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(Reprinted from *"TURRIALBA"*, Vol. 2, No. 2, p. 44-46, April-June 1952)

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THE shortage of protein of high quality for human consumption and for animal feeds is undoubtedly the most serious nutritional and agricultural problem confronting large areas of the world today. Efforts to improve this situation have been directed largely toward improving the supply of animal protein.

However, agricultural experts are agreed that for the present at least many of these areas cannot possibly support an animal economy sufficient to provide animal protein for all of their population on anything approaching the nutrition standards of North America and Western Europe. For some of these areas, not only is this true for the immediate future but also, unless present agricultural methods are changed, for an indefinite period. Fortunately it is possible to have an adequate protein intake through proper combinations of vegetable protein.

Under these circumstances, national and international efforts to solve the shortage of high quality protein by producing sufficient animal protein in under-developed areas, may not be facing the real problem. This is particularly true of efforts to supply the needed protein through cow's milk for all children in areas not now producing or consuming much milk. It should be recognized that even if people could afford to buy animal protein in optimal amounts and were educated to do so, there would simply not be enough to go around. Nevertheless, an adequate supply of protein must be provided for human nutrition if children are to grow and develop properly and the population is to be healthy and vigorous. Inadequate dietary protein does result in decreased resistance to disease, lowered physical capacity and diminished over-all productivity. Deficiency of high quality protein in the post-weaning infant and pre-school child is believed responsible for the high incidence of *Kwashiorkor* in over-populated and under-developed areas. Kwashiorkor is a serious nutritional disorder first described from Africa but common in most underprivileged regions. This deficiency can be overcome with either animal protein or suitable mixtures of proteins of vegetable origin. The shortage of adequate protein is also a factor in the diminished growth and stature of children in many areas.

The importation of protein foods is often attempted or suggested as an alternative to the production of an adequate supply of quality protein in a national or economic region. This method may be practical for high industrialized countries such as Great Britain and for countries with an abundance of valuable exportable raw material such as Venezuela. However, it has also been recommended that nonmilk producing countries could benefit by the permanent importation of "surplus" milk from countries like the United States and Australia. Such a procedure is not only economically dangerous for dollar short as well as protein short areas, but is a step away from a balanced economy and reasonable self sufficiency. Also, if for any reason the imported supply fails or becomes prohibitively expensive, any government subscribing to such a course as a matter of policy, will face serious difficulties.

The alternative for most countries must lie in the better development and utilization of vegetable sources of protein as well as in the maximum improvement of their animal industry. The need for a more effective handling of vegetable protein potentialities should under these circumstances be self-evident. Fortunately, the results of fundamental investigations in the field of nutrition are giving a better understanding of this basic problem as well as suggesting methods for solving it. Some of these are discussed below.

The nature of protein quality

It has been known for some time that protein is necessary in the diet in order to provide essential amino acids. Evidence indicates that only eight amino acids (methionine, tryptophan, phenylalanine, lysine, leucine, isoleucine, valine, threonine) are necessary for human maintenance although two more, argine and histidine, may prove necessary for growth. In general the proteins in foods of animal origin contain all ten of these amino acids in approximately the proportions required by the animal body to build tissue. Thus, the amino acids in animal protein are usually well utilized.

Plant proteins on the contrary, differ widely in amino acid composition. Some completely lack one or more of the essential amino acids, and all fall short of the nutritionally good amino acid distribution which characterizes foods of animal origin. Any attempt to solve shortages of good, high quality protein, by the use of vegetable protein must face this difficulty. Nevertheless, the attempt must be made.

Increasing the supply of high quality protein

On the basis of present knowledge, four principal methods may be suggested by which the protein intake of humans in under-developed areas may be increased in quality as well as quantity.

1. *The introduction into deficient areas of food plants*

* Received for publication March 26, 1952.

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that are rich in protein is an attractive method to the planner because it is dramatic as well as a highly satisfactory procedure from a theoretical point of view. Unfortunately such programs as the introduction of soybeans and peanuts have frequently failed because local food habits and prejudices were not taken into consideration. Prolonged and expensive education campaigns may be required to obtain consumer acceptance for the introduced product. The introduction of high protein food plants should be continued when practical, but the limitations of this method must be realized, and undue reliance should not be placed upon the outcome of such programs. Similar difficulties lie in the way of the exploitation of local plants that are theoretically of high nutritive value but are not generally used by the population for food.

2. *The utilization of complementary combinations of proteins from locally grown vegetable products* is a theoretically sound and an immediately applicable procedure. As mentioned above, vegetable protein differs from animal protein in its failure to supply the essential amino acids in amounts proportionate to requirements, when it is from a single source. Under such circumstances the other essential amino acids present in proportionately greater amounts than required are lost as far as protein metabolism for tissue building is concerned and the "biological value" of the protein is said to be low. However, if different, carefully selected plant proteins are included in the diet simultaneously, what one protein lacks in essential amino acids may be partly made up by the others, thus resulting in a combination of higher biological value. Combinations of vegetables are usually nutritionally superior to any single vegetable in supplying protein requirements.

Considerable benefit to protein metabolism as well as that of vitamins and minerals is thus likely to result from the introduction of variety in the diet. Research, however, is necessary to discover the combinations of local vegetable proteins that will best approximate animal protein in biological value. The adequate provision in the human diet of the amino acid methionine is one of the major problems to be solved because all vegetable proteins are proportionately lower in methionine than in the other essential amino acids.

3. *A more efficient distribution and utilization of available animal protein* is another important method that can be applied immediately. A relatively small amount of animal protein in the diet will greatly improve the over-all quality and palatability of vegetable protein combinations and make an otherwise inadequate diet satisfactory in respect to protein. When animal protein supplies, such as milk and cheese, are available for supplementary feeding programs, these supplies will be of greatest benefit to the nutrition of the country if they are distributed widely in small quantities and the balance of the protein required made up from local vegetable sources. It should also be understood that supplementing the diet with food which supplies the essential amino acids in quantities much greater than the body requires is of limited value since the excess is lost in the urine or is used for energy in place of fat and carbohydrate.

If proteins from plant sources are well utilized, it is by no means necessary, or even economically desirable, to raise animal protein consumption in all deficient areas to United States, or European, or Argentine levels in order to obtain optimal protein nutrition.

4. *The development of new genetic varieties of important food plants richer in key amino acids* such as methionine, tryptophan and lysine has exciting possibilities. A great deal of time and money has been successfully spent on the development of new plant varieties having higher total yields, and greater resistance to disease. Such selection has sometimes been associated with a steady drop in nutritive quality. Recently, attention has been paid to yields of essential nutrients. With the development of satisfactory methods for analyses not only for vitamins and minerals, but also for amino acids, there is no longer justification for ignoring nutritional value in the breeding and selection of basic food crops such as corn, beans, wheat and rice.

While in the more highly developed countries many desirable nutritive qualities have been lost in such crops as corn and wheat, a reservoir of great genetic variation in nutritive value still exists in areas where agricultural practices are less highly developed. Studies indicate that some varieties are superior to others in relative content of important nutrients.

The situation in regard to corn in Central America will serve as an example. The biological value of corn is usually considered to be less than 50%. This means that more than half of the amino acid nitrogen contained in the corn cannot be used for protein synthesis in the body because one or more of the essential amino acids are not present in adequate amounts. Zein, one of the principal proteins of corn, is deficient in tryptophan and lysine. In contrast to zein, the proteins of whole corn contain an adequate proportion of lysine for human nutrition. Methionine and tryptophan appear to be limiting amino acids. Recent studies made by the Institute of Nutrition of Central America and Panama, (INCAP), show that the proportion of methionine and tryptophan varies greatly among indigenous corns. [1] This variation is of enormous potential importance. Some Indian adults consume over 500 grams of whole corn as tortillas daily and receive over 80% of their protein from this source. According to analysis by INCAP of twenty-four locally grown varieties, this quantity of corn supplies lysine and phenylalanine far in excess of the minimum human requirements (Rose's standards) for these amino acids. However, sufficient tryptophan was

1 The concept of methionine deficiency in vegetable protein diets may have to be revised because of recent work of Dr. W. L. Rose who has replaced with cystine most of the methionine required in the adult diet for maintenance of nitrogen balance. In the case of corn for human consumption, tryptophan would become the limiting amino acid instead of methionine if cystine is available to make up some or all of the methionine deficiency. Until the cystine content of corn and other vegetables can be determined, and the replacement of methionine by cystine in human *growth* can be evaluated, definite conclusions are not possible. The partial replacement of methionine by cystine in animal nutrition has been known for several years.

supplied by only half of these varieties. With the exception of a pop-corn, all the varieties analyzed fell far short of the human requirements for methionine (see foot note on p. 45); *the range of variation among the varieties was from* 31 *to* 81% *of the minimum requirement.*

The widespread production and use of a corn with a better amino acid distribution than that found in the varieties now used would result in great improvement in human nutrition without an educational campaign or interference with existing cultural patterns. Such corns would also have a higher efficiency in animal feeds with the result that fewer pounds would be required to raise hogs and chickens to maturity. Fortunately, some of these nutritionally superior varieties are also higher yielding than those now in common use. The average farmer is practical in his approach to agriculture and will readily accept the varieties that are nutritionally better *if* they also grow better and yield more per unit of land. The studies mentioned above indicate that varieties of corn, superior agriculturally as well as nutritionally, can be found or developed. The potential importance of this to Central America is enormous.

Possible accessory food factors

Animals fed an all-vegetable diet have been shown to grow better when minute quantities of Vitamin B_{12} are also ingested. The oral administration of aureomycin, penicillin, terramycin, and other antibiotics has also resulted in improved growth. This, presumably, permits an increase in the proportion of intestinal bacteria synthesizing Vitamin B_{12} or like substances, or decreases the proportion of intestinal bacteria competing with the animal body for these factors, or results in control of generally harmful bacteria. For periods of a few months, it is doubtful if these factors have a detectable effect on the growth of children, even on very poor diets. However, studies made by INCAP, which are now in their third year, suggest that when long term observations are carried out with children on diets *very low in animal protein over an extended period,* the animal protein activity of B_{12} or antibiotics will be found to improve their growth. Because of the possible B_{12} requirement, care should be taken to include this nutrient animal protein containing it in the diet of growing children even when the amino acid requirements are apparently met. The minimum quantity of animal protein necessary to supply this factor has not been established. On the basis of preliminary work by INCAP and analogies with animal experimentation, it is possible that ten to fifteen grams of animal protein daily for a school child will prove sufficient in this respect. There is no evidence of a beneficial effect of B_{12} on adult maintenance.

Summary

A serious shortage of high quality protein in the so-called under-developed areas does exist. In many of these areas this shortage cannot be solved, for economic and agricultural reasons, by an increase in the quantity of animal protein alone. Introduction of vegetable proteins with high nutritional value, the use of complementary combinations of vegetable protein, and the effective distribution of the available animal protein throughout the population can all contribute to solving the problem. Of special promise is the development of a higher quantitative and qualitative protein content through selection and breeding of improved varieties of staple vegetables important as protein sources. Such development is possible only through the availability and application of laboratory techniques. The solution of the protein problem for the so called under-developed areas would seem to be within grasp of agriculturalists working in close cooperation with persons in allied fields and utilizing present knowledge.

RESUMEN

En las llamadas regiones poco desarrolladas existe seria escasez de proteína de alta calidad. Por razones económicas y agrícolas, esta escasez no puede remediarse en muchas de esas regiones exclusivamente a base de un aumento en la cantidad de proteínas de origen animal. La introducción de proteínas de origen vegetal de alto valor nutritivo, el uso de combinaciones complementarias de proteínas de origen vegetal, y la distribución adecuada dentro de la población de las proteínas de origen animal disponibles, pueden contribuir a resolver el problema. Ofrece muy buenas perspectivas el desarrollo, a través de la selección y el mejoramiento genético, de mayor cantidad y mejor calidad del contenido de proteína de variedades de plantas cuyos productos de consumo común constituyen importantes fuentes de proteína. Tal desarrollo sería posible solamente a través de la disponibilidad y utilización de las técnicas del laboratorio. La solución del problema de las proteínas en las llamadas regiones poco desarrolladas está al alcance de los técnicos agrícolas, en cooperación con los técnicos que trabajan en ramos afines, y utilizando los conocimientos actuales.