ESTIMATION OF PROTEIN QUALITY IN WEANING FOODS PREPARED FROM LOCAL RAW MATERIALS

by

Wisdom A, Plahar
and
Nana T. Hoyle

Food Research Institute
(C.S.I.R)
P. O. Box M.20
Accra

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ABSTRACT

A procedure was developed for calculating amino-acid scores for use in predicting protein quality of weaning blends of cereals and legumes. Amino acid composition of selected blends was determined with the amino acid analyser and the results were used to assess the relative accuracy or reliability of the theoretical prediction procedure developed. Calculated protein quality values were found to slightly overestimate true values determined by amino-acid analysis. A factor of 0.9 was obtained for converting calculated amino acid scores to assayed values.

The relative performance of local legumes and cereals in various possible weaning formulations was evaluated using the blend protein quality prediction procedure, to serve as a quick guide in local weaning formulations. Increasing legume concentration in blends improved the protein quality until a new limiting amino acid was imposed, thereafter reducing the rate of increase in the net protein value of the blend. Poorest quality blends were obtained in mixtures of cereals with groundnut due to the relative inadequacy of groundnut protein to complement cereal amino acids. When used in combination with cowpea , pigeon pea, soybean or wingedbean, the groundnut produced better quality blends than when used singly. Soybean, soybean Tempeh and winged bean produced the best quality blends (with cereals) followed by cowpea and pigeon pea in that order. No additional benefits could be derived in using pigeon pea in mixtures with cereals, beyond 20% of the legume concentration. Among cereals, blends containing millet gave the highest net protein values at each level of fortification, followed by maize-containing blends. In spite of its higher protein content over the other cereals, sorghum blends had the least net protein values.

INTRODUCTION

Protein Energy Malnutrition (PEM) has for a long time been associated mainly with the developing countries where the people rely on low-protein cereals and starchy roots as their main source of nourishment(Hanson, 1974, United Nations, 1973). The problem created by the inequitable distribution of the world protein supply (Deutscher, 1978) are aggravated further by the ever-increasing population rate. By the 21st Century the world population has been projected to almost double and the need for more protein will become accentuated. The worst hit by the situation are the vulnerable groups of the population, especially children. Traditional weaning foods in many developing countries are based on cereals without adequate supplementation with high quality protein source. Over-dependence on such poor protein sources is the main cause for the widespread PEM problems in these areas.

This widespread problem of infant malnutrition in the developing world has stimulated a great deal of effort in the area of research, development and extension by both local and international organisations. Several methods of approach are being adopted towards the solution of the problem. In most cases however, the solution is based on formulation of blends of locally available legumes (pulses and oilseeds) and cereals to increase the protein content and also improve on the protein quality through mutual complementation of their individual limiting amino acids. Several reports are available on the effects of such fortification attempts on the physicochemical, nutritional and sensory characteristics of the resulting blends (Glover, 1976; Ekpenyong et al, 1977; Sarwar et al, 1978; Plahar et al, 1983; Plahar and Leung, 1983; 1985).

Two main approaches being used in Ghana and other developing countries to combat the PEM problem are: (a) Campaign for domestic preparation of weaning foods by mothers using predetermined proportions of available legumes and cereals,and (b) the promotion of semi-industrial units for the production of ready-made weaning foods of high nutritional quality (also based on local cereals and legumes). In Ghana, the Food Research Institute, the Nutrition and Food Science Dept. of the Univ. of Ghana, Ministry of Health (Nutrition Division) UNICEF, Ghana National Commission on children, and World Vision International are the major organisations actively involved in research, development and extension work on such formulations. Both methods of approach may have their relative advantages and limitations regarding successful adaptation and practical implementation.

The ultimate success of these efforts however, lies with the effectiveness of the proposed blends in solving the PEM problem. The emphasis is not only on the protein content of the blends, but also (and may be more importantly) on the protein quality for maximum utilization by the body. Although legume supplementation in cereal diets increases the protein content, the protein quality and hence the net protein value (NPV) of the blend will depend on the types of legume and cereal used as well as the level of fortification.

Protein quality is defined in relation to the efficiency with which various food proteins are used for synthesis and maintenance of tissue proteins (Jansen, 1978). In nutrition, the degree to which the proteins are utilized is a function of factors such as digestibility, amino-acid composition and amino-acid requirement of the organism fed the protein (Hopkins and Steine, 1978). However, protein quality is determined primarily by the amino-acid composition (FAO/WHO, 1973). The estimates of essential amino acid requirements by humans (FAO/WHO, 1973) have provided a basis for evaluating protein quality in terms of these requirements. According to Pellet and Young (1980), amino acid scores obtained for a particular blend with the FAO/WHO estimates are comparable to results of actual biological assays.

An assessment of the amino-acid composition of any cereal/legume blend proposed for a weaning formulation can therefore be a useful tool in evaluating the protein quality and predicting the maximum proportion of the blend protein that would be utilized. Unfortunately, it is not easy to come by readily available equipment such as amino acid analysers for a quick assessment of the protein quality of proposed weaning mixtures in developing countries. In addition, considering the number of different legumes and cereals available and the different proportions that could be formulated, actual animal studies on all the possible blends for selection of the best could be time consuming and wasteful. For a group of particular legumes and cereals under consideration there is the need for a useful system for estimating the protein content and quality of the possilbe blends to obtain a few best combinations that could be further assessed in biological assay.

The purpose of this study was to obtain a model prediction procedure for the amino acid composition and amino acid scores of mixtures of cereals and legumes, and with this provide information on estimates of protein content and protein quality of several mixtures as a quick guide in weaning food formulations. A comparison between model predictions and measured values for a few blends was made to assess the accuracy of the calculations.

MATERIALS AND METHODS

Amino acid analysis:

Actual amino-acid determinations for comparison with calculated values were done with samples of dehydrated fermented maize meal fortified with soy flour at 10 and 20% concentrations. Dehydrated fermented maize meal was prepared by the method of Plahar et al (1983). Defatted soy flour (20 PDI) used for the fortification was supplied by Cargill (Minneapolis, MN). Facilities for amino acid analysis were by courtesy of the Dept. of Food Science and Technology, Washington State University, Pullman, Wa. 99164, U.S.A.

Samples for the analysis were digested under vacuum with 6N HCL in sealed ampules at 110^{o} for 24 hr. The hydrolysates were analysed for total amino acids on Beckman 121 Automatic Amino acid Analyser according to the methods of Spackman et al (1958). Cystine was determined as cysteic acid by performic acid oxidation (Hirs, 1967). The colorimetric technique of Opienska-Blauch et al (1963) was used for the determination of tryptophan in extracts prepared by the method of Subramanian et al (1970). Amino acid scores were calculated using the FAO/WHO (1973) reference pattern.

Calculation of Amino-acid Composition of Weaning Blends

The following step-wise procedure was used for the calculation of protein content, concentration of each essential amino acid, the Net Protein Value (NPV) of weaning blends from selected local legumes and cereals:-

1. On a work sheet prepared as shown in Table 1, the weights of blend components were recorded in grams.

2. Protein and Nitrogen contribution (in grams) by each component was calculated by multiplying the protein or nitrogen content of the component (average literature value) by the weight in blend and dividing by 100. The values obtained were recorded in the appropriate column on the work sheet.

3. For each blend component, individual essential amino-acid contributions to blend were calculated by multiplying the literature value (in g/gN) by the amount of nitrogen (as obtained in step 2 above). Literature values used in this study were provided by FAO (1970).

4. The weights or amounts of protein, nitrogen and individual amino acids contributed by the blend components were added up to get their respective totals in the blend.

5. The essential amino acid composition of blend was obtained in g/16 gN by dividing each amino-acid total by the total nitrogen (g) in blend and multiplying by 16. Per cent protein in blend was obtained by dividing the total protein content (g) by the total weight of blend (g) and multiplying by 100.

6. Amino acid scores were obtained by dividing the amount of each amino acid in blend (g/16g N) by the corresponding value (g/16g N) for the FAO (1973) pattern, and multiplying by 100.

7. The lowest amino-acid score (ie. limiting amino acid score) was then recorded as the score for the whole blend protein. This value multiplied by the protein content (%) of blend divided by 100, gave the Net Protein Value (NPV).

8. The NPV gives the approximate percent protein in the blend that could be fully utilized by the body.

The above procedure was used to estimate the protein quality in blends containing different concentrations of cowpea, pigeon pea, groundnut, soybean, soy tempeh or winged bean and cereals (maize, millet and sorghum).

Table 1. Sample calculation for protein quality factors in cereal/legume weaning blends.

	Blend Components		Total	Amino-acid Score (%)
	Maize	Soybean		
Amount in blend (g)	80	20	100	
Protein contribution (g)	8.16	7.84	16	
Nitrogen Contribution (g)	1.31	1.37	2.68	
Essential amino-acid Contribution (g)[a]				
Isoleucine	0.3013	0.3891	0.6904 (4.12)	103.0
Leucine	1.0257	0.6658	1.6915 (10.10)	144.3
Lysine	0.2188	0.5466	0.7654 (4.57)	83.1
Phenylalamine + Tyrosine	0.7126	0.6919	1.4045 (8.39)	139.8
Methionine + Cystine	0.2843	0.2219	0.5062 (3.02)	86.3
Threonine	0.2948	0.3302	0.6250 (3.73)	93.3
Tryptophan	0.0576	0.1096	0.1672 (1.00)	100.0
Valine	0.3969	0.4110	0.8079 (4.82)	96.4
Protein content (%)			16.00	
Protein Score (%)			83.1	
Net Protein Value (%)			13.3	
Limiting amino acid			Lysine	

[a] Bracketed values are in g/16 N.

RESULTS AND DISCUSSIONS

Accuracy of Calculated Protein Quality Values

Results for the comparison of amino-acid scores from calculated and assayed values are given in Table 2 for maize/soybean blends. As clearly indicated by the results, amino-acid scores obtained with the calculated values were fairly close to the corresponding assayed values. For the 10% and 20% soybean fortified blends, per cent ratios of assayed to calculated scores range between 85 and 97%, with a mean of 90.3 ± 3.3. The actual scores can therefore be assumed to be about 90% of the calculated values.

Based on this assumption, such calculations will result in only slight over-estimations of the real values. Since this over-estimation may be similar for all blends under consideration, the calculated values can be reliably used in blend quality comparisons. However, in order to establish a true correlation for a meaningful prediction of blend protein quality, more such studies are required on a wider range of formulations. Meanwhile, a correction factor of 0.9 may be used (based on the findings in this study) to convert calculated scores to values close to the actual scores. Further correction factors may be required when problems associated with digestibility and dietary availability are considered.

Estimated Protein Quality of Weaning Blends from Local Legumes and Cereals

Values for estimated protein quality of legume/cereal mixtures using the model prediction procedure are presented in Tables 3 to 8 (for mixtures containing 15, 20, 25, 30 and 40% legume based on 5% moisture content). At each level of concentration, the local legume (cowpea, groundnut, pigeon pea, soybean or winged bean) is assessed in mixtures containing each of three commonly grown local cereals (maize, millet and sorghum). Equal mixtures of groundnut and cowpea,

Table 2. Comparison of amino acid scores (%) from calculated and assayed values (for maize/soybean. blends)

Amino-acid	90% Maize + 10% Soybean			80% Maize + 20% Soybean		
	Calculated value	Assayed value	Percent Ratio[1]	Calculated value	Assayed value	Percent Ratio[1]
Isoleucine	98.5	91.8	93	103.0	100.0	97
Leucine	157.1	136.3	87	144.3	127.0	88
Lysine	69.6	64.2	92	83.1	78.2	94
Phenylalanine + Tyrosine	141.4	130.7	92	139.8	128.3	92
Methionine + Cystine	91.0	78.9	87	86.3	73.7	85
Threonine	91.8	79.3	86	93.3	82.5	88
Tryptophan	88.5	81.0	92	100.0	89.0	89
Valine	96.3	88.2	92	96.4	88.0	91
Mean % Ratio[1]		90.1 ± 2.9			90.5 ± 3.8	

[1] $\% \text{ Ratio} = \frac{\text{Assayed}}{\text{Calculated}} \times 100$

pigeon pea, soybean or winged bean were also evaluated in combination with each of the cereals (Tables 9 and 10). The estimated qualities of the individual blends are discussed below in terms of the limiting amino acid, the amino acid score and the resulting net protein value (in relation to the total protein content of the blend). The results are rearranged and presented in a form for easy comparison between the different legumes in mixtures with the cereals (Appendix A-E)

a. Cowpea/Cereal blends:

Lysine remained the limiting amino acid in all the cowpea/cereal mixtures (cowpea/maize, cowpea/millet and cowpea/sorghum) up to 25% of cowpea concentration. The effect of limitation by lysine decreased with increasing level of cowpea in the mixture, and thus increased the protein score by about 4-7% for each 5% increase in cowpea concentration. Above 25% cowpea level (ie. 30% and 40%), the sulphur-containing amino acids (s-aa) became limiting except in blends containing millet where lysine remained limiting up to 30% cowpea concentration. Threonine and s-aa became limiting in cowpea/millet mixture containing 40% of cowpea. Imposing a change in the limiting amino acid through high levels of cowpea fortification resulted in a decrease in the blend protein score and hence a decrease in the rate of increase in the NPV.

A constant increase in NPV of 1.5% was observed with increasing concentration of cowpea when the limiting amino acid was constant (as in the case of lysine) up to 30% concentration of cowpea. Above 30% this rate of increase in NPV reduced to 0.5% with the limiting amino acid being s-aa. It may therefore be assumed that where a limiting amino acid remains constant with increasing level of fortification, an increase in the protein content may effect a proportionate increase in the NPV of blends containing cowpea.

Table 3. Estimated protein quality of weaning blends containing COWPEA AND MAIZE MILLET OR SORGHUM at different concentrations

CEREAL	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
85%		15% Cowpea		
Maize	12.4	71.4	8.9	Lysine
Millet	12.6	80.9	10.2	Lysine
Sorghum	12.9	62.0	8.0	Lysine
80%		20% Cowpea		
Maize	13.2	77.3	10.2	Lysine
Millet	13.3	85.6	11.4	Lysine
Sorghum	13.6	68.7	9.4	Lysine
75%		25% Cowpea		
Maize	13.9	82.5	11.5	Lysine
Millet	14.1	89.8	12.6	Lysine
Sorghum	14.3	74.7	10.7	Lysine
70%		30% Cowpea		
Maize	14.6	81.7	12.0	s-aa[2]
Millet	14.8	93.3	13.8	Lysine
Sorghum	15.1	73.7	11.1	s-aa[2]
60%		40% Cowpea		
Maize	16.1	77.7	12.5	s-aa[2]
Millet	16.2	92.5	15.0	Threonine/s-aa
Sorghum	16.5	71.7	11.8	s-aa

[1] NPV = Net Protein Value

[2] s-aa = Sulphur containing amino acids

In general, there was not much difference in the protein content of mixtures of cowpea with the three different cereals: but differences in the protein quality of the mixtures resulted in significant differences in their net protein values at all levels of fortification. Although cowpea/sorghum blends were slightly higher in protein content than the other cowpea/cereal blends, they had the lowest score and hence the lowest NPV. Cowpea/millet blends had very high scores giving the highest NPV although these blends ranked second in protein content. Thus, at all levels of cowpea concentration, complementation of the cowpea amino acids was best effected by millet to give the best quality, followed by maize and sorghum in that order.

b. Groundnut/Cereal blends

The protein quality of blends of cereals with different concentrations of groundnut are given in Table 4. Although at each level of fortification the protein content for groundnut/cereal blends was similar to that of cowpea/cereal blends, the net protein values in the blends with groundnuts were significantly lower than those for cowpea blends. For each cereal, a 30% fortification with groundnut was required to give a net protein value similar to that obtained with only 15% cowpea concentration in the cereal. The high increase in protein content effected by blending cereals with groundnut is negated by the high degree of limitation in its effective utilization because of the low lysine content.

Lysine remained the limiting amino acid with all the cereal blends at all levels of groundnut fortification with scores ranging between only 54 and 64% even at 40% concentration (of groundnut). The rationale behind legume fortification of cereals is the mutual complementation of their respective limiting amino acids. In case of groundnut however, the lysine content is similar to that in cereals and the desired complementation is not achieved by blending.

Table 4. Estimated Protein quality of Weaning blends containing GROUNDNUT and MAIZE MILLET or SORGHUM at different concentrations

CEREAL	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
85%		15% Groundnut		
Maize	12.5	53.8	6.7	Lysine
Millet	12.7	62.7	8.0	Lysine
Sorghum	13.0	42.5	5.9	Lysine
80%		20% Groundnut		
Maize	13.3	55.3	7.3	Lysine
Millet	13.4	63.1	8.5	Lysine
Sorghum	13.7	47.8	6.6	Lysine
75%		25 Groundnut		
Maize	14.1	56.2	7.9	Lysine
Millet	14.2	63.3	9.0	Lysine
Sorghum	14.5	49.8	7.2	Lysine
70%		30% Groundnut		
Maize	14.8	57.3	8.5	Lysine
Millet	15.0	63.5	9.5	Lysine
Sorghum	15.2	51.5	7.8	Lysine
60%		40% Groundnut		
Maize	16.4	58.9	9.6	Lysine
Millet	16.5	63.6	10.5	Lysine
Sorghum	16.7	54.4	9.1	Lysine

[1] NPV = Net Protein Value

is is evidenced by the low rate of increase in NPV of the blends (about 0.6% increase in NPV for each 5% increase in groundnut concentration) with increasing groundnut concentration. Not much increase in the protein quality therefore, was achieved by increasing fortification with the groundnut.

The effect of the cereals on the protein quality of the blend was found to be similar to their effect in the cowpea/cereal blends. The relatively high scores in groundnut/millet blends resulted in a higher NPV than with sorghum or maize. Sorghum once again exhibited its inferior quality in complementing legume proteins as much as millet and maize.

. Pigeon Pea/Cereal blends:

As indicated by the results in Table 5, pigeon pea was ineffective in overcoming the tryptophan limitation for maize protein utilization. This amino acid therefore remained the limiting factor (decreasing in protein score with increasing pigeon pea concentration) at all levels in mixtures of pigeon pea and maize. Maize protein quality is limited by both lysine and tryptophan. Pigeon pea, the fortifying material, also has tryptophan as the limiting amino acid. However, at pigeon pea concentration of 20% the lysine limitation associated with cereals was overcome. Threonine and s-aa became the new limiting factors in pigeon pea mixtures with millet and sorghum respectively. This level of fortification gave the maximum scores for pigeon pea with all the cereals.

Rate of decrease in protein score for pigeon pea/sorghum mixtures beyond 20% of pigeon pea concentration was high enough to offset any increases in the blend protein content. Thus, the net protein value remained fairly constant and there was no beneficial effect in fortifying sorghum with pigeon pea above 20%. Similarly the slight increases in the NPV's for maize and millet blends with pigeon pea above 20% concentration, do not merit the additional expense involved in the fortification.

Table 5. Estimated protein quality of Weaning blends containing PIGEON PEA and MAIZE MILLET or SORGHUM at different Concentrations

CEREAL	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
85%		15% Pigeon Pea		
Maize	12.0	67.0	8.1	Tryptophan
Millet	12.2	84.0	10.2	Lysine
Sorghum	12.5	64.4	8.1	Lysine
80%		20% Pigeon Pea		
Maize	12.6	65.0	8.[illegible]	Tryptophan
Millet	12.8	88.3	11.3	Threonine
Sorghum	13.1	68.9	9.0	s-aa
75%		25% Pigeon Pea		
Maize	13.2	64.0	8.5	Tryptophan
Millet	13.4	86.5	11.6	Threonine
Sorghum	13.7	66.3	9.1	s-aa
70%		30% Pigeon Pea		
Maize	13.8	63.0	8.7	Tryptophan
Millet	14.0	85.0	11.8	Threonine
Sorghum	14.2	64.0	9.1	s-aa
60%		40% Pigeon Pea		
Maize	15.0	62.0	9.3	Tryptophan
Millet	15.2	81.7	12.4	s-aa
Sorghum	15.4	59.4	9.1	s-aa

[1] NPV = Net Protein Value

d. Soybean/Cereal blends:

Tables 6 and 7 give the protein quality of mixtures of soybean or soybean tempeh with cereals. Tempeh is a fermented product of soybean very popular in the Orient. Fermentation is known to improve on the nutritive value of grains by reducing significantly the antinutritional and inhibitory factors as well as increasing the vitamin and amino acid content. Blends containing tempeh are therefore presented here for quality comparison with the unfermented soybeans.

Both soybean and Tempeh blends recorded high protein content and net protein values (NPV) even at low levels of fortification. An average rate of increase in NPV of 2% for every 5% increase in legume concentration was observed up to a concentration when a change in limiting amino acid occurred. Such a change in the limiting amino acid resulted in a significantly reduced rate of increase in NPV (to about one-half of the original rate). In the soybean blends, lysine was the limiting amino acid up to soy concentrations of 20% for maize and sorghum and 30% in the case of millet. Thereafter, sulphur containing amino acids became the limiting factor with reduced scores.

At levels of fortification up to 25%, there were no significant differences between the NPV's of blends containing soybean and those containing tempeh. The superior quality of Tempeh was, however, exhibited at high levels of fortification (30 and 40%) with better protein scores and NPV's. Thus, the beneficial effects of fermenting soybean could be realised only at high levels of fortification. Fermentation could also result in better sensory and functional characteristics thus making it possible to incorporate soybeans in this form at higher levels than the unfermented grains.

Table 6. Estimated Protein quality of Weaning blends containing SOYBEAN and MAIZE, MILLET or SORGHUM at different concentrations

CEREAL	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
85%		15% Soybean		
Maize	14.6	77.3	11.3	Lysine
Millet	14.7	85.1	12.5	Lysine
Sorghum	15.0	69.5	10.5	Lysine
80%		20% Soybean		
Maize	16.0	83.1	13.3	Lysine
Millet	16.2	89.6	14.5	Lysine
Sorghum	16.5	76.2	12.5	Lysine
75%		25% Soybean		
Maize	17.5	84.6	14.8	s-aa
Millet	17.6	93.5	16.5	Lysine
Sorghum	17.9	77.7	13.9	s-aa
70%		30% Soybean		
Maize	18.9	83.1	15.7	s-aa
Millet	19.0	96.5	18.4	Lysine
Sorghum	19.3	77.0	14.7	s-aa
60%		40% Soybean		
Maize	21.8	80.9	17.6	s-aa
Millet	21.9	90.9	19.9	s-aa
Sorghum	22.2	76.6	17.0	s-aa

[1] NPV = Net Protein Value

Table 7. Estimated protein quality of Weaning blends containing SOYBEAN TEMPEH and MAIZE, MILLET OR SORGHUM at different concentrations

CEREAL	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
85%	15% Tempeh			
Maize	14.9	75.3	11.2	Lysine
Millet	15.1	82.9	12.5	Lysine
Sorghum	15.4	67.6	10.4	Lysine
80%	20% Tempeh			
Maize	16.5	80.5	13.2	Lysine
Millet	16.6	86.9	14.4	Lysine
Sorghum	16.9	74.0	12.5	Lysine
75%	25% Tempeh			
Maize	18.0	84.9	15.3	Lysine
Millet	18.2	90.2	16.4	Lysine
Sorghum	18.5	79.1	14.6	Lysine
70%	30% Sorghum			
Maize	19.6	88.4	17.3	Lys./S-aa
Millet	19.7	93.1	18.4	Lysine
Sorghum	20.0	83.1	16.6	Lys./s-aa
60%	40% Tempeh			
Maize	22.7	87.4	19.8	s-aa
Millet	22.8	94.1	22.2	Lys./s-aa
Sorghum	23.1	83.1	19.2	s-aa

[1] NPV = Net Protein Value

e. Wingedbean/Cereal blends:

Although blends with soybeans were slightly higher in protein content than those with wingedbean, the net protein values were similar (Table 8). This is because of a better complementation effect of the winged bean. Winged bean blends with millet ceased to exhibit any amino acid limitation beyond just 20% concentration of the legume. Even high concentration (40%) of the wingedbean could not change this. Tryptophan limitation in blends containing maize could not however, be offset by addition of wingedbean although the lysine problem was overcome at just 20% concentration of the winged bean.

f. Mixtures of groundnut and pulses in Legume/Cereal blends:

Because of the gross ineffectiveness of groundnut in complementing the amino acid pattern in cereal proteins, mixtures of equal amounts of groundnut and cowpea, pigeon pea, soybean or wingedbean were assessed at 20% and 30% concentrations in legume/Cereal blends. The results are presented in Tables 9 and 10.

Lysine remained the limiting amino acid at both levels of fortification in all the groundnut/pulse/cereal blends. This shows the strong effect of the low lysine content of groundnut since, individually, the pulses could have overcome the lysine limitations of the cereals at concentrations lower than 30%. It was observed that at both 20% and 30% levels of fortification, slight differences in the protein contents of legumes were levelled off by the addition of groundnut to give the same NPV for the blends. Thus, groundnut/cowpea/cereal mixtures gave the same NPVs as groundnut/pigeon pea/cereal blends. Similarly, groundnut/soybean/cereal blends had the same NPVs as groundnut/wingedbean/ cereal blends. For such blends, therefore, cowpea and pigeon pea can be used interchangeably; and also either soybean or wingedbean can be used without any effect on the resulting blend NPV.

Table 8. Estimated protein quality of weaning blends containing WINGED BEAN and MAIZE MILLET or SORGHUM at different concentrations

CEREAL	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
85%		15% Winged bean		
Maize	13.7	82.2	11.3	Lysine
Millet	13.9	90.7	12.6	Lysine
Sorghum	14.2	73.5	10.5	Lysine
80%		20% Winged bean		
Maize	14.9	84.0	12.5	Tryptophan
Millet	15.1	97.3	14.7	Lysine
Sorghum	15.4	82.0	12.6	Lysine
75%		25% Wingedbean		
Maize	16.1	86.0	13.8	Tryptophan
Millet	15.3	102.0	16.3	-
Sorghum	16.5	88.6	14.7	s-aa
70%		30% Wingedbean		
Maize	17.3	88.0	15.2	Tryptophan
Millet	17.4	104	17.4	-
Sorghum	17.7	89.1	15.8	s-aa
60%		40% Wingedbean		
Maize	19.6	91.0	17.9	Tryptophan
Millet	19.8	105.8	19.8	-
Sorghum	20.0	90.6	18.1	s-aa

NPV = Net Protein Value

Table 4 Estimated protein quality of weaning blends containing 10% GROUNDNUT, 10% COWPEA, PIGEON PEA, SOYBEAN OR WINGEDBEAN and 80% CEREAL

LEGUME	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
Groundnut +		MAIZE		
Cowpea	13.2	65.8	8.9	Lysine
Pigeon pea	12.9	67.1	8.6	Lysine
Soybean	14.6	70.2	10.3	Lysine
Winged bean	14.1	73.1	10.3	Lysine
Groundnut +		MILLET		
Cowpea	13.4	74.0	9.9	Lysine
Pigeon Pea	13.1	75.4	9.9	Lysine
Soybean	14.8	77.4	11.4	Lysine
Wingedbean	14.3	80.7	11.5	Lysine
Groundnut +		SORGHUM		
Cowpea	13.7	58.0	7.9	Lysine
Pigeon pea	13.4	59.1	7.9	Lysine
Soybean	15.1	63.1	9.5	Lysine
Winged bean	14.6	65.5	9.5	Lysine

[1] NPV = Net Protein Value

Table 10. Estimated protein quality of Weaning blends containing 15% GROUNDNUT, 15% COWPEA, PIGEON PEA, SOYBEAN OR WINGEDBEAN AND 70% CEREAL

LEGUME	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
Groundnut +		MAIZE		
Cowpea	14.7	71.5	10.5	Lysine
Pigeon Pea	14.3	73.4	10.5	Lysine
Soybean	16.9	76.4	12.9	Lysine
Wingedbean	16.1	80.4	12.9	Lysine
Groundnut +		MILLET		
Maize	14.9	77.8	11.6	Lysine
Pigeon Pea	14.5	80.2	11.6	Lysine
Soybean	17.0	81.7	13.9	Lysine
Wingedbean	16.2	86.2	14.0	Lysine
Groundnut +		SORGHUM		
Maize	15.1	65.1	9.8	Lysine
Pigeon Pea	14.7	67.1	9.9	Lysine
Soybean	17.3	70.9	12.3	Lysine
Wingedbean	16.5	74.4	12.2	Lysine

[1]NPV = Net Protein Value

At all concentrations and with whatever cereal, groundnut performed better in combination with other legumes than when used singly. About 20% increases over the original groundnut/cereal NPVs were realized when used in combination with relatively low protein pulses like cowpea and pigeon pea while high protein sources (soybean and winged bean) increased the NPVs by 50% of the original groundnut/cereal value. These beneficial effects of groundnut/pulses combinations can be used to advantage in areas where groundnut is obtained in fairly large quantities with one or more other legumes.

CONCLUSIONS

From the results of the study the following conclusions may be drawn:

- The step-wise procedure provided in this paper can be used to reliably predict and compare the protein qualities of legume/cereal weaning blends prepared from local materials. For absolute confidence in such predictions, however, more assays and animal studies are required to obtain a standard correlation between assayed and calculated values. Meanwhile, a factor of 0.9 is adequate for converting calculated values close to assayed values.
- For legume/cereal blends, increasing legume concentration in the blend generally raises the protein score until a new limiting amino acid is imposed. Further increases in legume concentration thereafter reduces the score and hence the rate of increase of Net Protein Value (NPV). This, in addition to functional and sensory factors, places a limit on the amount of legume fortification that could be used to nutritional advantage.
- As far as the legumes examined are concerned, no additional benefits could be derived in using pigeon pea in mixtures with cereals beyond 20% of the legume concentration. Net Protein Values remained fairly

constant in such blends after 20% fortifying level. Poorest blend qualities were obtained in mixtures of cereals with groundnut because of its low lysine content, and, consequently, its inadequacy in complementing cereal amino acids. Soybean, soy tempeh and winged bean are capable of giving high quality blends with cereals, followed by cowpea and pigeon pea in that order. For the same concentration of legume, bett r results can be obtained when groundnut is mixed in equal amounts with another legume (cowpea, pigeon pea, soybean or winged bean) to constitute a fortifying material, than when groundnut is used singly.

- With the cereals, blends containing millet give the highest NPV at each level of fortification showing a high amino acid complementing ability of the millet over the other cereals. Blends with maize rank second in quality while sorghum gives the least NPV in spite of its higher protein content over the other cereals.

- The foregoing implies that protein quality of blend components is of more important significance than the protein content in blend formulations. A high protein content does not necessarily imply a high NPV which determines the maximum utilization of the protein. Poor quality proteins give low net protein.values.

- Finally, the beneficial effects of legume/cereal mixtures in solving PEM can be realized only through closely monitored blend formulations and controlled processing techniques. Any improper combinations and processing procedures may result in a complete waste of effort and money. For this reason, semi-industrial set ups in towns and villages to produce weaning blends for distribution among mothers is likely to be more effective than the home-preparation of weaning foods by mothers.

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APPENDIX A - E

Estimated Protein Qualities of Weaning Blends Containing 15, 20, 25, 30 or 40% Legume and 85, 80, 75, 70 or 60% Cereal.

APPENDIX A

ESTIMATED PROTEIN QUALITY OF WEANING BLENDS CONTAINING 15% LEGUME AND 85% CEREAL

LEGUME (15%)	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
		MAIZE		
Cowpea	12.4	71.4	8.9	Lysine
Groundnut	12.5	53.8	6.7	Lysine
Pigeon pea	12.0	67.0	8.1	Tryptophan
Soybean	14.6	77.3	11.3	Lysine
Soy Tempeh	14.9	75.3	11.2	Lysine
Wingedbean	13.7	82.7	11.3	Lysine
		MILLET		
Cowpea	12.6	80.9	10.2	Lysine
Groundnut	12.7	62.7	7.9	Lysine
Pigeon Pea	12.2	84.0	10.2	Lysine
Soybean	14.7	85.1	12.5	Lysine
Soy Tempeh	15.1	82.9	12.5	Lysine
Wingedbean	13.9	90.7	12.6	Lysine
		SORGHUM		
Cowpea	12.9	62.0	8.0	Lysine
Groundnut	13.0	45.5	5.9	Lysine
Pigeon Pea	12.5	64.4	8.1	Lysine
Soybean	15.0	69.5	10.4	Lysine
Soy Tempeh	15.4	67.6	10.4	Lysine
Winged bean	14.2	73.5	10.5	Lysine

[1] NPV = Net Protein Value

APPENDIX D

ESTIMATED PROTEIN QUALITY OF WEANING BLENDS
CONTAINING 20% LEGUME AND 80% CEREAL

LEGUME 20%	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
MAIZE				
Cowpea	13.2	77.3	10.2	Lysine
Groundnut	13.3	55.3	7.3	Lysine
Pigeon Pea	12.6	65.0	8.2	Tryptophan
Soybean	16.0	83.1	13.3	Lysine
Soy Tempeh	16.5	80.5	13.2	Lysine
Winged bean	14.9	84.0	12.5	Tryptophan
MILLET				
Cowpea	13.3	85.6	11.4	Lysine
Groundnut	13.4	63.1	8.5	Lysine
Pigeon Pea	12.8	88.3	11.3	Threonine
Soybean	16.2	89.6	14.5	Lysine
Soy Tempeh	16.6	86.9	14.4	Lysine
Winged bean	15.1	97.3	14.7	Lysine
SORGHUM				
Cowpea	13.6	68.7	9.4	Lysine
Groundnut	13.7	47.8	6.6	Lysine
Pigeon Pea	13.1	68.9	9.0	s-aa
Soybean	16.5	76.2	12.5	Lysine
Soy Tempeh	16.9	74.0	12.5	Lysine
Winged bean	15.4	82.0	12.6	Lysine

[1] NPV = Net Protein Value

APPENDIX C

ESTIMATED PROTEIN QUALITY OF WEANING BLENDS CONTAINING 25% LEGUME AND 75% CEREAL

LEGUME (25%)	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
		MAIZE		
Cowpea	13.9	82.5	11.5	Lysine
Groundnut	14.1	56.2	7.9	Lysine
Pigeon Pea	13.2	64.0	8.5	Tryptophan
Soybean	17.5	84.6	14.8	s-aa
Soy Tempeh	18.0	84.9	15.3	lysine
Winged bean	16.1	86.0	13.8	Tryptophan
		MILLET		
Cowpea	14.1	89.8	12.6	Lysine
Groundnut	14.2	63.3	9.0	Lysine
Pigeon Pea	13.4	86.5	11.6	Threonine
Soybean	17.6	93.5	16.5	Lysine
Soy Tempeh	18.2	90.2	16.4	Lysine
Winged bean	16.3	102.5	16.3	-
		SORGHUM		
Cowpea	14.3	74.7	10.7	Lysine
Groundnut	14.5	49.8	7.2	Lysine
Pigeon Pea	13.7	66.3	9.1	s-aa
Soybean	17.9	77.7	13.9	s-aa
Soy Tempeh	18.5	79.1	14.6	Lysine
Winged bean	16.5	88.6	14.7	s-aa

[1] NPV = Net Protein Value

APPENDIX D

ESTIMATED PROTEIN QUALITY OF WEANING BLENDS CONTAINING 30% LEGUME AND 70% CEREAL

LEGUME (30%)	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
		MAIZE		
Cowpea	14.6	81.7	12.0	s-aa
Groundnut	14.8	57.3	8.5	Lysine
Pigeon Pea	13.8	63.0	8.7	Tryptophan
Soybean	18.9	83.1	15.7	s-aa
Soy Tempeh	19.6	88.4	17.3	Lys./s-aa
Winged bean	17.3	88.0	15.2	Tryptophan
		MILLET		
Cowpea	14.8	93.3	13.8	Lysine
Groundnut	15.0	63.5	9.5	Lysine
Pigeon pea	14.0	85.0	11.8	Threonine
Soybean	19.0	96.5	18.4	Thr./Lys.
Soy Tempeh	19.7	93.1	18.4	Lysine
Winged bean	17.4	104.0	17.4	-
		SORGHUM		
Cowpea	15.1	73.7	11.1	s-aa
Groundnut	15.2	51.5	7.8	Lysine
Pigeon Pea	14.2	64.0	9.1	s-aa
Soybean	19.3	77.0	14.7	s-aa
Soy Tempeh	20.0	83.1	16.6	s-aa/Lys.
Winged bean	17.7	89.1	15.8	s-aa

[1] NPV = Net Protein Value

APPENDIX I E

ESTIMATED PROTEIN QUALITY OF WEANING BLENDS CONTAINING 40% LEGUME AND 60% CEREAL

LEGUME (40%)	PROTEIN CONTENT (%)	PROTEIN SCORE (%)	NPV[1] (%)	LIMITING AMINO ACID
		MAIZE		
Cowpea	16.1	77.7	12.5	s-aa
Groundnut	16.4	58.9	9.6	Lysine
Pigeon Pea	15.0	62.0	9.3	Tryptophan
Soybean	21.8	80.9	17.6	s-aa
Soy Tempeh	22.7	87.4	19.9	s-aa
Winged bean	19.6	91.0	17.9	Tryptophan
		MILLET		
Cowpea	16.2	92.5	15.0	Thr./s-aa
Groundnut	16.5	63.6	10.5	Lysine
Pigeon Pea	15.2	81.7	12.4	s-aa
Soybean	21.9	90.9	19.9	s-aa
Soy Tempeh	22.8	97.1	22.2	s-aa/Lys.
Winged bean	19.8	105.8	19.8	-
		SORGHUM		
Cowpea	16.5	71.7	11.8	s-aa
Groundnut	16.7	54.4	9.1	Lysine
Pigeon Pea	15.4	59.4	9.1	s-aa
Soybean	22.2	76.6	17.0	s-aa
Soy Tempeh	23.1	83.1	19.2	s-aa
Winged bean	20.0	90.6	18.1	s-aa

[1] NPV = Net Protein Value