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Agricultural and food policies. Some concerns regarding their nutritional relevance

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SUMMARY. In recent times, nutrition analysts have been emphasizing the fact that the most critical nutritional unfulfilled need in underdeveloped countries is energy or quantity of food. This has prompted some leading food economist and agricultural policy makers to promote the extensive cultivation of high field inexpensive staples, including starchy roots and tubers. A typical example is cassava in many African countries and Indonesia. Theses foods not only have very little and poor quality protein, but also lack other essential nutrients.
Interestingly, underdeveloped populations seem to select the nutritionally poorest staples under condition of extreme economic constraints, for example cassava or sorghum. But as their economic level improves they switch to nutritionally better staples, like wheat or rice. The people seem to be able to «perceive» the need for quality rather than simply quantity as soon as an improved economic status allows them more choices. Some examples are given to support this' contention.
The present analysis emphasizes that the goals and objectives of nutrition scientists must be integrated with those of food and agricultural economists for the design of agricultural policies with increased relevance to human nutrition in a comprehensive way. Rather than proposing the cultivation of one inexpensive staple, these policies should consider a variety of complementary foods which would allow the people to chose diets providing sufficient quantities and balance of all essential nutrients in addition to energy.

RESUMEN. Políticas agroalimentarias. Algunas inquietudes sobre su relevancia en nutrición. En años recientes los analistas de los problemas nutricionales han resaltado el hecho de que la deficiencia más crítica insatisfecha en los países subdesarrollados es la de energía alimentaria, lo cual ha inducido a prominentes economistas agrícolas y de alimentos a promover el cultivo extensivo de «alimentos de primera necesidad» de alto rendimiento agronómico y baratos, incluyendo raíces y tubérculos. Un ejemplo típico es la yuca en varios países africanos e Indonesia. Estos productos no solamente contienen muy poca proteína y de mala calidad, sino además carecen de muchos otros nutrimentos esenciales.
De gran interés son estudios recientes los cuales revelan que poblaciones subdesarrolladas bajo condiciones de extrema limitación económica, parecen seleccionar los alimentos más pobres para satisfacer sus necesidades primarias, por ejemplo la yuca o el sorgo. Sin embargo, a medida que su nivel económico mejora, estas poblaciones prefieren y comienzan a consumir productos «primarios» nutricionalmente mejores, como son los cereales trigo y arroz. La gente parece poder «percibir» la necesidad de «calidad» en vez de simplemente «cantidad» tan pronto como su situación económica les permite más amplia escogencia. En el artículo se dan algunos ejemplos que ilustran este punto. El presente análisis señala la urgente necesidad de que los objetivos y metas de los científicos en nutrición se integren con los de los economistas agrícolas y de alimentos con el fin de diseñar políticas agrícolas orientadas hacia la satisfacción de los requerimientos nutricionales de las poblaciones en todos sus aspectos. En vez de proponer el cultivo de un alimento barato simplemente, estas políticas deben considerar una variedad de alimentos complementarios que le permitan a la población escoger dietas que provean suficiente cantidad y balance adecuado de todos los nutrientes esenciales, además de energía.

Perhaps more obviously than for any other scientific field, nutrition has undergone an apparent impact of fashion regarding the recognition of the nutronal problem or problems to be considered the most crucial and deserving of the attention of researchers and applied professional workers. The emphasis of these phases of concentrated interest has been either on a

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specific nutrient or type of nutrients, or it has centered around age groups and physiological stages for which the term «nutritionally vulnerable» was coined.

Readers of history of nutrition essays can easily recognize, in recent times, the following sequence which started around the end of the eighteenth century with Lavoisier whose contributions are now recognized as the **birth of modern nutrition**. Biological oxidation and energy expenditure occupied the minds of nutrition researchers. Proteins and nitrogen balance made their appearance around the end of the nineteenth century but still the three major food components, carbohydrates, fats, and proteins were mainly recognized as furnishers of energy for the body. Although through that same period the presence in the tissues and the role of calcium, phosphorus, sodium potassium, and iron were beginning to be revealed, these minerals did not become of major interest. The first half of the twentieth century witnessed perhaps the most impressive nutritional fashion as the organic essential compounds present in foods in micro quantities, the vitamins, came to be recognized. The elegant animal and human experiments demostrating their essential role and their relevance to the already known plagues, as beri-beri and scurvy generated concentrated enthusiasm for them, which lasted through the middle of the century. Then the protein and amino acid era was born, as a by-product of the work of Cecily Williams on severe protein deficiency in children (1) and the publication by Brock and Autret on «Kwashiorkor in Africa» (2). Because the manifestations of the acute syndrome were mainly in young children, attention to the «preschool child» became dominant. Essentially, the nutrition problem of the world was thought to be protein deficiency in children due to low intakes and poor quality of proteins, that is, inadequate amino acid pattern. As of the 1970s, however, this stance began to be challenged and evidence that the fundamental problem was energy intake (amount of food) became dominant. Dietary quality was still important but not the main issue. Coinciding with the advent of this new trend, the pregnant-lactating woman and the infant became a recognized vulnerable physiological-age group for both, the nutrition investigator and the applied nutrition worker.

In more recent times, including the present, the recognition that adquate energy intake is the most crucial challenge continues gaining acceptance. Furthermore, increased attention is being given to the association between nutrition of the adult, physical working capacity and productivity. This welcome turn has brought with it, however, a situation that requires careful analysis and insight if serious oversight of the qualitative variations among different food energy sources from the point of view of comprehensive human nutrition is to be avoided. Ignoring or overlooking such differences may have important negative consequences for food and agricultural policy analysis. Nutrition scientists have a direct responsability in this regard.

One important principle to be remembered is that no single food is nutritionally complete by itself, with the exception of species specific breast milk for the corresponding «infant». More important still, most staple foods, particularly starchy staples, are substantially incomplete, with some being critically incomplete and, therefore, nutritionally inadequate per se. The examination of the case of cassava root, for example, in the light of a few selected meaningful indicators (3) (see Appendix) will help clarify this point. Perusal of Tables 1 and 2 gives evidence of the extremely low density of some nutrients in this staple in relation to the nutritionally recommended standards, specially as a supplier of net protein, adequately concentrated energy, and vitamin A. These poor features become critically limiting when a food such as this would be the predominant basis for infant and young child feeding (Table 3). It would be impossible for a preschool-age child to ingest enough of this food to satisfy energy and protein needs.

TABLE 1
ADEQUACY OF ENERGY DENSITY AND NUTRIENT DENSITY OF CASSAVA
(MANIHOT ESCULENTA)[4]

	Nutrient density (amount of nutrient in 1000 kcal of edible portion)								
	Protein g	Fat g	Ca mg	Fe mg	Vit A µg	Thiamine mg	Riboflavin mg	Niacin mg	Vit C[3] mg
Root	5.4	2.0	243	7.4	33	0.40	0.30	4.7	270
% adequacy	(32)	(-)	(84)	(57)	(21)	(100)	(54)	(71)	(2076)
Flour	5.3	1.6	460	16.8	0	0.25	0.22	5.0	44
% adequacy	(32)	(-)	(158)	(129)	(0)	(62)	(40)	(76)	(338)
Nutrient Density recommended for (Child 3-4 years)				RDA (per 100 kcal)					
	16.6[1]	—	290	13.0[2]	161	0.40	0.55	6.6	13

[1] Assumed protein score of 70
[2] Estimated bioavailability of 5%
[3] Significant losses by oxidation during processing and cooking
[4] Source of data: references 13 and 14

TABLE 2
SOME INDICATORS OF THE PROTEIN-ENERGY NUTRITIONAL NATURE OF CASSAVA (*MANIHOT ESCULENTA*)

	Cassava	Recommended or desirable[1]
P^e%	2.1	11-12
NDpCal%	<1	7-8
F^e%	1.8	20-30
F^e/P^e	0.9	2- 2.5
E.D. (root)	1.5	
(flour)	3.2	>4

[1] Source of data: reference 3.

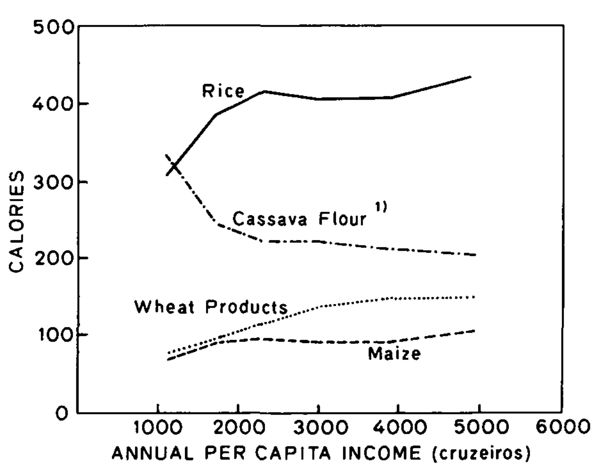
It follows that when one food or a very limited number and variety of foods provides the major portion of the energy intake, the biological (nutritional) nature of these foods becomes of crucial importance. The relevance of this issue for human nutrition is brought to light by the tendency for populations with marked economic constraints to consume predominantly the so-called «less-preferred» staples as income level decreases. This has been examined by Edirisinghe and Poleman in several countries' situations. Two examples are illustrated in Figures 1 and 2, taken from their publication (4).

TABLE 3
AMOUNT OF CASSAVA TO BE INGESTED DAILY BY A 3 YEAR OLD CHILD IN ORDER TO SATISFY HIS/HER ENERGY AND PROTEIN NEEDS

		Root (61% moisture)		
Energy[1] requirement (kcal)	Protein[1] safe-level (grams)	Intake for energy needs (grams)	Intake for protein needs (grams) Assuming protein qual. = egg or milk	Correcting for 50% utilization
1560	17.5	1054	2187.5	4375
		Flour (14% moisture)		
		488	1029	2058

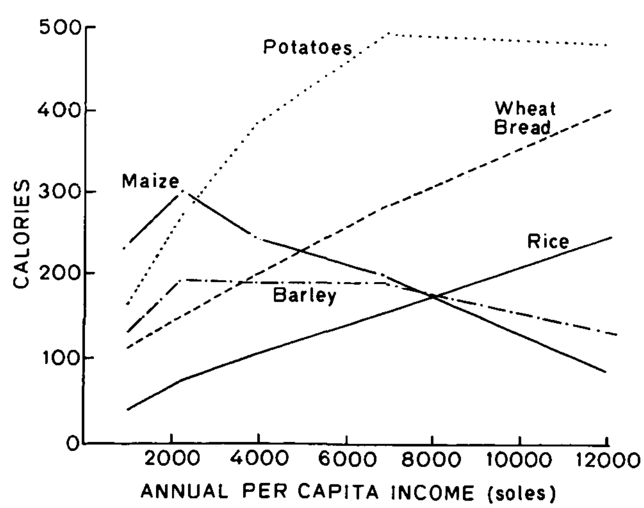
[1] Source of data: reference 15.

FIGURE 1
Apparent per capita daily consumption of major starchy staples among low income classes in Brazil, 1974-74 (taken from Edirisinghe and Poleman in reference 4)



1) Plus other roots and tubers (5 % of total)

FIGURE 2
Major starchy staples consumption among lower income classes in the central and southern sierra of Peru, 1971-72 (taken form Eridisinghe and Poleman in reference 4)



A relevant question here is, how do less-preferred staples differ from preferred staples? Edirisinghe and Poleman's concept of the starchy staples «quantity or quality» threshold implies that populations below critical incomes tend to satisfy their energy requirements with the most available and cheapest energy source without evidence of dietary quality considerations. In this poverty range, the staples chosen are, as will be postulated later, most nutritionally inadequate. Above a certain income-threshold level, nutritional quality considerations begin playing a more and more important role in the selection of the predominant food energy staple. That is, a switch from «less-preferred to preferred».

It is in this regard that I would like to present an intriguing speculation based on an analysis generated by Edirisinghe and Poleman's following statement: «The perception of adequacy is (first) in relation to the most basic of the energy requeriments. Beyond that, there may be many other less easily indentifiable but important thresholds of perceived satisfactions of other nutritional needs». After I read this, I was prompted to ask: why are preferred starchy staples preferred?

Nutritional biochemists have documented how the experimental rat has the «wisdom» to detect and select among others, that single diet with the protein of highest nutritional quality, all other things being equal. Weanling rats presented with a 10% protein casein (+ methionine) diet soon reach consumption figures of 18-20 grams of diet per day, while those offered a poor protein quality diet consume significantly less (5). If to the same rat two diets with different protein quality are available simultaneously, the rat prefers and ends up consumming the best diet. Studies at INCAP have shown clearly that the rat distinguishes between the highest protein quality combination of corn and beans (around 50:50 protein from each) and other ratios on both sides (6). Also, the rats eat more of a diet in which essential amino acid deficiencies have been corrected by supplementation than of the unsupplemented one (7). More recent evidence indicates that the demonstrated ability of the experimental rat to control the protein: carbohydrate ratio of the diet is mediated in the brain by alterations in serotonin synthesis and the concentration of tryptophan in the brain (8).

INCAP has further published observations indicating that preschool-age children under conditions of «no-constraints» (INCAP's recuperation unit) also select *ad libitum* the most appropriate mixture of corn and beans, that is, the one whith the highest protein quality (9). Wade et al (10) have also documented in their study with female twins that humans are able also to select protein: carbohydrate ratios within a narrow range, similar to the ratio chosen by experimental rats.

Combining these observations with Edirisinghe and Poleman's provocative statement, I postulate that, in view of their fundamental biological role, proteins ought to be the «next to calories» nutritional need to be perceived under conditions of decreasing constraints. The correspondence of the generally reported empirical order of «preferredness» with increasing protein quality indices, illustrated in Figures 3 and 4, is impressive. Sorghum, not included in Edirishinghe and Poleman's study, has been found to be the «next-down to corn» less-preferred cereal among El Salvador poor rural populations. The reason for seeking the relationship with lysine in addition to that with NDpCals% (net protein value) is that this essential amino acid is the most limiting in cereals1. Cassava is not included in Figure 2 because its protein content is so low that it cannot be considered in the same class with the other foods as a source of essential amino acids. I find these relationships very suggestive of the fact that humans do perceive protein quality much like the experimental rat does. The pattern of selection among starchy staples just discussed would fail to show when these are not predominant anymore as sources of energy because of the much higher availability and intake of high nutritive value foods such as those of animal origin. This seems the case in industrialized countries. In this situation the nutritive quality of the starchy staple loses relevance and other factors such as marketing, transportation convenience, cultural sophistication, cooking qualities or taste, seem to bear on the choice.

FIGURE 3

Starchy staples listed in order of increasing protein nutritional value. Correspondence with generally reported empirical order of "preferredness" as explained in the text.

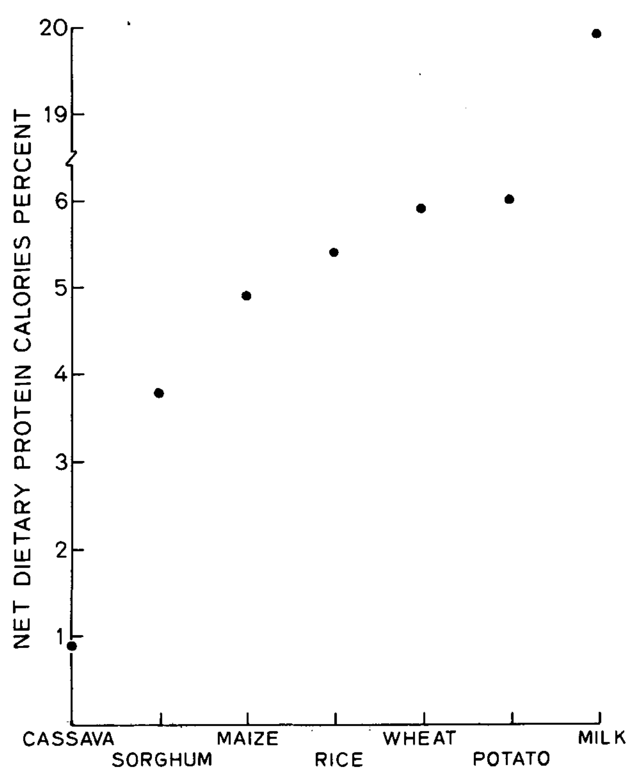
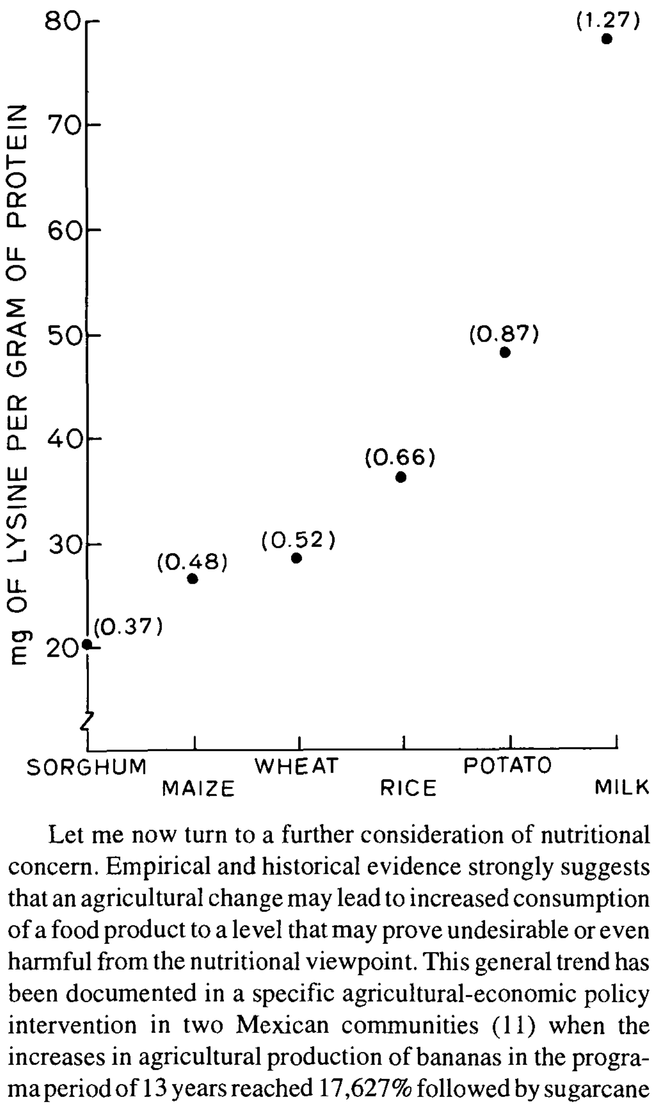


FIGURE 4
Starchy staples listed increasing lysine content per gram of protein (their lysine score is in parentheses).
Correspondence with generally reported empirical order of "preferredness" as explained in the text.



Let me now turn to a further consideration of nutritional concern. Empirical and historical evidence strongly suggests that an agricultural change may lead to increased consumption of a food product to a level that may prove undesirable or even harmful from the nutritional viewpoint. This general trend has been documented in a specific agricultural-economic policy intervention in two Mexican communities (11) when the increases in agricultural production of bananas in the programa period of 13 years reached 17,627% followed by sugarcane (994%), a successful economic program outcome. Beans and corn (maize) production increased only 21% and 116% in the same period. The authors discuss the discouraging finding that, although there was an evident overall improvement in the total and the average consumption of food and the average diet became more balanced, «the change did not affect equally throughout all sectors of the population». Approximately one-third of the total population (the poorest) did not participate of the improvement. The authors found that the consumption of bananas among children had already reached «a point close to being inconvenient, because its nutritive value is inferior to that of cereals which it is substituting».

It seems, therefore, that when agricultural projects succeed in expanding production of a staple crop resulting in its ample availability at a relatively low cost, this staple displaces other staples and other food stuffs from the diets of the population who are poor. If the staple food in question is nutritionally very poor, a risky situation may ensue.

Based on the principle of nutrient complementation, the natural way to make incomplete foods nutritionally useful is by their integration into diets where they are consumed combined, ideally, with a significant number and variety of other foods. The larger the number and the diversity in specific nutrient content of the food items the higher the probability of arriving at an adequate and balanced diet, with sufficiently high energy density, net protein concentration, and density of essential micronutrients (minerals and vitamins).

Consequently, it is of great importance that when planning the intensification of a crop of a high-yield starchy staple for economic purposes and to increase the availability of inexpensive food energy, extreme care must be exercised to do it within the frame of a whole diet system's approach. This point has been properly emphasized by Okigbo in his analysis of the case of cassava in the humid tropics of West Africa (12).

Among the strategies which have been suggested to accomplish this goal, the following have been commonly recognized: (a) the peasant-farmer should produce enough of the staple crop to sell and obtain money to buy some of the other food ingredients to balance the diet; (b) the agricultural program should include intercrop production of other foods with the highest possible protein concentration, amino acid complementarity potential, energy density (fat %), and density of other essential specific nutrients that the staple does not supply in sufficient amounts; and (c) nutrition education to orient the people about eating practices and about principles of feeding infants and young children in particular. Strategy (b) appears more promising than (a), since the complementary foods will be «there» and will not have to be obtained through sometimes hindering market channels. Obviously nutrition education would be fruitless if the desired foods in question were not made available through either of the two first strategies.

One additional problem to be considered is not only the types of complementary foods, but the quantities required which will depend on the nature of the basic predominant staple. Let me take, for example, the sensitive and nutritionally crucial case of protein quantity and quality. With starchy staples which have insignificant protein content, such as plaintain and cassava, the proportion of needed complementary protein food has to be very substantial and the essential amino acid pattern higly adequate. Examination of the data in Table 4 reveals that even with as much as 40 parts of beans (*Phaseolus*) to 60 parts of cassava, one attains a cassava protein: bean protein ratio of 10:90, a total protein concentration of 9.0 but a net protein calories percent of only 5.5. The latter is due to the low amino acid score of the mixture of proteins (score=57), since both are deficient in the same first limiting amino acids, methionine and cystine (SAA) and, therefore, they do not significantly complement their protein qualities.

TABLE 4
PROTEIN NUTRITIONAL QUALITY OF A MIXTURE OF BEANS AND CASSAVA

Amino Acid[1]	Beans (Phaseolus) Grams = 40 Protein =8.8g Mixture= 90%	Cassava flour Grams = 60 Protein= 1.0g Mixture= 10%	Parts by weight 40:60 Protein= 9.8 g/100g Protein ratio 90:10	Score
Isoleucine	37.7	2.8	40.5	101
Leucine	68.6	3.9	72.5	103
Lysine	64.8	4.1	68.9	125
SAA	17.5	2.7	20.2	57
AAA	69.7	4.1	73.8	123
Threonine	35.7	2.6	38.3	96
Tryptophan	9.1	1.1	10.2	102
Valine	41.3	3.3	44.6	89

$P^e\% = \frac{9.8 \times 4}{327} \times 100 = 12$

Apparent NDpCal% = 5.5 (corrected for score and 80% digestibility)

1 Source of amino acid data: reference 16.

The contrast with the superiority of the cereal-beans system becomes clear upon examination of tables 5 and 6. The best complementarity between corn (score=49; first limiting amino acid lysine) and beans (score=55; first limiting amino acid methionine-cystine) has been found for a 72:28 mixture (score=77), but even as little as 20 parts of beans to 80 parts of corn results in a protein concentration of 11.6 g/100g (corn-bean protein ratio 60:40; score=76) and a net dietary protein calories percent of nearly 8, a very acceptable value.

For the sake of simplicity, as mentioned before, the previous discussion focused on the nutritionally important aspect of protein value of the staples and the diets. The specific case of protein quantity and quality in food combinations has been discussed by others (17, 18), but it must be realized that the situations, natural or man-created, which result from unduly high reliance on a single staple such as a starchy root are bound to lead to an increased probability of deficiencies of other essential nutrients. Of common occurrence, for instance, is the high prevalence and severity of vitamin A deficiency, micronutrient which is essentially absent in starchy staples. Attention to good sources of retinol or high bio-availability carotenes would be, therefore, necessary. Again, as pointed out before, the very low energy density of such foods should constitute one of the issues of major concern, that is, the need for a higher fat content of the diets.

In the context of most underdeveloped countries characterized by large sectors in the very low socioeconomic level, it is observed that the potential of subgroups of population to self-complement a low nutritive value staple, is inversely related to socioeconomic level in general and to income in particular. A staple like maize in Central America or cassava in West Africa, is more inexpensive and accessible to the poor than desirable or needed complementary foods, such as meats, milk, or eggs, and even beans. This may lead directly to serious nutritional problems such as protein-energy malnutrition and other micronutrient deficiencies in the most vulnerable groups. Kwashiorkor, xerophthalmia, and anemia speak for themselves in this regard.

Efforts to prevent this type of nutritional damage have been made, particularly by the health sector of the countries and have taken the form of target-oriented and nutrient-oriented specific interventions. With some notable but unfortunatley few exceptions, these efforts have proved to have limited effectiveness. Nevertheless they do have useful role to play, and their efficency and effectiveness should be enhanced through operational research while a more permanent solution becomes feasible.

CONCLUSION

The considerations included in this paper are intended to highlight the need to integrate the goals, objectives and efforts of nutrition scientists with those of food and agricultural economists. This would result in the design of agricultural food policies with increased relevance to the comprehensive nutronal needs of the populations. Human nutrition should be considered a main disciplinary component of the scientific knowledge base of professionals in agricultural economy. This knowledge should deal with nutrients and foods, but principally, it should emphasize human diets in their ecological, cultural and nutritional context.

Footnote

1 Barley does not seem to conform to the pattern in Figure 4, as its lysine content (mg/g protein) is higher than in wheat. A cultural or agronomic factor may be confounding in this particular instance. Barley, in Perú, is usually consumed as a soup and is considered a cheap caloric food.

APPENDIX

Definition of indicators of the nutritional quality of food and diets.

Nutrient Density (N.D): Amount of the nutrient (customary units) per 1000 kcal of food or diet

Protein energy percent ($P^e\%$); kcal from protein per 100 kcal of food or diet

Net dietary protein calories percent (NDpCal %):

$$P^e\% \times \frac{score}{100} \times \frac{digestibility}{100}$$

where:

$$\text{(amino acid) score} = \frac{\text{mg/g protein of first limiting amino acid}}{\text{mg/g of same amino acid in reference pattern}} \times 100$$

Fat energy percent (F^e%):
kcal from fat per 100 kcal of food or diet

Amino acid complementarity:
The effect of mixing two or more proteins giving rise to a new amino acid pattern with a higher amino acid score than each of the components of the mixture.

REFERENCES

1. C.D. Williams, «A nutritional disease fo childhood associated with a maize diet». Arch. Dis Childh. 8: 423-433, 1933.
2. J. Brock and M. Autret, «Kwashiorkor in Africa». World Health Organization Monograph Series N° 8, WHO, Genve, 1952.
3. H. Araya, «Examining the nutritive value of basic Foods as a tool for the study of diets in poor countries». Food and Nutr. Bull. 3: 21-27, 1981.
4. N. Edirishinghe and T.T. Poleman, «Behavioral threshold as indicator of perceived dietary adequacy or inadequacy». Cornell Internationl Economic Study (A.E. res. 83-24). Department of Agricultural Economics, Cornell University, Ithaca, N.Y. 1983.
5. A.E. Harper, «Balance and imbalance of amino acids». Ann. N.Y. Acad. Sci. 69: 1025-1041, 1958.
6. L.G. Elías and R. Bressani, «Nutritinal factors affecting the consumption of leguminous seeds». Arch. Latinoamer. Nutr. 24: 365-378, 1974.
7. B. Sure, «Improvement in whole yellow corn with lysine, tryptophan and threonine». J. Agr. food Che, 1:626-629, 1953.
8. C.L. Theall, J.J. Wurtman and R.J. Wurtman, «Self-selection and regulatin of protein: carbohydrate ratio in foods adult rats eat». J. Nutr. 114: 711-718, 1984.
9. B. Torun, B. Caballero, S. Flores-Huerta and F. Viteri, «Habitual Guatemalan diets and catch-up growth of children with mild to moderate manlnutrition». Food and Nutr. Bull, Suppl. N° 10: 216-231; 1984.
10. J. Wade, J. Milner and M. Drondl, «Evidence for physiological regulation of food selection and nutrient intake in twins». Am J. Clin. Nutr. 34: 143-147. 1981.
11. M. Hernández, C. Pérez-Hidalgo, J. Ramírez-Hernández, H. Madrigal and A. Chávez, «Effect of economic growth on nutrition in a tropical community» Ecol. Food Nutr. 3: 283-294, 1974.
12. B.N. Ikibo, «Nutritonal implications of projects gibing high priority to the production of staples of low nutritive quality» food and nutr. Bull. 2: 1-20; 1980.
13. INCAP-ICNND, «Food composition table for use in Latin America». 1962.
14. WHO, Handbook of Humans Nutritional Requirements. World Health Org., Geneva, 1974.
15. WHO/FAO, «Energy and Protein Requirements». World Health Org. Tech. Rep. Ser. N° 522, Geneva, 1973.
16. FAO, «Amino Acid content of foods and biological data on proteins». Food and Agricultural Org. Nutritonal Studies N° 24, Rome, 1970)
17. FAO/WHO, «Protein Quality Evaluation» Report of the Joint FAO/WHO Expert Consultation. FAO Food and Nutrition Paper N° 51, Rome, 1989.
18. V.R. Young and P.L. Pellett. «Current concepts concerning indispensable amino acid needs in adults and their implication for international nutrition». Food and Nutr. Bull. 12: 289-300, 1990.

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