

ENRICHMENT OF LIME-TREATED CORN FLOUR *
WITH DEODORIZED FISH FLOUR¹

by
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NUMEROUS surveys in Latin America have shown that corn is the most important staple food for the rural populations. Table I shows the average daily consumption of corn in several Central American countries, and the average amounts of protein and calories contributed to the diet by this grain (1).

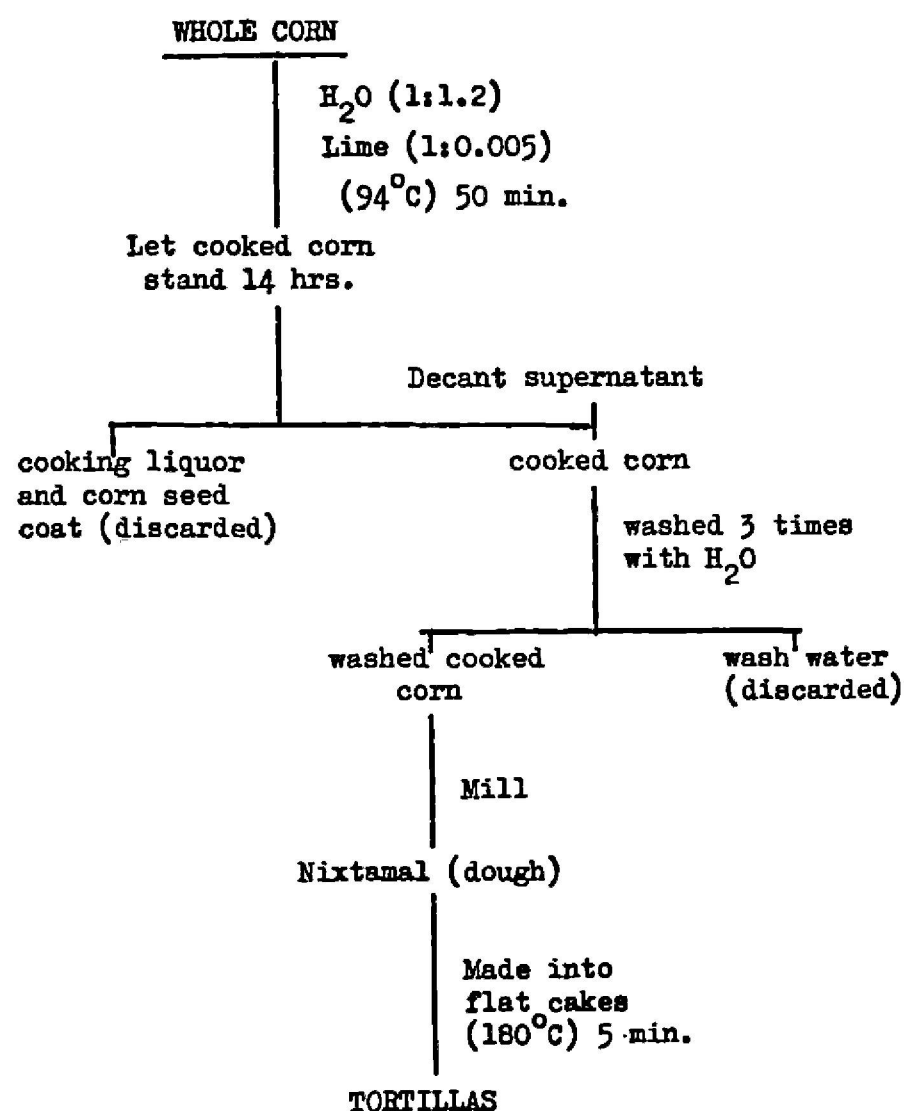


Fig. 1.* Method of preparing tortillas in Guatemala.

A great proportion of the corn in Central America is consumed in the form of tortillas made of lime-treated corn. Figure 1 shows how tortillas are prepared in Guatemala (2, 3). The process begins with lime-treating

TABLE I

Daily quantities of corn consumed in rural areas in central America per person¹

	Weight	Calories	% of total calories	Protein	% of total proteins
	g.			g.	
Costa Rica	185	635	34	15	32
Nicaragua	300	1030	57	24	40
Honduras	398	1370	69	32	48
El Salvador	374	1286	65	30	58
Guatemala	423	1456	64	34	49

¹ Data kindly supplied by Miss Marina Flores, INCAP

TABLEAU I

Quantités de maïs consommées par personne et par jour dans les zones rurales de l'Amérique Centrale

TABLA I

Cantidades de maíz consumidas por persona por día en zonas rurales de América Central

the whole grain; then cooking it, and letting it stand for 14 hours to remove the seed coat and soften the grain. Next, the lime and seed-coat are removed by repeated washing in water. When the grain is clean, it is finely ground, and the dough is patted into flat cakes which are baked for about 3 minutes. Lime-treated corn flour is made by drying and grinding the dough.

TABLE II

Chemical composition of raw and lime-treated corn (dry weight)

Nutrient	Corn	Tortilla
Ether extract, g. %	5.16	2.56
Crude fiber, g. %	1.51	1.21
Nitrogen, g. %	1.52	1.70
Ash, g. %	1.23	1.60
Calcium, mg./100 g.	13	305
Thiamin, mcg./g.	5.40	2.20
Riboflavin, mcg./g.	1.14	0.94
Niacin, mcg./g.	21.61	19.38
Carotene, mcg./g.	3.45	2.40

TABLEAU II

Composition chimique du maïs naturel et du maïs chaulé

TABLA II

Composición química del maíz crudo y del nixtamal

This processing of corn causes important changes in the chemical composition of the corn kernel (2, 3). Table II shows the vitamin changes, with significant decreases in thiamin, riboflavin, and carotene, and a slight decrease in niacin. Changes in the amino acid composition are also evident, as shown in Table III, with losses of arginine, histidine, leucine, lysine, and cystine. This Table also compares the amino acid pattern of tortillas and of raw corn with that of the FAO Reference Protein (4), showing that tortilla protein is deficient in lysine, tryptophan and methionine; whilst raw corn is deficient not only in these three but also in isoleucine.

The nutritive quality of the tortilla, as revealed by these data, is extremely poor; and the actual amount of nutritive material utilized by the rural population is even less than dietary surveys indicate. Therefore, in order to provide Central American populations with better quality protein and more vitamins, corn must be enriched.

Before lime-treated corn protein could be successfully enriched, however, it was necessary to determine the minimum of protein-rich foods of animal or vegetable origin which had to be added to it. This was learned by feeding young rats on diets of lime-treated corn, supplemented with increasing levels of protein-rich food. Figure 2 (right side) charts the improvement in nutritive value achieved by adding up to 5 per cent fish flour (5). The optimum supplementation was calculated by drawing two lines, one horizontal, the other diagonal, through as many points (marking various stages of sup-

* In Latin America corn flour which has been treated with lime is known as NIXTAMAL

¹ En: "Fish in Nutrition". International Congress, Washington, D. C., 1961, eds. Eirik Heen y Rulolf Kreuzer. London, England, Fish News (Books) Ltd., 1962, págs. 266-270. Publicación INCAP 1-222.

TABLE III

Essential amino acid composition of raw and lime-treated corn

Amino acid	Raw corn mg./g. N	Lime-treated corn mg./g. N	Change %	FAO Ref. Prot. mg./g. N	Raw corn Score	Lime-treated corn
Arginine	320	260	18.7	—	—	—
Histidine	170	150	11.7	—	—	—
Isoleucine	260	280	—	270	96	—
Leucine	760	600	21.0	306	—	—
Lysine	190	180	5.3	270	70	67
Methionine	120	120	—	144	68	65
Cystine	64	56	12.5	126	—	—
Phenylalanine	230	240	—	180	—	—
Tyrosine	240	240	—	180	—	—
Threonine	190	190	—	180	—	—
Tryptophan	31	33	—	90	34	37
Valine	280	300	—	270	—	—

TABLEAU III

Composition en acides aminés essentiels du maïs naturel et du maïs chaulé

TABLA III

Composición en aminoácidos esenciales del maíz crudo y nixtamal

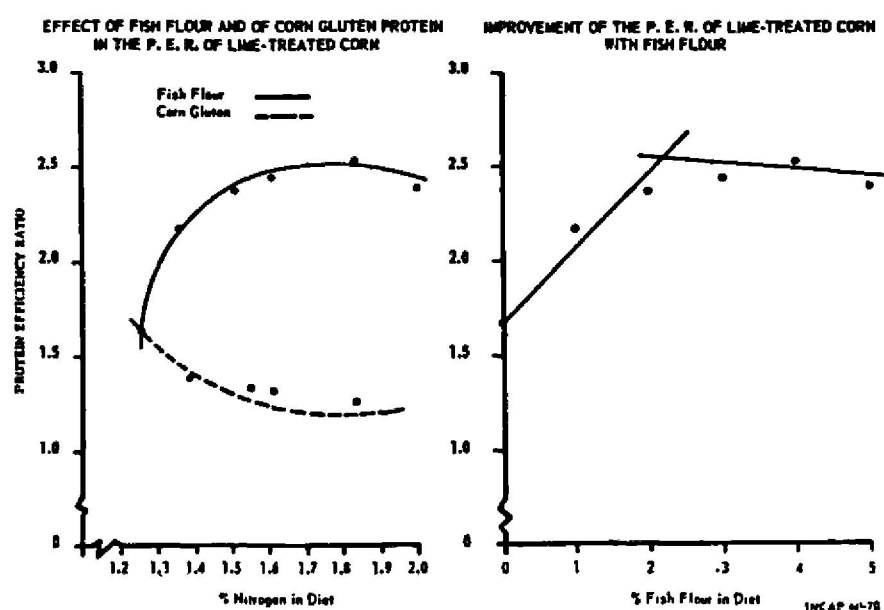


Fig. 2. Shows the improvement effected by adding fish flour.

plementation) as possible. The point of intersection represents the minimum supplementation necessary for maximum improvement in protein quality, which for fish flour is about 2.5 per cent. The left side shows the difference in PER obtained by increasing only the quantity of the protein (adding corn gluten), represented by the dotted line curving down; and by increasing both the quantity and quality of the protein (adding fish flour), as represented by the solid line curving up. It is evident that the nutritive value of lime-treated corn is not improved merely by adding more of the same quality protein.

Table IV shows the average weight gain and PER resulting from additions up to 10 per cent of deodorized fish flour to lime-treated corn. The maximum protein efficiency ratio was reached around the 3 per cent level, as in the previous experiment. Although the higher levels of fish flour did not significantly improve the quality of the protein, the rats gained more weight because of the higher protein levels in the diets.

TABLE IV

Enrichment of lime-treated corn flour with several levels of fish flour and effect of baking on nutritive value of enriched product

Fish flour % of diet	Protein in diet %	Average Final weight g.	PER
TRIAL 1 ¹			
0	9.5	21	1.01
2	11.0	61	1.95
4	12.1	88	2.10
6	13.9	104	2.18
8	15.3	127	2.24
10	17.2	125	2.06

TRIAL 2²

0			
No baking	7.0	18	1.34
2.7			
No baking	8.8	68	2.54
2.7			
Baking	9.0	59	2.69

¹ Experimental period: 28 days

² Experimental period: 21 days

TABLEAU IV

Enrichissement de la farine de maïs chaulé avec des taux différents de farine alimentaire de poisson et effet de la cuisson sur la valeur nutritive du produit enrichi

TABLA IV

Enriquecimiento de nixtamal con diversas cantidades de harina de pescado y efecto de la cocción en el valor nutritivo del producto enriquecido

Since tortillas are baked, tests were also made to determine whether this process altered the nutritive value of lime-treated corn flour enriched with fish flour. Table IV also shows these results, and indicates that baking did not reduce the PER of the enriched flour.

TABLE V

Amount of protein-rich foods, found optimum for supplementing lime-treated corn

Protein-rich Foods	Amount found % of diet	Protein Efficiency Ratio
None	—	1.00
Egg protein.	3.0	2.25
Casein (V.F.)	4.0	2.21
Meat flour	4.0	2.34
Fish flour	2.5	2.44
Soybean protein	5.0	2.30
Soybean meal	8.0	2.25
Cottonseed flour	8.0	1.83
Torula yeast	2.5	1.97
Pumpkin seed flour	5.5	1.73

TABLEAU V

Quantités d'aliments riches en protéines, déterminées comme optima pour la supplémentation du maïs chaulé

TABLA V

Cantidad de alimentos ricos en proteínas determinados como óptimos para complementar el nixtamal

Other protein-rich foods were also tested as supplements to lime-treated corn. The results are presented in Table V. Animal proteins in relatively small amounts improved the nutritive value significantly. Among the vegetable proteins, soybean protein and soybean meal improved the nutritive value of lime-treated corn as much as did the animal proteins. Although cottonseed flour, torula yeast, and pumpkin-seed flour also improved the nutritive value, they did not do so to the same degree as did the proteins of animal origin.

The enrichment of lime-treated corn was also studied through nitrogen balance experiments with young growing dogs (6). Figure 3 shows the improvement in nitrogen retention when lime-treated corn was enriched with 5 per cent skim milk or with amounts of lysine and tryptophan equal to those in skim milk.

Table VI shows the nitrogen balance results in dogs fed on diets of lime-treated corn enriched with yeast,

NITROGEN BALANCE IN YOUNG DOGS FED LIME-TREATED CORN ENRICHED WITH SKIM MILK OR AMINO ACIDS

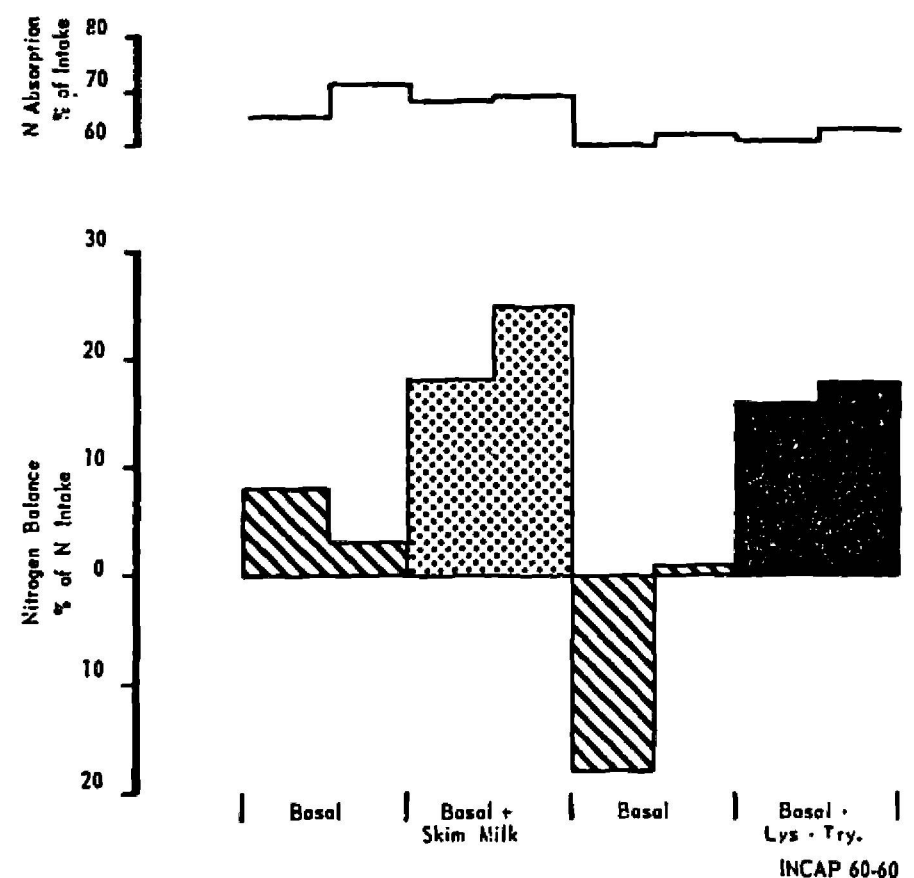


Fig. 3. Reveals the nitrogen balance in young dogs when fed with treated and enriched corn.

skim milk, and fish flour. Both yeast and skim milk improved the balance significantly, but the fish flour supplement did not improve it to the same degree. This lack of response may be attributed to a lower food intake with a consequent lower nitrogen absorption and retention. When the nitrogen retention is expressed on the basis of absorbed nitrogen, however, an improvement is seen.

To check this lowered retention, a third experiment with four growing dogs gave the results shown in Table VII. Skim milk supplementation gave better nitrogen retention values than did the unsupplemented diet. When fish flour was added, there was a significant improvement in nitrogen retention. This shows that the

TABLE VI

Nitrogen balance of dogs fed lime-treated corn flour enriched with various supplements
Average 3 dogs, 8 days/treatment

Supplement	N Intake mg./kg./day	N Absorbed % of intake	N Retained % of intake	N Retained % of absorbed
None	729	74.9	13.4	17.9
+ 5% skim milk	745	79.2	33.6	42.4
None	675	77.0	19.5	25.4
+ 3% torula yeast	674	77.7	34.7	44.6
None	539	76.1	24.5	32.2
+ 4% fish flour	454	66.1	26.0	39.3

TABLEAU VI

Bilan de l'azote chez des chiens nourris de farine de maïs chaulé enrichie de suppléments divers

TABLA VI

Equilibrio de nitrógeno en perros alimentados con nixtamal enriquecido con diversos complementos

TABLE VII

Nitrogen balance of dogs fed lime-treated corn flour enriched with various supplements
Average 4 dogs, 8 days/treatment

Supplement	<i>N</i> Intake mg./kg./day	<i>N</i> Absorbed % of intake	<i>N</i> Retained % of intake	<i>N</i> Retained % of absorbed
5% skim milk	479	74.5	17.9	24.1
None	494	74.3	12.1	16.3
4% fish flour	480	77.3	31.7	41.0

TABLEAU VII

Bilan de l'azote chez des chiens nourris de farine de maïs chaulé enrichie de suppléments divers

TABLA VII

Equilibrio de nitrógeno en perros alimentados con harina de nixtamal enriquecido con varios complementos

lack of response in the previous experiment was due to a decreased intake of nitrogen.

We can conclude, therefore, that the nutritive value of lime-treated corn protein can be improved by small additions of protein-rich foods of both animal and vegetable origin. Particularly effective were the small additions of fish flour, as evidenced by the increased PER in rats and the high nitrogen retention in dogs.

(INCAP Publication No. I-222).

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In an effort to find a suitable protein concentrate to enrich tortillas made from lime-treated corn, several protein concentrates of animal and vegetable origin were added to the corn at varying levels, and the effects of such supplementation were studied through growth trials with weanling rats, and through nitrogen balance trials in young growing rats.

The minimum levels of the protein concentrates for maximum protein efficiency ratios (PER) were: "VioBin" deodorized fish flour 3 per cent; whole egg protein 3 per cent; INCAP meat flour 4 per cent; nutritional Biochemicals Corporation vitamin-free casein 5 per cent; torula yeast 5 per cent; "Dracket" soybean protein 5 per cent; skim milk 7 per cent; local soybean flour 8 per cent and El Salvador cotton seed flour 8 per cent.

Fish flour added at levels up to 10 per cent of the diet did not lead to any significant improvement in PER beyond that with the 3 per cent addition. Slightly better growth with the 8 per cent fish flour diet was due to its higher protein level. When the basal diet was supplemented with corn gluten to give protein concentrations in the diets equal to those derived from the addition of the other protein supplements, growth increased slightly but the PER decreased. This decrease indicates that the improvement in PER, obtained by the addition of protein supplements or lysine and tryptophan, was due largely to a real improvement in protein quality rather than to higher level of protein in the diets.

In the nitrogen balance studies carried out with young growing dogs, addition of 5 per cent skim milk or 3 per cent torula yeast or 0.17 per cent *L*-lysine HCl plus 0.025 per cent *dl*-tryptophan improved nitrogen retention significantly. The addition of 4 per cent fish flour also improved nitrogen retention during the first four-day balance period. An unexpected decrease in food intake during the second four-day period in all three dogs resulted in a decreased nitrogen absorption and nitrogen retention, when expressed in absolute figures and as percentage of the nitrogen intake. When the nitrogen balance results were calculated as percentages of the nitrogen absorbed, the diet containing fish flour gave better results than did the basal diet.

L'ENRICHISSEMENT DE LA FARINE DE MAIS CHAULE AVEC DE LA FARINE ALIMENTAIRE DE POISSON DESODORISEE

Pour tenter de trouver un concentré protéique convenable qui puisse permettre à l'enrichissement des "tortillas" faites de maïs chaulé on a ajouté à des taux différents plusieurs concentrés protéiques d'origine animale ou végétale; on a analysé les effets d'une telle supplémentation par des études de croissance sur des rats en sevrage et par des études de bilan d'azote sur de jeunes rats en cours de croissance.

Les taux minimum de concentrés protéiques pour obtenir les rapports d'efficacité protéique (REP) maximum ont été: farine alimentaire de poisson désodorisée "VioBin", 3%; protéine d'oeuf entier, 3%; farine de viande INCAP, 4%; caséine nutritive sans vitamines de la Biochemicals Corporation, 5%; levure de torula, 5%; protéine de soja "Dracket", 5%; lait écrémé, 7%; farine de soja local, 8%; et farine de graines de coton El Salvador, 8%.

La farine alimentaire de poisson ajoutée à des taux atteignant 10% du régime alimentaire ne conduisait à aucune nouvelle amélioration du REP par rapport au taux de 3%. Une croissance légèrement meilleure avec un taux de 8% de farine alimentaire était imputable au taux protéique plus élevé. Quand le régime de base était supplémente avec du gluten de maïs pour obtenir dans les régimes des concentrations en protéines égales à celles qui provenaient de l'addition des autres suppléments protéiques, la croissance augmentait légèrement, mais le REP diminuait. Cette diminution indique que l'amélioration dans le REP, obtenue par l'addition de suppléments protéiques ou de lysine et de tryptophane, était largement due à une amélioration de la qualité des protéines plutôt qu'à des taux élevés de protéines dans le régime.

Dans les études de bilan d'azote conduites sur de jeunes chiens en cours de croissance, l'addition de 5% de lait écrémé ou de 3% de levure de Torula ou de 0,17% de *L*-lysine HCl avec 0,025% de *dl*-tryptophane améliorait d'une façon nette la rétention de l'azote. L'addition de 4% de farine alimentaire de poisson améliorait également la rétention de l'azote au cours des quatre premiers jours de la période de bilan. Une diminution inattendue de la consommation d'aliment au cours des quatre jours suivants de cette période chez tous les trois chiens étudiés s'est traduite par une diminution de l'absorption d'azote et de sa rétention, quand on les exprimait en chiffres absolus et en pourcentages de l'azote consommé. Quand les résultats du bilan de l'azote étaient calculés en pourcentages de l'azote absorbé, le régime qui contenait la farine alimentaire de poisson donnait de meilleurs résultats que le régime de base.

ENRIQUECIMIENTO DE NIXTAMAL CON HARINA DE PESCADO DESODORIZADA

Con objeto de encontrar un concentrado de proteínas adecuado para enriquecer tortillas hechas con nixtamal, al maíz se adicionaron diversas proporciones de concentrados de proteínas animales y vegetales, y los efectos de cada complementación se estudiaron mediante ensayos de crecimiento con ratas recién destetadas y de equilibrio de nitrógeno con ratas jóvenes en crecimiento.

Las proporciones mínimas de concentrados de proteína para alcanzar la máxima razón de aprovechamiento fueron: harina de pescado desodorizada "VioBin", 3%; proteína de huevo entero, 3%; harina de carne INCAP, 4%; caseína nutritiva sin vitaminas de la Biochemicals Corporation, 5%; levadura de torula, 5%; proteína de soja "Dracket", 5%; leche descremada, 7%; harina de soja local, 8%; harina de semilla de algodón de El Salvador, 8%.

Adicionar hasta un 10% de harina de pescado a la alimentación, no mejoró la razón de aprovechamiento de la proteína por encima de lo logrado con un 3%. El crecimiento un poco más rápido con la ración que contenía un 8% de harina de pescado se debió a su mayor concentración de proteína. Cuando la ración básica se complementó con gluten de maíz de manera que las concentraciones de proteínas en los alimentos fueran iguales a las obtenidas mediante la adición de otros complementos proteicos, el crecimiento fue un poco más rápido, pero disminuyó la relación de aprovechamiento. Esta disminución indica que la mejora en dicha relación lograda con la adición de complementos proteicos o de lisina y triptófano, se debió principalmente a una mejora real de la calidad de la proteína y no a su mayor concentración en los alimentos.

En los estudios de equilibrio de nitrógeno realizados con cachorros de perro, la adición de un 5% de leche descremada o un 3% de levadura de torula o un 0,17% de *L*-lisina más 0,025% de *dl*-triptófano mejoró sensiblemente la retención de nitrógeno. La adición de un 4% de harina de pescado dio el mismo resultado en los cuatro primeros días del periodo de equilibrio, pero durante el segundo periodo de cuatro días disminuyó inesperadamente la cantidad de alimento consumida por los tres cachorros y con ello la absorción y retención de nitrógeno expresados en términos absolutos y como porcentaje del ingerido. Cuando se calcularon los resultados como porcentajes del nitrógeno absorbido, la ración que contenía harina de pescado dio mejores resultados que la básica.

In Latin America corn flour which has been treated with lime is known as NIXTAMAL.

¹ En: "Fish in Nutrition". International Congress, Washington, D. C., 1961, eds. Eirik Heen y Rudolf Kreuzer. London, England, Fish News (Books) Ltd., 1962, pág. 266. (Extracto) Publicación INCAP I-216.