Nutritive Value of Chicken and Corn Flour Mixtures in Formulas for Infants with Lactose Intolerance[1]

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ABSTRACT

The nutritive quality of chicken and lime-treated corn flour (CF) mixtures were assessed as a first stage in the development of formulas for infants with lactose intolerance. Seven mixtures were developed to find the best quality mixture: five with chicken-CF and two with different parts of chicken without CF. Determinations performed on the raw materials and mixtures were: proximate analysis; net protein ratio (NPR) and digestibility; amino acid and mineral content of raw materials; and physical characteristics in tentative formulas. Dried chicken breast had the highest protein concentration. Chicken liver had the highest fat content. The limiting amino acids were valine in leg, isoleucine in breast, and leucine in liver protein. The NPR of chicken parts was similar to that of casein (3.36). The NPR of CF was 2.73. The four chicken-CF mixtures with the highest NPR were: 1) liver-CF, 50:50 protein content ratio, NPR 4.95; 2) liver-CF, 25:75 protein content ratio, NPR 4.09; 3) breast-CF, 50:50 protein content ratio, NPR 4.17; 4) breast-CF, 25:75 protein content ratio, NPR 4.10. Tentative feeding formulas were prepared from these mixtures. Chicken protein combined with lime-treated CF has a good protein quality and a reasonable cost as an infant formula.

Infants and preschool children have the highest demand for nutrients; therefore, they are the population most vulnerable to protein-energy malnutrition (Burton 1969).

Malnutrition has complex causes. Alone, or in association with chronic gastrointestinal infections, it can induce a state of lactose intolerance caused by a temporary deficiency of intestinal lactase (Fomon et al 1974). Different treatments have been used to solve this problem, including feeding babies diluted cow's milk or lactose-free formulas most commonly prepared with casein and soybean (Fomon and Filer 1974, Shenai et al 1981, Sotelo et al 1984). In México, chickpea formulas are also used (Sotelo et al 1987).

Malnourished children with lactose intolerance or infants that are born with this deficiency have been favorably treated with a chicken breast formula used at the Pediatric Hospital of the Instituto Mexicano del Seguro Social in México (Coello 1984). Also, lime-treated corn (masa) has long been used for this treatment. As gruel for weaning babies, it has high acceptability among the low-income natives in many regions of Mexico and Central America (Burton 1969). The objectives of this work were to evaluate the nutritive qualities of chicken and lime-treated corn flour (CF) mixtures and to develop tentative feeding formulas.

MATERIALS AND METHODS

Raw Materials

Deboned and skinless chicken breast, legs, and liver were separately autoclaved (120°C, 15 psi) for 15 min and dried without broth in aluminum trays in a conventional oven (80°C, 16–29 hr). Dried material was milled with a 40-mm sieve (Thomas Scientific, Swedesboro, NJ). A commercial lime-treated (nixtamalized) corn flour used in the formulation was run through a 60-mm sieve (Maiz Industrializado, S.A., México). Both CF and chicken parts were obtained from a local market in Mexico City.

The ingredients used in diets prepared for the biological evaluation of the protein were: mineral mix (Roger Harper), nonnutritive fiber (cellulose type), and vitamin mix (Teklad Test Diets, Madison, WI); casein (Sigma, St Louis, MO); and glucose (Arancia, S.A., México, DF). Lard and corn oil were obtained from a local market of Mexico City. Guar gum (H: Kohnstamm de México, S.A.) and soy lecithin (Quimisol, S.A., México, DF) were used as stabilizer and emulsifier, respectively.

Methods

The proximate analysis of the raw materials were performed according to AOAC (1984) techniques (e.g., moisture, ash, fat, protein, fiber, and carbohydrates by difference). The initial moisture content of chicken tissue was also determined. The minerals Fe, Zn, Na, K, and Ca were determined (AOAC 1984) in the ash by atomic absorption in a spectrophotometer (model 500, Perkin Elmer, Norwalk, CT). Phosphorous was determined by the molibdovanadophosphate method (AOAC 1984). The amino acid content was determined with an autoanalyzer (Alpha Plus 4151, LKB, Sweden) after acid hydrolysis of the samples using 6*N* HCl at 140°C for 4 hr (Lucas and Sotelo 1982). Tryptophan was measured using the fluorometric method (Udenfriend 1962). The chemical score was calculated using the FAO pattern as reference (FAO/WHO 1973). Biological evaluation of protein quality (NPR and digestibility determinations) in the raw materials and mixtures were done according to Pellet and Young (1980).

Mixtures

Seven mixtures were developed to find the best quality mixture: five with chicken-CF and two with different parts of chicken.

Diets

A total of 11 samples (Table I) were prepared at 10% protein concentration. CF, however, was prepared at 7% protein concentration. It was impossible to reach the 10% protein concentration of the other samples because the protein content of CF was 8.6% and adding other ingredients (vitamin and mineral mix, fat, etc.) decreased the protein percentage. The 7% protein concentration diet did not affect the NPR or protein efficiency ratio determinations (Bressani and Marenco 1963). The total energy of the diets was around 422 Kcal (1,765 Kj) per 100 g. Besides the 10.0 g of protein (7.0 g in the case of CF), the basal diet included: 64.0 g of carbohydrate (20.0 g of glucose, 19.0 g of sucrose, and 25.0 g of dextrin); 14.0 g of fat (6.0 g of corn oil and 8.0 g of lard); and 5.0 g of cellulose. This composition was fitted according to the proximate analysis of the raw materials.

Animals

Weaning male rats (strain Fisher 344) from our animal breeding house were 21–23 days old and weighed 40–50 g. The animals were kept in individual cages under controlled conditions in the animal house (12 hr light and 12 hr dark, at 21°C). Groups of seven rats were fed ad libitum with each diet for 10 days. Water was unrestricted. During the last four days, the feces were collected, dried at room temperature, weighed, and milled. The nitrogen was measured for digestibility determination. The study was conducted in three stages. Each stage included a casein control

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TABLE I
Composition of Experimental Diets Prepared with Different Cooked and Dried Chicken Parts and Corn Flour (CF) (g/100 g of sample)[a]

Ingredients	Breast	Leg	Liver	CF	Leg and CF (50:50)	Breast and CF (50:50)	Liver and CF (50:50)	Liver and Leg (50:50)	Liver and Breast (50:50)	Breast and CF (25:75)	Liver and CF (25:75)	Casein (control)	Protein-Free Diet
Breast	12.2	...	...	...	...	6.1	...	...	6.1	3.0	...	...	...
Leg	...	14.0	...	...	7.0	...	...	7.0	...	...	...	...	...
Liver	...	...	14.2	...	...	...	7.1	7.1	7.1	...	3.2	...	...
CF	...	...	...	81.4	58.1	58.1	58.1	...	...	78.5	78.5	...	...
Casein	...	...	...	...	...	...	...	...	...	...	...	11.4	...
Corn oil	5.7	5.0	5.0	4.7	4.5	4.8	4.4	4.7	5.0	4.6	4.4	6.0	6.0
Lard	7.1	6.4	5.7	6.3	6.0	6.4	5.8	6.3	6.7	6.2	5.9	8.0	8.0
Sucrose	19.0	19.0	19.0	...	6.1	6.1	6.1	19.0	19.0	...	...	19.0	19.0
Glucose	20.1	20.1	20.1	...	5.8	5.8	5.8	20.1	20.1	...	...	20.1	30.1
Dextrin	25.0	25.0	25.0	...	7.6	7.6	7.6	25.0	25.0	...	...	25.0	25.0
Fiber	5.2	5.2	5.5	2.8	...	0.3	0.2	5.4	5.4	3.2	3.3	4.5	5.9
Vitamin Mix	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Mineral mix	3.7	3.3	3.5	2.6	2.8	2.8	2.9	3.4	3.6	2.8	2.7	4.0	4.0
Kcal	422	422	422	421	417	416	419	419	421	418	418	422.4	422.4
Kj	1,765	1,765	1,767	1,762	1,745	1,739	1,752	1,753	1,762	1,747	1,750	1,766.7	1766.7

[a]The figures 50:50 and 25:75 represent the protein content ratio (or percentage of protein from each of the components) in the different mixtures.

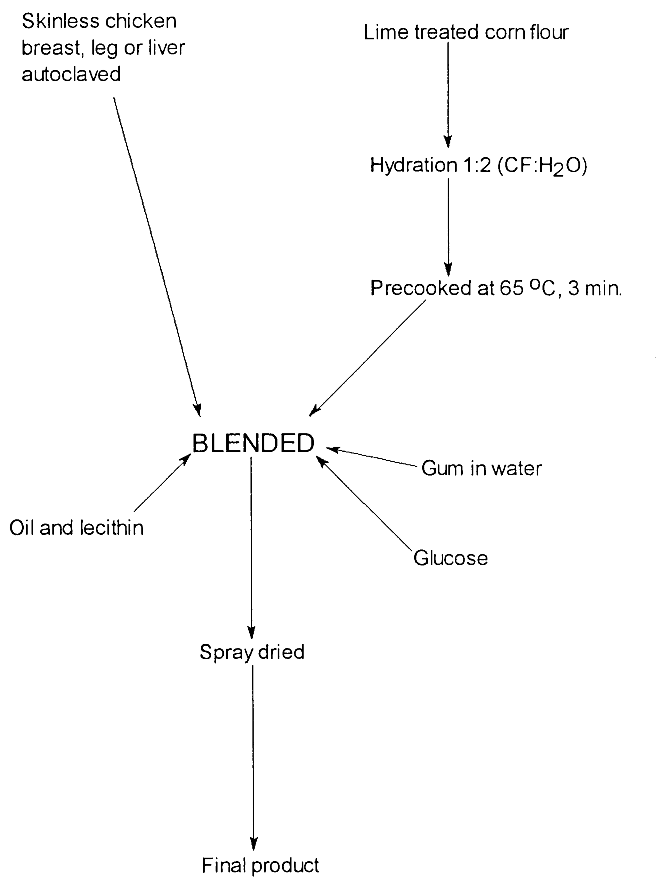

Fig. 1. Procedure used to produce infant feeding formulas.

diet and a protein-free diet (starch instead of protein).

Four mixtures with the highest NPR were used to prepare four powdered formulas (Fig. 1). Cooked (nondried) chicken parts were used to prepare the mixtures.

All the ingredients were homogenized for 10 min in a blender (Osterizer Mod. 463, México, DF) and then dried using a spray dryer (Swenson, Harvey, IL) under the following conditions: 32 psi feed pressure, 37 psi atomization pressure, 32 psi inlet pressure, 35 psi inlet air pressure, 250°C inlet air temperature, and 90°C outlet air temperature.

Statistical Analysis

Proximate analysis, amino acid, and mineral content results are reported as means of duplicate determinations. One-way analysis of variance and least significant difference were employed in NPR determination (Statgraphics program, version 5, STSC, Rockville, MD).

TABLE II
Proximate Analysis and Mineral Content in Raw Materials

Components (g/100 sample)[a]	Corn Flour	Leg	Liver	Breast
Moisture[b]	7.0	(72.4)[c] 4.9	(71.5)[c] 8.4	(76.4)[c] 4.8
Dry basis				
Ash	1.6	5.4	3.4	2.9
Fat	3.9	19.7	23.9	10.7
Protein	9.2	74.9	72.7	86.4
Fiber	2.8	...	...	...
Carbohydrate	82.5	...	...	...
Minerals (mg/100 g of dried sample)				
Sodium	23.26	222.27	181.77	162.77
Potasium	317.69	761.61	544.81	966.54
Zinc	3.01	9.55	17.40	2.90
Iron	3.82	6.10	5.53	5.00
Calcium	165.49	46.53	16.17	22.74
Phosphorous	307.93	588.93	800.98	687.44

[a]Average of two determinations.
[b]Moisture content in the cooked and dried chicken parts.
[c]Initial moisture content of chicken parts.

RESULTS AND DISCUSSION

Proximate analysis and mineral content of the raw materials and final formulas are shown in Table II. Moisture contents of the raw chicken parts were similar (71–76%). Protein content was highest in chicken breast (86.4%); fat content was highest in the liver (23.9%). The CF showed a chemical composition similar to that previously published (Woot-Suen and Flores 1966).

The Na, K, and P content was higher in chicken than in CF, and the highest Zn concentration was observed in chicken liver. The highest calcium content was found in CF, due to the beneficial lime treatment (Trejo-Gonzalez et al 1982, Serna-Saldivar et al 1991). All chicken parts and the CF had a low iron content compared to that of meat, although it was higher in chicken than previously reported by others (Hernandez et al 1974).

The essential amino acid content in chicken liver was higher than the FAO pattern, except in leucine, which was its limiting amino acid. Nevertheless, its chemical score was 92 (Table III). The limiting amino acid was valine in chicken leg and isoleucine in breast; lysine and tryptophan were the limiting amino acids in CF.

Table IV shows the results of the NPR and the true digestibility. The calculated NPR values were compared with the average value

TABLE III
Amino Acid Composition of Cooked and Dried Chicken Parts and Lime-Treated Corn Flour (CF)[a]

Amino Acid	FAO/WHO Pattern[b]	Breast	Leg	Liver	CF
Threonine	4.00	3.81	3.70	4.75	2.86
Valine	4.96	4.46	3.00	5.60	2.50
Methionine + cysteine	3.52	3.73	3.36	6.48	3.63
Isoleucine	4.00	2.19	2.94	5.50	2.22
Leucine	7.04	5.36	6.14	6.43	10.48
Phenylalanine + tyrosine	6.08	5.65	6.54	8.59	6.88
Lysine	5.44	8.01	7.86	6.03	2.16
Tryptophan	0.96	1.28	1.17	1.48	0.36
Histidine		2.27	2.10	2.45	2.19
Arginine		5.58	5.52	4.89	3.49
Aspartic acid		9.20	7.17	10.56	5.11
Serine		3.65	3.65	6.38	3.95
Glutamic acid		11.55	10.75	13.26	15.17
Glycine		2.37	4.00	4.45	3.30
Alaline		3.39	5.18	5.92	6.16
Limiting amino acid		Iso	Val	Leu	Try, Lys
Chemical score[c]		55	73	92	37,39

[a]Grams per 16 g of N. Average of two determinations.
[b]FAO/WHO 1973.
[c]Chemical score = amino acid in sample/amino acid in pattern × 100.

TABLE IV
Net Protein Ratio (NPR) and Digestibility of Cooked and Dried Chicken Breast, Liver, and Leg in Mixtures with Lime-Treated Corn Flour (CF)

Diets	Protein Content Ratio	NPR[a]	True Digestibility[a]
CF		2.73 ± 0.27 d	86.8 ± 2.25 e,f
Casein[b]		3.36 ± 0.24 c	94.6 ± 2.44 a
Leg		3.47 ± 0.52 c	89.2 ± 2.02 c,d
Liver		3.47 ± 0.20 c	84.1 ± 4.61 c,f
Breast		3.67 ± 0.46 c	88.2 ± 1.74 c,d
Liver and CF	50:50	4.95 ± 0.41 a	78.5 ± 2.35 b,i
Breast and CF	50:50	4.17 ± 0.33 b	80.9 ± 2.47 f,g,h
Liver and Breast	50:50	4.11 ± 0.25 b	86.6 ± 2.93 e,f
Breast and CF	25:75	4.10 ± 0.58 b	78.7 ± 7.07 g,h
Liver and CF	25:75	4.09 ± 0.17 b	82.3 ± 2.85 f,g
Liver and Leg	50:50	3.51 ± 0.31 c	90.9 ± 1.46 b
Leg and CF	50:50	3.41 ± 0.38 c	76.9 ± 3.88 i
Sobee®[c]		3.64 ± 0.19	

[a]Mean ± standard deviation of seven rats per group. Different letters indicate statistically significant differences at 5% level.
[b]Average value of three experimental casein determinations in groups of seven rats each: 3.46 ± 0.44, 3.53 ± 0.45, and 3.13 ± 0.50.
[c]Sotelo et al (1987).

of three experimental casein NPR determinations (3.36), which was used to compare the results of all diets. The highest NPR value in the chicken-CF mixtures was obtained in the liver-CF mixture at 50:50 protein content ratio (NPR 4.95). The protein qualities of the breast-CF 50:50, breast-CF 25:75, liver-CF 25:75, and liver-breast 50:50 were similar. Leg-CF mixtures showed a significantly lower NPR compared to that of the other chicken mixtures, but it was similar to that of the different parts of chicken alone and to that of casein. As expected, CF showed the lowest NPR value.

Digestibility of casein (94.57%) was superior to all mixtures tested, followed by leg-liver mixture, leg alone, and breast alone. No significant correlation coefficient was found between NPR and digestibility as previously described by Hernandez et al (1979).

Based on the NPR values obtained, at least five mixtures could be utilized in the formula preparation. Considering the cost of the raw materials, only the four chicken-CF mixtures with NPR values of 4.09–4.95 were selected. The final amounts of oil, glucose, lecithin, guar gum, and water to be added to the chicken-CF in the final dried formulation (Table V) were chosen after several attempts to obtain the formula with the best emulsion and stability characteristics. The proximate analysis of the final product is

TABLE V
Formulations of Selected Mixtures with Other Ingredients to Obtain Dried Powdered Products

Ingredients, g	Liver and CF[a] (50:50)[b]	Liver and CF (25:75)[b]	Breast and CF (50:50)[b]	Breast and CF (25:75)[b]
CF	68.58	86.75	70.07	87.54
Liver[c]	31.42	13.25	...	...
Breast[c]	...	...	29.93	12.46
Oil	12.00	10.00	13.00	10.00
Glucose	6.00	6.00	6.00	6.00
Lecithin	2.00	2.00	2.00	2.00
Guar gum	0.06	0.04	0.06	0.04
Water, ml	1,000	1,000	1,000	1,000

[a]Lime-treated corn flour.
[b]Protein content ratio.
[c]Cooked (nondried) chicken.

TABLE VI
Proximate Analysis of Four Powdered Infant Formulas[a]

Components	Liver and CF (50:50)[b]	Liver and CF (25:75)[b]	Breast and CF (50:50)[b]	Breast and CF (25:75)[b]
Moisture	8.1	4.9	7.6	4.1
Ash	1.9	2.0	1.9	1.6
Fat	16.3	18.0	18.2	13.5
Protein	13.8	10.9	11.4	8.9
Fiber	1.8	2.2	1.8	2.3
Carbohydrates	58.1	62.0	59.1	69.6
Energy (Kj)	1,784	1,898	1,865	1,822

[a]Grams per 100 g of sample. Average of two determinations.
[b]Protein proportion.

shown in Table VI. The results (*data not shown*) of some physical tests performed on the four formula powders were different than those of Sobee®, a soy-based formula (Mead Johnson, México, D.F.) used for comparison. The powder formula had lower density and higher wetability and penetrability than that of Sobee. The powdered formula showed higher moisture content (4–8%) than the 3.0% that has been reported as safe for long-term storage. These variations have to be corrected in future work.

In brief, four experimental formulas with the best protein quality are potential nonlactose formulas for infant feeding. Adding minor quantities of chicken to CF not only increased the initially low protein content but also the quality of the CF protein (as seen from the NPR values). Thus, the chicken-CF mixtures would have the same protein quality and a lower cost than the formulas prepared with chicken alone. From the practical point of view, considering the availability of both raw materials in Latin America, two mixtures with a similar high quality might be the most convenient for the final formula: breast-CF 50:50% protein content ratio and breast-CF 25:75% protein content ratio.

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