values reported here fails to reveal any particular class of materials which is either very high or very low in tyrosine.

No literature values could be found for the tyrosine content of many of the farm feeds reported in this communication. Gunness, Dwyer, and Stokes (*7*) determined tyrosine in some food materials by microbiological assay after basic hydrolysis. The values reported by these investigators are somewhat lower for blood meal, milk, rye, brewer's dried yeast, soybean meal, and alfalfa leaf meal than those given in the present communication. In the case of wheat, corn, and barley, the values obtained in the present investigation are either in satisfactory agreement or they are slightly lower for some varieties than those reported by Gunness, Dwyer, and Stokes (*7*).

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CORN NUTRIENT LOSSES

Chemical Changes in Corn during Preparation of Tortillas

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Corn consumed in the form of flat cakes (tortillas) is the principal food of lower income families in Central America. Important changes in nutritive value result from heating the corn in lime water to soften it for tortilla preparation. The changes in samples of white and yellow corn used by two families in a Guatemalan highland Indian village were determined. For the white corn, the combined physical and chemical loss from corn to masa, the dough from which the tortilla cakes are made, averaged 60% of the thiamine, 52% of the riboflavin, and 32% of the niacin, as well as 10% of the nitrogen, 44% of the ether-extractable portion, and 46% of the crude fiber. The yellow corn lost 65% of the thiamine, 32% of the riboflavin, 31% of the niacin, and 21% of the carotene originally present, as well as 10% of the nitrogen, 33% of the ether-extractable portion, and 32% of the crude fiber.

In spite of the great importance of tortillas as the daily staple for many people in Mexico and Central America, relatively few studies have been made of their chemical composition and nutritive value. Tortilla preparation is not standard among all countries where it is a basic food, and additional studies are required to determine the manner in which the different methods influence nutritive value.

Tortilla preparation in Mexico, as described by Illescas (*14*), involves the addition of one part of whole corn to two parts of approximately 1% lime solution. The mixture is heated to 80° C. for 20 to 45 minutes and then allowed to stand overnight. The following day the cooking liquor is decanted, and the corn, now referred to as "nixtamal," is washed two or three times with water without removing the episperm or the germ. The cooked corn is then ground to a fine dough called "masa." About 50 grams of dough are patted flat and cooked on both sides on a hot iron plate.

Pérez y Pérez (*22*) has presented data on the mineral and protein content, and Cravioto and coworkers (*2*) have studied the chemical composition of tortillas made in Mexico. They have reported relatively small losses in thiamine, niacin, and riboflavin, and a 40% loss in the carotene content of yellow corn. The phosphorus and iron contents increased 15 and 37%, respectively, and because of the treatment with lime water, the calcium increased 2010%.

Massieu and coworkers (*19*) and Cravioto and associates (*3*) showed that tortillas were deficient in lysine and tryptophan, and that during preparation considerable change occurred in the original histidine, threonine, arginine, and tryptophan content of the corn. Although Tapia and coworkers (*25*) reported that the Mexican preparation of tortillas impairs the biological value of corn proteins, Cravioto and associates (*4*) and Laguna and Carpenter (*17*) have shown that rats fed tortillas gained weight faster on a diet deficient in niacin and tryptophan than rats fed untreated corn. This has been confirmed by Squibb and coworkers (*24*).

Jaffé (*16*) described the method used for making tortillas (arepas) in Venezuela and showed large losses of fat, thiamine, riboflavin, and niacin. Both the germ and episperm are separated by mechanical maceration, leaving only the endosperm. The Venezuelan method thus gives a product nutritionally inferior to that prepared in Mexico and Central America.

The present work was undertaken to study the effects of the lime treatment on the chemical composition of corn in the making of tortillas in Guatemala. The data obtained in this study are of practical value to dietitians, nutritionists, and institutions attempting to study the prob-

Table I. Data on Tortilla Preparation by Two Guatemalan Families

Family	Type of Corn	Trial	Initial Amt. of Corn, G.	Water Added, Ml.	Lime Added, G.	Lime Concentration, %	Duration of Cooking, Min.	Av. Wt. of Tortillas, G.	Av. Diam. of Tortillas, In.
A	White	1	4994	4800	11.5	0.24	40	20.7	4.7
		2	4994	4700	8.0	0.17	65	19.8	4.9
		3	4540	5650	12.0	0.21	46	18.7	4.8
	Yellow	1	4994	5700	26.3	0.46	58	21.9	5.0
		2	4994	5000	23.3	0.46	67	19.0	5.0
		3	4994	5030	26.0	0.52	58	18.0	4.9
B	White	1	4994	5000	29.2	0.58	49	13.4	4.2
		2	5448	5000	22.0	0.44	40	21.3	4.8
	Yellow	1	5448	6000	28.0	0.47	50	20.6	4.8
		2	5448	6000	26.5	0.44	40	20.9	4.6

lem of nutrition in the Central American area.

Experimental

Source of Corn. One hundred pounds each of a white and a yellow corn variety, representative of the types commonly used in this region for human consumption, were obtained for the study. On the day a trial was run, the necessary amount of each type of corn was weighed and taken to two families (A and B) in the town of Magdalena Milpas Altas, Guatemala, who made tortillas from it. The preparation of these tortillas and the collection of samples were carried out three times with each corn variety by family A and twice with each by family B.

Preparation of Tortillas. The general method of tortilla preparation was as follows:

The raw corn was placed in a 5-gallon can and covered with a 0.38 to 0.47% lime solution. The mixture was heated for 45 to 61 minutes to a temperature of 94° C., the boiling point of water at the altitude of the town, and then allowed to stand for about 14 hours (overnight). The supernatant liquor was decanted and the corn washed 4 to 5 times with water. The treatments up to this stage resulted in both the shedding of the episperm and the softening of the endosperm and the germ. The cooked corn was then ground to a fine dough in a commercial mill and about 45 grams of this dough used to make each flat, round cake. The cakes were heated for about 3 minutes on each side on a hot plate made of baked clay, whose temperature averaged 212° C. in the middle and 170° C. on the edges.

Data on Preparation. The basic data related to the preparation of tortillas by the two families studied in Magdalena Milpas Altas, Guatemala, are presented in Table I. An approximately equal volume of water was added to the corn in the preparation of nixtamal. The amount of lime added per kilogram of corn varied from 1.6 to 5.8 grams, and there was a tendency to add more lime to yellow than to white corn. The differences in the amount of lime added appeared to be primarily a family characteristic. The average cooking time of 51 minutes and the dimensions of the tortilla also varied from family to family and from batch to batch, although the differences were not consistent.

Collection and Handling of Samples. Samples taken at each stage of tortilla preparation, including the cooked corn (nixtamal), dough (masa), and tortillas, were brought to the laboratory on the same day. Aliquots destined for mineral analysis were ground in a procelain mortar; the others were first run through a meat grinder and then mixed in a Waring Blendor. The resulting material was divided into two equal parts and subsamples were placed in amber bottles for storage at 4° C. until the time of analysis. The assays were also carried out on the cooking liquor stored in the same way. These samples consisted of the liquid itself plus the episperm of the grain lost as a result of the lime treatment. Episperm, endosperm, and germ, before and after lime cooking, were separated; and the distribution of the thiamine, riboflavin, and niacin within the kernel was measured.

Analytical Methods. Moisture, fat, crude fiber, ash, calcium, and the digestion of nitrogen were determined by the Association of Official Agricultural Chemists' official methods (*1*), and the distillation and titration for the latter carried out as recommended by Hamilton and Simpson (*9*). Phosphorus determinations were carried out colorimetrically according to Fiske and Subbarow (*5*), as modified by Lowry and López (*18*). Iron was determined colorimetrically according to the method of Jackson (*15*) and Moss and Mellon (*21*).

Carotene analyses were carried out by the method of Guilbert (*8*). Total carotenoids were estimated on a second sample by washing the petroleum ether extract with 90% methanol in order to remove the lutein and zeaxanthin fractions from the other petroleum ether-soluble pigments. The amount remaining in the petroleum ether phase after concentration was measured in an Evelyn colorimeter with a 440-mμ filter. This solution was not passed through a chromatographic column as for the β-carotene determinations.

Riboflavin was determined fluorometrically by the method of Hodson and Norris (*12*), and thiamine determinations were carried out by the thiochrome method of Hennessey and Cerecedo (*10*). Niacin was determined by the chemical method of Friedemann and Frazier (*6*), but the color reaction was measured according to the method of Melnick (*20*), carbohydrates were calculated by difference, and the number of calories per 100 grams was obtained by using the factors 9 for fat, 4 for carbohydrates, and 4 for proteins.

Results

Physical Changes. In the making of tortillas the chemical constituents of corn are lost in two ways—by a physical loss

Table II. Loss of Solids of Raw Corn during Tortilla Preparation

Family	Type of Corn	Trial	Raw Corn Dry Wt.,[a] G.	Cooked Corn (Nixtamal) Moisture, %	Cooked Corn (Nixtamal) Total dry wt., g.	Corn to Nixtamal, Solids Lost, %	Dough (Masa) Moisture, %	Dough (Masa) Total dry wt., g.	Nixtamal to Masa, Solids Lost, %	Total Solids Lost, %
A	White	1	4204	48.5	3741	11.0	61.3	3428	8.4	18.5
		3	3823	48.3	3287	14.0	62.1	3010	8.4	21.3
	Yellow	1	4390	49.1	4159	5.3	61.2	3700	11.0	15.7
		2	4390	47.4	4177	4.9	61.6	3732	10.2	14.6
		3	4390	50.9	4013	8.6	61.6	3750	6.6	14.6
B	White	1	4204	47.2	3836	8.7	57.0	3805	0.8	9.5
		2	4590	49.0	3936	14.2	61.2	3700	6.0	19.4
	Yellow	1	4790	47.2	4313	10.0	61.8	3991	7.5	16.7
		2	4790	45.9	4299	10.2	57.4	4063	5.5	8.9

[a] White and yellow corns had 15.9 and 12.2% moisture, respectively.

of the components of the grain during the processing, and by their chemical destruction. Table II presents data on the magnitude of these losses. The physical loss of solids from raw corn to the nixtamal stage varies from 5 to 14%.

An average of about 6% additional solids was lost in the grinding of cooked corn to make the dough, and averages of 17 and 14%, respectively, of the solids present in raw white and yellow corn were lost in the processing up to the end of the dough, or the masa, stage. For both stages the losses in the solids tended to be greater with yellow than with white corn and some family differences were observed.

Chemical Changes. The average chemical composition of the white and yellow corn and corresponding nixtamal, masa, and tortillas prepared by each of the two families of Magdalena Milpas Altas is presented in Table III. The combined physical and chemical loss of each nutrient from corn to nixtamal and then to masa was calculated (Table IV). Although the quantity of tortillas produced was not recorded in this experiment, the analytical values for tortillas are very similar to those for masa.

The slight differences that occur from one family to another in the method of the preparation of nixtamal and masa had no appreciable influence on the total loss of nutrients. The differences in the loss from raw corn to nixtamal depended much more on the type of corn than on family practices. Although nitrogen and thiamine were lost almost equally from both types of corn, larger fractions of ether extract, crude fiber, iron, riboflavin, and niacin were lost from white than from yellow corn. The chemical losses in the making of masa from nixtamal were very small as compared to those observed in the making of nixtamal from corn.

It can be seen from Table III that the calcium and phosphorus contents increased from corn to tortilla. For these nutrients, family practices were more important. Family A used less lime than family B with correspondingly lower amounts in the tortillas prepared. Although the tortillas made from yellow corn contained more calcium than those prepared from white corn, there was no difference in phosphorus content.

To provide composition data for interpreting diet records of families consuming large amounts of tortillas, the average total losses are given in Table V. Relatively larger fractions of iron, riboflavin, ether extract, and crude fiber were lost from white corn than from yellow corn. The loss of nitrogen, thiamine, and niacin up to the making of masa was the same irrespective of the type of corn used. From as low as 10% to as high as 82% of the nutrients originally present in the corn was lost up to the making of

Table III. Composition of White and Yellow Corn Products in Preparation of Tortillas by Two Guatemalan Families[a]

Nutrient	Raw Corn	Nixtamal A	Nixtamal B	Masa A	Masa B	Tortilla A	Tortilla B
			White Corn				
Moisture, %	15.9	49.1	48.1	61.9	59.1	47.3	48.3
Ether extract, %	4.83	2.09	1.87	1.57	1.56	1.14	0.91
Nitrogen, %	1.29	0.83	0.87	0.63	0.68	0.85	0.89
Crude fiber, %	1.58	0.78	0.68	0.54	0.42	0.78	0.70
Ash, %	1.28	0.78	0.80	0.60	0.65	0.82	0.85
Calcium, mg./100 g.	4	90	105	81	91	120	129
Phosphorus, mg./100 g.	80	127	101	95	83	133	113
Iron, mg./100 g.	1.60	0.07	0.33	0.07	0.39	0.12	0.38
Thiamine, γ/g.	3.84	1.38	0.80	1.04	0.72	1.23	0.75
Riboflavin, γ/g.	1.14	0.45	0.41	0.32	0.30	0.36	0.43
Niacin, γ/g.	20.00	10.77	10.37	8.15	7.21	10.52	9.79
Carbohydrates, %	70.04	42.80	43.80	31.99	34.45	44.60	44.35
Calories/100 g.	356	211	214	158	169	210	208
			Yellow Corn				
Moisture, %	12.2	49.1	46.6	61.5	59.8	47.1	48.6
Ether extract, %	4.53	2.00	2.21	1.50	1.72	1.60	1.08
Crude fiber, %	1.33	0.65	0.68	0.47	0.50	0.63	0.63
Nitrogen, %	1.34	0.84	0.86	0.66	0.68	0.91	0.87
Ash, %	1.08	0.78	0.84	0.63	0.64	0.84	0.83
Calcium, mg./100 g.	11	135	151	118	123	139	178
Phosphorus, mg./100 g.	121	115	112	91	86	127	118
Iron, mg./100 g.	1.49	0.41	0.45	0.24	0.58[b]	2.52[b]	2.47[b]
Carotene, γ/g.	3.03	1.78	1.64	1.34	1.19	1.35	1.16
Total carotenoids,[c] γ/g.	13.18	5.56	...	4.79	...	4.13	..
Thiamine, γ/g.	4.78	1.17	1.38	0.69	1.11	1.01	1.28
Riboflavin, γ/g.	1.00	0.42	0.49	0.37	0.36	0.49	0.49
Niacin, γ/g.	18.98	10.06	9.84	6.55	7.25	10.47	9.75
Carbohydrates, %	73.86	42.85	45.02	32.26	33.59	44.81	44.08
Calories/100 g.	370	210	221	159	167	216	208

[a] All values are averages of 3 independent samples (2 determinations per sample) expressed at the moisture content found in samples.
[b] Values reported are high because of contamination.
[c] Pigments washed with 90% methanol and not chromatographed.

Table IV. Nutrient Changes in Preparation of Tortillas

Nutrient	Type of Corn	Family	In Row Corn	In Nixtamal Total	In Nixtamal Loss, %	In Masa Total	In Masa Loss from raw corn, %
Ether extract, g./100 g.	White	A	4.83	2.98	38	2.77	43
		B	4.83	2.68	45	2.75	43
	Yellow	A	4.53	3.24	28	2.90	36
		B	4.53	3.22	29	3.15	30
Crude fiber, g./100 g.	White	A	1.58	1.11	30	0.95	40
		B	1.58	0.98	38	0.74	53
	Yellow	A	1.33	1.05	21	0.91	32
		B	1.33	0.99	26	0.92	31
Nitrogen, g./100 g.	White	A	1.29	1.18	9	1.11	14
		B	1.29	1.25	3	1.20	7
	Yellow	A	1.34	1.36	...	1.28	4
		B	1.34	1.25	7	1.25	7
Ash, g./100 g.	White	A	1.28	1.11	13	1.06	17
		B	1.28	1.15	10	1.15	10
	Yellow	A	1.08	1.26	...	1.22	...
		B	1.08	1.22	...	1.17	..
Iron, g./100 g.	White	A	1.60	0.12	92	0.12	92
		B	1.60	0.47	71	0.69	57
	Yellow	A	1.49	0.66	56	0.48	69
		B	1.49	0.66	56	1.06	23
Thiamine, γ/g.	White	A	3.84	1.97	49	1.83	52
		B	3.84	1.15	70	1.27	67
	Yellow	A	4.78	1.89	60	1.34	72
		B	4.78	2.01	58	2.06	57
Riboflavin, γ/g.	White	A	1.14	0.64	44	0.56	51
		B	1.14	0.58	49	0.53	54
	Yellow	A	1.00	0.68	32	0.72	28
		B	1.00	0.71	29	0.66	34
Niacin, γ/g.	White	A	20.00	15.37	23	14.37	28
		B	20.00	14.88	26	12.72	36
	Yellow	A	18.98	16.29	14	12.68	33
		B	18.98	14.34	24	13.29	30
Carotene, γ/g.	Yellow	A	3.03	2.88	5	2.59	15
		B	3.03	2.39	21	2.18	28

masa. Only one tenth of the protein present in corn was lost, whereas a decrease of approximately one third of the ether extract, crude fiber, and niacin was observed. In making tortillas by the Guatemalan method, the most susceptible nutrients in corn were thiamine, iron, and riboflavin. There was also a 21% loss of the carotene of yellow corn in the making of masa.

The distribution of thiamine, riboflavin, and niacin in the main fractions of the corn grain before and after lime treatment is presented in Table VI. As in other cereal grains (*13*), both thiamine and riboflavin are concentrated in the corn germ. Niacin is contained in similar amounts in both germ and endosperm in white corn but not in the yellow variety. As niacin is found mainly in the aleurone layer (*7*, *13*, *26*), it is possible that this was lost excessively with the seed coat.

With the lime treatment, significant losses of thiamine and riboflavin from the germ occurred while the endosperm gained in these nutrients. These results are similar to those obtained by the parboiling of rice (*11*, *23*). Nevertheless, only a small part of the loss in thiamine and riboflavin from the corn germ is accounted for by the gain in the two vitamins in the endosperm; the remainder is due to absolute losses of these nutrients due to the lime treatment. It is evident from Table VII that the loss of the seed coat does not account for a major portion of the chemical constituents lost.

Table V. Average Values for Use in Calculating Nutrient Losses at Successive Stages of Making Tortillas from White and Yellow Corn

Nutrient	Lost from Raw Corn to Making of Nixtamal, %		Lost from Nixtamal to Making of Masa, %		Total Lost before Making Tortillas, %	
	White	Yellow	White	Yellow	White	Yellow
Ether extract	42	28	2	5	44	33
Crude fiber	34	24	12	8	46	32
Nitrogen	6	7	4	3	10	10
Iron	82	56	0	0	82	56
Thiamine	60	59	0	6	60	65
Riboflavin	46	30	6	2	52	32
Niacin	24	19	8	12	32	31
Carotene	...	13	...	8	...	21

Table VI. Distribution of Thiamine, Riboflavin, and Niacin in Component Parts of Corn Kernel before and after Cooking with Lime

Type of Corn and Status	Fraction of Corn Kernel	Moisture, %	Thiamine, γ%	Riboflavin, γ%	Niacin, γ%
White raw corn	Episperm	6.6	0.35	0.61	16.89
	Germ	17.3	33.73	2.62	23.33
	Endosperm	15.4	0.62	0.34	25.33
White corn cooked with lime	Episperm + supernatant liquor[a]	...	0.23	0.06	2.49
	Germ	55.8	5.21	0.93	6.43
	Endosperm	38.9	1.28	0.42	16.10
Yellow raw corn	Episperm	18.1	0.93	1.26	27.70
	Germ	16.9	36.02	3.02	14.61
	Endosperm	13.8	1.06	0.49	22.63
Yellow corn cooked with lime	Episperm + supernatant liquor[b]	...	0.06	0.09	27.77
	Germ	44.9	10.55	1.86	8.21
	Endosperm	36.2	1.31	0.48	15.24

[a] Concentration in γ/ml. in total volume of 400 ml. resulting from the processing of 400 grams of white corn.
[b] Concentration in γ/ml. in total volume of 170 ml. resulting from the processing of 295 grams of yellow corn.
The episperm constituted 6.2 and 5.3%, respectively, of white and yellow corn kernels.

Table VII. Comparison of Loss of Selected Vitamins from Corn and from Episperm

Nutrient	Type of Corn	Lost from Corn in Making of Nixtamal, γ/G.	Content in Seed Coat, γ	Lost, % Episperm	Lost, % Germ	Lost, % Endosperm
Thiamine	White	2.28	0.02	1	69	0
	Yellow	2.83	0.05	2	56	0
Riboflavin	White	0.53	0.04	8	29	0
	Yellow	0.30	0.07	33	7	0
Niacin	White	4.88	1.05	22	41	9
	Yellow	3.67	1.52	41	15	5

Discussion

In the cooking of corn, the different nutrients analyzed were not lost to the same extent. This supports the earlier evidence that the losses in cooking are of a chemical as well as a physical nature. The physical loss is due to the complete or partial separation of some of the components of corn kernel, thereby removing the nutrients contained in them. The chemical loss involves removal, during the washing with water or destruction by treatment, of different nutrients. The family differences in losses due to cooking may be partly attributed to the degree of stirring, which will obviously determine the separation and the removal of episperm and will consequently expose the other parts of corn kernel to further physical and chemical damages.

Up to the end of the lime cooking stage, approximately 12 and 8% of the solids were lost from white and yellow corn, respectively. The larger fractions lost from white corn may be explained by the fact that the episperm is a larger fraction of the kernel (6.2% of the white and 5.3% of the yellow corn kernels). However, the loss of episperm does not account for the major portion of the chemical constituents lost as may be observed from Table VI. Of the nutrients analyzed, almost 60 to 99% of the amount lost originated from fractions other than the episperm. In general, the germ suffered a greater loss than did the endosperm.

During the process of milling, the loss of total solids and that of each of the nutrients were approximately equal. This would support the common belief that the loss during the milling is due to inefficiency of the process, the ground material sticking to the grinding mechanism.

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LIME-HEAT EFFECTS ON CORN NUTRIENTS

Effect of Lime Treatment on in Vitro Availability of Essential Amino Acids and Solubility of Protein Fractions in Corn

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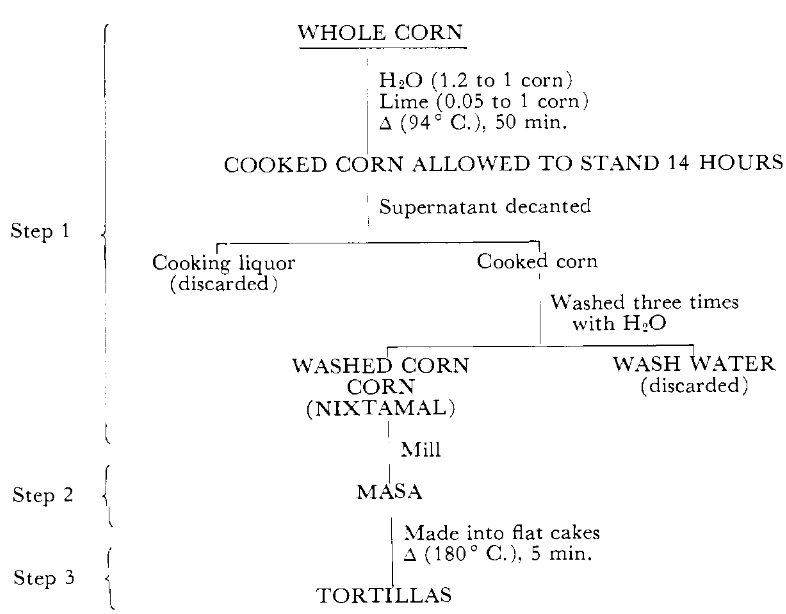
CORN consumed in the form of tortillas is the basic staple of diets in Mexico and Central America. In work carried out in Mexico, Tapia, Miranda, and Harris (*30*) reported that the protein of tortillas was inferior in quality to that of corn, and Massieu and associates (*23*) indicated that during tortilla preparation there are considerable losses of tryptophan, histidine, threonine, and arginine. Nevertheless, rats and pigs fed on tortillas or on alkali-treated corn grow better than when given raw corn (*9, 12, 16, 18, 22, 27, 28*). In view of the fairly high losses in niacin during the process of tortilla formation, Cravioto and coworkers (*9*) and Squibb and collaborators (*28*) postulated that this is because of changes in amino acid rather than niacin availability. Furthermore, Pearson and coworkers (*27*) cite evidence that the improved rat growth occurs when the corn is merely boiled, whether or not lime is added.

Evidence that cereal proteins may be altered by heat treatment has been reviewed and summarized by the National Research Council (*25*) and by Liener (*19*). Determinations of the solubility of the proteins and the in vitro release of essential amino acids provide information as to the nutritive value and amino acid availability of foods and help to supplement and explain the results of in vivo experiments. The present paper reports such studies after the combined lime and heat treatment on corn protein.

Materials and Methods

Samples of corn and tortillas were collected, during a nutritional survey in Guatemala City, and air-dried before grinding to pass 40 mesh. Protein fractionation of corn and tortillas was carried out as indicated by Nagy, Weidlein, and Hixon (*24*). Protein nitrogen determinations were done by the micro-Kjeldahl method (*1*), α-amino nitrogen by the method of Van Slyke, MacFadyen, and Hamilton (*31*), and amino acid assays on acid, alkaline, and enzymatic hydrolyzates using media proposed by Steele *et al.* (*29*) and *Leuconostoc mesenteroides, Leuconostoc citrovorum,* and *Streptococcus faecalis.* The process of tortilla preparation as described by Bressani, Paz y Paz, and Scrimshaw (*5*) is summarized below.



Results

Nitrogen Fractionation. The changes taking place in total nitrogen content during the process of preparing tortillas from corn are shown in Table I. There

Table I. Per Cent of Total Nitrogen at Each Stage of Tortilla Preparation[a]

Type of Corn	Raw Corn	Masa	Tortilla	Cooking Liquor
Lowland	1.43	1.41	1.49	0.05
Highland	1.19	1.25	1.22	0.04

[a] Values expressed on basis of raw corn moisture content of 12.85%.