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FORMULATED VEGETABLE MIXTURES

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The following discussion will indicate the nutritional factors to be considered in the scientific formulation of foods rich in protein which are used for human feeding.

The animal feed industry has reached a high level of efficiency in many countries of the world because of available knowledge of nutrient requirements at different stages of growth and of the chemical and amino acid composition of foods. This knowledge enables the manufacturer to mix several feed ingredients, following scientific principles, which will result in complete and balanced diets utilized to their maximum efficiency by the animal. A similar trend must be followed in the feeding of the human population if this rapidly increasing population is to be adequately fed. Although nutrient requirements in humans are not as well established as similar requirements for domestic animals, there is enough information available to permit the formulation of foods which provide the nutrients required for growth and maintenance. Protein is one of the most important nutrients to be considered in the development of food mixtures for human feeding.

Factors Affecting Protein Quality

Recognized factors which affect the efficient utilization of protein are as follows:

1. Protein concentration
2. Amino acid content and balance
3. Protein digestibility and amino acid availability
4. Other factors, such as toxic compounds

Processing conditions affect protein, and can be a factor in determining digestibility and amino acid availability.

Improvement of Protein Quality

From the nutritional point of view, the essential amino acid pattern is the most important property of proteins. Satisfactory protein foods can be produced from incomplete vegetable proteins by at least four methods: (1) amino acid supplementation, (2) supplementation with other protein sources which have a high biological value, (3) the appropriate combination of two or more proteins, which are deficient by themselves, and (4) by combinations of the three previous methods.

Amino Acid Supplementation.—Appropriate supplementation of vegetable proteins alone or combined with synthetic amino acids has been shown to improve their value for the growth of animals and to increase the efficiency of utilization of dietary protein.[1,2] The amount of the first limiting amino acid that can be supplemented effectively is governed mainly by the concentration of the second limiting amino acid present in the food. Proper supplementation is achieved only when the amount of the first limiting amino acid is in the correct proportion to the amount of the second limiting amino acid and to the rest of the amino acids, according to the needs of the species. All other essential nutrients must be present in the diet to assure full utilization of the

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protein. Little practical use has been made of this method for improving the human diet, although clinical studies have demonstrated significant improvements in nutritional quality of the amino acid supplemented protein for man.[3-8]

Supplementation With Other Protein Sources.—A second way in which the nutritive value of a low quality vegetable protein can be properly increased is by supplementation of the deficient protein with small amounts of protein concentrates which are rich sources of deficient amino acids. Lime-treated corn has been supplemented with fish protein concentrate (FPC), with a 3% or a 4% addition of FPC significantly improving the protein value of the corn (Fig 1). This method of improving the nutritional value of some proteins results in formulations of high quality protein. Although the method has been tested quite extensively, it has been applied only in very limited areas of the world.

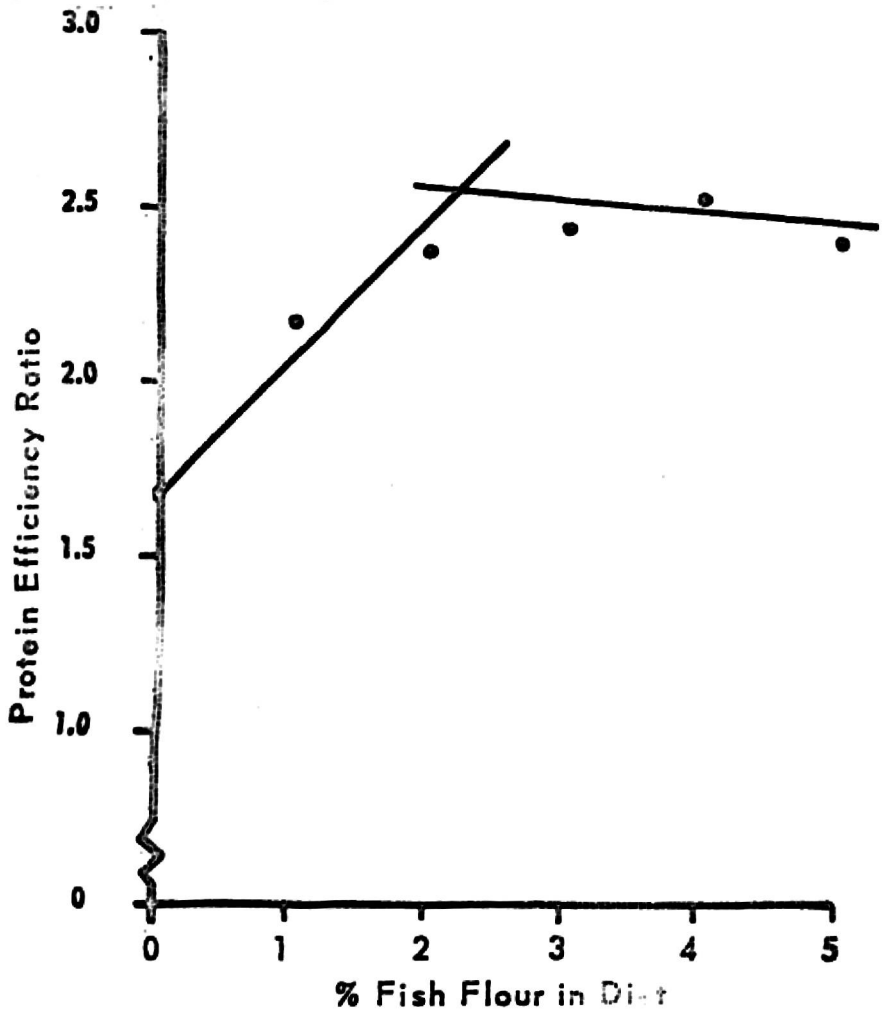

Fig 1. Improvement of the protein efficiency ratio of lime-treated corn with fish flour (INCAP 60-70).

Combination of Two or More Proteins.—The nutritional value of proteins can also be increased by the proper combination of two or more poor protein sources. A higher protein quality is obtained when the amino acid pattern of one protein source complements the amino acid pattern of the other source.

When mixing two or more proteins, four types of products can be formed. Theoretical lines representing these four types are shown in Figure 2. Type I results from the mixture of two proteins of different protein concentration, but with similar biological value. The nutritive value of the protein in the combination is equal to that of either component.

Type II is a combination that results in a protein value of the mixture equal to that of the component of higher protein content, thus, higher than the protein value of the ingredients of low protein content.

Type III is that which occurs when there is a synergistic supplementation or when there is complementation of the two protein components being mixed. The main characteristic of mixtures of this type is a protein value higher than that of either ingredient alone.

Type IV is that in which the protein value is intermediate between the protein value of either component according to the proportion in which they are combined.

Examples of the four types of mixtures are found in the literature as reported by several investigators. Figure 3 shows the biological results of studies in

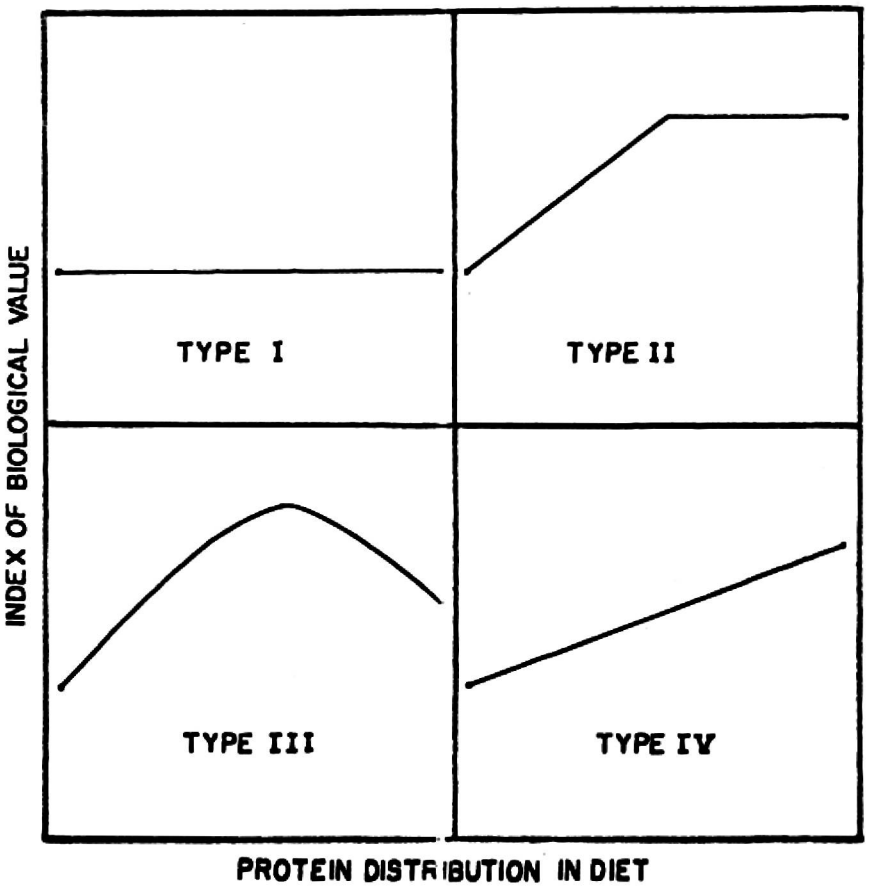

Fig 2. Theoretical lines representing four types of protein combinations (INCAP 65-576).

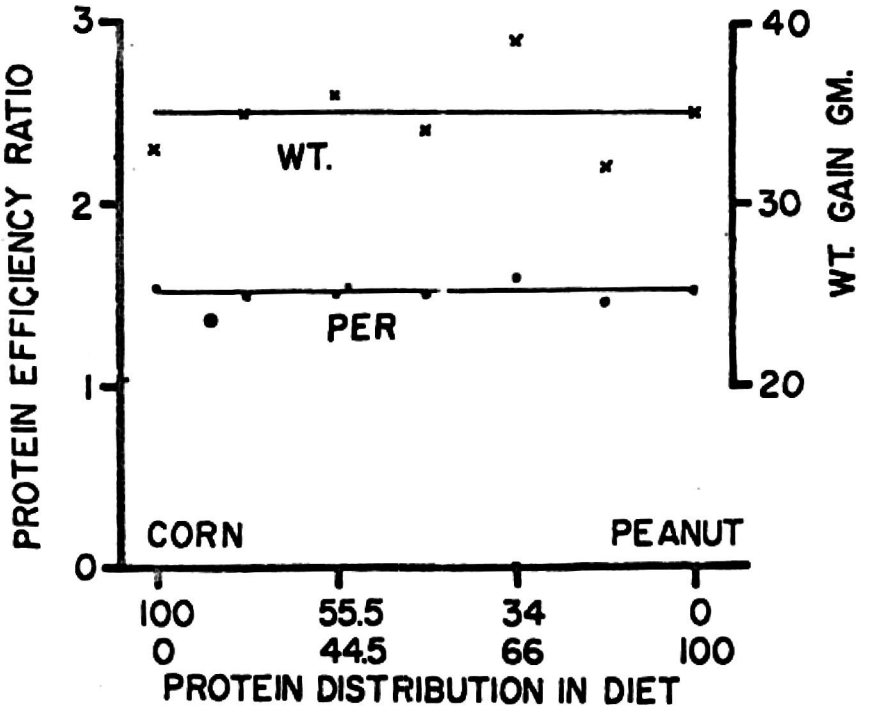

Fig 3. Nutritive value of combinations between corn and peanut flour—Type I (INCAP 65-574).

which combinations of corn and peanut proteins result in a Type I mixture.[9,10] These two proteins do not supplement each other because both are deficient in lysine,[3,11] and peanut protein is also deficient in methionine.[11] The relative excess of methionine in corn protein is not enough to fill the deficiency of

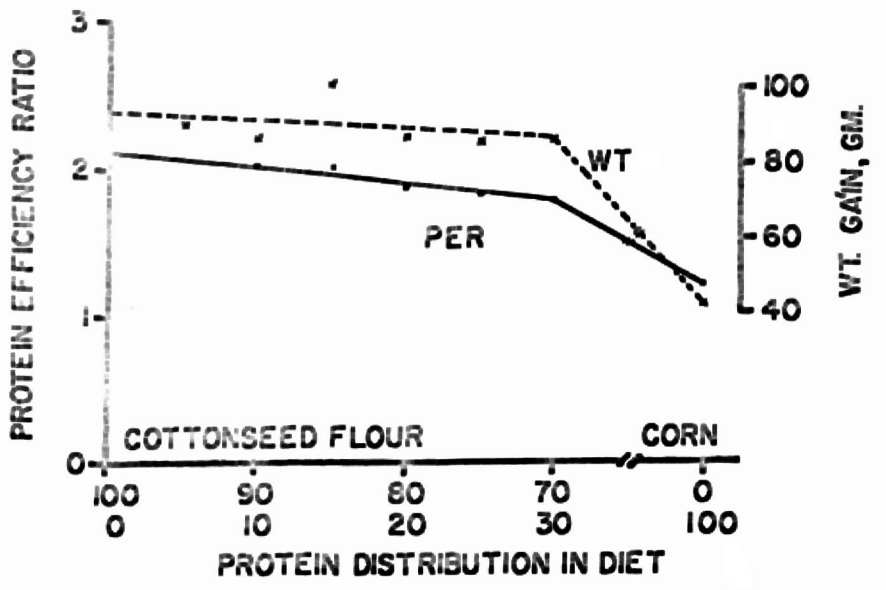

Fig 4. Nutritive value of combinations between corn and cottonseed flour—Type II (INCAP 65-560).

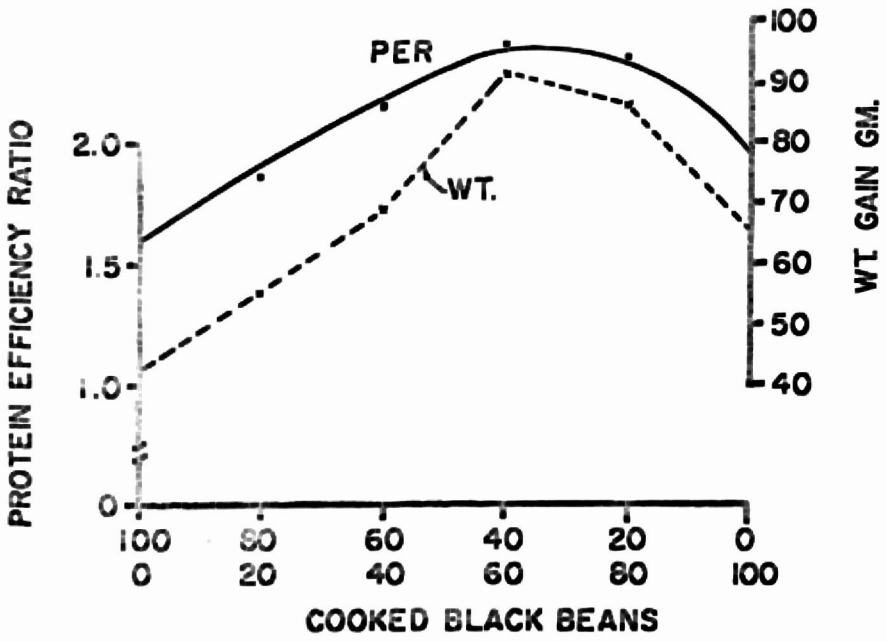

Fig 5. Nutritive value of combinations between cooked black beans and cottonseed flour—Type III (INCAP 65-575).

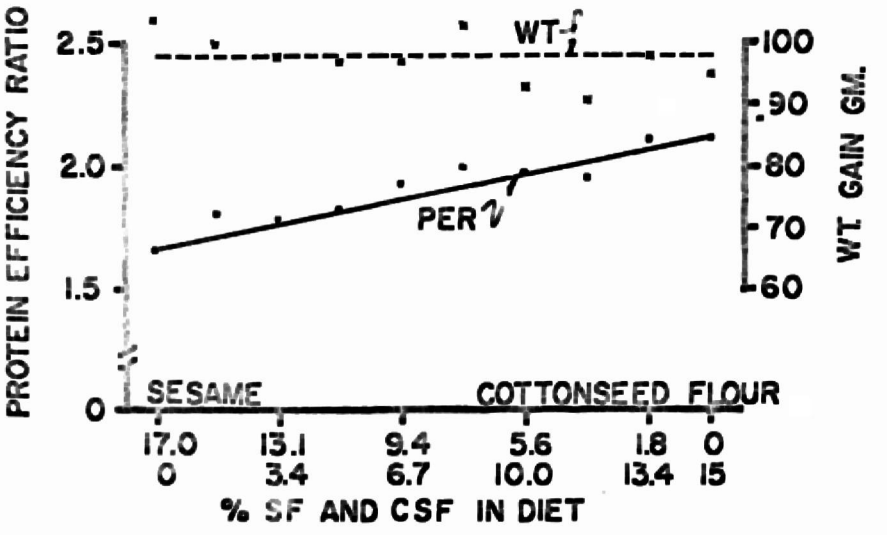

Fig 6. Nutritive value of combinations between cottonseed flour and sesame flour—Type IV (INCAP 65-579).

methionine in peanut protein; furthermore, the deficiency of lysine is relatively greater than that of methionine.

An example of Type II combinations is given by mixtures of corn and cottonseed protein as shown in Figure 4. Cottonseed protein can be diluted up to 70% to 80% with corn protein without decreasing the protein quality of the cottonseed flour. These results are the basis for INCAP Vegetable Mixture 9.[12] Cottonseed protein is low in lysine, but it contains more of this amino acid than corn protein. Cottonseed flour, however, cannot supply all the lysine needed to meet the deficiency of this amino acid in corn and balance the other essential amino acids as well.

An example of a mixture in the Type III group is shown in Figure 5. Black bean protein and cottonseed combined in a protein ratio of 40:60, give a good protein efficiency ratio of 2.34.[10,13] In this situation, the essential amino acids of one protein source complement very closely the essential amino acid pattern of the other protein component, resulting in a product with a higher protein quality than either food source fed alone.

Examples for the Type IV group are shown in Figure 6. There is no supplementary effect between cottonseed and sesame flour and the protein value is proportionate to the amount of each ingredient in the mixture.[12] Mixtures within this group usually result from the combination of foods having different protein values but a common essential amino acid deficiency, although in differing degrees.

Formulation of Vegetable Protein Mixture

There are at least three practical methods by which the protein in different foods can be combined in order to develop a mixture with a high protein quality.

One method is the mixing of two or more protein foods according to their respective essential amino acid patterns in regard to a reference protein. Formulation of protein foods by this method usually takes into consideration the fact that some proteins are limiting in one or two amino acids which must be supplied by a second protein. Although, theoretically, it should be possible to arrive at good mixtures following this technique, the result is generally not the one expected because the availability of the amino acids in the different food proteins is not usually considered.

A second method for the formulation of mixtures results from the data of studies on supplementation, such as shown in Table 1. In this particular case, 5 gm of FPC efficiently supplemented 20 gm of cottonseed protein at the 10% protein level in the diet.[11] If the level of total protein desired is, for example, 30%, the two basic figures should be multiplied by 3 resulting in a formula with 18% FPC and 60% cottonseed protein concentrate. This method of formulation, used at INCAP, has several advantages: (1) the level of protein can be varied significantly,

TABLE 1.—SUPPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE (CSF) WITH FISH PROTEIN CONCENTRATE (FPC).*

Amount of FPC added %	Average gain in weight† gm	PER‡	Protein control amount of CSF§ %	Average gain in weight gm	PER‡
0	101	2.22	....	....	....
2	132	2.56	3.2	120	1.98
4	144	2.17	6.4	133	2.03
6	163	2.28	9.6	141	2.03
8	161	2.02	12.8	154	1.82

*All diets contained 20% cottonseed flour.
†Twenty-eight day experimental period.
‡Protein efficiency ratio.
§Amount of CSF equivalent in nitrogen content to the respective levels of FPC.

(2) the filler can be a simple or complex carbohydrate or a food low in protein quality and quantity and (3) the mixture of the two protein concentrates alone can be used directly to supplement poor quality protein diets.

The third method of formulating protein mixtures has been developed from data obtained from biological tests in which the amino acid pattern of one protein complements the amino acid pattern of a second protein, such as replacing cottonseed by soybean proteins (Fig 7). It is apparent that obtaining more than 40% of the dietary protein from soybean does not improve the quality of the cottonseed-soybean mixture. Therefore, a protein with 60% from cottonseed and 40% from soybean can be used as the base for formulating other mixtures. If a mixture with 25% protein is required, it will consist of 57 gm of cottonseed flour and 38 gm of soybean flour as a good quality protein base. INCAP Mixture 15 was formulated using the results shown in Fig 7.

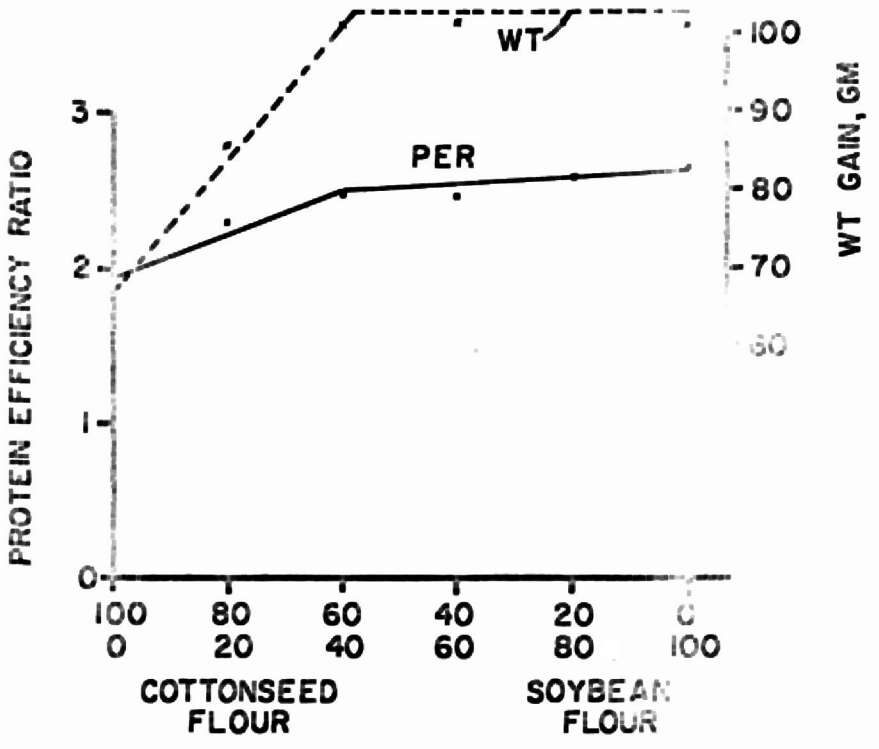

Fig 7. Nutritive value of combinations between cottonseed and soybean flour—Type II (INCAP 55-577).

Finally, the last method of formulating mixtures is by means of amino acid supplementation, of protein supplementation, or both; this method attempts to improve the protein quality of formulas developed by the previously discussed methods (Table 2). Using INCAP Mixture 15 as the basic protein, amino acid supplementation is used to improve the protein quality of the basic mixture.

It is obvious that it is possible, by following the last three methods of incorporating vegetable proteins, to arrive at food mixtures of excellent protein quality.

Significance of Scientific Formulation

The main purpose in developing protein rich foods from mixtures of vegetable and animal protein concentrates is to supply protein of good quality and satisfactory quantity for supplementary feeding in human diets. Mixtures should also contain other nu-

TABLE 2.—NUTRITIVE VALUE OF INCAP FORMULA 15 SUPPLEMENTED WITH AMINO ACIDS

Amino acid	Supplement % of diet	Weight gained* gm	PER†
VM 15‡	0	101	2.52
+ L-lysine HCl	0.20	116	2.66
+ L-lysine HCl + DL-threonine + DL-methionine	0.20 0.20 0.20	144	2.86

*Twenty-eight day feeding period.
†Protein efficiency ratio.
‡19% CSF (cottonseed flour), 19% SBF (soybean flour), 58% corn, 3% torula yeast, 1% calcium phosphate, 4,500 IU vitamin A per 100 gm.

trients, particularly those which are deficient in [illegible] quality diets usually consumed in developing countries. It is essential for these mixtures to have the highest nutritive value possible, if they are best to fulfill their purpose.

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OILSEED PROTEIN FOODS