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Maïze – Soybean Mixtures as Protein Sources of High Biological Value

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With 5 tables

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Introduction

After many years of work in Mikalay-Luluabourg WAUTERS (1961) formulated his experience as follows: "Fifty percent of the efforts by the medical services, fifty percent of all the expended money is wasted if the nutritional status of the population is not increased. The alimentary regime is clearly insufficient not in quantity, but in quality. There is a lack of proteins, there often is a complete absence of proteins." Since the independence of the Congo Republic many physicians of the W. H. O. have complained of the inefficiency of their medical practice. They are unable to control nutrition which is the basic factor of health for the population, which there is mainly dependent on the supply of proteins of high biological value.

In some circumstances, import of proteins of high biological value can be a temporary, but never a permanent solution. In under-developed countries the purchasing power is insufficient. The weekly wages of a labourer hardly amount to the price of 2 kg. of meat. Therefore it is obivous that cattle-raising and fish-breeding have to be intensified. On long term this can, may be, solve the problem, if at the same time the purchasing power of the population is raised sufficiently to buy these normally high priced animal proteins. An other solution would be to favour the natural production of animal proteins e. g. fishing, hunting, insects. But for the moment and for many years still, because of the population increase, there will be an important shortage of animal proteins. Therefore it appears necessary to solve the problem by plant proteins. Ground-nuts, to a lower extent beans and sometimes voanszous (voandzeia subterramea THOU) are cultivated in the Luluabourg area. The growth of these, especially the first two, is highly encouraged, because they produce many proteins, even of a lower biological value. An other possibility would be the introduction of the soybean culture. Indeed from a nutritional point of view this could be a valuable improvement. The soybean, adequately treated, is quantitatively and qualitatively one of the best vegetable protein sources. From an agricultural standpoint the soybean growth in this area is more favourable than that of other leguminosae as to yield, vegetation period, edaphic conditions, etc. Because of the local production and the low cost-price, this culture would, in a short time, bring sufficient proteins of high quality in the reach of the population. However, from a psychological point of view, a comsumption problem arises which is: the incorporation of the soybean in the very one-sided diet of the people.

Different preparation methods, mainly from oriental origin, were tried with little or no success. Because of the unhealthly conditions during the preparation, and the short period of conservation, soybean-milk though nutritionally about equivalent to cow milk, did not give satisfaction. The local feeding habits are mainly based upon preparations of manioc- and maïze-meal. The basic food is the "bidia" which is a consistent dough of about 80% manioc- and 20% maïze-meal. For babies a pap of manioc-meal is used. Therefore, a soybean-meal product, that is directly usable, was looked for. Because of its high biological value a mixture of 25% soybean-meal and 75% maïze-meal is proposed in this paper.

With the collaboration of the W. H. O. a recipe for babies was developed. It is based on the 3/1 maïze/soya mixture and sweetened with a piece of a well-matured banana. This recipe was tested on several hundreds of babies and pre-school-aged children of different environments. It was succesfully accepted. The toasted soybean-meal was quasi spontaneouisly used in the bidia, the basic food of adults.

In this way the population disposes of a food which completely fulfills the requirements of a protein source for the underdeveloped countries: exclusively based on local products, fully appreciated by children and adults, prepared following local customs and being of a high nutritional value. The aim of this article is to justify the proposed 3/1 maïze-soya mixture from the point of view of biological value.

Calculation and Discussion

In their literature survey Block and Stekol (1946) stated that, in the nitrogen balances of growing rats, the biological value of maïze protein was found to be 54 and that of soybean protein 57. These authors, when comparing these figures with the amino acid composition of the whole egg, calculated a chemical score of 28 for maïze, lysine being the limiting essential amino acid, one of 49 for soya, methionine being limiting. Dean (1953) stated that lysine for maïze and methionine for soya were the first limiting essential amino acids. Henderickx (1963) recalculated the chemical score of different proteins comparing them with the target values of Bender (1960) for growing rats. In this study maïze obtained a chemical score of 58 with lysine as the limiting essential amino acid, and soya 56 with methionine as the limiting essential amino acid. It is clear that separately for these protein sources lysine or methionine are among the first factors lowering the biological value. Therefore it is possible, by judicious mixing of maïze and soybeans, to obtain a mixture of which the mentioned limitations are partly or completely eliminated. Also the chemical score and probably the biological value of such a mixture will be higher thant hat of maïze or soybean separately. This benificial supplementing effect of maïze and soya was already mentioned by Jacquot (1957). In the same line of research experiments were performed on the supplementary effect of soya flour on the protein of wheat flour (JARQUIN et al. 1966), on other cereal grains (DEAN 1958) and on maïze protein (BRESSAIN and ELIAS 1966).

Table 1. The calculated concentration of protein, methionine, sulfur containing amino acids and lysine for different mixtures maïze/soya.

	Maïze	Maïze/Soya 80/20	Maïze/Soya 60/40	Maïze/Soya 40/60	Maïze/Soya 20/80	Soya	FAO provisional ref. pattern
% protein	9.8	15.4	21.1	26.7	32.4	38.0	
mg% methionine	304	395	486	578	669	760	
mg% S-amino acids	451	657	863	1068	1274	1480	
mg% lysine	196	597	998	1398	1799	2200	
methionine g/100 g protein	3.1	2.6	2.3	2.2	2.0	2.0	2.2
S-am. ac. g/100 g protein	4.6	4.3	4.1	4.0	3.9	3.9	4.2
Lysine g/100 g protein	2.0	3.9	4.7	5.2	5.6	5.8	4.2

For practical reasons the mixture was only studied in simple ratios. Table 1 shows the calculation of the percentage of lysine, methionine and the sulfur containing amino-acids for different mixing ratios. The amino acid composition of maïze and soybean is borrowed from JACQUOT's contribution in the FAO-course on tropical nutrition (1957). The FAO (1957) provisional reference protein was the basis of comparison. From this table is clear that a maïze/soybean mixture between 80/20 and 60/40 closely approaches the FAO reference protein in the first limiting essential amino-acids namely lysine. methionine and the sulfur containing amino-acids. Calculation confirms that, approaching the FAO reference protein for methionine, a minimum ratio maïze/soya of 46/54 is required, for sulfur containing amino-acids a minimum of 75/25, for lysine on the contrary a maximum of 77/23. From this it can be concluded that a maïze-soya mixture of 75/25 or for practical use 3/1 is most convenient to eliminate the first limitations of the biological value. In table 2 the concentration of the other essential amino-acids in the maïze/soya 3/1 mixture is calculated, also the percentage of these amino-acids in the protein of the mixture. The basic figures again are quoted from JACQUOT (1957). In table 3 the concentration of the essential amino acids of the proposed mixture is compared with the FAO provisional reference protein and the procentual ratio between both is calculated. The lowest ratio is the chemical score of the mixture (BLOCK and MITCHELL 1946). From table 3 it clearly appears that the proposed mixture compared with the FAO provisional reference protein does not show a deficiency of methionine, only one of 2% of lysine. The purpose of improving the biological value, by eliminating the deficiency of lysine and methionine, has thus been reached. Cystine however shows a 15% deficiency, but, the amount of sulfur containing amino-acids being equal to that of the FAO provisional reference protein, this has not to be taken in account. Tryptophan shows the lowest procentual ratio 71% and therefore a 29% deficiency. Consequently the 3/1 maïze/soya mixture has a chemical score of 71. This means an increase of the chemical score when compared to that of the single components maïze and soya. The limiting amino-acid of the mixture now is tryptophan. ALLISON (1964) remarked that the amount of tryptophan in the FAO pattern is higher than in every other reference protein. HOWE et al. (1960) reported that the protein effect of the FAO provisional reference protein did not change the growth of rats when the amount of tryptophan was lowered from 50 to 33%.

Table 2. The concentration of protein and of essential amino acids for maïze, soya and the 3/1 maïze-soya mixture.

	Maïze		Soya		Maïze/Soya 3/1	
	mg/100 g maïze	g/100 g protein	mg/100 g soya	g/100 g protein	mg/100 g mixture	g/100 g protein
Lysine	196	2.0	2204	5.8	698	4.1
Tryptophan	78	0.8	456	1.2	173	1.0
Phenylalanine	490	5.0	2166	5.7	910	5.4
Tyrosine	539	5.5	1558	4.1	794	4.7
Phen + Tyr	1029	10.5	3724	9.8	1704	10.1
Methionine	304	3.1	760	2.0	418	2.5
Cystine	147	1.5	722	1.9	291	1.7
Meth + Cyst	451	4.6	1482	3.9	709	4.2
Threonine	363	3.7	1379	4.0	617	3.7
Leucine	2156	22.0	2508	6.6	2244	13.3
Isoleucine	392	4.0	1786	4.7	741	4.4
Valine	490	5.0	1596	4.2	767	4.6
Protein	9.8	–	38.0	–	16.85	–

Table 3. Comparison of the amino acid pattern of the 3/1 maïze/soya mixture with the FAO reference pattern (1957).

	g amino acid/ 100 g protein of the mixture	g amino acid/ 100 g protein of the FAO reference protein	procentual comparison
Lysine	4.1	4.2	98
Tryptophan	1.0	1.4	71
Phenylalanine	5.4	2.8	100
Tyrosine	4.7	2.8	100
Phen + Tyr	10.1	5.6	100
Methionine	2.5	2.2	100
Cystine	1.7	2.0	85
Meth + Cyst	4.2	4.2	100
Threonine	3.7	2.8	100
Leucine	13.3	4.8	100
Isoleucine	4.4	4.2	100
Valine	4.6	4.2	100

SWENDSEID et al. (1962) concluded from their experiments that the tryptophan concentration of the FAO pattern is too high for young men and women and that a 20% decrease of this amino acid below the FAO requirement did not influence the nitrogen balance. Taking in account this last figure the concentration of tryptophan in the reference may be lowered from 1.4 g/100 g protein till 1.1 g/100 g protein.

Because the 3/1 maïze-soya mixture contains 1 g tryptophan/100 g protein, tryptophan shows a 9% deficiency. This should bring the chemical score of the proposed mixture up to 91%. If the concentration of tryptophan in the reference should be lowered by 30%, which is not so low as the values of HOWE et al. (1960), then there should not be a tryptophan deficiency. Then the chemical score of the mixture should be dependent only on the lysine ratio which is 98%. With regard to his amino acid composition, the 3/1 maïze/soya mixture can be considered giving an excellent protein.

In table 4 the amino-acid pattern of the 3/1 maïze/soya mixture is compared with other proteins of high biological value. The analytical figures come from the food tables of SOUCI, FACHMANN and KRAUT (1962). It is clear that the proposed mixture has a much better chemical score than human milk and cow milk. Therefore from the point of view of amino-acid supply the maïze-soya mixture can advantageously replace the proteins of human milk.

Table 4. Comparison of the amino acid pattern of the 3/1 maïze-soya mixture with other protein sources for the critical amino acids.

	Human milk	Cow milk	Whole egg	Maïze/soya 3/1	FAO reference protein
		g/100 g protein			
Lysine	6,4	7,7	5,2	4,2	4,2
Tryptophan	1,8	1,4	1,4	1,0	1,1*)
Methionine	1,8	2,5	5,2	2,5	2,2
Cystine	2,3	0,9	2,2	1,7	2,0
Cyst + Meth.	4,1	3,4	6,4	4,2	4,2
		Chemical Score			
	82	81	100	91	100
		Limiting amino acid			
	Methionine	Cyst + Meth	—	Tryptophan	—

*) Figure calculated from SWENDSEID et al. (1962).

The foregoing calculations are based on the figures of the FAO course on tropical nutrition. Attention has to be paid to the fact that the analytical figures can differ very much. From the food tables of SOUCI, FACHMANN and KRAUT (1962) it appears that the protein contents of maïze, expressed per 100 g edible portion, fluctuates between 8,2 and 10,6 and of soybean between 34,0 and 40,0. Therefore the protein contents of 3/1 mixture lies between 14,7 and 18,0. Because of this fluctuation the chemical score of the proposed mixture was recalculated for the most critical essential amino acids, in this case lysine, methionine, tryptophan, and sulfur containing amino acids. This calculation now is based on the figures of the precited food tables. It is important to stress that calculation assumes that both protein sources should be at the same time on the lowest or the highest level. Therefore the figures given in table 4 show the extreme values which can be expected. From this table it is clear that the lowest chemical score can be 59, the highest 100 and the average 81. It looks as if these figures are not in full accordance with the previous ones. However the difference comes from the fact that the calculations obtained in tables 1, 2 and 3 are based on figures expressed as g amino-acid per 100 g total protein, while these in table 4 on figures expressed as g amino acid per 100 g protein of the edible partion. If, for practical conditions, the average chemical score is certainly usable it would be of more interest to know the exact analysis and its variability in the used maïze and soya. From this the exact chemical score can be derived so that in particular cases the minimum amount of protein needed can be precisely defined.

Table 5. Comparison of the amino acid pattern of the 3/1 maïze/soya mixture for the extreme values of the critical amino acids with the FAO pattern.

	FAO reference protein	Maïze/Soya 3/1 mixture					
		Lowest value		Average value		Highest value	
	g/100 g protein	g/100 g protein	% of the FAO protein	g/100 g protein	% of the FAO protein	g/100 g protein	% of the FAO protein
Lysine	4.2	2.6	62	4.5	100	6.2	100
Tryptophan*)	1.1	0.7	64	1.0	91	1.4	100
Methionine	2.2	1.3	59	1.8	82	2.9	100
S cont. am. ac.	4.2	2.5	60	3.4	81	5.3	100

*) Figure deduced from Swendseid et al. (1962).

In the biological value of a protein exclusively depends on his amino acid composition, then the chemical score is equivalent to the biological value Block and Mitchell (1946), Bender (1954), Henderickx (1963). Soybeans however contain toxic substances interferring with some metabolic processes. Among these the antitryptic factor(s) and haemagglutinic factor are the most important. Both these factors can be destroyed by heat treatment. Therefore if crude soybeans are used the conversion of the chemical score into biological value has to be accepted with reservation. If the soybeans are adequately treated which means destruction of the toxic factors and no damage to the proteins the conversion can be made.

Because its many qualities, among these the most important high biological potency, local production, easy preparation and incorporation in the local diet the proposed 3/1 maïze/soya mixture is very promising. However more work has to be done to find a simple and adequate treatment so that this biological potency will become a biological value.

Summary

In order to find a protein source of high biological value which can be locally produced and easily incorporated in the local feeding habits for the population of the Luluabourg area (Republic of Congo), the optimum mixing ratio between maïze and soybean has

been calculated. In regard of the FAO provisional reference protein a 3/1 maïze/soya mixture with a chemical score of 91 was estimated the optimum mixing ratio. The value and the fluctuation of this chemical score was evaluated. Restriction has been made to the conversion of the chemical score to the biological value if the soybeans are not adequately treated.

References

Allison, in: Munro, Mammalian Protein Metabolism (New York and London 1964). — Bender, J. Sci. Food Agric. **7**, 305 (1954). — Bender, Clin. Chim. Acta **5**, 1 (1960). — Block and Stekol, Nutr. Abstr. Rev. *16*, 249 (1946). — Bressani and Elias, J. Food Sci. **31**, 626 (1966). — Dean, Medical Research Council – Spec. Rep. Series no. 279. H. M. Stationery off. (London 1953). — Dean, in: Altschul, Processed Plant Protein Foodstuffs (New York and London 1958). — FAO, Protein Requirements FAO Nutr. Stud. no. 16 (Rome 1957). — Henderickx, Z. Ernährungswiss. **3**, 158 (1963). — Howe, Gilfillan, and Allison J. Nutr. **70**, 385 (1960). — Jacquot, in: Nutrition et Alimentation Tropicales FAO Rapport no. 20 (Rome 1957). — Jarquin, Noriega, and Bressani, mentioned by Bressani and Elias (1966). — Swendseid, Watts, Harris, and Tuttle, J. Nutr. **75**, 295 (1961). — Swendseid, Harris and Tuttle, J. Nutr. **77**, 391 (1962). — Souci, Fachmann, and Kraut, Die Zusammensetzung der Lebensmittel (Stuttgart 1962). — Wauters, Esquises d'une campagne de soya au Kasaï (1961). Personal report to Mgr. Bakole.

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Le facteur antipellagreux et le métabolisme énergétique

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Avec 8 tableaux

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Les observations de Frontali (1), Barić et Gelineo (2), Bogićević et Jevtić (3), Isakov (4), Petrović et Jović (5), et Krvavica et coll. (6) parlent en faveur d'une augmentation du métabolisme énergétique lors d'une carence du facteur antipellagreux (PPF). Par contre, Renato (7) affirme que les quantités élevées du PPF stimulent la consommation de l'oxygène.

Afin d'élucider ce problème nous avons mesuré l'augmentation du poids ainsi que le bilans d'azote chez deux groupes de poussins, dont un groupe recevait de hautes doses du PPF.

Méthode

Les expériences furent effectuées sur 30 poussins des deux sexes hybride Wyandott-New Hampshire, qui au début étaient agés de 5 à 6 jours. L'expérience a duré 60 jours.