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BETTER CEREALS SOUGHT IN FIGHT AGAINST WORLD HUNGER PROBLEM

PRODUCTIVE CEREALS with more and better protein are on plant breeding drawing boards. Some agricultural research teams are betting that such cereals will be a key to solution of the world's hunger problem.

Two billion or roughly two-thirds of the world's people depend upon rice and wheat as their basic food. Add to these the millions who rely upon maize (we call it corn), sorghum, rye, or millet and you have some idea of the importance of the food from this group of crop plants.

At least one of the cereals can be grown successfully anywhere in the world where the climate will support crop production. Rice, maize, sorghum, and millet are found from the tropics to the temperate regions. Wheat, rye, barley, and oats extend from the subtropics to the northern latitudes. Wheat has a particularly broad range of adaptation.

Cereal grains are an inexpensive source of both carbohydrate and protein. Their importance as a protein source is not well recognized by people in developed countries where meat, animal products, and a wide array of other foods are readily available. Yet more protein and essential amino acids can be produced from wheat on an acre of land than from livestock on the same land. Meat and animal products to satisfy the major portion of protein needs of people may be a luxury that few developing countries can afford.

The cereals, particularly wheat and rice, have been prized as food since early in recorded civilization. They are well established in the eating habits of people. Substitution of new unfamiliar foods, however nutritious, encounters a strong resistance, even among the malnourished. Cereals with improved nutritional value, then, would have distinctive acceptance advantages over unfamiliar replacement foods.

There are acute shortages of both carbohydrates and protein on a world scale. The protein problem is considered the more serious, although it cannot be treated independently.

Carbohydrates can be considered fuel for the body. They provide the energy needed for work and physical activities. In contrast, protein is necessary for tissue synthesis and body growth.

Protein malnutrition has particularly serious implications for the very young because of its effect on early brain development.

Unfortunately, the protein requirement of a person cannot be satisfied without also providing his minimal carbohydrate needs. This is because protein will be utilized for energy instead of growth if there is insufficient carbohydrate in the diet. Improved productivity of the cereal grains, therefore, is basic to their nutritional improvement.

Breeders have achieved spectacular successes in increasing yields of the cereal crops. The impact of hybrid maize and sorghum on the productivity of these cereals is a matter of record. In the United States the average corn yield rose from 28 bushels per acre in 1940 to 78 in 1968. Sorghum yields jumped from 20 bushels per acre in 1954 to 60 in 1968.

Maximum wheat yields now have been pushed above the 200 bushel per acre mark in the United States. Average wheat yields in Mexico rose from approximately 11 bushels per acre in 1945 to 41 bushels per acre in 1967. Mexico has been self-sufficient in wheat production since 1956.

New highly productive dwarf wheat and rice varieties that respond to fertilizer, water, and improved farming practices are revolutionizing production in India, Pakistan, Iran, Iraq, and Turkey. It is predicted that these countries, where population long ago overran food production, can become self-sufficient in wheat as did Mexico.

Cereal breeders and production specialists are demonstrating that enough cereal grains to feed hungry people can be grown. Many are now turning their attention to the job of improving the nutritional quality of cereals. It is a significant development and a logical second step to the production advances. There have already been some notable successes.

Protein consists of many amino acids which serve as building blocks for the body. All proteins are not the same for they may vary in number and quantity of amino acids.

Of the known amino acids, eight are considered essential in human diets because they must be present in the food eaten. The body cannot synthesize these amino acids as it can the others.

Maximum utilization of protein by a person can occur only when the eight essential amino acids are present in the protein consumed in approximately the relative amounts required by the body. Protein also varies in digestibility according to source as well as composition.

The high nutritional value of meat and animal products stems from the fact that the essential amino acids are present in approximately the required ratio, and digestibility of the protein is high.

Cereal proteins contain all eight essential amino acids but not in the amounts needed for maximum utilization of the protein. The amino acid lysine is in shortest supply in all cereals and has received the most

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attention thus far by cereal researchers. Some other amino acids also are a problem. In ordinary maize tryptophan is in short supply, while in wheat and rice it is threonine and methionine.

The question confronting cereal breeders is whether different strains or varieties of a cereal are inherently different in the amount of protein they produce or in amino acid composition of the protein. In order to breed varieties with more or better protein, such genetic or inherited differences must be present in the cereal species.

Little was known in 1950. Investigators at the University of Illinois had conducted long-time selection experiments beginning near the turn of the century with open pollinated maize to see if they could increase its protein content. They were successful in increasing crude protein from the usual 11 percent to about 20 percent, but the extremely poor quality of the protein and low productivity of the high protein selections discouraged others from pursuing the work.

Concerted efforts to increase the protein content of wheat by breeding trace to 1954. At that time, Gordon K. Middleton, Charles E. Bode, and Burton B. Bayles reported that the soft wheat varieties Atlas 50 and Atlas 66 released by the North Carolina Experiment Station in 1949 were significantly higher in protein than other soft wheat varieties. Evidence pointed to the Brazilian variety Frondoso, a parent of the Atlas wheats, as the donor of genes for high protein.

This finding stimulated Agricultural Research Service (ARS) and State wheat researchers at the University of Nebraska to embark upon a cooperative wheat protein research project in 1954 that has continued without interruption since that time.

Only limited laboratory facilities were available for wheat protein research at the university. The Nebraska Wheat Commission comprised of wheat farmers provided needed initial financial assistance. Not only did the commission support the research but it provided funds to establish and equip a wheat quality laboratory that has since been the focal point of the research.

Our cooperative ARS-Nebraska effort helped clarify several wheat protein questions. We now know that higher protein in wheat is heritable and can be transferred readily from one variety to another. The Atlas 66 genes promote two to three percent more actual protein in most production and soil fertility situations.

We have not found it possible to fix wheat protein at a predetermined level by breeding because of the strong effect of growing conditions on level of protein. High protein can best be achieved by the use of high protein varieties combined with timely heavy applications of nitrogen fertilizer.

We also determined that amino acid balance in high protein lines from Atlas 66 crosses was not adversely affected. The relative amounts of essential amino acids in the protein of several lines remained about the same as in other varieties. This meant that lysine, threonine, and methionine could be increased merely by making the protein content of wheat higher.

Other sources of high protein in wheat have been uncovered. In 1965, Harry McNeal, ARS wheat breeder at Montana State University, tentatively identified three wheats from the World Collection as high protein types. One of these, the Brazilian variety Frontiera, probably possesses the same protein genes as Frondoso. The other two varieties were from Africa and India.

In 1963 we crossed the spring variety Aniversario from Argentina with a hard winter variety and identified high protein lines among the progeny of the cross. A fertility-restoring experimental wheat used in the Nebraska hybrid program also appears to possess high protein genes.

Crosses among these different high protein wheats may push the grain protein level even higher than is now possible with Atlas 66.

A tremendously significant breakthrough in the improvement of the nutritional quality of cereal protein occurred in 1963. The Purdue University research team of Oliver E. Nelson, Edwin T. Mertz, and Lynn Bates produced the first evidence of large genetic differences in amino acid composition of cereal protein.

They discovered that an old maize strain known to breeders as opaque-2 because of its chalky textured grain was twice as high in lysine and tryptophan as ordinary maize. For the first time, a maize that possessed protein with relatively well balanced amino acid composition had been identified. Was it actually as good nutritionally as chemical analyses indicated? The answer was soon forthcoming.

Opaque-2 stocks were quickly distributed to researchers in several countries and nutritional experiments organized. When diets in which opaque-2 was the only source of protein were given to children suffering from Kwashiorkor, a serious protein deficiency disease in Latin America, the disease symptoms disappeared. Ordinary maize had been the main food for many of the afflicted children.

The high lysine opaque-2 maize was comparable to skim milk in nutritional value. No cereal had ever rated so high before. Here was a grain that held out hope of life and health for countless millions of people in Latin countries for whom maize is the most common food!

The high lysine find triggered further intensive nutritional research efforts in maize as well as in the other cereals. The Purdue team soon identified a second maize strain called floury-2 as also having high lysine properties. The search of germ plasm collections of other cereals was begun. There have already been some exciting finds.

Discovery of a high protein wild oat species from the Mediterranean region was reported by the U.S. Department of Agriculture in 1967. It produces grain with 30 percent protein, compared to 18 to 19 percent in the best commercial oat varieties. It is not yet known whether the high protein content can be bred into plump-seeded commercial varieties.

The Swedish Seed Association of Svalof, Sweden, and USDA jointly announced in 1969 the discovery of a high protein-high lysine barley variety. It has been appropriately named "Hyproly". The lysine content of Hyproly, a hull-less, wrinkled-seeded variety, is 20 to 30 percent higher than ordinary barley varieties. It is already being studied extensively in barley breeding programs throughout the world.

The ARS-Nebraska research team is screening the USDA World Collection of wheats. Since 1967 we have measured the protein and lysine content of 15,000 strains. This work is supported in part by funds from the Agency for International Development, U.S. Department of State.

Wide differences in both protein and lysine have been detected. Lysine ordinarily constitutes about three percent of wheat protein. We have analyzed samples with over four percent lysine. Our wheat effort is closely coordinated with the International Wheat and Corn Improvement Center (CIMMYT), Mexico City.

An international winter wheat performance nursery was organized by the ARS-Nebraska group in 1968 to evaluate winter wheats with unusual yield and nutritional properties on an international scale. It is grown in 26 different countries. A similar international nursery in spring wheat, initiated by Norman E. Borlaug of the Rockefeller Foundation in 1960, was instrumental in early identification of the varieties that are now revolutionizing wheat production in India and Pakistan.

Work on nutritional improvement of rice is underway in several countries. The International Rice Research Institute (IRRI) in the Philippines has utilized worldwide germ plasm in a concerted effort to improve rice agronomically and nutritionally.

As with wheat, new stiff strawed varieties that can tolerate heavy fertilization and produce high yields are making an impact in the rice producing countries. Protein and lysine differences have been identified which are being evaluated for their usefulness in rice breeding programs.

A sorghum research program directed by Robert C. Pickett at Purdue University has uncovered substantial variations in protein level and amount of lysine among the sorghums. This work has financial support from the Agency for International Development. Potentially useful variations in sorghum protein also are reported by the Rockefeller Foundation and from India. Yellow endosperm sorghums from Africa have been found to be high in vitamin A.

Development of a new cereal crop called Triticale has aroused worldwide interest since 1967. Triticale was created from two different cereals, wheat (*Triticum aestivum* L. or *T. Durum* Desf.) and rye (*Secale cereale* L.). Its name is based on the names of the parent species.

Triticale was initially a biological curiosity but chromosome juggling in university laboratories around the world resulted in a new crop type that may be superior to either parent species.

New lines emanating mostly from research at the University of Manitoba at Winnipeg, Canada, and CIMMYT have given new hope for success of this new crop. The lines show promise of high yields of grain with protein content equal to or higher than wheat.

There is no longer much question that large differences in amount and composition of protein exist in all cereal species. Opaque-2 maize, Hyproly barley, and Atlas 66 wheat provide ample evidence. Now it remains for cereal breeders to build new varieties that are nutritionally better than the old ones. The task is not easy but the stakes are high. The past record of accomplishments would indicate that cereal breeders can and will meet the challenge.

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