**Mertz E T, Bates L S & Nelson O E.** Mutant gene that changes protein composition and increases lysine content of maize endosperm. *Science* 145:279-80, 1964.
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The endosperms of maize seeds homozygous for the opaque-2 mutant gene have a higher lysine content than normal endosperms. In kernels on the same ear, opaque-2 endosperms had a different amino-acid pattern and 69 percent more lysine than normal endosperms. [The *SCI*® indicates that this paper has been cited in over 475 publications.]

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When I arrived at Purdue University in 1946, I was invited to become a member of a Utilization Research Committee that had just been formed in the Agricultural Experiment Station to find new uses for the cereal grain surpluses then piling up in government storage bins. I decided to start a project on corn proteins. My objective was to try to improve the nutritional value of corn proteins, which had to be combined with more expensive supplements such as meat, eggs, whole legumes, soybean meal, or milk protein in animal and human diets. The major protein in normal corn (zein) is almost devoid of two essential amino acids, lysine and tryptophan. Therefore, normal corn cannot serve as the only source of protein in human and animal diets.

My students and I began a search for a corn kernel that had a lower content of zein and higher levels of other more nutritious proteins (such as albumins, globulins, and glutelins). The first screening for corn with these qualities was carried out by my student Ricardo Bressani from 1953 to 1957 and was continued by my student Lynn S. Bates in the early 1960s. At first we analyzed corn endosperms for zein; then, in the early 1960s, we obtained one of the first automatic amino-acid analyzers and looked only for higher lysine levels in the endosperm.

From 1957 to 1961, Herbert H. Kramer, Department of Agronomy, sent over corn varieties, both normal and mutant, including floury-1 but not floury-2, for our analysis. None were high in lysine. When Kramer left the university in 1961, Oliver E. Nelson, Department of Botany and Plant Pathology, took his place and supplied us with samples for analysis. The first set of samples from Nelson came from the Mexican seed bank and represented many races from Central and South America. They showed the normal low values and very little variation in lysine content when expressed as grams of lysine per 100 grams of protein.

Nelson was aware of the fact that we had found a lower level of lysine (g/100 g endosperm protein) in Illinois High Protein (about 18 percent protein) than in Illinois Low Protein (about 4 percent protein). He also noticed that the High Protein endosperm was vitreous and the Low Protein endosperm much more floury. Thinking that flouriness might be associated with high lysine, he sent us four types of floury mutant kernels: floury-1, floury-2, opaque-1, and opaque-2. On November 18, 1963, the endosperms of these samples were analyzed. Floury-1 and opaque-1 contained 2 g of lysine per 100 g of protein (normal levels), floury-2 contained 3 g of lysine, and opaque-2 contained 4 g of lysine per 100 g of protein. Since two samples of floury kernels (floury-1 and opaque-1) had normal lysine levels, flouriness was not closely linked to high lysine. Nevertheless, Nelson's thought that it *might* be linked to lysine paid big dividends. The opaque-2 mutant still ranks above all single viable mutants of corn in levels of lysine, even though the list of high-lysine mutants in 1975 had nine viable types. Opaque-2 endosperms also contain double the level of tryptophan found in normal corn endosperms.[1]

In 1965 feeding tests with young rats[2] showed that animals receiving only opaque-2 corn, minerals, and vitamins gained almost four times more weight in 28 days than those receiving standard hybrid corn. This was repeated with weanling pigs. In Guatemala Bressani showed that opaque-2 corn had 90 percent of the value of milk protein in young children.[3]

The International Maize and Wheat Improvement Center in El Batan, Mexico, in a long-term breeding program, developed strains of opaque-2 corn that are not floury. They are hard, vitreous kernels that cannot be distinguished from normal kernels and are intended for human use. In the US the floury type of opaque-2 kernel is still produced in high-yielding hybrids for animal feed.

The publication of this paper led to worldwide research on mutant types of corn, more than 1,000 journal articles, a symposium publication,[4] a book,[5] a review of the biochemistry of opaque-2 corn,[6] and a monograph on "quality protein maize" now in press and to be published soon by the National Academy of Sciences (NAS). It also prompted a search for high-lysine mutants in other cereals, which resulted in the discovery of high-lysine mutants in barley and sorghum.

High-lysine corn was an important factor in the election of Nelson and me to the NAS, and we received a dozen awards from different societies, institutions, and foundations for its discovery.

1. **Misra P S, Jambunathan R, Mertz E T, Glover D V, Barbosa H M & McWhirter K S.** Endosperm protein synthesis in maize mutants with increased lysine content. *Science* 176:1425-7, 1972. (Cited 55 times.)
2. **Mertz E T, Veron O A, Bates L S & Nelson O E.** Growth of rats fed on opaque-2 maize. *Science* 148:1741-2, 1965. (Cited 105 times.)
3. **Bressani R.** Protein quality of opaque-2 maize in children. (Mertz E T & Nelson O E, eds.) *Proceedings of the High Lysine Corn Conference*, 1966, Lafayette, IN. Washington, DC: Corn Industries Research Foundation, 1966. p. 34-9. (Cited 45 times.)
4. **Mertz E T & Nelson O E,** eds. *Proceedings of the High Lysine Corn Conference*, 1966, Lafayette, IN. Washington, DC: Corn Industries Research Foundation, 1966. 186 p.
5. *High-quality protein maize: proceedings of the CIMMYT-Purdue International Symposium on Protein Quality in Maize*, 1972, El Batan, Mexico. Stroudsburg, PA: Dowden, Hutchinson & Ross, 1975. 524 p.
6. **Mertz E T.** Genetic and biochemical control of grain protein synthesis in normal and high lysine cereals. *World Rev. Nutr. Diet.* 48:222-62, 1986.



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