PROBLEMS IN THE ESTIMATION OF CORN CONSUMPTION IN LONGITUDINAL STUDIES IN RURAL GUATEMALA[1]

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SUMMARY

A series of studies were conducted in a coffee plantation in rural Guatemala to evaluate sources of variability in corn tortilla weights and to validate a methodology to estimate accurately corn consumption in 24-hour-recall diet surveys. The following sources of variance were studied: between family, between day, within family between day, and within family within day. The mean value of tortilla weights was 45.7 ± 12.0 g and values ranged from 19.6 to 94.4 g. The weight of tortillas prepared on different days was statistically different at least to $P < 0.05$.

Within-family variance accounts for 51.9% of the between-family variance and variability within the same lot of tortillas only 13.8%. The correlation coefficient for all possible comparisons of tortillas prepared by the

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same families on consecutive days is low, 0.28 and 0.86 for comparisons of tortillas prepared by women in the same lot. The correlation obtained between morning and afternoon tortillas prepared by the same women is only 0.47.

A series of tortilla models were prepared based on the relation of weight and diameter, and validated to ascertain if women were capable of identifying from the models the size of tortillas most resembling those they had prepared the previous day.

Results obtained in the studies of sources of variance in tortilla weights and in the validation of the models suggest that for estimating corn consumption in 24-hour-recall surveys in longitudinal studies, the use of models is superior to the application of mean village or family specific tortilla weights derived from cross-sectional studies.

In-depth studies on consumption of staple foods are strongly recommended prior to the design and execution of diet surveys in developing countries.

INTRODUCTION

The recall dietary survey is the most practical technique available for repeatedly estimating food intake of large numbers of people, a necessity in long-term nutrition field studies where estimates of the usual intake of individuals and population groups are often required (1). Methods with greater validity, such as the direct weighing technique would not be suitable, for they would require prohibitively large numbers of personnel and informants' time (1).

The most commonly used recall dietary survey is the 24-hour method. The advantages, over longer-term recall surveys, are that memory errors are minimized and that less time is required to carry it out. However, the simplicity of the 24-hour recall dietary survey introduces many sources of error (2, 3), and many investigators are reluctant to use the method or to accept conclusions derived from such data for estimates of dietary intake at the individual level (2-4).

One of the main sources of error of the 24-hour recall survey has to do with household weights and measures. The investigator must estimate the weight of the various foods eaten the previous day so as to convert this information, provided by informants, to nutrient intake data by use of food composition tables. The importance of obtaining accurate weight estimates, particularly for frequently consumed foods, is obvious.

No other food item in rural Mesoamerica accounts for more of the protein and energy intake than corn. At least 50% of the total calories consumed by families in Guatemala are derived from corn (5). This staple is most often consumed in the form of "tortilla" which is prepared by boiling the corn in lime water, grinding it to a dough, and cooking it on a metal or clay plate. A family of two adults and three children may easily consume 100 or more tortillas a day. Given the quantity involved, the weight of the tortillas consumed must be determined accurately in 24-hour recall dietary surveys.

Two options have generally been utilized in obtaining tortilla weight estimates for the 24-hour recall method. Tortillas may be weighed at the time of the interview to provide estimates for those consumed the previous day. This may be done at each interview or only on selected occasions. Alternatively, a community mean weight my be used. Again, this estimate may be derived from one or more cross-sectional surveys in some or all individuals of the study populations.

Both options may be fraught with problems. The use of previously determined weights for each specific family, particularly if the number of occasions on which these were obtained is small, would not be acceptable if the within-family day-to-day variation is large. Several factors may account for variability in tortilla size in rural Guatemala. First, tortillas are made twice or three times a day and, in some families, they may be prepared by more than one individual. When there is not much wood available for cooking or when the tortilla maker is pressed for time, larger than usual tortillas are made. In a similar fashion, utilizing the village mean as an estimate for the weight of tortillas of all families clearly leads to serious sources of error because the between-family variance in tortilla weight may be large.

As current methodological approaches for estimating tortilla weights may not be entirely adequate in 24-hour recall surveys, serious efforts should be made by researchers involved in the measurement of home diet to provide better estimates of consumption of this food in rural Mesoamerica.

The purpose of this study was to describe the various sources of variability in estimating tortilla weight, and to propose and evaluate a suitable method to determine consumption of this staple in longitudinal studies.

MATERIALS AND METHODS

Sources of variability in tortilla weights were studied in a coffee plantation located on the slopes of the mountain plains facing the Pacific coast of Guatemala. All families included in the present study were of Indian culture. Data available on health and nutritional status of children indicate high mortality rate, poor dietary intakes, and marked stunting of growth (6). As is usually the case in rural Guatemala, all families reported that they ate tortillas every day.

Three studies were carried out to estimate the following sources of variance in tortilla weight: between family, between day, within family between day, and within family within day.

1. *First study*

This was carried out to evaluate within-family variance in tortilla weight, as well as to determine variability both within and between successive days. The design was as follows: 118 families, representing all families with children less than five years of age, were identified and assigned at random to one of seven groups. The first group of families was studied for three consecutive days beginning on Monday, the second for three consecutive days beginning on Tuesday, and so on till the seventh group, for which the study began on Sunday. The seventh group was larger than the rest because more surveyors were available on Sunday, Monday and Tuesday. Each family was visited on each of the three days of the survey by at least two different dietary surveyors who weighed. at least five tortillas selected at random from all available tortillas, in scales previously calibrated with brass weights. The tortillas were weighed together and the average weight was calculated. The families were allocated at random to each of the 10 surveyors who participated in the study. Table 1 presents the number of families visited each day; the number of missing cases appears in parentheses. Missing cases were due to absence from the house or lack of tortillas at the time the family was visited. Data for 337 family-days were obtained out of a possible 357, a coverage rate of 94.4%.

2. *Second study*

Forty-two families, selected at random from the initial 118

TABLE 1

SAMPLE SIZES FOR THE FIRST DESIGN
(Missing cases in parentheses)

Groups	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
I	12 (3)	15 (0)	14 (1)				
II		16 (0)	15 (1)	14 (1)	1*		
III			11 (2)	13 (0)	13 (0)		
IV				14 (1)	13 (1)	13 (2)	1*
V	1*	1*			13 (1)	11 (2)	11 (2)
VI	14 (1)	1*				16 (0)	16 (0)
VII	28 (2)	30 (0)					30 (0)
Total studied by day	55 (6)	63 (0)	40 (4)	41 (2)	40 (2)	40 (4)	58 (2)

* These cases represent situations where it was possible to obtain tortilla weights for the family one or two days later than planned.

families, were included in a second study designed to estimate variability between tortillas made on the same day by the same person. On a single day two tortillas were collected from each family, weighed individually in the field, placed in plastic bags and packed in ice and weighed again on more sensitive laboratory scales in the city. The contour of the tortilla was carefully traced, and its diameter measured. Because the tortillas were not always perfectly circular, vertical and horizontal diameters were measured and an average calculated.

3. *Third study*

This pursued three objectives: a) to estimate within-day variability among tortillas prepared by women in the morning and in the afternoon; b) to corroborate results between tortillas made on the same batch by the same person, and c) to test how accurate women were in estimating the size of their tortillas from models of distinct tortilla sizes. Thus, a random sample of 38 families was selected from the original 118 included in this study. Each family was visited in the morning and in the afternoon and, during each visit, two tortillas from the same batch were collected, packed in ice, and weighed on a scale in the laboratory. A surveyor returned the next day with three wooden boards. Tortilla models of size 2 (smaller) and 4 (larger) were represented on the first board in the form of flat discs. The second board had sizes 1, 2, and 3 (the three smallest) while the third board had sizes 3, 4, and 5 (the three largest). Size 3 was present in both the second and third boards. The woman was shown the first model and asked which disc most resembled the tortillas she made in the morning or afternoon. If she answered that it was the second, she was shown the board with sizes 1, 2, and 3 and the same question was asked again. Similarly, if her response was that it was size 4 that most resembled her tortilla, she was shown sizes 3, 4, and 5 and asked again for her opinion.

RESULTS

A. *Sources of Variability of Tortilla Size*

The frequency distribution of tortilla weights in the 118 families of the first study, is shown in Figure 1. Each of the 337 values

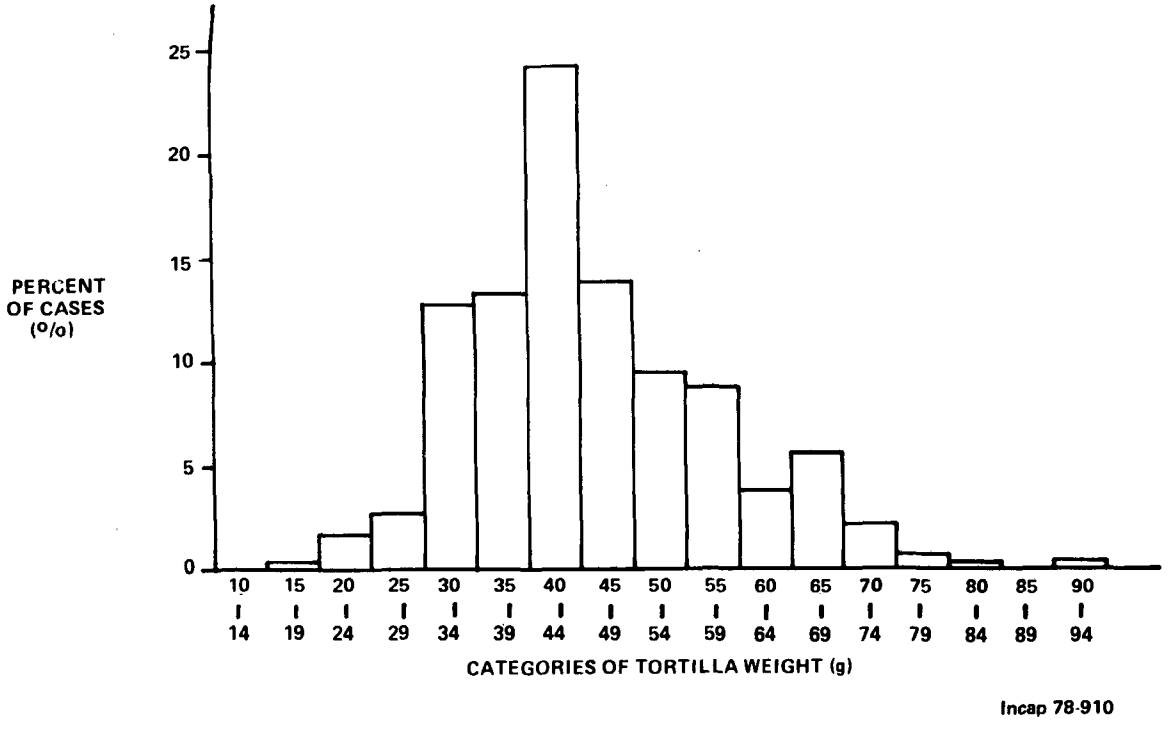

FIGURE 1

Per cent distribution of tortilla weights (n = 336 family-day observations)

included represents the mean weight of at least 5 tortillas. As was shown in Table 1, most of the 118 families had values for three different days. As expected, the curve is skewed to the right. The median tortilla weight was 43.4 g and the mean and standard deviations, 45.7 and 12.0 g, respectively. Values ranged from 19.6 to 94.4 g.

Figure 2 presents the means and standard deviations of tortilla weights by day of the week, for the same 118 families. It was determined that tortillas were heavier on Saturday, Sunday and Monday. Thus, Monday was significantly different from Wednesday ($t = 2.31$, $df = 93$, $P < 0.05$); Saturday was significantly different from Wednesday ($t = 2.72$, $df = 78$, $P < 0.01$), Thursday ($t = 2.24$, $df = 78$, $P < 0.05$), and Friday ($t = 2.34$, $df = 78$, $P < 0.05$). Similarly, the tortillas prepared on Sunday differed significantly when compared to those of Wednesday ($t = 2.90$, $df = 96$, $P < 0.01$), Thursday ($t = 2.39$, $df = 97$, $P < 0.01$), and Friday ($t = 2.47$, $df = 96$, $P < 0.01$). As observed, the largest mean difference occurs between Saturday and Wednesday, 6.9 g, or approximately six tenths the size of the pooled standard deviation.

The sources of variance in tortilla weight are presented in Table 2. Within-family variability is an important source of variance as it constitutes 51.9% of the between-family variance. Variability within the same lot is, however, low, accounting only for 13.8% of the between-family variance.

Correlation analyses corroborated the data in Table 2. The correlation between the weight of tortillas made on different days was 0.28 ($n = 318$; $P < 0.01$) for all possible pairs of the 118 families studied during three days. This finding indicates that the variability from day to day within the same family is rather large.

Correlations of tortilla weights for the 42 families selected for both the first and the second studies are presented in Table 3. Correlations between consecutive days were somewhat higher than those observed for the total sample, but similar in magnitude to those for days three weeks apart. However, correlation between tortillas made on the same day at approximately the same time (the same batch) was very high, 0.86 ($n = 42$; $P < 0.01$) as ascertained from data collected in the second study. Tortilla makers are apparently very consistent once they decide what tortilla size they will be making at a given time.

Results obtained from the third study of variability within the same batch for both morning and afternoon tortillas closely agree with those of previous studies. The correlation between the

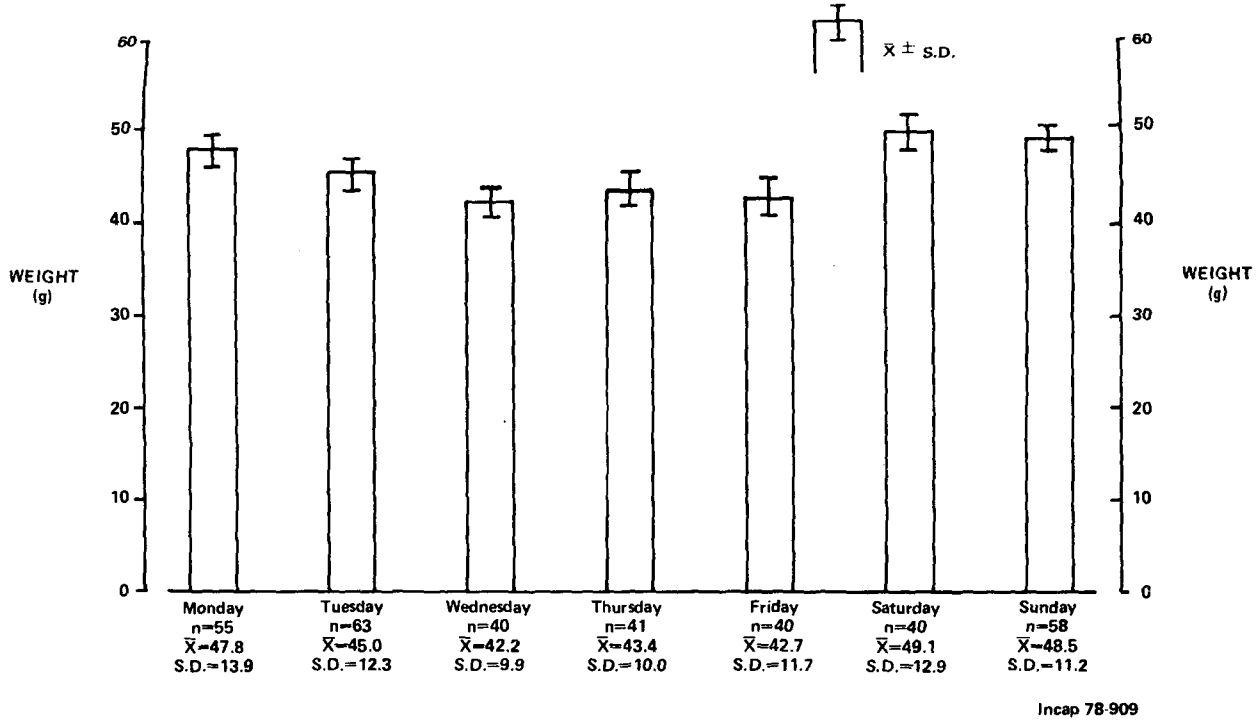

FIGURE 2
Mean tortilla weights (g) by day of the week

TABLE 2

SOURCES OF VARIANCE IN TORTILLA WEIGHT

Sources of variance	Variance (g)	Between-family variance (%)
Between familes (n = 337 observations)	144.0	100.0
Within families* (n = 318 pairs of observations)	74.8	51.9
Between tortillas made by the same person on the same day** (n = 42 pairs of observations)	19.9	13.8

* Obtained through the following formula:

$\sqrt{} = \frac{\Sigma (a - b)^2}{2n}$ where a and b are tortilla weights of all possible pairs within the family and n is the number of pairs.

** Weights obtained in the field were utilized. The correlation between weights determined in the field and in the laboratoy is 0.99 (df = 40, P $<$0.01). Moreover, there were no systematic mean differences between both measurements. This indicates that the field scales used in the first study were reliable and accurate.

morning tortillas was 0.88 (n = 37; P $<$ 0.01) and that between the afternoon tortillas, 0.91 (n = 37; P $<$ 0.01). However, correlation between morning and afternoon tortillas elaborated by the same family was much lower, 0.47 (n = 37), a value that precludes the use of either weight of morning or afternoon tortillas as the only criteria for estimating tortilla consumption for a whole day.

B. *Elaboration and Evaluation of Models of Distinct Tortilla Size*

One way to circumvent the problem of large between and

TABLE 3

CORRELATIONS* BETWEEN WEIGHTS OF TORTILLA MADE ON DIFFERENT DAYS

	Day 1		Day 2		Day 3		3 weeks later	
	n	r	n	r	n	r	n	r
Day 1	—	—	39	0.50	37	0.52	41	0.48
Day 2			—	—	37	0.45	39	0.61
Day 3					—	—	38	0.49

* Days 1, 2, and 3 refer to data collected in the first study for the 42 families later chosen for further study. Three weeks later refers to values collected in the second study.

All correlations were significant ($P < 0.01$).

within-family variance in tortilla weight, is the use of models of distinct tortilla sizes. The procedure entails asking the woman to identify the model most similar to the tortillas that she made in the morning and during the afternoon of the previous day.

In constructing the models, we first investigated whether differences in tortilla weight were explained by varying diameter and/or thickness. A plot of weight against diameter is presented in Figure 3. These data indicate that, although the diameter explains most of the variance in weight ($r = 0.87$, $n = 84$; $P < 0.01$), thickness also plays a role.

Five initial models of tortilla sizes were chosen from the range of 19.6 to 94.4 g. The weights and diameters of the initial models are given in Table 4. The first and last values, 20 and 71 g, were chosen to pick up the specially light and heavy tortillas (see Figure 1). The second size, 39 g, includes the median (43 g) found in the data shown in Figure 1. The third and fourth values were intermediate.

Diameters were then estimated through the regression line found between weight and diameter ($W = 76.97 + 9.69D$), where W and D are, respectively, the weight and the diameter of tortillas.

The weight ranges which each model should cover in theory are given in Table 4. Sizes 1 and 5 exhibit the widest ranges, but

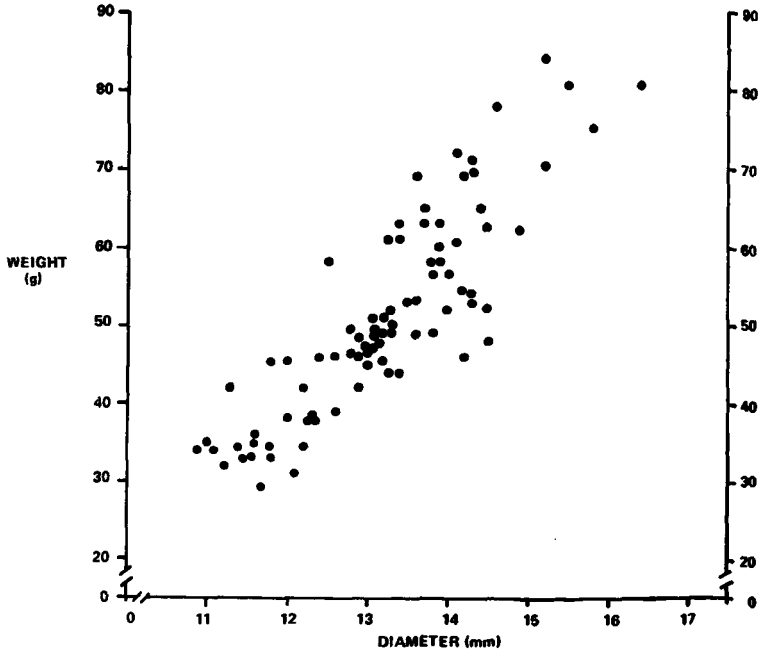

FIGURE 3

Plot of diameter (mm) against weight (g) of tortilla (n =84)

these are also the models with the least number of cases within the weight range.

Table 5 presents the results on the evaluation of the models. It is clear that the models were useful in classifying the tortillas according to their real weights. However, the models presented some problems. Women who chose models 1 and 2 underestimated the real weight of their tortillas. Conversely, women who chose models 4 and 5 overestimated the weights of their tortillas. Underestimation problems of the tortilla size were, however, larger; in total, 44o/o of the cases were correctly identified within the ranges.

DISCUSSION

There are large differences in tortilla weights ranging from 19 to 94 g that preclude the application of mean community weights

TABLE 4

MODELS OF TORTILLAS OF VARYING SIZE

Size of models	Proposed weight of model (g)	Estimated diameter (cm)*	Weight range (g)**
1	20	10.0	19.6 – 29.5
2	39	12.0	29.6 – 44.0
3	49	13.0	44.1 – 51.1
4	63	14.4	51.2 – 67.0
5	71	15.2	67.1 – 94.4

* Estimated from Figure 3 as follows: Diameter $=$ (Weight $- b_0)/b_1$, where b_0 is the constant and b_1 the slope from the simple linear regression on weight on diameter.

** Ranges in weights which should be classified as belonging to a specific size. Size 1 begins from 19.6 g, the lowest value, and extends to 29.5, the midpoint between sizes 1 and 2.

to the family data, particularly when it is important to have accurate estimates of individual dietary intakes.

The use of family specific weights elaborated from one measurement is a problematic issue, since families are not consistent from day to day in preparing tortillas of similar weight. This fact is clearly demonstrated in these studies by the low correlation value of the weights of tortillas prepared on different days.

Problems of simplifying the process of gathering accurate tortilla weights are enhanced by the fact that tortillas are usually prepared in rural Guatemala twice a day, morning and afternoon, and the correlation between morning and afternoon tortillas for the same families is also low. Large errors in estimates of diet intake will result if one value, either morning or afternoon, is applied to all tortillas consumed on a given day.

There is, however, a very high correlation between tortillas from the same batch, prepared either in the morning or in the afternoon. This suggests that once mothers decide to prepare tortillas their weights will be very similar.

Thus, there are at least two ways for precisely estimating the

TABLE 5

RESULTS FROM TEST OF VALIDITY OF PROPOSED MODELS

Models	n*	Mean weight and standard deviation (g)*	Percentage of cases in weight range**	Average deviation from model ($\bar{x} \pm SD$)*** (observed minus model weight)
1	8	38.5 ± 5.1	0.0	18.5 ± 5.1
2	23	48.2 ± 12.2	52.2	9.9 ± 12.2
3	12	51.4 ± 12.2	33.3	2.4 ± 12.2
4	16	57.0 ± 9.4	62.5	−6.0 ± 9.4
5	14	63.5 ± 16.8	43.0	−7.5 ± 16.7

* Tortillas classified by mothers in different models.

** Cases correctly classified by mothers.

*** Average difference between real values classified in the model and estimated weight of the respective model.

weight of tortillas. One can either weigh morning and afternoon tortillas the day before the recall survey, or make use of tortilla models. The first solution, although precise, is time-consuming for both the surveyor and particularly the informant. The results herein presented suggest that the use of models is an appropriate technique for field studies intended to have more accurate estimates of intakes of individuals, since women are able to discriminate among large, medium and small tortillas.

A factor not standardized in the present study is the weighing of tortillas within a given time after they are prepared. Tortillas weighed right after they are prepared have not lost water, while tortillas weighed 3 hours after their preparation, do. Nevertheless, this type of error does not obscure the major conclusions derived from the present study.

On the basis of our findings, we recommend that the mean weight of tortillas of distinct sizes, identified by women in a validity study, be used instead of the weight obtained through the regression formula. This technique represents a significant improment over the use of mean village tortilla weights or family specific weights obtained in a single cross-sectional survey. Thus

the use of models to improve the accuracy of dietary intake information in longitudinal field studies in rural Mesoamerica is strongly recommended, as well as the need to conduct in-depth studies on staples consumption in other developing areas prior to the design and implementation of cross-sectional and longitudinal dietary studies.

RESUMEN

PROBLEMAS EN LA ESTIMACION DEL CONSUMO DE MAIZ EN ESTUDIOS LONGITUDINALES EN EL MEDIO RURAL DE GUATEMALA

Se efectuó una serie de investigaciones en una finca cafetalera del área rural de Guatemala con el propósito de evaluar las fuentes de variabilidad en el peso de las tortillas, y así validar una metodología para estimar con mayor precisión el consumo de maíz en la práctica de encuestas dietéticas de recordatorio de 24 horas. Se estudiaron las siguientes fuentes de variabilidad: entre las familias, entre un día y otro, dentro de una misma familia, entre un día y otro, y dentro de una familia dentro de un mismo día. El peso promedio de las tortillas fue 45.7 ± 12.0 g, y los valores oscilaron entre 19.6 y 94.4 g. El peso de tortillas preparadas en días diferentes fue estadísticamente diferente, por lo menos a $P < 0.05$.

La variabilidad dentro de la misma familia constituye el 51.9o/o de la observada entre familias, y la variabilidad dentro de las tortillas preparadas de un mismo lote, por la misma persona, sólo de 13.8o/o. El coeficiente de correlación del peso de las tortillas para todas las comparaciones posibles, en las mismas familias y en días consecutivos, es bajo, 0.28, y alcanza un valor de 0.86 para las tortillas preparadas de un mismo lote por la misma persona. La correlación entre el peso de las tortillas preparadas por la misma persona, por la mañana y por la tarde, es sólo de 0.47.

En base a la relación de peso y diámetro, se prepararon y validaron una serie de dibujos de contorno de las tortillas, con el fin de evaluar si las amas de casa podían identificar, en los dibujos, el tamaño de las tortillas más parecidas a las que habían preparado el día anterior.

Los resultados de los estudios de fuentes de variabilidad en cuanto a los pesos de las tortillas y en la validación de los dibujos, sugieren que, para evaluar el consumo de maíz en encuestas dietéticas de recordatorio de 24 horas, por lo general, el uso de dibujos es más aconsejable que la aplicación de valores promedio de los pesos de las tortillas obtenidos en una comunidad, en el transcurso de estudios transversales.

Se recomienda la realización de estudios más a fondo sobre las características de consumo de alimentos básicos, antes de diseñar y efectuar encuestas dietéticas en los países en vías de desarrollo.

BIBLIOGRAPHY

1. Lechtig, A., C. Yarbrough, R. Martorell, H. Delgado & R. E. Klein. The one-day recall dietary survey: a review of its usefulness to estimate protein and caloric intake. Arch. **Latinoamer. Nutr.**, **26**: 243-271, 1976.
2. Flores, M. Metodología de encuestas alimenticias entre preescolares. **Arch. Latinoamer. Nutr.**, **22**: 359-384, 1972.
3. Fox, H. C., V. S. Campbell & H. G. Lovell. A comparison of dietary data obtained in Jamaica by twenty-four-hour recall and by weighing. **Arch. Latinoamer. Nutr.**, **18**: 81-97, 1968.
4. Sundararaj, R., A. Begum, G. Jesudian & S. M. Pereira. Seasonal variation in the diets of pre-school children in a village (North Arcot District). Part I. Intake of calories, protein and fat. **Indian J. Med. Res.**, **57**: 249-259, 1969.
5. **Evaluación Nutricional de la Población de Centro América y Panamá. Guatemala.** Instituto de Nutrición de Centro América y Panamá (INCAP); Oficina de Investigaciones Internacionales de los Institutos Nacionales de Salud (EEUU); Ministerio de Salud Pública y Asistencia Social de Guatemala. Guatemala, Instituto de Nutrición de Centro América y Panamá, 1969.
6. Division of Human Development of the Institute of Nutrition of Central America and Panama. Effects of protein-calorie dietary interventions on human growth, morbidity and mortality. Proposal submitted to the Agency for International Development (AID), Guatemala, INCAP, 1978.