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UNITED STATES GOVERNMENT

Memorandum

TO : Distribution DATE: July 30, 1971

FROM : TA/AGF, Omer J. Kelley, Director O J Kelley
Office of Agriculture & Fisheries
Technical Assistance Bureau

SUBJECT: Technical Paper "Breeding Food Crops for Improved Protein Quality"

The attached copy of Technical Paper No. 3 continues the series of these papers initiated February 10, 1971. The subject of the current paper should be of interest to all plant breeders operating in LDCs, and to the Administrators of agricultural research programs.

Breeding food crops for improved protein quality constitutes a relatively new application of science to human nutritional needs, but this objective appears to be compatible with crop improvement for yielding ability, resistance to pests, and other desirable agronomic traits.

The FAO publication cited in this Technical Paper is one which does not normally come to the attention of plant breeders. However, it is quite unique in the global information provided; and may serve as an extremely useful aid in orienting plant improvement programs. If desired, this office will assist in providing copies of the FAO publication to the Field Missions.

Enclosure: Paper No. 3, Technical Series, Agricultural Technology Division, TA/AGF, AID-Washington, August 1971, "Breeding Food Crops for Improved Protein Quality"

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Bureau for Latin America and AID Field Missions
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BREEDING FOOD CROPS FOR IMPROVED PROTEIN QUALITY

The plant breeder has a key role to play in helping to meet the food quality situation in developing countries. He should be dedicated to the development of higher yielding strains and/or hybrids of all important food crops, but should also be aggressive in insuring that such crops have acceptable protein content and protein quality. Further, he should apply his expertise to incorporating higher nutritive quality of protein into as many as possible of the productive strains and/or hybrids of crops that are developed for distribution to growers, so that each plant foodstuff becomes more nearly adequate to serve human needs.

Plant proteins are evaluated as to their protein nutritive quality, by the content of certain nutritionally essential amino acids in the protein complex, and the balance between these essential amino acids. It is now well established that the plant breeder has the capability of incorporating desired protein qualities in crop plants, as well as that of developing higher yielding strains or hybrids that are well adapted to the environmental conditions of a region that are also readily acceptable to the consumer. Pioneering work of this nature was first done with maize, and has now been extended to wheat. Studies on other species are underway.

Breeding for improved protein quality is an important and relatively new method of dealing with deficiencies in the diets of people in developing countries. There now seems to be no scientific obstacle to extending the

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* Paper No. 3 of Technical Series; by the Agricultural Technology Division, TA/AGF, AID-Washington, August 1971.

principles established for improving the nutritive quality of proteins of maize and wheat, to all other food crops. However, each plant species constitutes a different type of genetic situation; and individual breeding programs will be required for each species to achieve desired nutritional objectives. The initial step is the search through the germ plasm collections of each plant species to identify the genetic traits that are desired. Worldwide collections of the germ-plasm resources have now been made for a considerable number of food crops, and these may be acquired by plant breeders. When once found, the protein quality traits may then be utilized in breeding programs to produce strains that combine the nutritive qualities with ecological adaptation, yielding ability, and other desirable production characteristics.

An exceedingly useful publication for plant breeders concerned with breeding crops for improved protein quality has been issued by FAO: "Amino-Acid Content of Foods; and Biological Data on Proteins". FAO: Nutritional Studies, No. 24, Rome 1970. This publication summarizes data from the world literature on this subject, and provides information on foods of plant origin, as well as for other food stuffs. Since all information is reported in three languages (English, French, and Spanish), the data is readily available to all scientists.

The plant breeder will find useful information for orienting a breeding program to improve the protein quality of food crops in the "Foreword" and "Explanatory Notes", as well as in Part I "Amino-Acid Content of Foods". Section I of Part I gives the Mean Values for protein and for individual amino acids for cereals (30 items), starchy roots and tubers (13 items), dry legumes and legume products (35 items), nuts and seeds (91 items), vetetables (107 items), and fruits (22 items). Perhaps the most important information in Section I of Part I is the biological evaluation of the protein, expressed as a chemical score based on the hen's eggg as a standard for human diets.

In Section II of Part I, the range in content of each amino acid is given for the major plant foods - a total of 310 items. The breeder will be most concerned with the range in values for the four essential amino acids most likely to be deficient in plant food stuffs, namely; lysine, threonine, methionine, and tryptophan. In general, plant proteins are not well balanced in these essential amino acids, so that the biological value of the total protein is substantially below the value of the indicator protein of the chicken egg.

Since the chemical score is based on the amino acid in shortest supply in food stuff, an increase in content of the one or two limiting amino acids may drastically improve the nutritive value of the toal protein content. The reported range in content of each amino acid is of particular concern, since it may indicate differences due to genetic composition of individual lots that were tested. However, it is not known how much of the reported variation may have been caused by other factors, such as the conditions under which the crop was grown, variations in analytical procedures in different laboratories, or errors of various types. Since other evidence is very clear for actual genetic differences in maize, wheat, and rice, it is expected that a diligent search for lines, strains or types in each of the other food crops may disclose breeding stocks that have value in a plant improvement program to increase both total protein and protein quality as required to meet human needs.

The plant breeder may need to establish a relatively simple measure of protein quality to expedite the task of screening large numbers of strains or types to use as breeding stocks. A convenient index is that the four amino acids most likely to be deficient in plant food stuffs should be present in the ration of four parts lysine, three parts methionine,* two parts threonine, to one part of tryptophan, when each is expressed in milligrams per gram of nitrogen in the sample analyzed. Any of these amino acids that are so low as to affect the desired balance, becomes the limiting factor in determining nutritive value as human food.

In undertaking to breed for improved protein quality, the first goal is to identify strains or selections of the crop species, that have a higher content of the limiting amino acid(s). Thus, in the food grain legumes, methionine generally constitutes the limiting factor in protein quality; and the identification of strains or selections legume strains that excel in this amino acid should constitute a step in the process of breeding for higher protein quality in such species. These FAO tables may assist the plant breeder in identifying the key amino acid deficiencies in any specific crop, as well as providing some indication of the variability that may be present in that species.

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* Methionine and cystine are sulfur-containing amino acids; and some nutritionists add some part of the cystine to the methionine in estimating nutritive values.

PERSPECTIVES ON BREEDING FOR PROTEIN
QUALITY IN CROPS

Appendix to Paper No. 3 of Technical Series; by the Agricultural Technology Division, TA/AGF, AID-Washington.

A major objective of the plant breeder is the development of strains or hybrids that possess greatly increased yielding capacity. To achieve these high yields it has been necessary to develop a suitable package of cultural practices including the appropriate place of the crop in cropping systems; improved soil and water management systems; good quality seed; adequate and timely fertilizer usage; satisfactory date of planting; plant populations sufficient to fully utilize potential water and soil fertility; and protection of the crop from diseases, insects and weeds. Higher yields are of prime importance, but improved nutritive quality is a necessary corollary if the ultimate objective or providing foods to meet basic nutritional requirements is to be realized.

The food supply in the LDCs is falling below the total quantities required to feed their people, while the population numbers continue to increase by leaps and bounds. In 1960, total calories in the diets of underdeveloped countries avaraged only 75% of the amount needed to meet minimum dietary requirements; but total protein averaged only about 70% of the minimum amount needed.*

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* A practical nutritional goal is to provide about 2,500 calories per person per day, and 75 grams of total protein, of which 30 grams should be of animal origin (meat, milk, eggs, fish, etc.). The animal proteins may be replaced by plant proteins to the extent that the plant proteins are altered in content to provide the necessary balance in essential amino acids, or are supplemented by additions of the deficient amino acids.

After considering all available alternatives, the comprehensive analysis of "The World Food Problem," published in November 1966 as a report of the President's Science Advisory Committee, stated that "the bulk of the increase in food supply must come from increased production of farm crops." Although the more advanced nations may help in critical food-shortage situations by donations and sales of foods on easy terms, the long term solution is to expand agricultural production within each country.

The plant breeder's role in helping meet the world food situation can be a most rewarding one since he has in his power the ability to not only increase food production but he can also improve the quality by genetic control. In order to do this he must be concerned not only with the development of higher yielding varieties of important crops, but also insure that these varieties are superior in both protein content and quality.

For this objective, the breeder must be concerned with the amounts of essential amino acids that can be stored in the edible portion of the crop plant.

Other factors which must be taken into account in meeting the nutritional needs of the human population include: (1) the fate of these essential amino acid components in the crop processing, marketing, and storage, (2) the efficiency and results of the cooking processes (partial losses of essential amino acids by excessive heat, prolonged cooking, discarding of water containing the soluble constituents, etc.), and (3) the actual delivery of highly nutritious foods to the most nutritionally sensitive segments of the population.

The greatest need for diets of adequate protein quality is for pregnant women, nursing mothers, and infants below school age. The second greatest nutritional need is that of growing children. Normal adults who usually have first choice of all foods, have the lowest need for protein, especially when they have enough calories to support necessary physical activity.

Without a sustained and balanced supply of the four most important amino acids (in the approximate ratio of tryptophan 1 part, threonine 2 parts, methionine 3 parts, and lysine 4 parts) in the total diet of the infants, the development of the brain and nervous system may be permanently impaired. Without a continuing supply during the growth of the child from age 4 to about 12, the further development of the nervous system and vital organs may be adversely affected. Hunger must be satisfied to meet the urgent needs of man, but the invisible hunger for essential amino acids is equally important.

The plant breeder looks to the nutritionist to provide reliable information on the actual amino acid deficiencies in the total diets of nutritionally sensitive population groups. Such deficiencies will indicate the goals for development of crop varieties that will have the desired nutritional value. The actual utilization of protein by sensitive segments of the population can seriously be affected by any single essential amino acid that falls below the optimum ration. For example, if methionine constitutes the limiting factor in a particular diet, the addition of lysine will not correct the deficiency. The plant breeder should strive for improved protein quality in both the actual amounts and the ratios of the more important amino acids. He should not be concerned only with improving protein or lysine content even though both may be very important.

Unlike animals (and fish), plants do not synthesize and store amino acid components of protein in the ratios appropriate to man's nutritional requirements. However, it is now known that wide variations occur in the amino acids composition of plant proteins of many species, (perhaps all) and some knowledge has been gained as to the genetic controls determining amino acids composition. It now seems feasible to breed for desired amino acid content and ratios between these, within each crop species. The plant breeder should set his goals to meet the specific needs in the geographic region where the crop is to be grown and utilized.

The plant breeder should combine crop yielding ability with improved protein content, but he must not assume that total protein is a satisfactory nutritional index. He must go further to assure that improved strains or hybrids also have adequate protein quality. He should know the content of at least 4 most important essential amino acids - tryptophan, methionine, threonine, and lysine, and that they are present in the proper ratios.

It is now possible to use "automatic amino acid analysers" in biochemical laboratories to rapidly determine the amino acid composition of foodstuffs. As a goal for determination of nutritive value, the content (and ratios between them) of the 4 most important amino acids should be such that the improved crop will not only be adequate as a single food, but be high enough in certain amino acid components to help supplement other foods that are primary sources of calories (energy).

The plant breeder has powerful genetic techniques at his disposal. Not only are total protein, and the content of individual amino acids under a high degree of genetic control, but each of these components tends to be inherited separately. Thus, it is possible to breed for a wide range of compositions, in which high, medium or low contents may be combined at will with various levels of each of the other components.

These genetic controls of the amino acids content of plant proteins are supplementary to any effects of the environment or cultural practices upon protein quality and amount.

To exploit this new dimension in plant improvement, it will become necessary that there be access to laboratories that can analyze for amino acids content. Such sophisticated equipment capable of making thousands of samples yearly, permits the breeder to identify superior parental stocks and to screen segregating populations, or hybrid combinations for actual content of essential amino acids.