).

(11) British Medical Association. Report of the Committee on Nutrition. British Medical Association (London, 1950).

(12) National Academy of Sciences - National Research Council. Recommended Dietary Allowances (6th edition). A Report of the Food and Nutrition Board. Publication 1146, National Academy of Sciences - National Research Council (Washington, D.C., 1964).

(13) Young, E. "Dietary Standards," Nutrition: A Comprehensive Treatise, ed. G. Beaton and E. Mchenry (New York: Academic Press, 1964), v. II.

(14) National Nutrition Council. "Recommended Minimum Daily Dietary Standards," South African Medical Journal, 30: 108 (1956).

(15) National Academy of Sciences - National Research Council. Evaluation of Protein Nutrition. A Report of the Food and Nutrition Board. Publication 711, National Academy of Sciences - National Research Council (Washington, D.C., 1959).

(16) World Health Organization. Calcium Requirements. A Report of an FAO/WHO Expert Group - WHO Technical Report Series No. 230 (Geneva, 1962).

(17) Dubach, R., Moore, C. and Callender, S. "Studies in Iron Transportation and Metabolism," J. Lab. Clin. Med., 45: 599 (1955).

(18) Sherman, H. Chemistry of Food and Nutrition. New York: MacMillan Co., 1946.

(19) Booher, L., Callison, E. and Hewston, E. "An Experimental Determination of the Minimum Vitamin A Requirements of Normal Adults," J. Nutr., 17: 317 (1939).

(20) Sherman, H. Calcium and Phosphorus in Foods and Nutrition. New York: Colombia University Press, 1947.

(21) National Academy of Sciences - National Research Council. The Role of Dietary Fat in Human Health. A Report of the Food and Nutrition

Board. Publication 575, National Academy of Sciences - National Research Council (Washington, D.C., 1962).

(22) Instituto Nacional de Nutricion, Division de Investigacion. Recomendacion Diaria de Calorias y Nutrientes Para la Poblacion Colombiana. Publicacion EPI - 65-03. (Bogota, 1965).

(23) Roberts, L. "Beginnings of the RDA," J. Am. Dietet. Assoc., 34: 903 (1958).

(24) Medical Research Council, Great Britain. "Vitamin C Requirement of Human Adults," Lancet, 1: 853 (1948).

(25) Hume, E. and Krebs, H. Vitamin A Requirements of Human Adults. Special Report Series No. 264, Medical Research Council, Great Britain. (London, 1949).

(26) Interdepartmental Committee on Nutrition for National Defense. Manual for Nutrition Surveys (2nd edition, 1963). Interdepartmental Committee on Nutrition for National Defense, National Institutes of Health, Bethesda, Md.

(27) Keys, A., et al. The Biology of Human Starvation. Minneapolis: University of Minnesota Press, 1950.

(28) Youmans, J. et al. "Surveys of the Nutrition of Populations", Am. J. Public Health, 33: 955 (1943).

(29) Holmes, E., Stanier, M. and Thompson, M. "The Serum Protein Pattern of Africans in Uganda: Relation to Diet and Malaria," Tr. Roy. Soc. Trop. Med. and Hyg., 49: 376 (1955).

(30) World Health Organization. A Report of the Expert Committee on Medical Assessment of Nutritional Status. World Health Organization Technical Report Series No. 258 (1963).

(31) Association of Life Insurance Medical Directors and Actuarial Society of America. Medico-Actuarial Mortality Investigation. 1: 38 (1912).

(32) National Academy of Sciences - National Research Council. Manual for the Study of Food Habits. A Report of the Committee on Food Habits. Bulletin 111, National Academy of Sciences - National Research Council (Washington, D.C., 1945).

(33) National Academy of Sciences - National Research Council. The Problem of Changing Food Habits. A Report of the Committee on Food Habits. Bulletin 108, National Academy of Sciences - National Research Council (Washington, D.C., 1943).

(34) Food and Agriculture Organization of the United Nations. Education and Training in Nutrition. Freedom from Hunger Campaign Basic Study No. 6 (Rome, 1963).

(35) Stigler,G. "The Cost of Subsistence," J. of Farm Economics, 27: 303 (1945).

(36) Food and agriculture Organization of the United Nations. Third World Food Survey. Freedom from Hunger Basic Study No. 116 (Rome, 1963).

(37) Time, December 7, 1959, p.84.

(38) Lee, D. "Cultural Factors in Dietary Choice," in Symposium on Nutrition and Behavior. Symposium Series No. 14. New York: The National Vitamin Foundation, Inc., 1957.

(39) Mckenzie,J. "Food Trends: The Dynamics of Accomplished Change," Changing Food Habits, ed. J. Yudkin and J. MaKenzie (London: Macgibbon and Kee, 1964).

(40) Hawley, E. Economics of Food Consumption. New York: McGraw-Hill Book Co., Inc., 1932.