Formulation, Nutritive Value and Sensory Evaluation of a New Weaning Food Based on Sweet Corn (Nutrimaiz) Dehydrated Pulp

Rosires DELIZA,1 Valdemiro C. SGARBIERI,2 and Amauri ROSENTHAL1

1 Instituto de Tecnologia de Alimentos, Caixa Postal 139, 13073 Campinas-SP, Brasil
2 Departamento de Planejamento Alimentar e Nutrição, Faculdade de Engenharia de Alimentos, Universidade Estadual de Campinas, Caixa Postal 6121, 13081 Campinas-SP, Brasil

(Received April 7, 1990)

Summary The objective of the present work was to develop a formulation for complementary infant and child feeding employing linear programing as a mathematical model for optimization. High lysine/high tryptophan sweet corn pulp in the dehydrated form was used as the main ingredient. The restrictions imposed on the model were nutrient requirements, adequate protein/energy ratio and minimum cost. The formula derived by the computer (FC) matched the amino acid requirements, the protein/energy ratio (NDPCa1%) and was rated high in laboratory tests in terms of sensory qualities. The cost determined for this formula was competitive in relation to commercial products used for the same purpose. Formula A, which contained 5% more sweet corn pulp and 10% less whole powdered milk, did not differ in nutritional, sensorial and functional properties from the formula FC and was chosen for the field acceptability trial because of its lower cost. Formula A had protein efficiency ratio and Biological Value similar to casein for the rat but protein digestibility and net protein utilization were statistically lower (p < 0.05) for formula A than for casein. Acceptability tested on children who were 8–18 months of age ranged from 80–90%, average value 87%.

Key Words mathematical model, linear programing, infant formula, complementary feeding, nutritive properties, acceptability

Protein-energy malnutrition is considered one of the most important health problems in developing countries. For some investigators (1–3) mother’s milk is considered the ideal food for the infant. It presents biochemical, nutritional, psychological and economic advantages. Nevertheless, beyond six months of age mother’s milk becomes insufficient for the energy and nutrient requirement of the
child (4). The introduction of semi-solid easily digested food becomes necessary to prevent undernutrition. The utilization of regional raw material for development of infant formula has been recommended. The main reason for this recommendation is to increase the utilization of the local products and not change the eating habits of that particular population. The objective of this investigation was to develop a basic nutritionally adequate formula for the child after six months of age, with good acceptability, using as the main ingredient the dehydrated pulp of a special sweet corn (Nutrimaiz) which had been nutritionally improved by genetic manipulation.

EXPERIMENTAL

Raw material. The sweet corn cultivar utilized in this research was developed at University of Campinas from crossing of a Cuban sweet corn (Pajimaca) with a Maya Opaque-2, originating the double mutant (suo2) which was named Nutrimaiz. From Nutrimaiz were selected two promising isogenic lines (L60 and L90) both with genotype suo2, which by backcrossing originated the first generation of hybrid (F1). The hybrid contained protein of high nutritive value, higher oil and sugar and lower starch contents (5). The hybrid had a productivity 20% higher than the synthetic variety (6) and was harvested at 25 DAP (days after pollination) for processing.

Processing. The scheme utilized in the processing of the fresh corn is shown in Fig. 1. The ears were sequentially dehusked, the grains blanched on the cob (5 min, boiling water), cooled in running water and then removed from the cobs. The grains were ground first in a hammer mill and then in a colloidal mill. Coarse fiber was separated in a pulper and the fine pulp was dehydrated in an experimental double drum dryer of 18×18 inches (Richards Simons and Sons) with knives applied at 3/4 of the drums' circumference from the feeding point. The operation conditions were: steam pressure, 60 psig; velocity of the drums, 2.5 rpm; distance between the drums, 0.15 mm; pulp layer at feeding surface of the drums maintained at about 10 cm during operation.

Chemical determination. Water content (moisture) and ash were determined by the AOAC procedures (7), total lipids by the method of Bligh and Dyer (8), neutral detergent fiber by the method of Southgate (9), crude protein according to AACC (10); amino acids were determined in a Technicon Autoanalyser TSM model (Beckman Instruments, Palo Alto, USA), following the analytical procedures recommended by Beckman (11), except for tryptophan which was determined by the colorimetric method of Spies (12).

Linear program utilized. Three types of information were necessary for the mathematical model: nutritional requirement of the target age group; percent composition of each ingredient; the cost of each ingredient (13). The problem can be adjusted mathematically to the equation (14).
Fig. 1. Scheme utilized in the preparation and dehydration of fresh corn pulp.

\[
\text{Min } F = \sum_{j=1}^{n} c_j x_j
\]

Subjected:

\[
\sum_{j=1}^{n} a_{ij} x_j < b_i \quad (i = 1, \cdots, n)
\]

\[
x_j > 0 \quad (j = 1, \cdots, n)
\]

where: \( F \) is the total minimum cost for the formula; \( c_j \) (\( j = 1, \cdots, n \)) the unit cost of ingredient “\( j \)”; \( x_j \) (\( j = 1, \cdots, n \)) represent the quantity of ingredient “\( j \)” in the elaboration of the formula; \( a_{ij} \) (\( i = 1, \cdots, n \), \( j = 1, \cdots, n \)) represent the contribution of each ingredient in the formula to the nutritional requirements; \( b_i \) (\( i = 1, \cdots, n \)) represent the maximum (or minimum) levels of nutritional requirement.

The criterion of optimization adopted was based on minimum cost but with restriction as to nutritional and sensory properties. The nutritional restriction imposed to the mathematical model in the formulation is shown in Table 1 (15).

Total energy, crude protein, total lipids, carbohydrates and essential amino acids for the ingredients utilized in the formula are shown in Table 2.

The information of Tables 1 and 2 was fed to the computer and resulted in the basic minimum cost formulation (Formula FC). By modifying the proportions of powdered milk and of dehydrated sweet corn pulp in the formula FC, two other
Table 1. Nutritional restriction imposed to the mathematical model in the production of an infant formula (FAO/WHO, 1976).

| Component                  | Range |
|----------------------------|-------|
| Energy (kcal/100 g)        | 430–480 |
| Protein (g/100 g)          | 12–14  |
| Lipids (g/100 g)           | 10–15  |
| Sucrose (g/100 g)          | 10–15  |
| Other carbohydrates        | 50–60  |
| Essential amino acids* (g/100 g) |       |
| Ile                        | 0.47   |
| Leu                        | 0.91   |
| Lys                        | 0.67   |
| Met+Cys                    | 0.37   |
| Phe+Tyr                    | 0.78   |
| Thr                        | 0.51   |
| Trp                        | 0.11   |
| Val                        | 0.60   |
| His                        | 0.32   |

*For the essential amino acids, only the minimum amount (g/100 g product) was used.

Table 2. Composition and cost of the ingredients utilized in the infant formula.

| Component                  | Ingredients |
|----------------------------|-------------|
| Energy (kcal/100 g)        | 1  2  3  4  5  6  7  8 |
| Protein (g/100 g)          | 13.76 25.61 — — — 7.39 — — |
| Lipids (g/100 g)           | 5.88 25.44 — — — 0.86 — 98 |
| Other carb. (g/100 g)      | 64 37.70 98 98 98 80.40 — — |
| Sucrose (g/100 g)          | 4.5 — — — — — — 98 — |
| Essential amino acids (g/100 g) | 0.37 1.32 — — — 0.30 — — |
| Ile                        | 0.73 2.48 — — — 0.63 — — |
| Leu                        | 0.46 1.82 — — — 0.24 — — |
| Lys                        | 0.25 0.88 — — — 0.28 — — |
| Met+Cys                    | 0.57 2.46 — — — 0.68 — — |
| Phe+Tyr                    | 0.43 1.05 — — — 0.26 — — |
| Thr                        | 0.08 0.36 — — — 0.09 — — |
| Trp                        | 0.55 1.61 — — — 0.44 — — |
| Val                        | 0.22 0.72 — — — 0.18 — — |
| His                        | 0.078 0.268 0.017 0.026 0.019 0.027 0.027 0.062 |

1, dehydrated corn pulp; 2, whole powdered milk; 3, corn starch; 4, waxy corn starch; 5, cassava starch; 6, rice flour; 7, sucrose; 8, corn oil.

J. Nutr. Sci. Vitaminol.
Table 3. Proportion of the various ingredients in the formulas FC, A and B.

| Ingredients                  | Formulas |
|------------------------------|----------|
| Dehydrated sweet corn pulp   | FC 45.0  |
| Whole powdered milk          | A 50.0   |
| Rice flour                   | B 45.0   |
| Corn starch                  | FC 30.0  |
| Sucrose                      | A 20.0   |
| Corn oil                     | B 25.0   |
|                             | FC 0.5   |
|                             | A 5.5    |
|                             | B 5.5    |
|                             | FC 15.0  |
|                             | A 15.0   |
|                             | B 15.0   |
|                             | FC 6.5   |
|                             | A 6.5    |
|                             | B 6.5    |
|                             | FC 3.0   |
|                             | A 3.0    |
|                             | B 3.0    |

products (A and B) were obtained (Table 3).

*Sensory evaluation*. The formulas FC, A and B were submitted to sensory evaluation by the method of Quantitative Descriptive Analyses described by Stone and Sidel (16). Because the products were to be used in infant feeding, the panel was composed of 10 mothers as recommended by Amerine *et al.* (17) and Oyeleke *et al.* (18).

The statistical design was randomized complete blocks with six replications. The descriptors evaluated were: appearance (homogeneity, color); fresh corn flavor; consistency; off-flavor; overall impression. They were evaluated in a nine-point non-structured scale. The results were submitted to analysis of variance and of differences among means were evaluated by the Tukey test.

*Acceptability test*. The formulas were tested with children from 8–18 months of age from a nursery/kindergarten at the Campus of the University of Campinas, São Paulo, Brazil. The formulas were mixed with water to the consistency of a porridge and were served to the children for seven weeks once a week, after their regular meal at lunchtime. At the end of the test 330 children had received the formula. Acceptability was evaluated by the Acceptability Index (A.I.) (19) given by the expression:

\[
A.I. = \frac{\text{weight of prepared porridge} - (\text{unconsumed prepared porridge} + \text{leftover from servings})}{\text{weight of prepared porridge} - \text{unconsumed prepared porridge}}.
\]

*Nutritional evaluation*. Nutritional evaluation of the formulas was performed by PER and nitrogen balance. Male rats (35–52 g) of the Wistar strain were used and obtained from the University of Campinas Animal Center.

Diets were prepared as recommended in AOAC (7). Throughout the experiments water and diets were offered *ad libitum*. The animals, six per treatment, were distributed in groups on randomized blocks. The temperature was maintained at 22 ± 1°C with alternating light-dark periods of 12 h.

For the PER determination the animals were maintained on the diets for four weeks. For the nitrogen balance the rats were maintained individually in metabolic cages for 10 days. Feces and urine were collected during the last five days and
submitted to nitrogen determination. NPU, BV and digestibility, apparent, were determined according to Pellet and Young (20).

RESULTS

The proportions of the various constituents in the product developed by linear programing (FC) and the two other variants (A and B) are shown in Table 3. Formula FC contains more powdered milk and less rice flour than the other two. Formula A, in relation to FC contained higher proportion of sweet corn pulp, lower proportion of whole powdered milk and a higher proportion of rice flour. Formula B, compared to FC, presented the same proportion of fresh corn pulp, lower proportion of whole powdered milk and higher proportion of rice flour.

The proximate percent composition, the energy density and the relative estimated cost for the three formulas are shown in Table 4.

The contents of protein, lipids, and energy are slightly higher in formula FC as compared with A and B. On the other hand, the estimated cost of FC is higher than A and B, due to the greater proportion of powdered milk in the formula FC.

The amino acid profiles determined for the three formulas are shown in Table 5 and the essential amino acid contents are compared with the FAO/WHO (21) recommendation. It is apparent from Table 5 that the amounts of all the essential amino acids in the three formulas are similar and in excess of the FAO/WHO recommendation, except for the sulfur-containing amino acids which are slightly below.

The results of the nutritional evaluation of the protein in the three formulas as compared to casein are shown in Table 6. There were no statistical differences in the protein nutritive value among the three formulas. PER and BV were identical.

Table 4. Proximate percent chemical composition, energy density and relative estimated cost of three products developed for infant feeding.

| Determination                  | Formulas |
|-------------------------------|----------|
|                               | FC       | A        | B        |
| Nutrients (g/100 g)           |          |          |          |
| Humidity                      | 5.05     | 5.53     | 5.53     |
| Protein (%N × 6.25)           | 15.67    | 14.48    | 15.11    |
| Total lipids                  | 13.60    | 11.25    | 12.23    |
| Ash                           | 2.82     | 2.34     | 2.10     |
| Fiber                         | 1.98     | 2.37     | 2.10     |
| Carbohydrate (difference)     | 60.88    | 64.04    | 62.63    |
| Energy (kcal/100 g)           | 430      | 415      | 421      |
| NDPCal (%)                    | 9.8      | 8.7      | 9.3      |
| Cost (US$/100 g)              | 0.122    | 0.100    | 0.109    |
| Cost (US$/100 kcal)           | 0.028    | 0.024    | 0.026    |
| Cost (US$/NDPCal%)            | 0.0124   | 0.0115   | 0.0117   |

J. Nutr. Sci. Vitaminol.
Table 5. Amino acid composition of formulas FC, A and B. Comparison with FAO/WHO (21) essential amino acid recommendation.

| Amino acid | Formulas | FAO/WHO* |
|------------|----------|----------|
|            | FC (g/100 g) | A (g/100 g) | B (g/100 g) | (g/2.4 g N) |
| Lys        | 1.00      | 0.82     | 0.98     | 0.82       |
| His        | 0.58      | 0.56     | 0.54     |            |
| Arg        | 0.58      | 0.60     | 0.54     |            |
| Asp        | 1.72      | 1.59     | 1.51     |            |
| Thr        | 0.68      | 0.58     | 0.59     | 0.60       |
| Ser        | 0.85      | 0.76     | 0.82     |            |
| Glu        | 2.92      | 2.80     | 2.84     |            |
| Pro        | 1.75      | 1.37     | 1.75     |            |
| Gly        | 0.56      | 0.58     | 0.54     |            |
| Ala        | 1.14      | 1.15     | 1.09     |            |
| Val        | 1.19      | 1.06     | 1.14     | 0.74       |
| Met+Cys    | 0.43      | 0.49     | 0.45     | 0.52       |
| Ile        | 0.73      | 0.63     | 0.71     | 0.60       |
| Leu        | 1.43      | 1.45     | 1.39     | 1.06       |
| Tyr+Phe    | 1.38      | 1.13     | 1.40     | 0.91       |
| Trp        | 0.49      | 0.39     | 0.44     | 0.16       |

*FAO/WHO reference protein in gram amino acid/2.4 g N (average N/100 g of formulas FC, A and B).

Table 6. Protein nutritive value of the three formulated products for infant feeding compared with casein.

| Determined index* | Casein (10%) | Formulas | FC | A | B |
|------------------|--------------|----------|----|---|---|
| PER              | 2.7±0.2a     | 2.6±0.1a | 2.6±0.2a | 2.7±0.2a |
| Dₐ (%)           | 90.1±1.5a    | 79.4±1.1b | 80.5±2.7b | 81.1±1.9b |
| BVₐ (%)          | 86.8±6.1a    | 85.5±3.8a | 79.8±8.0a | 80.0±5.2a |
| NPUₐ (%)         | 75.5±7.5a    | 67.9±3.1ab | 62.7±6.3b | 64.8±4.8b |

*Values are mean±deviation of six animals. Dₐ, digestibility (apparent); BVₐ, biological value (apparent); NPUₐ, net protein utilization (apparent). ab Different letters on the horizontal lines indicate statistically significant differences (p<0.05).

to that of casein; however, digestibility was higher for casein than for the formulas protein and NPU was higher for casein than for the formulas A and B (p<0.05).

The results of the sensory evaluation of the formulated products are shown in Table 7. The results are mean values of 10 panelists and of six replications.

The acceptability index for formula A in seven different trials is illustrated graphically in Fig. 2. Acceptability ranged from 80 to over 90%, average acceptability 87%.

Vol. 36, No. 6, 1990
Table 7. Results of Quantitative Descriptive Analysis of three formulated products for infant feeding.

| Descriptors*          | Formulas |
|-----------------------|----------|
|                       | FC       | A         | B         |
| Appearance (homogeneity, color) | 8.0±0.4\textsuperscript{a} | 7.9±0.3\textsuperscript{a} | 8.0±0.5\textsuperscript{f} |
| Fresh corn flavor     | 8.0±0.5\textsuperscript{b} | 7.7±0.5\textsuperscript{b} | 7.8±0.3\textsuperscript{b} |
| Off-flavor            | 1.6±0.6\textsuperscript{c} | 1.7±0.3\textsuperscript{c} | 1.7±0.3\textsuperscript{c} |
| Consistency           | 5.0±0.6\textsuperscript{d} | 6.0±0.2\textsuperscript{e} | 5.5±0.2\textsuperscript{de} |
| Global impression     | 7.8±0.5\textsuperscript{f} | 7.4±0.2\textsuperscript{f} | 7.7±0.2\textsuperscript{f} |

*Values are mean±deviation of 10 panelists in six replications (nine-point non-structured scale). \textsuperscript{a,b,c,d,e,f} Identical letters in the horizontal lines indicate absence of statistically significant difference (\(p<0.05\)).

---

**DISCUSSION**

A comparison of Table 1 with Table 4 shows that the restrictions imposed (Table 1) for total energy, protein and lipids were essentially matched in the three formulations (Table 4). The protein content of the formulas was slightly higher than the upper limit established and superior to similar products developed in France and England (22). This may have resulted from the fact that the protein...
values for the ingredients were taken from the literature and it seemed to have been underestimated. The NDPCal% between 8–9 is within the recommendation (21) and represents the percentage of the total calories provided by utilizable protein in the formulas.

A comparison of Table 1 with Table 5 shows that all essential amino acids appear in the Formulas (Table 5) in excess to the minimum requirement established in Table 1. The formulas also satisfy the amino acid profile established by FAO/WHO (21) for a reference protein. The slight deficit of sulfur-containing amino acids and the large excess of tryptophan in the formulas, as related to the reference protein, may be due to a methodological problem in the determination of these amino acids. Acid hydrolysis is known to degrade cysteine, mainly in the presence of large amounts of carbohydrate. On the other hand, the method used for colorimetric determination of tryptophan (12) seems to have overestimated this amino acid in our formulas.

The indices for protein nutritive value (Table 6) resemble casein (10%) with respect to PER and biological value and were statistically inferior to casein in digestibility. NPU was similar to casein for formula FC and inferior to casein for A and B. This means that the protein in the formulas is as well utilized in the body as casein but due to the lower protein digestibility it is expected that for equivalent growth promotion one should ingest a slightly higher proportion of protein than that provided by the formulas; this can be accomplished either by raising protein concentration in the formulas or by higher food intake. The growth obtained in the PER assay (28 days) with 10% dietary protein was 78.0, 81.0, 82.0, and 83.0 g for the formulas FC, A, B, and for casein, respectively, which was not statistically different (p<0.05). The protein nutritive value in the formulas was adequate for infant and child complementary feeding according to the criterion of PAG (23), which recommends NPU values not inferior to 60%.

The results of the sensory evaluation appear in Table 7. The values of appearance, fresh corn flavor and global impression did not differ among the three formulas. The low values for off-flavor were also a desired characteristic and also did not differ among the three formulas. The ideal value for consistency, which should be in the middle of the scale (nine points), was approached by formula FC, which did not differ from formula B but was statistically better than formula A. Formulas A and B were similar with regard to consistency.

For the field trial, formula A was chosen based on the lower cost. The acceptability (Fig. 2), which was 87%, as an average, could be considered good according to published data (24).

The study reported in this paper permitted the conclusion that the linear programing is a useful tool in food formulation and that the product obtained based on dehydrated fresh corn pulp is perfectly adequate for complementary infant and child feeding due to its high nutritive value, convenience in storage and preparation, and good acceptability. It is also competitive with regard to price in relation to similar products already available in the market that range in cost from US$ 0.19
to US$ 0.23/100 g.

REFERENCES

1) Jelliffe, D. B. (1968): Infant nutrition in the subtropics and tropics, 2nd ed., WHO Monographs No. 29, Geneva.
2) Cameron, M., and Hofvander, Y. (1976): Manual on Feeding Infants and Young Children, 2nd ed., UNICEF, New York.
3) Martins Filho, J. (1987): Como e Porque Amamentar, 2nd ed., Sarvier, São Paulo.
4) Fomon, S. J., Filer, L. J., Jr., and Anderson, T. A. (1979): Recommendation for feeding normal infants. Pediatrics, 63, 52–59.
5) Sgarbieri, V. C., Silva, W. J., Antunes, P. L., and Amaya-F. J. (1977): Chemical composition and nutritional properties of a sugary-1/opaque-2 (su_{1}o_{2}) variety of maize (Zea mays, K.). J. Agric. Food Chem., 25, 1098–1101.
6) Silva, W. J., Teixeira, J. P. F., Arruda, P., and Lovato, M. B. (1978): Nutrimaiz, a tropical sweet maize cultivar of high nutritional value. Maydica, 23, 129–136.
7) AOAC (Association of Official Agricultural Chemists). (1975): Official Methods of Analysis, 11th ed. Washington, D.C.
8) Bligh, E. C., and Dyer, W. J. (1959): A rapid method of lipid extraction and purification. Can. J. Biochem. Physiol., 37, 991–997.
9) Southgate, D. A. T. (1976): Determination of Food Carbohydrates, Applied Science Publishers, London, pp. 132–134.
10) AACC (American Association of Cereal Chemists). (1976): Approved Methods of AACC. The Association, St. Paul, Minn.
11) Beckman Instruments, Spinco Division. (1977): Amino Acid Analyser's Instruction Manual, Palo Alto.
12) Spies, J. R. (1967): Determination of tryptophan in proteins. Anal. Chem., 39, 1412–1415.
13) Norback, J. P., and Evans, S. R. (1983): Optimization and food formulation. Food Technol., 37, 73–80.
14) Puccini, L., and Campos, S. D. (1981): Introdução à Programação Linear, Livros técnicos e científicos Editora S/A, Rio de Janeiro.
15) FAO/WHO. Food Standards Programme. Codex Alimentarius Commission. (1976): Recommended International Standards for Foods for Infants and Children, Roma.
16) Stone, H., and Sidel, J. L. (1985): Sensory Evaluation Practices. Academic Press Inc., Orlando, Florida.
17) Amerine, M. A., Pangborn, R. M., and Roessler, E. B. (1965): Principles of Sensory Evaluation of Foods, Academic Press, New York, pp. 349–397.
18) Oyeleke, O. A., Morton., I. D., and Bender, A. E. (1985): The use of cowpeas (Vigna unguiculata) in improving a popular Nigerian weaning food. Br. J. Nutr., 54, 343–347.
19) ABIA (Associação Brasileira das Indústrias de Alimentação). (1986): Formulação e Padronização de Processos de Avaliação de Serviços de Nutrição em Diferentes Entidades. São Papulo, p. 88.
20) Pellet, P. L., and Young, V. R. (1980): Evaluación Nutricional de Alimentos Proteicos, Launiversidad de Las Naciones Unidas, p. 69.
21) FAO/WHO. (1973): Energy and protein requirements. Report of a Joint AD Hoc
22) Khan, M. A., and Kissana, A. S. (1985): Nutritional evaluation of some commercial baby foods consumed in Pakistan. *J. Sci. Food Agric.*, 36, 1271–1274.

23) PAG (Protein Advisory Group of the United Nations Systems). (1971): Guidelines on Protein-rich Mixtures for Use as Weaning Foods. Studies No. 8, FAO/WHO/UNICEF, United Nations, New York.

24) Head, M. K., Giesbrecht, F. G., and Johnson, G. N. (1977): Food acceptability research: comparative utility of three types of data from school children. *J. Food Sci.*, 42, 246–251.