

13. ABSORPTIVE CAPACITY OF ADULT GUATEMALAN RURAL MALES LIVING UNDER DIFFERENT CONDITIONS OF SANITATION

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This brief report summarizes the results of two studies carried out with healthy adult males from the rural Pacific lowlands of Guatemala consuming a diet qualitatively similar to that habitually eaten in that region. Some of these men lived for certain periods of time in environments with improved sanitary conditions, as described below.

Objectives

1. To determine the apparent absorption of total energy, protein, and fat from the customary rural diet in: (a) military conscript males (soldiers) who were born and had lived all their life in rural Guatemala except for the two years before being studied, during which they lived in military installations with better sanitary conditions than those prevailing in their rural homes; and (b) men living in two rural communities.
2. To evaluate the effect of sanitation measures, such as the introduction of an intra-domiciliary water supply system and a sanitary education programme, on the absorptive capacity of men from one of the rural communities studied.

Hypothesis

Environmental sanitary conditions influence the capacity of Guatemalan adults to absorb the major food nutrients present in their habitual diet. If this is true, the soldiers should absorb the nutrients better than men living in their rural homes.

Experimental Details

1. Absorption Studies in Soldiers

One hundred soldiers who were born and had always lived in the lowlands of Guatemala and who had been for two years at an army station (MZ) near Guatemala City were interviewed and evaluated clinically. Besides being exposed during this period to improved environmental sanitation, these men had been eating a better diet than the one commonly eaten in rural areas. From this group 13 volunteers, 18 to 22 years old, who fulfilled the following criteria were selected: (a) there was no history of acute or chronic gastrointestinal diseases; (b) the result of the physical check-up was normal; (c) there was normal urinary excretion of d-xylose five hours after an oral dose of 25 g; and (d) two direct examinations of fresh stools for ova and parasites proved negative. Table 1 gives the volunteers' pertinent characteristics.

The soldiers lived for 21 days in a metabolic unit set up at the military post infirmary in Guatemala City (altitude 1,500 metres above sea level; temperature 19° to 22° C; low humidity). The experimental protocol followed was: Days 1 and 2: adaptation to the typical rural diet. Days 3 to 18: five consecutive three-day balance periods (Balances 1 to 5). Days 19 and 20 were used to complete faecal collections. A final physical check-up was done on day 21 before discharging the subjects from the unit.

2. Absorption Studies in Men from Two Rural Communities

In 1973, two villages, Guanagazapa (GU) and Florida Aceituno (FA), located in the lowlands near the Pacific coast of Guatemala, were chosen in order to carry out a study to evaluate the effect of introducing sanitation measures on the absorptive capacity of their inhabitants. The villages were within one hour's drive from Guatemala City, with a distance of 32 km between the two villages. Their altitudes were 200 and 235 m above sea level, with an annual rainfall of 2,000 mm. Temperature was 20° C during the day and cooler at night. Their populations of 973 for GU and 923 for FA were approximately 20 per cent Maya Indian and 80 per cent Ladino (mixed Maya and Caucasian descent). Both communities had water supplies of poor quality consisting of private wells and some communal faucets.

Studies were carried out for four years in both villages, divided into three stages: (a) two years of basal studies were made (1973–1974); (b) sanitary measures were implemented in GU (test village). In December 1974 an intra-domiciliary water supply system became operative, and a sanitary education programme was started in early 1975 — neither measure was implemented in FA (control village); (c) two years were spent evaluating the impact of the sanitary interventions (1975–1976).

TABLE 1. General Characteristics of the 13 Soldiers Studied

Age, years	20.7 ± 1.2*
Body weight, kg	60.1 ± 4.5
Height, cm	164.0 ± 4.6
Body surface, m ²	1.66 ± 0.39
Weight/height (kg/m)	37.0 ± 0.04
D-xylose, % excreted	28.3 ± 4.6
Plasma proteins, g/dl	8.1 ± 0.8
Haemoglobin, g/dl	16.4 ± 1.5
Haematocrit, %	49.0 ± 2.4
Urine analysis	Normal
Two direct stool examinations	Negative for parasites
Ethnic background	Maya Indian or Ladino (mixed Maya/Caucasian descent)

* Mean ± S.D.

In 1973, 60 male volunteers aged 14 to 45 years were randomly chosen in each community among those men who had lived there at least ten years. By 1974 some had emigrated and were replaced by others of the same ages, also chosen at random, in order to study 120 men each year. The same procedure was followed in 1975 and 1976. Therefore, at the end of the four years there was a "longitudinal" group formed of men who participated one, two, or three times in the study. Table 2 gives the number of subjects in both groups each year. All were healthy at the time of the studies. Table 3 gives their characteristics. All men had mild or moderate infestations with one or more of the following intestinal parasites: *Ascaris lumbricoides*, *Trichuris trichiura*, hookworms.

Absorption studies were carried out between May and November in four consecutive years beginning in 1973. The men were housed in groups of 8 to 10 in a rural metabolic unit built adjoining the hospital of a nearby city (Escuintla) with the same climate as that of the study villages. The groups alternated between men of each village and they lived in the metabolic unit for five days in 1973 and for eight days in

TABLE 2. Number of Subjects Included in the Statistical Analyses

	Balance I				Balance II		
	1973	1974	1975	1976	1974	1975	1976
Guanagazapa							
Longitudinal	34	34	34	34	34	34	34
Non-longitudinal	12	13	14	15	13	14	15
Whole sample	$\overline{46}$	$\overline{47}$	$\overline{48}$	$\overline{49}$	$\overline{47}$	$\overline{48}$	$\overline{49}$
Florida Aceituno							
Longitudinal	28	28	28	27*	28	28	28
Non-longitudinal	18	23	23	26	23	23	26
Whole sample	$\overline{46}$	$\overline{51}$	$\overline{51}$	$\overline{53}^*$	$\overline{51}$	$\overline{51}$	$\overline{54}$

* One of the longitudinal subjects from FA was excluded from Balance I in 1976 due to diarrhoea.

TABLE 3. General Characteristics of the Men from Florida Aceituno (FA) and Guanagazapa (GU), 1973

	FA	GU
Number of men	46	46
Body weight, kg	$50.2 \pm 6.8^*$	57.1 ± 9.5
Height, cm	155.6 ± 6.8	162.5 ± 7.9
Body surface, m ²	1.47 ± 0.13	1.62 ± 0.42
Weight/height, kg/m	32.0 ± 3.5	32.2 ± 3.1
D-xylose, % excreted	18.5 ± 6.4	19.9 ± 5.8
Plasma proteins, g/dl	6.8 ± 1.2	6.9 ± 1.6
Haematocrit, %	40.6 ± 7.7	44.0 ± 4.9

* Mean \pm S.D.

each of the following years. Metabolic-balance studies began on the day after admission; in 1973 only one three-day metabolic-balance study was performed, and in each of the following years two consecutive three-day balance studies were done (hereafter referred to as Balance I and Balance II). During the last two days, faecal collections were completed and d-xylose absorption tests were carried out.

3. Rural Diet Study

The same diets were used in the absorption studies with soldiers and with men from GU and FA. The diet was prepared with the foods and recipes used by the population from which these men came, except it included certain amounts of commercial canned black beans and more animal protein, since the men did not eat meat every day at home. Table 4 gives the amounts of food offered each day, divided into three meals. These amounts provided 2,800 kcal (28 per cent of animal origin), 95 g protein (34 per cent animal protein), and 35 g fat (22 per cent animal fat). The men were encouraged, but not forced, to eat all the food served in the metabolic unit.

The maximum amount of food offered to each man from GU and FA in 1973, 1975, and 1976 provided 2,800 kcal/day, based on the mean intakes of 75 men from each village surveyed in 1972. In 1974, diets that provided 2,000, 2,400, or 2,800 kcal/day were offered during the first three days (Balance I) to each man, depending on his personal dietary history; during the following five days (which included Balance II), food amounts equivalent to 2,800 kcal/day were offered to all men. This was done in an effort to assess the effect of the usual dietary intakes preceding admission to the metabolic unit. The proportions of nutrients offered were constant at all levels of energy intake, since the changes were achieved through proportional variations in the amounts of each food served.

4. Measurements

The amounts of each food eaten by each man were weighed at every meal, and the nutrient intake was calculated from the analyses of representative food aliquots. Complete urine and faecal collections were also obtained, using carmine red as the faecal marker. Aliquots of the foods and of the three-day stool collections from each balance period were analysed, and their contents of total energy (bomb calorimetry), nitrogen (macro-Kjeldahl), and fat (Van de Kamer) were used to calculate apparent absorptions. Urinary nitrogen was also determined (macro-Kjeldahl) to calculate apparent nitrogen balance.

Summary of Main Results

1. Soldiers

Table 5 summarizes the results of the five consecutive three-day balance periods. One man's data were excluded from Balances III and IV because he had diarrhoea.

**TABLE 4. Amount of Food Prepared and Offered
Daily in the Metabolic Unit, in Grams**

Cooked beans*	307
Fried beans*	40
Corn tortilla	570
Rice	200
Bread	45
Sweet rolls	66
Meat	107
Cheese	109
Chayote**	100
Squash	68
Carrots	66
Sugar	37
Total energy 2,800 kcal	
Total protein 95 g = 380 kcal (13.6% energy)	
Total protein 95 g = 380 kcal (13.6% energy)	
Total fat 35 g = 315 kcal (11.2 % energy)	

* Black beans: *Phaseolus vulgaris*.

** Chayote: *Sechium edule*.

- a. There was a clear tendency to gain weight throughout the 15 days. This suggests that energy intake was in excess of expenditure.
- b. Stool weight was higher in the first balance period. This might be due to faecal residues of the food ingested before coming into the metabolic unit and suggests that two days are not enough for "adaptation" to the new diets.
- c. Apparent absorption of nitrogen and of total energy was also lower during the first balance period. This is probably related to the larger faecal excretion in that balance period.

TABLE 5. Guatemalan Soldiers: Results of Metabolic-Balance Studies in Five Consecutive Three-Day Periods (Mean \pm S.D.)

Measurement	Three-day balance periods					Average of balance periods II-V	Least significant difference**
	I (13)*	II (13)	III (12)	IV (12)	V (13)		
Body weight, kg ^a	62.27 \pm 3.08	62.77 \pm 3.02	63.30 \pm 2.91	62.47 \pm 2.98	63.21 \pm 2.94	62.94 \pm 2.89	0.17
Stool weight, g/3 days	789 \pm 303 ^c	627 \pm 291 ^b	633 \pm 255 ^b	660 \pm 273 ^b	630 \pm 261 ^b	636 \pm 261 ^b	60
Nitrogen, mg/kg/day							
Intake	289 \pm 14	285 \pm 14	286 \pm 13	286 \pm 14	285 \pm 13	285 \pm 13	
Faecal	60 \pm 16 ^c	40 \pm 20 ^b	43 \pm 20 ^b	46 \pm 20 ^b	37 \pm 14 ^b	41 \pm 18 ^b	11
Urinary	200 \pm 27	193 \pm 21	213 \pm 33	194 \pm 29	216 \pm 23	204 \pm 28	
Apparent	30 \pm 20 ^b	52 \pm 22 ^c	30 \pm 31 ^b	47 \pm 24 ^c	32 \pm 25 ^b	40 \pm 27	15
Apparent absorption, %	79 \pm 5 ^b	86 \pm 6 ^c	85 \pm 6 ^c	84 \pm 6 ^c	88 \pm 5 ^c	86 \pm 6 ^c	3.8
Energy, kcal/kg/day							
Intake	50 \pm 3	50 \pm 2	49 \pm 2	50 \pm 2	49 \pm 2	49 \pm 3	
Faecal	6 \pm 3 ^c	4 \pm 2 ^b	4 \pm 2	4 \pm 1 ^b	4 \pm 2 ^b	4 \pm 2 ^b	1.4
Apparent absorption, %	89 \pm 5 ^b	93 \pm 4 ^c	92 \pm 3	92 \pm 2 ^c	93 \pm 5 ^c	92 \pm 4 ^c	3.0
Fat, mg/kg/day							
Intake	556 \pm 27	583 \pm 28	515 \pm 23	586 \pm 28	547 \pm 25	558 \pm 38	
Faecal	87 \pm 32	88 \pm 34	80 \pm 28	71 \pm 27	68 \pm 31	70 \pm 32	
Apparent absorption, %	84 \pm 6	85 \pm 3	84 \pm 5	88 \pm 5	88 \pm 6	86 \pm 6	

* Number of men in parentheses. ** L.S.D. shown only when groups differed by analysis of variance, $p < 0.05$.^a Linear tendency to gain weight with time. ^b Lower than values with superscript c, $P < 0.05$.

- d. Urinary nitrogen excretion was constant throughout the five balance periods.
- e. Nitrogen balance was lower in Balance I than in Balances II and IV. It did not differ from the overall mean balance of Balances II to V.

2. Rural Men

- a. There were some differences between Balances I and II but they were not consistent throughout the four years of the investigation. Based on these findings, on the studies in the soldiers, and on the fact that some men were offered less than 2,800 kcal of diet in Balance I of 1974, the data from the second Balance period were used for comparisons.
- b. There were no consistent differences between 1974, 1975, and 1976 in FA or between 1974 and 1975 in GU. Absorption of nutrients was higher in GU in 1976 than in other years (see tables 6 and 7).
- c. There were no differences between the "longitudinal" and "non-longitudinal" groups.
- d. Table 6 summarizes the results of the second Balance periods in 1974 and 1976. Table 7 shows the differences in absorption of nutrients and in nitrogen balance between the two communities and between them and the soldiers.
- e. The differences in nitrogen balance seem to be mainly due to the high urinary nitrogen excretion in GU in 1976.
- f. The men from FA had a tendency for larger stool volumes throughout the four years of the study than those of men from GU and MZ, although the differences were not always statistically significant.
- g. The men from FA were thinner and weighed less. Consequently, dietary intakes per unit of body weight tended to be higher in them than in GU and MZ men.
- h. The apparent absorption of nutrients was lower in 1974 and 1975 in both villages than in MZ. In 1976, however, the men from GU absorbed as well or better than those from MZ.
- i. All men from GU and FA had between one and seven intestinal parasite species at the metabolic-balance studies (*A. lumbricoides*, *T. trichiura*, hookworm, *Enterobius vermicularis*, *Giardia lamblia*, *Enterococcus coli*, *Entamoeba histolytica*). All were asymptomatic, and ova counts suggested mild-to-moderate infections. There was no correlation between apparent absorption of nitrogen total energy and the number of parasite species in the host's intestine.

TABLE 6. Guatemalan Rural Men: Results of Metabolic-Balance Studies after Three Days in the Metabolic Unit (Balance II, Longitudinal Group) and Comparison with Soldiers^a

Measurement	FA-1974 n=28 ^b	GU-1974 n=34	FA-1976 n=28	GU-1976 n=34	MZ - 11 n=13
Body weight, kg	50.35 ± 5.67 ^c	58.86 ± 10.39	51.02 ± 5.51	60.69 ± 10.53	62.77 ± 3.02
Stool weight, g/3 days	1,056 ± 442	776 ± 238	928 ± 442	759 ± 229	627 ± 291
Nitrogen, mg/kg/day					
Intake	324 ± 46	300 ± 62	329 ± 42	303 ± 49	285 ± 14
Faecal	83 ± 32	70 ± 29	71 ± 24	44 ± 20	40 ± 20
Urinary	194 ± 40	171 ± 51	220 ± 37	225 ± 46	193 ± 21
Apparent balance	59 ± 62	79 ± 25	34 ± 39	31 ± 26	52 ± 22
Apparent absorption, %	75 ± 8	77 ± 8	78 ± 9	84 ± 6	86 ± 6
Energy, kcal/kg/day					
Intake	57 ± 8	53 ± 10	56 ± 6	49 ± 8	50 ± 2
Faecal	7 ± 3	5 ± 2	6 ± 3	3 ± 1	4 ± 2
Apparent absorption, %	88 ± 5	90 ± 3	89 ± 6	95 ± 2	93 ± 4
Fat, mg/kg/day					
Intake	702 ± 78	589 ± 106	574 ± 60	573 ± 89	583 ± 28
Faecal	150 ± 51	115 ± 45	96 ± 46	54 ± 26	87 ± 34
Apparent absorption, %	79 ± 6	81 ± 6	84 ± 7	91 ± 7	85 ± 3

^a Men from villages FA and GU in 1974 and 1976, and soldiers from MZ (Balance II).

^b Number of men.

^c Means ± S.D. Results of comparisons between groups shown in table 7.

TABLE 7. Comparisons between the Second Metabolic-Balance Periods Rural Men (FA and GU, 1974 and 1976) and Soldiers (MZ)^a

	FA – 1974 Compared with				GU – 1974 Compared with			GU – 1976 Compared with	
	GU 1974	MZ	FA 1976	GU 1976	MZ	GU 1976	FA 1976	MZ	FA 1976
Stool weight, g/3 days	↑**b	↑**	—	↑**	—	—	—	—	—
Apparent absorption									
Nitrogen	—	↓**	—	↓**	↓**	↓**	—	—	↑**
Total energy	—	↓**	—	↓**	↓**	↓**	—	—	↑**
Fat	—	↓**	↓**	↓**	↓**	↓**	—	↑**	↑**
Nitrogen balance, mg/kg/day									
Intake	—	↑**	—	—	—	—	↓*	—	↓*
Faecal	—	↑**	—	↑**	↑**	↑**	—	—	↓*
Urinary	—	—	↓**	↓**	—	↓**	↓**	↑*	—
Balance	—	—	—	↑*	↑**	↑**	↑**	↓*	—

a From data shown in table 6.

b Mean values were higher (↑) or lower (↓) based on student's grouped "t" test with $p < 0.05$ (*) or 0.01 (**).

Conclusions

The results indicate that adult men from rural areas of a developing country who live under conditions of poor sanitation, without appropriate use of potable water, and who eat diets largely based on corn and black beans with some animal protein and low fat (about 11 per cent of total energy intake) have apparent absorptions of the order of 90 per cent of total energy, 75 to 80 per cent of protein, and 75 to 85 per cent of fat. It is also evident that these men's absorptive capacity improves after they have lived for two years in environments with better sanitation and have modified their hygiene habits through education. Their apparent absorptions become about 93 per cent of total energy, 85 per cent of protein, and 90 per cent of fat.

If we assume faecal obligatory losses of 12 to 14 mg N/kg/day, the "true" nitrogen digestibilities would be about 5 per cent higher than apparent digestibilities.

The diets used in this study were typical of the region, although their protein content (P% about 13.6) and the contribution made by protein of animal origin (about 34 per cent of total protein) were higher than those in the diets of most men of similar ethnic, cultural, and socio-economic conditions in other parts of the country. It is conceivable that protein absorption may be somewhat lower in the latter, whose diets have a P% closer to 10 than 13, with animal proteins contributing only 20 to 25 per cent to the total.

The results obtained also indicate that future research studies involving measurements of absorptive capacity in rural subjects should allow about five days of dietary adaptation before starting the metabolic-balance studies.

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